Appendix A – Schedule of Cowichan WUP Public Meetings

Appendix A provides a summary of the meetings held for the Public Advisory Group and the Technical Sub-Groups during the planning process.

Public Advisory Group Meetings		Aquatic and Riparian Technical Sub-Group Meetings		Lakefront Technical Sub-Group Meetings	
Mtg #1	November 22, 2017	Mtg #1	December 13, 2017	Mtg #1	November 10, 2017
Mtg #2	February 1, 2018	Mtg #2	January 18, 2018	Mtg #2	December 5, 2017
Mtg #3	March 8, 2018	Mtg #3	February 8, 2018	Mtg #3	January 16, 2018
Mtg #4	May 8, 2018	Mtg #4	February 22, 2018	Mtg #4	February 20, 2018

In addition, a number of interagency Steering Committee meetings were held throughout the Cowichan WUP planning process.

In addition, two public information meetings were held and open to the general public in relation to the Cowichan WUP planning process. These meetings were held on October 23, 2017 and June 11, 2018.

Cowichan Water Use Plan

Public Advisory Group

Appendix B - Terms of Reference[1]

Prepared by Compass Resource Management
November 16, 2017

A community planning initiative in partnership with:

CVRD Cowichan Watershed Board Catalyst

[1] *As reviewed and accepted by the Cowichan WUP Public Advisory Group at their November 22, 2017 meeting*

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Cowichan Water Use Plan
Public Advisory Group Terms of Reference

1 Introduction

The Cowichan Valley Regional District (CVRD), Cowichan Tribes, the Cowichan Watershed Board, and Catalyst Paper have partnered together to initiate a community planning process that will explore future water use needs alongside a range of different potential water supply and storage options. The goal is to seek agreement on a long-term solution to ensure water resources are sustainable and available to meet the region's current and future water use requirements. This community planning initiative is referred to as the Cowichan Water Use Plan (WUP) and it will follow a structured process as outlined in a separate Process Guidelines document that was based on BC's provincial WUP Guidelines.

To ensure a Water Use Plan is reflective of the diverse interests and priorities of the residents and businesses of the region, a public advisory group (PAG) will be formed to work collaboratively through the planning process.

These terms of reference (TOR) outline the roles and responsibilities of the PAG (and any Technical Sub-Committee members) to ensure participants are aware of their mandate, expectations, and how the PAG and TSG will function, and the advisory nature of these committees.

2 Cowichan WUP Public Advisory Group

2.1 Mandate and Purpose

The mandate of the PAG is to work through the planning steps as outlined in the Cowichan WUP Process Guidelines (a separate document). Central to this mandate is for the PAG to identify and explore different water use alternatives[1] for the Cowichan Lake system and collaboratively develop recommendations for consideration to the Partner Organizations[2] which may lead to submission a WUP to the provincial government. The water control facilities to be included in the WUP are located at the outlet of Cowichan Lake (i.e., the weir and pumping system).

To develop recommendations, the PAG will:

- consider the needs and interests of all different water uses, including drinking water supply, fisheries, wildlife, lake front property owners, the environment, recreation, culture and heritage, flooding and erosion, water management costs, energy self-sufficiency, and other uses identified during the planning process;
- take into account the best available information about the consequences of proposed alternatives relative to current conditions;
- identify a preferred alternative and other considerations seen to be within the scope of the WUP;

[1] Water use alternatives include potential changes to minimum flow requirements for the Cowichan River, rule curve and water levels for Cowichan Lake, water storage capacity in Cowichan Lake, and potential enhancement projects to mitigate adverse effects.

[2] Cowichan Valley Regional District (CVRD), Catalyst Paper, Cowichan Tribes and Cowichan Watershed Board.

- outline criteria for any ongoing monitoring and assessment program, where required and appropriate; and
- establish timing for periodic review of a future WUP.

2.2 Role

The role of the PAG is advisory. The PAG will report to the Partner Organizations on the content of the WUP. Should the Partner Organizations move forward with an application of a WUP, the PAG recommendations will be included with the submission to the provincial and federal agencies.

The provincial Comptroller of Water Rights reviews water use plans under the provisions of British Columbia's *Water Sustainability Act*, and involves Fisheries and Oceans Canada, other provincial agencies, First Nations, and holders of water licences who might be affected by the plans.

The PAG may form Technical Sub-Groups as described later in this document.

2.3 Structure and Membership

Membership on the PAG consists of a diverse range of water use interests and include representatives from the CVRD, First Nations, Catalyst Paper, residents, local community and interest groups (e.g., lakefront property owners, environmental, recreation, agriculture, etc.), provincial and federal governments, and the Cowichan Watershed Board. The work of the PAG will be managed by an independent consulting team that has been hired to run and facilitate the community planning process (and their specific roles are described later in this document).

Members of the PAG do not receive remuneration.

Membership of the PAG has been established in accordance with Steps 2 and 3 of the Provincial WUP Guidelines. PAG members have been invited to participate based on:

- Their constituency, agency, organization or group being considered a key interest group by the Cowichan WUP Steering Committee (which includes Partner Organizations and federal and provincial regulatory agencies);
- Their ability to represent their constituency, agency, organization or group;
- Their knowledge and experience on these systems;
- Their commitment to participate in an open, inclusive and engaged manner with the goal of working collaboratively toward mutually acceptable solutions;
- Their commitment to attend all PAG meetings, and read all pre-meeting materials, understanding that the process is likely to involve approximately about four full day meetings over the course of about 8 months; and
- Acceptance of the organizational structure of the PAG.

2.4 Alternate Members

Continuity is important. It is expected that PAG members will attend all meetings. In the event that a designated PAG member is unable to attend a meeting, it is their responsibility to arrange for an alternate to attend on their behalf. Members are responsible for ensuring that their alternate is familiar with these

Terms of Reference and is fully up-to-date on the issues being discussed. Designation of an alternate must be communicated to the Facilitator at least one week in advance of the meeting in question.

2.5 New Members

Following adoption of these Terms of Reference, only under rare conditions will any individual or organization be considered to apply for membership on the PAG. New members may however, be considered through written requests to the Facilitator to be discussed by the PAG at their next meeting. Members of the PAG will consider new applications based on the principle of an equitable, open and inclusive process, and the merits and drawbacks of expanding membership to the PAG.

Any new PAG member will be required to:

a. abide by the Terms of Reference;

b. inform themselves with the past deliberations and work of the PAG; and

c. accept previous decisions of the PAG.

2.6 Technical Sub-Groups (TSGs)

Technical Sub-Groups may be established by the PAG to undertake specified technical work between PAG meetings. Technical Sub-Groups will:

- Be open to all PAG members;
- Include non-PAG members, such as technical or scientific experts, as appropriate;
- Include a Facilitator from the consulting team to support their meetings and work;
- Abide by Terms of Reference established by the PAG; and
- Undertake work and make recommendations as defined through PAG instructions.

2.7 Observers and Guests

Observers may attend meetings but may not participate in PAG and TSG discussions unless called upon. If an Observer wishes to attend an upcoming meeting, they must inform the Facilitator in advance and permission may be dependent on meeting room logistics.

Guests may be invited to attend meetings to provide technical presentations or respond to questions on a subject relevant to the PAG. Any invitation to a guest must be coordinated through the Facilitator in advance of the meeting.

3 PAG Scope

3.1 Deliberations

Deliberations by the PAG will include those issues that are related to a water use issues that are affected by water control facilities at the outlet of Cowichan Lake. The PAG will consider:

a) alternatives to how water is stored and released from Cowichan Lake and this includes consideration of flow releases down the Cowichan River, lake levels and the rule curve for Cowichan Lake, and potential new storage options (e.g., weir modifications, pumps, etc.);

b) potentially new mitigation measures or programs (in lieu of flow alterations), such as habitat enhancement;

c) monitoring or research studies to address any critical datagaps during the implementation of any new recommended changes.

The PAG will also be asked to provide advice on the preferred methods of communication between members, including meeting dates/times, and agenda topics.

New scope issues that arise during the consultative process that cannot be resolved by the PAG may be referred to the Steering Committee for direction.

Issues determined to be outside the scope of the process will be documented and, where applicable, referred to the appropriate agency. It needs to be emphasized that issues involving broader topics such as watershed management issues (e.g., forestry and land use practices, development applications, environmental management) that are beyond the scope of what can be addressed through the *Water Sustainability Act*, will be documented during the process but otherwise will be considered outside the scope to be discussed during the meetings.

3.2 Deliverable

The PAG will sign off on a report that summarizes their deliberations. The report will both summarize the process followed and outline the final recommendations of the PAG, noting areas of agreement and disagreement. The report will also document water use interests, objectives and performance measures considered, information collected, operating alternatives reviewed, and the trade-offs identified and considered. Recommendations in the final PAG Summary Report will be made available to the public and submitted to the Partner Organizations at the end of the process.

The PAG Summary Report will be written by the consulting team Facilitator on behalf of the PAG.

4 PAG Member Responsibilities

4.1 Member Responsibility

Members of the PAG are responsible for:

a) attending each meeting of the PAG and any meetings of subcommittees or working groups to which they belong, or assigning an alternate to do so. Members of the PAG who are absent, or do not assign an alternate, for **two meetings may be moved to observer status;**

b) providing comments in advance or appropriate information to the Facilitator in the event of an expected absence;

c) preparing for each meeting by reading meeting minutes, studies, subcommittee reports and other material distributed as part of this consultative process. Every effort will be made to distribute pre-reading materials at least seven days prior to PAG meetings;

d) regularly updating members of their constituency, agency, organization or group regarding the deliberations, progress and decisions of the PAG;

e) being accountable to other PAG members and the general public; and

f) abiding by the code of conduct during the process (as outlined below).

4.2 PAG Operating Guidelines

Members of the PAG have the task of listening to and understanding the various interests around the table. The PAG will collaboratively develop recommendations that best meets the needs of all those interests. Specifically, PAG members will:

a) follow the planning steps as described by the Facilitator (and consistent with the Process Guidelines);

b) express the concerns and interests of their organization;

c) establish Technical Sub-Groups and provide direction on the scope of their work;

d) engage in deliberations in an equitable, open and transparent manner with a view to developing a consensus recommendation;

e) communicate and engage with their constituents / organization, including distribution of minutes and materials after they have been approved;

f) sign-off on the final summary report, provided it is an accurate representation of the process.

The PAG will be disbanded following their submission of the final report to the Partner Organizations.

4.3 Code of Conduct

All PAG members will endeavour to:

a) work constructively and collaboratively to address areas of mutual concern;

b) support an open and inclusive process;

c) treat others with courtesy and respect;

d) listen attentively with an aim to understand;

e) be concise in making a point;

f) speak in terms of interests instead of positions;

g) be open to a range of outcomes (as opposed to being attached to certain outcomes in advance of the process);

h) let opposing views co-exist;

i) avoid disruption of meetings (e.g., cell phones, caucusing at the table, etc.);

j) allow issues that fall outside the meeting agenda to be addressed at a later time; and

k) deliberate with a view to arriving at consensus.

5 Consensus Decision-Making

5.1 Consensus

Consensus is a goal but not a requirement of the WUP process. The Provincial Water Use Guidelines define consensus as a decision that participants can accept, without having to agree on all the details of the recommendations put forward. Meeting documentation will identify areas of agreement, areas of discord, and underlying trade-offs between alternative water uses.

The decision making process to determine the PAG's position on a particular issue or when making a recommendation will not be by majority votes. In fact, there will be no voting per se, but there will be ranking exercises carried out at various points to gain insight of where broad agreement may lie.

Throughout the planning process, the PAG may decide to re-visit areas of agreement if:

1. significant new information becomes available that is relevant to a past decision
2. by consensus, the PAG decides it needs to review specific agreements that are part of a larger, final package of agreements.

When the PAG cannot identify a preferred final recommendation (non-consensus), the final summary report will record and indicate differences of opinion and reasons for non-consensus. Members in disagreement with a 'preferred option(s)' will be responsible for describing what part(s) of the agreement do not meet their needs and possible alternative and acceptable solutions.

5.2 Openness and Criticism

If left unaddressed, dissatisfaction can become destructive and undermine the effectiveness of the PAG. Members agree to raise criticisms of the process or the emerging results as agenda items for discussion by the PAG in an open manner rather than taking them behind the scenes and talking negatively about the process. PAG members will bring issues of dissatisfaction or criticism to the attention of the Facilitator to be addressed in between meetings or raised at upcoming meetings.

6 PAG Support

6.1 Consulting Team – Process and Facilitation

The consulting team serves as an independent resource and support to the PAG throughout the planning process. The consulting team plays the dual role of providing technical support and managing and facilitating the public process. The consulting team consists of staff from Compass Resource Management, Ecofish Research, and Kerr Wood Liedal. Compass is responsible for the overall project and they will serve as the Facilitators for the PAG meetings.

The Facilitator will assist the PAG's deliberations through:

a) coordinating and managing the overall planning process;

b) structuring the meetings to encourage free and open discussion of relevant issues;

c) remaining impartial and objective throughout the process;

d) ensuring that the Code of Conduct is followed;

e) ensuring that all parties are heard and that differences are adequately addressed;

f) creating a collaborative problem-solving environment for the PAG, and promoting creative thinking to overcome road blocks and obstacles;

g) being respectful of participants' time and making the best use of PAG meeting time;

h) preparing draft meeting summaries within a timely fashion after each meeting;

i) preparing and coordinating pre-reading packages for PAG members to come to meetings prepared; and

j) preparing a final PAG Summary Report for sign off by members.

6.2 Cowichan WUP Steering Committee

A steering committee was established to initiate the Cowichan WUP planning process and to provide direction on matters of the scope of the planning process. As mentioned previously, the membership on the Steering Committee consists of representatives from the Partner Organizations and provincial and federal regulatory agencies.

The Steering Committee will support the PAG through:

- Initiating a selection process for membership on the PAG that is diverse and representative of the water use interests in the region;
- Provide advice and direction on matters of scope, process, and future regulatory requirements related to a water use plan;
- Clarifying the scope of the water use alternatives that can be considered during the public planning process;
- Moderating conflicts around process issues and/or personality differences between stakeholders or PAG members that can not be fully addressed during meetings by the Facilitator or consulting team;

7 Public Communication

The public planning process is intended to be an open, transparent process.

The consulting team will manage external communications about the PAG process with the public. They will prepare materials and updates and manage the dissemination of materials for public consumption as appropriate. Final summary meeting notes will be posted on the Cowichan WUP public website.

No member should speak to the media on behalf of the PAG. All media requests will be directed to Compass who will in turn address them and report back to the PAG.

8 Changes to this Terms of Reference

The Terms of Reference presented in this document may be amended from time to time by the facilitator with input from the SC members.

9 Confidentiality

Unless otherwise indicated, all material provided directly to PAG members should be considered confidential and draft until they have been discussed in person at the next meeting. Any requests to distribute materials beyond the PAG will be made on a case by case basis by the Facilitator until such time as they are discussed by the full PAG. This will ensure open and frank discussions and sharing of information.

Cowichan Water Use Plan

Appendix C - Process Guidelines[1]

Prepared for
Public Advisory Group

Prepared by
Compass Resource Management Ltd.
www.compassrm.com

Date
November 10, 2017

A community planning initiative in partnership with:

CVRD Cowichan Watershed BOARD Catalyst

[1] *As reviewed and accepted by the Cowichan WUP Steering Committee at their November 16, 2017 meeting*

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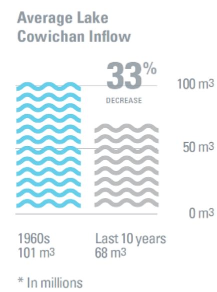
1 Overview

1.1 Introduction

These Process Guidelines serve as the roadmap to guide the approach, steps and methods for the community planning process of the Cowichan Water Use Plan (WUP). These guidelines provide additional details and context specific to the Cowichan WUP, but should be read in tandem with the Province of BC's *Water Use Plan Guidelines*[1] (and, in particular, Steps 4 through 8 of the consultative process). These process guidelines (along with the provincial WUP Guidelines) are based on a Structured Decision Making (SDM) framework, which is described in greater detail in this document.

1.2 Background

Changes in water demand, land use, and a shifting hydrological cycle from climate change are placing increasing pressures on the availability of water resources in the Cowichan Watershed to meet current, let alone future, water use needs of residents, businesses and the environment. Water scarcity and summertime droughts have increased significantly over past years (e.g., average spring and summer inflows to Cowichan Lake have decreased by about a third since the 1960s) and these conditions are projected to worsen[2] with longer drier periods and warmer summer temperatures.



The current Cowichan water management system was designed in the 1950s to support industry, the community and environment, and includes a weir at the outlet of Cowichan Lake to store additional water and supplement flows down the Cowichan River through the summer and early fall. These designs were based on conditions that are now not relevant and the system no longer has the capability to reliably support the varied water uses that have come to be expected. According to Catalyst Paper (who own and operate the weir), 8 out of the last 15 years have been drought summers (including three of the last four). In 2016, drastic measures were needed to reduce flows from the weir throughout the entire late spring and summer period; water levels on Cowichan Lake were so low in September that pumps were installed with the anticipation of having to pump water over the weir to keep the Cowichan River flowing.

The current situation will only lead to more intense and frequent water insecurity problems that will threaten the long-term supply of water from Cowichan Lake to the Cowichan River and associated groundwater aquifers to meet the region's needs. These events will directly and indirectly impact interests that are important to residents, businesses, industries and community groups.

The Cowichan Valley Regional District (CVRD), Cowichan Tribes, the Cowichan Watershed Board, and Catalyst Paper have partnered together to initiate a community planning process that will explore future water use needs alongside a range of different potential water supply and storage options. The goal is to seek agreement on a long-term solution to ensure water resources are sustainable and available to better meet the region's current and future water use requirements.

This initiative has been financially supported by the provincial and federal governments.

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[1] https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/water-planning/water_use_plan_guidelines.pdf

[2] According to the CVRD's recent climate change study, "*Climate Projections for the Cowichan Valley Regional District"* (2017), it is projected that by the 2050s the April 1 snowpack depth will decrease by 85%, the amount of summer rain will decrease by 17%, and the duration of dry spells will be lengthened by about 20%.

1.3 Water Use Planning in BC

Water use planning has been carried out in the province for close to 20 years and provides a community based framework to explore and balance competing water uses where there are limited water resources to meet all the demands. The province developed Water Use Plan Guidelines in 1998 to serve as a template for carrying out the public planning and meeting the regulatory requirements towards a possible future water license application.

Water use plans (WUPs) are meant to clarify how rights[3] to provincial water resources should be exercised and to recognize other social and environmental values associated with those resources. A WUP is a document that, when authorized by the Comptroller of Water Rights (under the *Water Sustainability Act*), will define the operating parameters for existing or new water management facilities. WUPs must recognize existing legal and constitutional rights and responsibilities, as set out in legislation and court decisions (for more information, please refer to the Province's Water Use Planning website).

Water control facilities are subject to the federal *Fisheries Act*, which governs the protection of fish and fish habitat in Canada. WUPs offer a mechanism for meeting DFO's *Policy for the Management of Fish Habitat* under the *Fisheries Act* at individual facilities throughout British Columbia*.*

A WUP follows a 13-step process that consists of a core community planning stage during *steps 4 through 8*. The other planning steps involve regulatory requirements on the part of provincial and federal government agencies or on a water licensee or proponent. The process described in the guidelines is designed to seek consensus on a set of operating rules and, in some cases, proposed changes to the water control facilities in order to better satisfy the full range of water use interests at stake.

1.4 Cowichan WUP and Public Involvement

The planning process for the Cowichan WUP will involve two parallel tracks of community involvement: 1) a core public group will be formed to work through the planning steps, and 2) a broader public process will be carried out to engage the public at large.

A public advisory group (PAG) will be formed to work collaboratively through a structured process *(i.e., Steps 4 through 8 in the provincial WUP Guidelines)* towards recommending a balanced long-term solution to meet the community's water use needs into the future. The PAG will be comprised of about 20 members representing the diverse range of water use interests and the priorities of the residents and businesses in the watershed. The PAG will be supported through a number of technical working groups and through input and feedback received from the broader public at key points in the process.

The broader public process will consist of a suite of communication measures designed to both inform the broader public about the WUP process and collect input. Measures will range from web-based information and surveys to email updates and press releases to structured public meetings to be held to report out on progress and provide opportunities for more in-depth review and feedback.

A multi-agency steering committee consisting of representatives from First Nations and government agencies and Catalyst Paper provide guidance on matters related to the scope and process for carrying out the planning.

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[3] These rights are not in relation to aboriginal rights and title which are protected under Section 35 of Canada's Constitution (refer to Section 3.4 of the BC Provincial WUP Guidelines for more detail on this).

1.5 Cowichan WUP Scope Considerations

The WUP will encompass the Cowichan Watershed, but will primarily focus on water related uses and issues directly related to potential changes in lake levels on Cowichan Lake and potential changes in flows down the Cowichan River[4]. Accordingly, the scope of options to be considered and explored during the planning process will be centered on potential changes to the:

- Minimum flow requirements[5] for the Cowichan River,
- Rule Curve (and water levels) for Cowichan Lake, and
- Water storage capacity of Cowichan Lake (e.g., weir modifications, permanent pump station, etc.)

Consistent with the provincial guidelines, however, there may also be opportunities to consider new enhancement projects as a substitute to changes in flow. Where it can be shown that such works are both technically feasible and cost effective, they can be considered as part of the WUP deliberations.

2 Process Overview - Structured Decision Making (SDM)

The community planning process for the Cowichan WUP will follow a SDM approach, consistent with Steps 4 through 8 in the provincial WUP Guidelines. This section outlines the general steps, principles, and some of the tools of SDM that will be relied upon.

2.1 SDM Overview

Structured Decision Making, or SDM, is an organized framework for making defensible choices in situations where there are multiple interests, high stakes, and uncertainty. It is designed to provide stakeholders and decision makers with insight about the decision by clarifying objectives, identifying creative alternatives, evaluating how well different objectives are satisfied by different alternatives, exploring how risky some alternatives are relative to others, and exposing the fundamental trade-offs or choices that need to be made. It is particularly useful for groups working together on complicated planning and decision-making projects.

SDM helps people make decisions that are defensible (based on sound technical information), value-based (based on “what matters” to people), transparent (based on clearly communicated reasons), and efficient (with people’s time and resources). It estimates impacts based on best available information, which can include both science and traditional and local knowledge, and it actively deals with uncertainty. The collaborative process promotes dialogue and constructive debate and helps people focus on interests rather than positions.

SDM is based on well-recognized methods developed in the decision sciences. As a result, it’s rigorous, defensible and well-suited for decisions that will be subject to a high degree of scrutiny. Importantly, although it’s based in sound theory, it’s adapted for use in the real world, and it’s proven itself in a wide range of applications. It has formed the basis for Water Use Planning processes in British Columbia over the past twenty years, has been formally adopted by provincial and federal agencies in Canada and in the United States (USEPA, USFW, USACE, etc.).

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[4] Other tributary rivers off the Cowichan River (or above Cowichan Lake) may be considered within the scope of the Cowichan WUP depending on the relationship of a particular issue/interest with changes in water management at the outlet of Cowichan Lake.
[5] Minimum flow requirements will be defined through the course of the public planning during the Cowichan WUP.

2.2 SDM Principles

SDM is based on a set of core principles[6] which will be followed during the Cowichan WUP.

Transparency and Accountability. The planning process will follow a defined set of steps designed to ensure that participants and observers know what to expect at each stage of the process. The use of clear objectives and evaluation criteria will improve the quality of the planning process and help to ensure that the rationale for the resulting recommendations is clear. Timely communication to the larger community of interested parties will be provided.

Multiple Objectives and Value-Based Choices. Recommendations from the process will be based on consideration of multiple objectives. It is understood that different parties will attach different importance to different objectives. The process will ensure that all objectives, even those that are hard to quantify, are addressed explicitly as part of the process. While there are likely to be some win-wins, it is understood that options will involve trade-offs – or value based choices –among objectives. Deliberations about difficult choices will be based on seeking an acceptable balance across multiple objectives.

Informed Choices. All participants should have a full understanding of the issues, the alternatives proposed to address them, and the likely consequences of the alternatives. They should have timely access to the same information (e.g., data, studies, reports/reviews) and work toward building a common understanding of technical findings. Technical information will be presented in a manner that is accessible to non-technical participants. Knowledge from both scientific and local or traditional sources will be respected and incorporated where appropriate as part of the decision framework. All sources of knowledge will be subject to review by a community of peers. The extent and nature of uncertainty and its implications will be explored and documented.

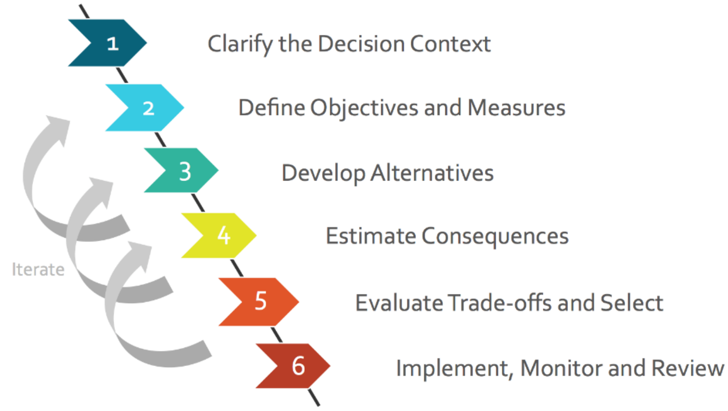
Collaborative Process. The process should provide opportunities for interested parties to be involved in a meaningful way. Decisions will respect the different views of participants and will be made on the basis of shared discussions. Although it is recognized that different viewpoints – both technical and value-based – may exist among participants, a collaborative process requires that these views be clearly expressed and be open to discussion as to their origins, strength, relevance and implications. The process will be solutions-oriented, with the shared goal of finding alternatives that are mutually acceptable. In general, an SDM process will strive for and support the development of consensus. However, it is explicitly not required. Areas of agreement and disagreement will be clearly documented along with reasons for each.

Learning, Adaptive Management and Review. Recognizing that uncertainty will always be present, provision should be made for ongoing review and refinement of the understanding of social, cultural, economic and ecological systems and their response to the different options. The timing of, and participation in, a future review processes should (so far as possible) be established in advance. Data needs in support of future decisions should be clarified before monitoring is initiated.

[6] These principles are consistent with and build upon the seven principles outlined by the province and BCH for Water Use Planning in BC (http://www.em.gov.bc.ca/dl/electricitydev/PrinciplesWUP.pdf).

2.3 SDM Planning Steps

SDM is centred on a set of core steps that serve as a guide for working through a planning process (see figure). These steps are supported by structuring tools and methods that help groups deal with the complexities of technically intensive decisions and difficult group dynamics.



What exactly is done at each step, to what level of rigour and complexity, will depend on the nature of the decision, the stakes and the resources and timeline available. In some cases, the appropriate analysis may involve complex modeling that has been the subject of years of fieldwork; in others, it will involve structured elicitations of expert judgment conducted over several days. In still others, a careful structuring of objectives and alternatives may be all that is needed to clarify thinking around a particular decision and a qualitative analysis will suffice. A key point is that structured methods do not have to be time consuming; even very basic structuring tools and methods can help to clarify thinking, minimize errors and biases and ensure that the technical and values basis for difficult decisions is transparent.

The goal of an SDM process here will be to identify and explore core trade-offs, inform deliberations, and ultimately achieve a consensus-based recommendation. The process laid out in these guidelines essentially follows steps 1 through 5 of the SDM process in order to reach a recommendation.

Each of the steps are described in more detail below.

1 Clarify the Context

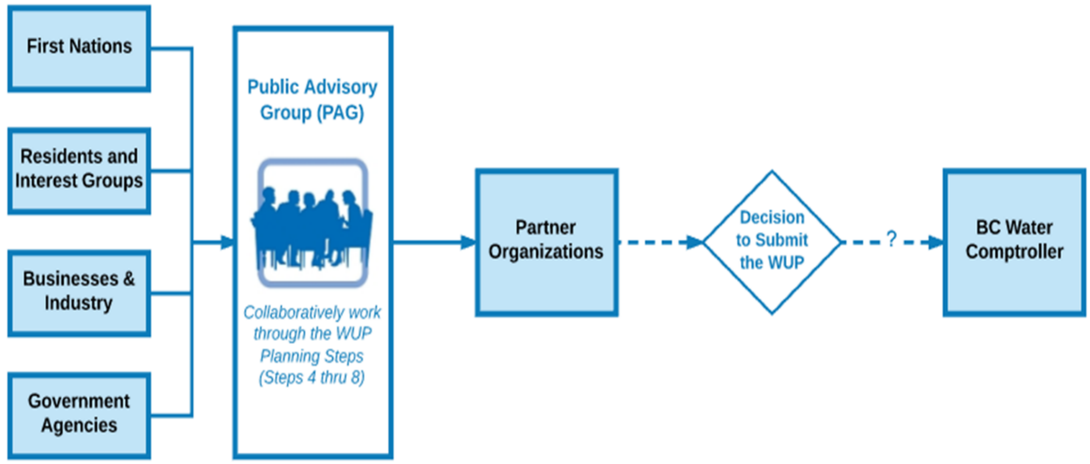
The first step of any process is to clarify the scope and decision process. This entails defining the limitations and constraints of the planning process and the decisions to be made, the relationship of this process to other decisions or related initiatives, clarifying the roles and responsibilities of participants and of the various committees (e.g., PAG, technical sub-groups, and steering committee), confirming the information base and technical analyses available to support the planning, and being clear about the timelines and resources to carryout the planning.

Most of this context is summarized through these guidelines and the provincial ones. As well, a separate Terms of Reference (TOR) document will be prepared for members of the PAG (and technical subcommittees) and these TORs will outline the roles and responsibilities of each participant on these groups in further detail.

A key point to emphasize about the scope of this community planning initiative is that it is **advisory in nature**. The PAG will strive for consensus on recommendations for a long-term solution to meet the region's water use needs in the future. These recommendations will be the subject of consultations with the broader public. The PAG recommendations along with the community feedback will be forwarded to the Partner Organizations[7] for a decision to

[7] Partner Organizations include Catalyst Paper, CVRD, Cowichan Tribes, and Cowichan Watershed Board.

move forward with submitting a WUP (as per Step 9 in the provincial WUP Guidelines) to the provincial government or not. The PAG process is estimated to be completed in the spring of 2018.

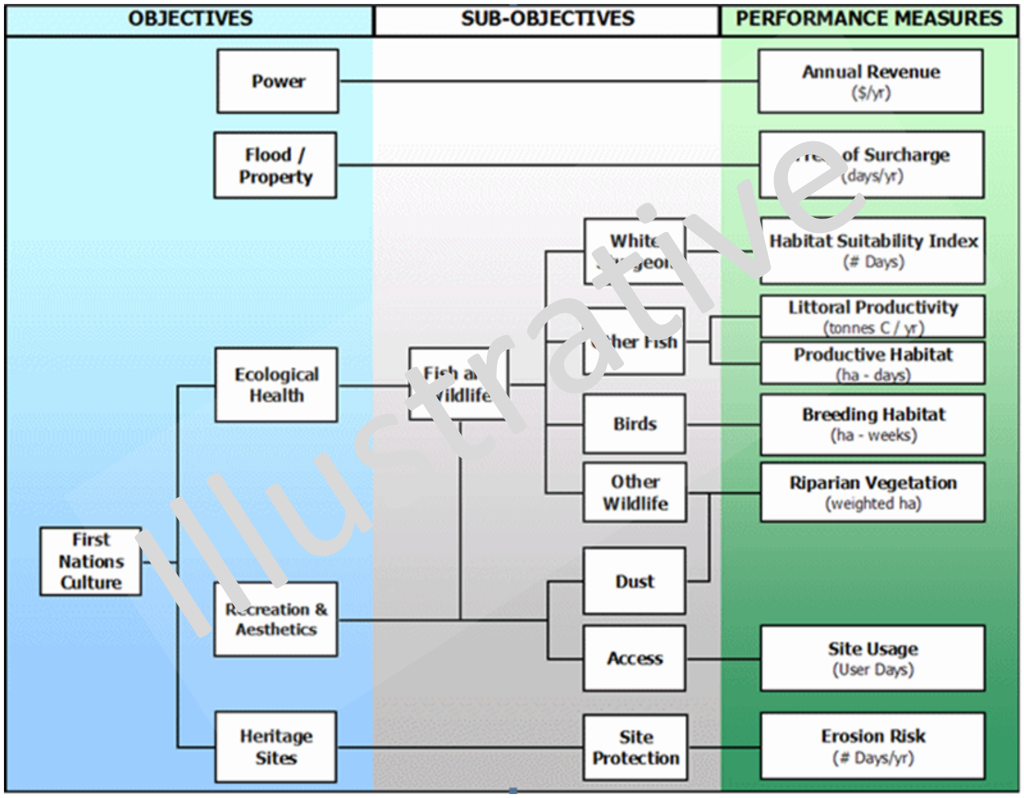


2 Identify Objectives and Measures

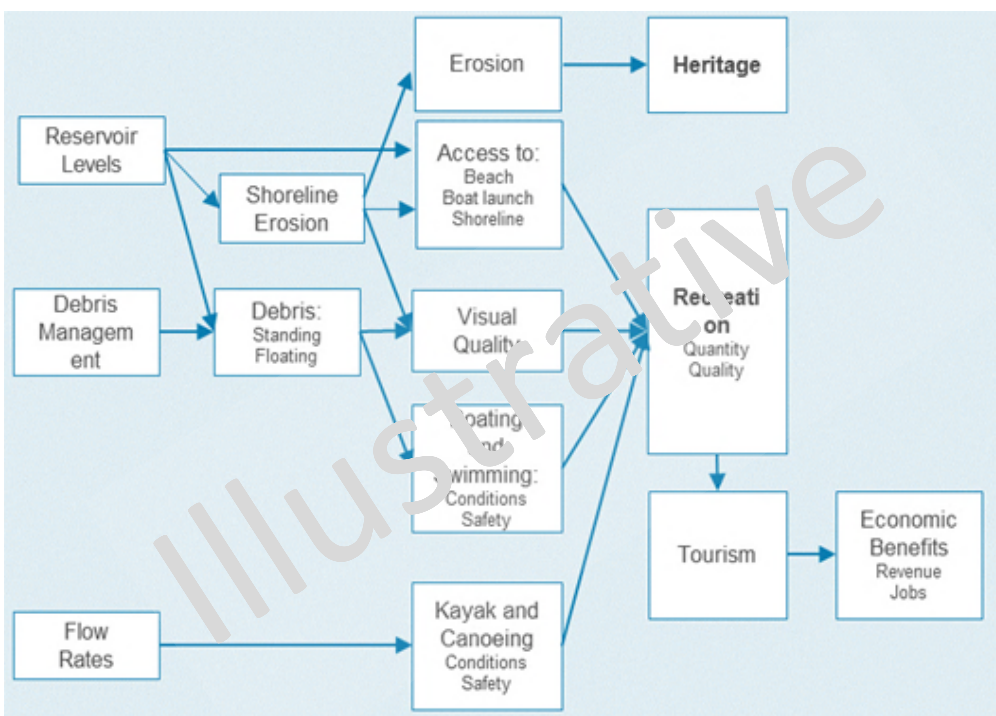
At the core of an SDM process is a set of well-defined objectives and performance measures that clarify "what matters" – the things that people care about and could be affected by the decision. Objectives should include all the things that matter, not just the ones that are easily quantified (e.g., increase the abundance of salmon, minimize greenhouse gas emissions, increase cultural value, etc.). Together, objectives and performance measures drive the search for creative alternatives and become the framework for comparing alternatives.

Clearly stated objectives only need to state the object of importance and the direction of preference (e.g., maximize habitat). The process for developing sound objectives begins with simple brainstorming, followed by the use of structuring tools like:

- Objectives hierarchies that group objectives by category and organize sub-objectives that provide a fuller description (see the illustrative hierarchy below), and



- Means-ends diagrams that visually show the relationship between policy alternatives (means) at one end and fundamental objectives (ends) at the other (see illustrative diagram below). These are useful for developing a conceptual understanding of a system, for helping separate interests (objectives) from positions (means), and for identifying potential evaluation criteria.



As objectives are the foundation for all that follows, care should be taken to develop a set that are **complete** (fully addressing all the things that matter when evaluating alternatives within the defined scope), **concise** (with no redundancy or double counting), **controllable** (meaning that they are sensitive to or affected by the range of alternatives under consideration), **meaningful** (understandable and relevant to all participants), and **preferentially independent** (meaning that the importance assigned to one objective does not depend on the values taken on by other objectives).

Performance measures (or evaluation criteria) are defined normally for each sub-objective within the objectives hierarchy. Performance measures (PMs) for fisheries might include specific measures for fish habitat, for drinking water quality they might include a water quality index, for example. Collectively, the PMs represent the information that decision makers will have for choosing among policy alternatives; they should cover all the important aspects of the decision. They play a central role in the decision process as they are used to:

- Compare alternatives accurately and consistently;
- Expose trade-offs including trade-offs among different degrees of uncertainty;
- Generate productive discussion about better alternatives;
- Prioritize information needs;
- Communicate the rationale for and improve the transparency of decisions.

Like objectives, PMs should be complete, concise, controllable and meaningful. They should also be **direct** (in that they accurately and unambiguously report as directly as possible on the endpoint itself), **measurable** (in the sense of being able to consistently report expected difference in performance across alternatives, but not excluding qualitative measures), and **explicit about uncertainty** (in that they expose the risk profiles or range of possible outcomes of different alternatives).

3 Developing Alternatives

Once objectives are clear, SDM is fundamentally about the search for creative solutions. It focuses on identifying, comparing and iteratively refining alternatives. For the Cowichan WUP, alternatives may include changes in flow releases to Cowichan River and/or potential new physical works to increase storage in Cowichan Lake (such as increasing the weir height or permanent pumping stations to be installed). Ideally alternatives will not be simply tweaks of the status quo. Alternatives should reflect substantially different approaches to the problem or different priorities across objectives, and should present a range of possible options. It is usually important to search for alternatives that are robust to key uncertainties or that reduce them over time.

Developing good alternatives is an iterative task. In environmental management, the number and diversity of alternatives can be overwhelming, and individual actions may need to be thoughtfully combined into packages.

The development of alternatives is an iterative process. For the Cowichan WUP there will be two or three rounds of alternatives that will likely be explored. During each round of assessment, alternatives that are not performing well will be dropped and those that are doing okay, will be held over to the next round of assessment or improved upon.

Eventually, a short list of alternatives that expose fundamental trade-offs will be highlighted and these will require value-based discussions towards finding a balanced and preferred alternative.

4 Estimating Consequences

At this step the consequences of the alternatives for each objective are estimated or characterized. A consequence table summarizes the estimated consequences of each alternative on each objective, as reported by the measures. It creates a shared understanding of how different alternatives affect different values and stakeholders, and it exposes key trade-offs among objectives across the alternatives under consideration. Simple color coding of key trade-offs can be effective.

A good consequence table summarizes the best available information about what will happen to the objectives under each alternative. It needs to be understandable to the entire audience, and to highlight any uncertainties. Consequences are estimated using available knowledge, and both quantitative and qualitative methods may be applied. A colour-coded consequence table can be helpful in highlighting significant differences across the alternatives (in the illustrated table below, all the alternatives are compared to the blue highlighted Alternative "C" to get a better sense of its performance: a red cell means Alt "C" is performing better, green worse, and a clear cell implies it is the same).

Objective	Units	Dir	BASE	A	B	C	D
Upper Campbell							
Erosion	risk days per year	L	37	13	4	3	3
Recreation	rec days per year	H	43	40	[illegible]	158	158
Fish - Littoral Zone	hectares	H	91	107	93	214	215
Lower Campbell							
Erosion	risk days per year	L	3	[illegible]	13	-	-
Recreation	rec days per year	H	[illegible]	43	83	167	170
Fish Cutthroat	hectares	H	[illegible]	[illegible]	95	79	79
Fish Rainbow	hectares	H	[illegible]	3	49	49	47
Campbell River							
Flooding	flood days per year	L	34	48	24	59	59
Recreation	rec days per year	H	66	83	51	81	79
Fish - Spill Risk	spill days per year	L	118	214	102	176	177
Fish - Spawning	% success	H	55.0	89.0	78.0	59.0	59.0
Fish - Rearing	risk index	L	0.53	0.48	0.53	0.50	0.49
Salmon River							
Canoe Route	canoe days	H	162	167	153	204	183
Fish and Wildlife Habitat	habitat risk index	L	0.54	0.47	0.44	0.48	0.53
System Wide							
Power	revenue $ per year	H	$ 68.5	$ 64.6	$ 68.6	$ 65.1	$ 65.3

5 Evaluate Trade-offs and Select

The goal is to choose a preferred alternative based on achieving a balance across multiple objectives. Although the SDM process often delivers "win-wins," most decisions will still involve trade-offs of some kind and hence will require value-based choices. Evaluation tools such as consequence tables (along with other supporting technical information) will help to inform choices, but will not make them. Participants in the process will acknowledge and openly discuss difficult trade-offs and review options for achieving an acceptable balance across all objectives.

The SDM process requires that participants make explicit choices about which alternative is preferred based on their own values and their understanding of the values of those affected. This can be done holistically by reviewing the trade-offs in the consequence table and assigning ranks or preferences to the alternatives directly. In this approach, participants implicitly think about which impacts are more or less important, and which set of trade-offs is more or less acceptable. Alternatively, a variety of structured preference assessment tools are available (such as multi-attribute trade-off analysis, for example). Such tools are used not to prescribe a formulaic solution, but to provide insight, to clarify sources of agreement and disagreement (do participants disagree about facts or values for example), and to focus and structure dialogue in ways that support decision making.

It's worth pointing out that the SDM framework supports but does not require the weighting of objectives and criteria. When used in support of complex, high-stakes, one-time decisions that require a high level of support across different interests (e.g., selecting a flow regime for a regulated river, developing a species recovery plan, etc.), weighting may have limited utility relative to structured dialogue and the insights that come from relating alternatives to a range of clearly defined, value-based objectives.

While consensus is desirable in the SDM process, it is not mandatory. Areas of agreement and disagreement among participants and the reasons for disagreement will be fully documented. To the extent that there is a significant difference between the views of technical specialists and the views of non-technical stakeholders, these differences and the reasons for them will also be highlighted.

6 Implementation, Monitoring and Learning

A commitment to learning is one of the things that sets SDM apart as a framework for decision making. Throughout the process, people participating in SDM will need to be prepared to listen and learn about values, to explore completing hypotheses about cause-effect relationships, and to build a common understanding of what constitutes the best available information for identifying alternatives and assessing consequences. This forms the basis for working collaboratively on solutions.

At this final stage, the SDM process focuses on what learning is needed to improve future decision making. The challenge is to implement the decision in a way that reduces uncertainty, improves the quality of information for future decisions, and provides opportunities to revise and adapt based on what is learned.

Where uncertainty about outcomes affects the selection of a preferred alternative, commitment to structured learning over time and a formal review of a decision when new information is available can be the key to reaching agreement on a way forward. SDM is consistent with and supports a formal adaptive management process. To make best use of resources, it's necessary to focus on the most important sources of uncertainty, those for which reductions would be of greatest value to future decision makers. To ensure the relevance to future choices any monitoring programs will be closely linked to the objectives and performance measures used to evaluate management alternatives. For the Cowichan WUP, if there were important datagaps and uncertainties associated with a particular recommendation for different flows or storage requirements, the PAG may make recommendations on needed research studies and/or monitoring and a review period to be implemented with any future changes to the water management system.

3 Summary

The SDM framework is not a formula. It prescribes a flexible yet rigorous process that can effectively guide the deliberations of parties involved in with making decisions and recommendations, and identify information needed to make defensible and robust decisions. It structures and focuses technical analyses to encourage informed dialogue, transparent results, and equal access among all parties to findings. It structures and focuses deliberations to address the values of participants and to encourage the creative and collaborative exploration of alternatives, trade-offs and uncertainties. The framework is designed to support participants in reaching an informed consensus, but does not guarantee it. Where disagreements remain, the areas of agreement and disagreement will be documented, along with the reasons why. This information can then be presented to those designated as final decision makers.

For more information about SDM please refer to:

www.StructuredDecisionMaking.org

http://www.amazon.com/Structured-Decision-Making-Environmental-Management/dp/1444333429/ref=sr_1_1?ie=UTF8&qid=1337372422&sr=8-1

http://applcc.org/resources/video-gallery-and-webinars/webinars/structured-decison-making-webinar-series

Appendix D – List of PAG and TSG Membership

Public Advisory Group

Name	Alternate(s)	Affiliation / Background
Aaron Hamilton		Lake Cowichan First Nation
Carol Milo		Cowichan Valley Naturalists Society
Cheri Ayers		Member of public / farmer and consultant
Clay Reitsma Shaun Chadburn[1]		North Cowichan
Dale Desrochers	Wilf Luedke	Fisheries and Oceans Canada (DFO)
Darryl Slater	David Robinson	MFLNRO (Water Authorizations)
Graham Kissack		Catalyst Paper
Greg Allen		Member of public / lakefront property owner
Joe Allen		Member of public
Kate Miller	Brian Carruthers	Cowichan Valley Regional District (CVRD)
Larry George	Eamon Gaunt, Melissa Tokarek	Cowichan Tribes
Leroy Van Wieren	Parker Jefferson	Cowichan Lake and River Stewardship Society
Michelle Geneau	Emmet McCusker, Danica Rice	City of Duncan
Michelle Mahovlich		Edelweis Chalets Strata / lakefront property owner
Mike McCulloch	Jaro Szczot	MFLNRO (Fisheries)
Nagi Rizk	Joe Fernandez	Town of Lake Cowichan
Pam Jorgenson		TimberWest
Paul Slade		Member of public / local business owner
Tom Rutherford		Cowichan Watershed Board

Note. PAG meetings were facilitated by Michael Harstone and Jennifer Steele (Compass Resource Management) and were supported by Craig Sutherland (Kerr Wood Leidal), Todd Hatfield (Ecofish Research Ltd.) and Jonathan Abell (Ecofish Research Ltd.).

[1] Shaun Chadburn replaced Clay Reitsma from PAG Meeting #2 onwards.

Aquatic and Riparian Technical Sub-Group

Name	
Brian Houle	Catalyst Paper
Dave Preikshot	Independent Scientist
Heather Pritchard	Cowichan Lake and River Stewardship Society
James Craig	British Columbia Conservation Foundation
Jaroslaw Szczot	MFLNRO
Kevin Pellett	Fisheries and Oceans Canada (DFO)
Mike McCulloch	MFLNRO
Parker Jefferson	Cowichan Lake and River Stewardship Society
Tim Kulchyski	Cowichan Tribes
Tom Rutherford	Cowichan Watershed Board

Note. ARTSG meetings were facilitated by Todd Hatfield and Jonathan Abell (Ecofish Research Ltd.) and were supported by Jennifer Steele (Compass Resource Management).

Lakefront Technical Sub-Group

Name	
Diana Gunderson	Member of public / lakefront property owner
Greg Allen	Member of public / lakefront property owner
Kate Miller	Cowichan Valley Regional District (CVRD) / lakefront property owner
Michelle Mahovlich	Edelweis Chalets Strata / lakefront property owner

Note. LTSG meetings were facilitated by Jennifer Steele (Compass Resource Management) and were supported by Craig Sutherland (Kerr Wood Leidal).

Note. Brian Farquhar (CVRD, Parks and Trails) attended LTSG Meeting #2 to provide support on lake recreational structures.

ASSESSING AQUATIC AND RIPARIAN IMPACTS

1. ROLE OF THE AQUATIC AND RIPARIAN TASK SUB-GROUP

The Aquatic and Riparian Task Sub-Group (ARTSG) consisted of experts in fisheries and/or riparian vegetation and wildlife of the Cowichan River watershed. The ARTSG supported the Public Advisory Group (PAG) by providing science-based technical advice. Qualified candidates were identified based on discussions with representatives from the Cowichan Watershed Board, FLNRORD, DFO and the CVRD. Candidates were invited to attend, with the resulting group comprising ten individuals who were affiliated with either Cowichan Tribes, regulatory agencies, Catalyst, or non-governmental organizations (Table 1).

Table 1. Aquatic and Riparian Task Sub-Group Participants.

Participant	Affiliation
Tim Kulchyski	Cowichan Tribes
Brian Houle	Catalyst
Heather Pritchard	Cowichan Lake & River Stewardship Soc.
Parker Jefferson	Cowichan Lake & River Stewardship Soc.
Tom Rutherford	Cowichan Watershed Board
Dave Preikshot	Independent scientist
James Craig	BCCF
Mike McCulloch	FLNRORD
Jaroslaw Szczot	FLNRORD
Kevin Pellet	DFO

Broadly, the ARTSG was responsible for responding to the PAG's needs for technical information regarding fish and wildlife issues. Specific responsibilities included:

- Assisting with identifying key issues and objectives;
- Developing performance measures and using them to estimate outcomes of alternatives;
- Describing data gaps and needs;
- Providing input to alternatives if requested, and;
- Providing input to the design of future studies and monitoring to reduce outstanding uncertainties.

The ARTSG met four times: November 17 (all day; in person), December 5 (partial day; teleconference), January 16 (partial day; teleconference), and February 20 (all day; in person).

2. DEVELOPING PERFORMANCE MEASURES TO EVALUATE AQUATIC AND RIPARIAN COMPONENTS

2.1. Overview

The ARTSG developed performance measures (PMs) to evaluate how the water management alternatives will affect aquatic and riparian issues. The steps to develop and apply PMs were:

1. Develop a list of important aquatic and riparian issues;
2. Conduct an initial screening exercise to remove issues from the list for which: a) there is no mechanism for water management alternatives to cause an effect, or; b) other issues provide a suitable proxy;
3. Develop PMs for each issue based on available data and expert opinion of the ARTSG;
4. Calculate PM values for the bookend alternatives that encompassed the range of potential outcomes. Conduct a shortlisting process to screen out PMs that: a) are insensitive to the range of alternatives (the PMs do not need to be considered when making a decision), or; b) provide results that are highly correlated with other PMs (the PMs are redundant and do not provide useful unique information that needs to be considered when making a decision).
5. Present results for the shortlisted PMs using plots and tables to help the PAG evaluate strengths and weaknesses of each alternative, and trade-offs among alternatives.

The environmental issues and corresponding performance measures are summarized in Table 2. Sections 2.2 and 2.3 below describe the screening process outlined above.

Table 2. Summary of environmental issues and performance measures (PMs).

River/Lake Issue	Name	Species	Focus	Status
Cowichan River Performance Measures				
Water Quality	n/a	All	Water temperature	Grey
Geomorphology	PM1a: # yrs exceeding median peak flow	All	Channel maintenance	Dark green
	PM1b: mean # days/yr exceeding median peak flow	All	Channel maintenance	Dark green
	PM2: mean # days/yr > 200% MAD	All	Flushing flow	Dark green
Connectivity (lateral)	PM1: side channel connectivity	All	Sidechannel connectivity with mainstem	Light green
	PM2: relative side channel discharge	All	Sidechannel discharge	Dark green
Biology - fish passage	PM1a: CH smolt outmigration	Chinook	Fish passage - Chinook	Dark green
	PM1b: CH adult summer-run	Chinook	Fish passage - Chinook	Light green
	PM1c: CH adult fall-run	Chinook	Fish passage - Chinook	Light green
	PM2a: CO smolt outmigration	Coho	Fish passage - Coho	Dark green
	PM2b: CO adult	Coho	Fish passage - Coho	Dark green
	PM3a: CM fry outmigration	Chum	Fish passage - Chum	Dark green
	PM3b: CM adult	Chum	Fish passage - Chum	Dark green
Biology - salmonid rearing	PM1a: ST fry	Steelhead	Fish habitat - juvenile rearing habitat	Dark green
	PM1b: ST parr	Steelhead	Fish habitat - juvenile rearing habitat	Light green
	PM2: CH fry	Chinook	Fish habitat - juvenile rearing habitat	Light green
	PM3a: CO emergent fry	Coho	Fish habitat - juvenile rearing habitat	Dark green
	PM3b: CO rearing fry	Coho	Fish habitat - juvenile rearing habitat	Dark green
	PM4: invertebrates	Invertebrates	Invert habitat - rearing hab; PM uses IFS hab rating curve	Dark green
Biology - salmonid spawning	PM1a: early spawning	Steelhead	Fish habitat - spawning habitat	Dark green
	PM1b: early incubation	Steelhead	Fish habitat - incubation habitat	Light green
	PM2a: late spawning	Steelhead	Fish habitat - spawning habitat	Dark green
	PM2b: late incubation	Steelhead	Fish habitat - incubation habitat	Dark green
Biology - wildlife and riparian	PM1: riparian habitat area	Wildlife/riparian	Relative loss of permanent riparian habitat area along shoreline	Dark green
	PM2: cottonwood germination	Wildlife/riparian	Cottonwood community	Dark green
	PM3: amphibians and water shrew	Wildlife/riparian	Water dependent wildlife species (amphibians, American water shrew)	Grey
	PM4: terrestrial predation	Wildlife/riparian	Terrestrial and avian spp. (herons, cormorants, weasels, racoons) prey on fish stranded in shallow or isolated areas	Grey
	PM5: invasive species	Wildlife/riparian	Flooding of the channel banks aids in the dispersal of plant propagules (Japanese knotweed, yellow flag iris, Eurasian milfoil)	Grey
Cowichan Lake Performance Measures				
Connectivity (lake tributaries)	n/a	All	Tributary connections to lake	Grey
Water quality	PM1a: # yrs with drawdown below zero	All	General lake WQ indicator	Grey
	PM1b: annual mean WQ risk score	All	General lake WQ indicator	Grey
Biology - Vancouver	PM1: annual availability of lamprey rearing habitat (qualitative assessment)	Lamprey	Vancouver Lamprey rearing habitat	Light green
Biology - lake littoral habitat	PM1a: availability of littoral rearing habitat	Fish	Littoral habitat area	Dark green
	PM1b: availability of littoral rearing habitat	Fish	Littoral habitat area	Dark green
	PM2a: productivity of littoral rearing habitat	Fish	Littoral habitat productivity	Light green
	PM2b: productivity of littoral rearing habitat	Fish	Littoral habitat productivity	Dark green
Biology - wildlife and riparian	PM1: riparian habitat area	Wildlife/riparian	Relative loss of permanent riparian habitat area along shoreline	Dark green
	PM2: amphibians	Wildlife/riparian	Water dependent wildlife species (amphibians, American Water Shrew)	Grey

Grey	Scoped out during initial screening
Dark green	PM (or proxy) developed but screened out during PM shortlisting
Light green	PM shortlisted and used to evaluate final results

2.2. Initial Screening

Based on initial screening, the following environmental issues were removed from further consideration:

Water quality (river): The ARTSG recognized that water quality is an important component of riverine habitat; however, this issue was screened out for further consideration because the ARTSG concluded that there was no pathway of effect for the potential water management operations to affect water quality in the river. The ARTSG recognized that water temperature is a particularly important component of river water quality because river water temperatures in the summer and early fall are undesirably high from a fisheries perspective. The ARTSG identified that deep-water (hypolimnetic) withdrawal from the lake has the potential to alleviate these adverse conditions; however, the ARTSG determined that this water management option was not within the scope of options that the PAG had been asked to consider.

Wildlife and riparian (river): The ARTSG identified five separate riverine wildlife and riparian sub-components that could be affected by changes in flows generally (Table 2). The ARTSG agreed that two of these sub-components would be encompassed by an existing PM, while the remaining three sub-components did not need to be considered further. Specifically, the ARTSG agreed to the following:

- Riparian habitat area: Use Lateral Connectivity PM 1 as a proxy;
- Cottonwood germination: Use Geomorphology PM 2 as a proxy;
- Amphibians and American Water Shrew: Limiting habitat for these species is not in the river so the operations do not have potential to affect these species;
- Terrestrial predation: Low flows would benefit terrestrial predators. A PM is unnecessary because the ARTSG does not support promoting alternatives that increase predation on fish, and;
- Invasive species: The spread of the most pernicious species is related to peak flows, which generally occur outside of the weir control period.

Based on this, separate PMs were not developed to evaluate riverine wildlife and riparian issues in the river.

Connectivity in lake tributaries: The ARTSG agreed that this is an important issue but it is insensitive to the operational changes that were being considered.

Water quality (lake): The ARTSG identified three potential pathways of effect: 1) inundation of potential pollution sources on the lake shoreline; 2) change in lake productivity due to change in water residence time, and; 3) change in water quality due to erosion of the exposed shoreline following drawdown.

The first pathway was screened out because the alternatives would not increase the annual maximum lake elevation, which occurs outside of the control period. The second pathway was screened out based on reviewing the outcomes of water residence time analysis. A draft PM was developed to evaluate the third pathway; however, this PM was not applied because the ARTSG decided that the magnitude of the risk was low and therefore this issue should not be identified as a focus for the PAG. The ARTSG also acknowledged that this risk could not be precisely quantified.

Wildlife and riparian (lake): The ARTSG agreed that a PM was unnecessary for amphibians because the proposed alternatives were considered not to pose a risk to these species; instead, they may improve condition by inundating riparian areas in the spring.

2.3. Short-listing Performance Measures

PMs were "winnowed" to produce a shortlist of PMs that could be used for effective decision-making, recognizing that it is difficult for the PAG to evaluate trade-offs among a large number of PMs. The PMs were short-listed based on the two steps described below to examine sensitivity and redundancy.

PMs were first reviewed to identify those that are insensitive to the bookend alternatives. Sensitivity was quantified by expressing the range in calculated PM values as a percentage of the maximum value. Values ranged from 0% to 100%. Based on this analysis, two PMs were screened out from further consideration as sensitivity was 0%. One additional PM with low sensitivity (15%) was also screened out.

The remaining PMs were then reviewed to identify PMs that were redundant because they were highly correlated with other PMs, meaning that it was reasonable to retain only one of the correlated PMs for decision-making. Correlated PMs were identified by reviewing pairwise scatterplots and reviewing Pearson correlation coefficient values. A Pearson correlation coefficient value of 0.80 was used as a threshold above which PMs were defined as redundant; however, in all cases, judgements were informed by reviewing scatterplots, with PMs retained in some cases if the relationships were non-linear. Decisions regarding which PMs to retain or screen out were reviewed by the ARTSG to ensure that the final shortlist adequately encompassed the range of biological values that were considered important.

Thus, no PMs were screened out at this stage because they were considered to be of lesser biological importance; instead, PMs were only screened out if the ARTSG determined that it would not be helpful for the PAG to consider them. Further, the PAG was advised that values of all original PMs could be provided at any time throughout the process.

The final shortlists of PMs for the lake and river are presented below.

Cowichan River:

- Connectivity PM 1a (juvenile Chinook and Coho)

- Fish Passage PM 1b (adult summer Chinook) and PM 1c (adult fall-run Chinook migration)
- Rearing PM 1b (steelhead parr) and PM 2 (Chinook fry)
- Spawning PM 1b (early steelhead incubation)

Cowichan Lake:

- lamprey PM (qualitative only)
- littoral habitat PM 2a

Table 3 describes the shortlisted PMs, including specifications of the calculation periods, i.e., the periods of the year that were analyzed. For each PM, information sheets are also appended; these provide conceptual background to each issue and precise details each PM calculation.

Table 3. Descriptions of final shortlist of performance measures.

Issue	Performance Measure Name	Units	Preferred Direction	Description
Cowichan River PMs				
Connectivity	PM 1b: Side channel connectivity (juvenile Chinook Salmon and Coho Salmon)	%	↑	The Cowichan River has important lateral habitats such as side channels that are important for fish, especially juvenile life stages. Low flows can cause these habitats to become disconnected from the mainstem, adversely affecting fish. This PM represents the estimated proportion of side channels that are connected to the mainstem at a specific flow, based on surveys. This PM relates to the requirement for side channel connectivity during Chinook Salmon and Coho Salmon rearing and smolt outmigration in the spring for the period from April 1 to June 15. During this period, emergent Chinook Salmon fry are rearing in lateral habitats and Coho Salmon smolts are migrating from lateral habitats to the mainstem. This PM is calculated as the 10th percentile of the values for each year to characterize lateral connectivity during relatively low flow conditions for that period of the year.
Fish Passage	PM 1b: Adult summer-run Chinook Salmon migration PM 1c: Adult fall-run Chinook Salmon migration	Habitat suitability index	↑	Provides a measure of habitat suitability based on estimated relationships between flow and suitability for fish passage. Relationships and calculation periods vary among species and life history stages. The adult summer-run Chinook Salmon PM is calculated for the period April 1 to July 31 and adult fall-run Chinook Salmon PM is calculated for the period September 1 to November 30. This PM is calculated as the 10th percentile of the values for each year to characterize fish passage during relatively low flow conditions for that period of the year.
Rearing	PM 1b: Steelhead parr	Habitat suitability index	↑	Provides a measure of habitat suitability based on estimated relationships between flow and suitability of rearing habitat. Relationships and calculation periods vary among species and life history stages. The steelhead parr PM is calculated for the period March 1 to December

Issue	Performance Measure			
	Name	Units	Preferred Direction	Description
	PM 2: Chinook Salmon fry			31 and the Chinook Salmon fry PM is calculated for the period March 1 to April 30. These PMs are calculated as the 10th percentile of the HSI values for each year to provide a focus on periods when habitat is likely to be limiting; however, fish are expected to tolerate short periods of restricted rearing habitat availability.
Spawning	PM 1b: Early steelhead incubation	Habitat suitability index	↑	Provides a measure of habitat suitability based on estimated relationships between flow and suitability of spawning/incubation habitat. This PM relates to incubation habitat constraints to the progeny of early-spawning steelhead. This curve spans flows that are sufficiently high for redds to remain wetted and maintain suitable hydraulic habitat characteristics. This PM is calculated for the period January 15 to March 31 and as the 10th percentile of the HSI values for each year.
Cowichan Lake PMs				
Vancouver Lamprey (Lake)	Lamprey rearing habitat	N/A	↑	Vancouver Lamprey productivity is assumed to be proportional to the area of lamprey rearing habitat in Cowichan Lake. Higher lake levels are assumed to provide more habitat and lower lake levels less habitat. There is not enough known about the specific habitat use and influences of reduced habitat value on the overall abundance of Vancouver Lamprey to develop a relationship between lamprey productivity and lake elevation at this time. At this stage, potential impacts to lamprey will be considered qualitatively when comparing alternatives.
Littoral Habitat	PM 2a: Productivity of littoral rearing habitat	Relative Productivity score	↑	Relative Productivity score that provides an index of littoral habitat productivity based on lake elevation. This PM is calculated for the control period from April 1 to November 5. The minimum value is used to provide a measure of the ecologically poorest conditions that occur each year.

Appendix F: Description of issues for consideration in the Cowichan Water Use Plan

Table F-1: Traditional Use, Culture and Heritage

Issue	Description	Cowichan WUP Relevance
Access for spear fishing	The concern was raised that safe access to Skutz Falls for spear fishing could be prohibitively dangerous if high flow levels occur earlier in fall. A review of the hydrology modeling across the bookend alternatives did not show any noticeable increases in river flows during the fall period. While important, this issue is not expected to be affected across the water use alternatives that were considered.	This issue was documented during the Cowichan WUP.
First Nations FSC Rights	First Nations right to access salmon for FSC purposes is a constitutional right (i.e. not like other interests). Potential impacts on First Nations access and opportunities for harvesting fish (for FSC purposes) are tied to taking the best care of the fish and ecosystem.	This issue was documented during the Cowichan WUP. The Fish PMs were used as a proxy for this issue area.
Lost cultural knowledge	Lack of water limits access to fish in river in fall and spring (early chinook run), which in turn results in less people fishing and loss of cultural knowledge. These potential impacts are directly tied with First Nations harvesting opportunities and impacts on aboriginal fisheries.	This issue was documented during the Cowichan WUP. The Fish PMs were used as a proxy for this issue area.
Ceremonial bathing / cultural practices	Lack of water impacts adequate flows and access to practice ceremonial bathing and other cultural practices. Whether there could be impacts on this interest depends on the timing and location of these cultural practices and whether potential changes in river flows across the alternatives would lead to adverse effects.	Led to an objective and a placeholder for the creation of a ceremonial bathing performance measure.
Archaeological sites	Important lake sites could be submerged by higher levels, and important river eroded with higher river flows. Based on the hydrology modeling of the bookend alternatives, it was shown that increased summertime lake levels (i.e., +1.0m) are below the normal high water lake level and considerably lower than lake levels during the winter time and late fall period, and that river flows are not associated with any increases in river levels compared to historical and current levels. Accordingly archaeology sites are not expected to be affected by the water use alternatives.	This issue was documented during the Cowichan WUP.
Heritage River Status	The concern was raised that the Cowichan River's Heritage status could be affected by proposed water use alternatives. This depended on the outcome from the planning process (supported alternatives and recommendations). The WUP planning process strove to minimize and balance potential impacts to the natural, cultural and recreational values which the Cowichan River's Heritage River designation is based on. No specific action in relation to this issue was required for during the public planning phase of the WUP planning process.	This issue was documented during the Cowichan WUP.
Naturalness	Concern was raised that increased manipulation of a permanent pumphouse and increased technological dependency could reduce natural ability of the river. It was also recognized that the Cowichan is already a heavily managed and has not be operating as a natural system since construction of the original weir in the 1950s. All alternatives explored during the WUP planning process included some form of water management infrastructure. No specific action in relation to this issue was required for during the public planning phase of the WUP planning process.	This issue was documented during the Cowichan WUP.

Table F-2: Environment

Issue	Description	Cowichan WUP Relevance
RIVER: Geomorphology	Changes in the frequency and duration of high flows can cause changes in river geomorphology (i.e., channel maintenance and shape), which could have adverse environmental effects. PMs developed to assess impacts to channel maintenance and flushing flow frequency were shown to be insensitive to the alternatives and they were therefore not shortlisted. This reflects that high flows generally occur outside of the control period.	Led to an objective and development of PMs.
RIVER: Erosion	The concern was raised that there are ongoing erosion issues along the river which can affect water quality and fish habitat. Erosion effects were partly considered by assessing changes to river geomorphology. Also, erosion is greatest outside of the control period and is therefore largely out of the operational influence of the Cowichan WUP.	This issue was documented during the Cowichan WUP.
RIVER: Fish passage / migration (upstream and downstream)	Some migration barriers in the Cowichan River are flow dependent, meaning that upstream or downstream migration of fish is hindered or prevented at low or high flows. The potential for a fish to pass a barrier at a specific flow varies among species and life stages. Fish passage is relevant to upstream migration of adult salmon and steelhead, as well as downstream migration of smolts in the spring. There is presently a data gap in information regarding the run timing of spring/summer Chinook Salmon.	Led to an objective, development of PMs, and a recommendation for a monitoring study.
RIVER: Sedimentation	Sedimentation is an issue in the river, i.e., aggradation of gravel that is mobilized during high flow events, predominantly in the winter. This is particularly a concern in the lower river as sediment is transported downstream through the watershed over multiple years. Sedimentation can adversely affect fish habitat and impede fish passage.	Concerns about this issue were captured in the geomorphology and fish passage PMs.
RIVER: Lateral fish habitat	Cowichan River has important lateral habitats such as side channels that are important for fish, especially juvenile life stages. Such areas provide important rearing and overwintering habitat for salmonids. Lateral connection with tributaries is also necessary for fish to access spawning habitats. Low flows can cause these habitats to become disconnected from the mainstem, adversely affecting fish. Information on side channel and tributary connectivity in the Cowichan River is available from an analysis undertaken using data collected at 35 side channels in the 1980s.	Led to an objective, development of PMs, and a recommendation for a monitoring study to update the dataset and analysis.
RIVER: Rearing habitat	The availability of rearing habitat for fish and invertebrates in the Cowichan River varies depending on flow. Conditions that maximize the area of suitable rearing habitat typically occur over a narrow range of flows that are specific to a given species and life history stage. Outside of this optimum flow range, habitat availability can decline rapidly, particularly as flows decline towards zero. There are limitations in the current understanding of the relationship between spring rearing conditions and juvenile survival of Chinook Salmon.	Led to an objective, development of PMs, and a recommendation for a monitoring study.
RIVER: Spawning habitat	Changes in flows can affect access of fish to spawning habitat and the quality of spawning habitat. Reductions in flow during incubation can dewater redds, causing mortality of eggs and alevins. Effects relating to access to spawning habitats by adult fish are considered separately in relation to fish passage.	Led to an objective and development of PMs.
RIVER: Wildlife / riparian	Changes in flow can affect riparian habitats and associated wildlife. For example, changes in flow can affect riparian habitat area. The ARTSG identified five separate riverine wildlife and riparian sub-components that could be affected by changes in flows generally: 1) riparian habitat area; 2) cottonwood germination; 3) amphibian and American Water	Led to an objective. These issues were considered to be captured by existing PMs or not to be impacted by the water use alternatives.

Issue	Description	Cowichan WUP Relevance
	Shrew breeding; 4) feeding by terrestrial predators, and; 5) colonization of invasive plant species.	
RIVER: Water temperature	Water temperatures in the Cowichan River are high during the summer, which poses a biological risk, e.g., to rearing salmonids. The concern was raised that water temperatures in the river are affected by changes in flow and increased groundwater abstraction. The likelihood of the alternatives to cause changes in water temperature was discussed by the ARTSG. Water temperature was considered to be insensitive to the alternatives. Further, groundwater contributes a small fraction of the overall flow in the river. Therefore, any increases in water abstraction were not expected to interact with the alternatives to cause significant changes in river water temperature.	This issue was documented during the Cowichan WUP.
RIVER: Estuary	Low flows in summer could negatively impact the estuarine ecosystem, e.g., due to higher salinity, creation of fish passage barriers, increased predation on fish, or changes to eelgrass habitat. The ARTSG considered these issues during initial scoping and discussed conducting analysis if required. Ultimately, the ARTSG agreed that it was unnecessary to consider these issues further because the alternatives would increase summer flows, relative to the status quo.	This issue was documented during the Cowichan WUP and is either considered to be captured by existing PMs or not considered to be negatively impacted by the water use alternatives.
RIVER: Fish stranding	Rapid decreases in river flow can strand fish, potentially causing mortality. The ARTSG recognized that current ramping rates are considered precautionary, but considerable water savings may be achieved if ramping requirements are relaxed to allow faster ramping. The ARTSG recommended that a quantitative ramping study be undertaken to support evaluations of the trade-off between stranding risk and reliability of target flows.	This issue was documented during the Cowichan WUP and led to a recommendation for a study.
LAKE: Fish passage	The ARTSG considered the potential for changes to the elevation of Cowichan Lake to affect passage of fish such as juvenile Coho Salmon in lake tributaries. The ARTSG determined that connectivity of lake tributaries is an important issue but it is not strongly related to lake level and is therefore insensitive to the alternatives. Instead, tributary connectivity is primarily influenced by stream flow and gravel accretion in the tributaries.	This issue was documented during the Cowichan WUP.
LAKE: Fish habitat (salmonids)	Nearshore habitats are important for salmonid rearing and kokanee spawning. Lake drawdown can reduce the area and quality of nearshore (littoral) habitats, with the magnitude of the decline in habitat quality diminishing as the shoreline retreats from the existing riparian zone. A lack of bathymetry data was an obstacle to evaluating this issue.	Led to an objective and development of PMs, and a recommendation for a monitoring study to address knowledge gaps.
LAKE: Vancouver Lamprey	Vancouver Lamprey is listed under the *Species at Risk Act* as Threatened. The species is only found in Cowichan, Mesachie and Bear lakes, and their tributaries. Changes in lake levels likely compress the area of available spawning and rearing habitat for Vancouver Lamprey, such that higher lake levels provide more habitat and lower lake levels less habitat. Changes in habitat are assumed to have potential impacts to the species; however, there is limited information about Vancouver Lamprey biology, including habitat use and life history, to quantify potential impacts.	Led to an objective, development of a PM, and a recommendation for a study to address knowledge gaps.
LAKE: Amphibians	Changes to lake level can affect amphibian habitats in riparian and littoral areas. The WUP alternatives were considered not to pose a risk to amphibian species. Instead, they may improve condition by inundating riparian areas in the spring.	This issue was documented during the Cowichan WUP
LAKE: Water quality	Two mechanisms by which water management operations in general could affect lake water quality were identified: 1) inundation of potential	Led to an objective and development of a PM.

Issue	Description	Cowichan WUP Relevance
	pollution sources such as septic tanks or log storage areas, and; 2) erosion of exposed shoreline following drawdown. The ARTSG scoped out the need to assess the first mechanism for the Cowichan WUP because the alternatives would not increase the annual maximum lake elevation, which occurs outside of the control period. A draft PM was developed to evaluate the second mechanism; however, the magnitude of the risk was considered to be low and therefore not a focus for the Cowichan WUP.	
LAKE: Pelagic Productivity	In theory, changes to lake levels could affect pelagic production in the lake due to changes in residence time that affect plankton flushing rates. Based on a review of the outcomes of water residence time analysis for Cowichan Lake, the ARTSG scoped out this issue for further consideration for the Cowichan WUP.	This issue was documented during the Cowichan WUP.
LAKE: Terrestrial habitat and wildlife	In theory, changes to lake level could affect terrestrial habitats and wildlife. Based on a review of lake water level projections for the bookend alternatives, the ARTSG agreed that this issue would not be affected and scoped it out for further consideration for the Cowichan WUP.	This issue was documented during the Cowichan WUP.
General: Environmental sustainability	Water management strategies should all be viewed through the lens of environmental sustainability.	Goal to seek a sustainable and balanced water management recommendation for the Cowichan WUP.

Table F-3: Industrial and Commercial

Issue	Description	Cowichan WUP Relevance
Catalyst Paper	Concerns were expressed in relation to meeting minimum river flows to provide water for industrial operations at the Crofton mill and that an improved level of water security for Catalyst mill operations is important in the face of climate change.	Led to an objective and development of a PM.
Groundwater Wells	Concerns were raised relating to the potential of aquifer drawdown as a result of groundwater withdrawals and the associated impacts to surface water flows during low flow season. A groundwater modelling study carried out for the lower Cowichan River indicates that current pumping rates result in an insignificant change in river flows. Increasing pumping rates by 10 times the current pumping rate results in a flow reduction of less than 20% in the river during summer baseflow period. Flow monitoring studies carried out by the Ministry of Environment have been inconclusive on whether any reduction in river flow can be directly attributed to pumping in the underlying aquifer.	This issue was documented during the Cowichan WUP.
Agriculture / irrigation	Concerns were raised relating to increased water use by agriculture for increased local food production and the surface water-groundwater interaction at irrigation wells within close proximity of river tributaries, including the impacts of decreased river flows on irrigation and agriculture / local food growing abilities in the region. The surface water-groundwater hydrological interface is complicated in terms of estimating the degree to which aquifer levels could be affected through decreased river flows (see above).	This issue was documented during the Cowichan WUP.

Issue	Description	Cowichan WUP Relevance
Fish Hatcheries	Concerns were raised relating to production and injection wells. It was expressed that there should be no net groundwater loss and that injection water should be monitored and strictly regulated for groundwater protection. Monitoring and regulations of groundwater is outside the scope of the Cowichan WUP.	This issue was documented during the Cowichan WUP.
Commercial Fisheries	The commercial value of recreational fisheries was noted. FLNRORD's perspective is that commercial benefits are derived from taking the best care of the fish and ecosystem.	This issue was documented during the Cowichan WUP. The Fish PMs were used as a proxy for this issue area.

Table F-4: Lakefront Properties, Flooding, and Erosion

Issue	Description	Cowichan WUP Relevance
LAKE: Flooding and Inundation	Concern was raised regarding the potential for flooding and/or inundation of lakefront properties and areas as a result of higher lake levels. This included loss of property use, aesthetic concerns, and property damage (e.g., septic fields, homes, secondary structures, campsites at the western end of lake, etc.). An earlier control period and an increased weir height could increase the maximum level in the lake during potential spring flooding events. Lake levels at the end of the control period could influence the first fall peak and increase flood risk associated with fall storms. Concern was raised regarding the potential for inundation of lakefront areas and private properties as a result of higher spring and summer lake levels. Inundation effects related to the degree (extent of inundation area) and duration of time that areas are inundated. The extent of inundation effects related the storage of water in relation to the "natural boundary" for determining where lakefront property rights begin and where compensation may be warranted if water were to be stored above this point. This is a complicated issue around Cowichan Lake for multiple reasons, including that the natural boundary is dynamic (varies according to soil type, vegetation, exposure, gradient, erosion, etc.) and there has been differences in interpretation over the past 60 years.	Led to objectives, development PMs, supplemental analyses, design considerations for the water use alternatives, and supporting recommendations for the Cowichan WUP.
RIVER: Flooding and Inundation	Flooding and/or inundation of riverfront properties as a result of higher river levels. Based on the hydrology modelling, high river flows are not expected to increase during the control period. Accordingly, the water use alternatives considered should not increase in downstream high flow events that could result in seepage, inundation or flooding of downstream areas (below the lake). Concerns for increased logjams and debris jams by bridges/trestles related to river flooding and inundation that could cause increased flooding risk are considered outside the scope of the WUP.	This issue was documented during the Cowichan WUP.
Weir / Dam Failure	Concerns were expressed that a raised weir would fail and pose increased flooding risks downstream. The safety and standards of any new infrastructure is governed by other legislation and registrations.	This issue is considered outside the scope of the Cowichan WUP.
LAKE: Erosion	Concerns were raised regarding potential for changes to the erosion zone (levels, wave action, or rate of changes in lake levels), the effects on property loss / aggregation, and the potential for impacts on riparian and littoral plant communities. This is very hard to assess across a range of alternatives (and may need to rely on professional opinion). A shoreline erosion assessment for Cowichan Lake (Kerr Wood Leidal, 2014) was reviewed to help characterize this issue for the Cowichan WUP process. It was concluded that there are uncertainties with respect to increased risk	This issue was documented during the Cowichan WUP and led to a recommended study upon implementation.

Issue	Description	Cowichan WUP Relevance
	of erosion. Given this result, a post WUP study to assess and address potential erosion risk was recommended.	
LAKE: Private Property Lakefront Areas	Concerns were raised about the potential loss of exposed lakefront areas for aesthetic and property value impacts, including effects on adjacent private or public lakefront areas. This issue is linked to loss of property use of property rights and is captured under inundation, recreational beach areas and recreational lake aesthetic issues.	Led to an objective and development of a PM.
LAKE: Private Lakefront Beaches	Higher summer time lake levels could reduce and significantly affect the size, accessibility and use of the private beaches (or public beaches) in front of lakefront properties.	Led to an objective and development of a PM (under general recreation category).
LAKE: Docks and Wharves	Changes in lake levels should not require modifications or damage to lakefront structures including docks and wharves. Potential impacts from higher lake levels scoped out as the alternatives were within the current annual range. Alternatives evaluated later in the process were designed to minimize lake level drawdowns and impacts on navigation and the use of docks and wharves (located in shallow areas) was accounted for under the recreational performance measures.	Led to an objective and a placeholder for PMs.
LAKE: Water pump intakes	Dropping lake levels could affect the reliable access of water supply from private and municipal pumps that have their intakes in the lake	Led to an objective. The municipal water supply PMs were used as a proxy for this issue.

Table F-5: Municipal Water Supply

Issue	Description	Cowichan WUP Relevance
RIVER / AQUIFERS: Drinking Water Supply	The concern was raised regarding water supply reliability for municipal systems to ensure adequate access to drinking water, taking into account surface water to groundwater connectivity and the potential need to protect aquifers for municipal and rural wells along river corridor. This issue was raised relating to both impacts to the river from water supply withdrawals and impacts to water supply from changes in river flow. The surface water-groundwater hydrological interface is complicated in terms of estimating the degree to which aquifer levels could be affected through decreased river flows (as described above). The estimated loss of river flows to recharge aquifers down the length of the river is a small fraction of the total volume of water flowing down the river. Accordingly, the likelihood that domestic drinking water supply from aquifers will be affected in any meaningful way, is quite small. The municipal water systems for North Cowichan and Duncan withdraw from groundwater. The current maximum withdrawal is about 0.3cms, and the projected increase in demand for the 2050s is about 55% (based on North Cowichan's annual growth rate of 1.3%) to about 0.45cms. While some of this water likely comes from the river, it is difficult to know exactly how much. Population growth was incorporated into potential impacts of different alternatives on future water demand. The amount of water withdrawn for community water supply is relatively small in comparison to that required for environmental river flows.	This issue was documented during the Cowichan WUP.
LAKE: Drinking Water Supply	Concern was raised with respect to impacts from lower lake levels on the Town of Lake Cowichan water supply intake.	Led to an objective and development of PMs.

Issue	Description	Cowichan WUP Relevance
	Town of Lake Cowichan withdrawals water directly from the Cowichan Lake to supply municipal water service. Projected Increase in Water Demand is about 60% for 2050s (Lake Cowichan annual growth rate of 1.5%). Current maximum average monthly water withdrawal is 0.032cms which occurs in August. By 2050s this is projected to increase to 0.05cms. These water withdrawals were considered minor relative to other withdrawals from the river and were not included as part of the assessment.	The water withdrawals for Lake Cowichan were documented during the Cowichan WUP but not included as part of the assessment.
LAKE: Drinking Water Quality	Concerns were raised about potential impacts to drinking water quality for Cowichan Lake associated with lake level drawdowns. Catalyst's Environmental Management Plan for pumping during drought conditions considered impacts of pumping activities to achieving water quality objectives; impacts were not anticipated for lake water quality.	This issue was documented during the Cowichan WUP.
LAKE and RIVER: Sewerage Infrastructure	Concern was raised for sewage back-ups/overflow from increased lake levels. A review of the hydrological modeling of lake levels across the bookend alternatives did not show any difference in lake levels above the normal high water level. River levels are greatest outside of the control period when water is not being managed. Accordingly, this issue was not expected to be affected through the WUP alternatives.	This issue was documented during the Cowichan WUP.
RIVER: Wastewater Dilution	Concerns were raised regarding potential adverse effects caused by discharging wastewater during lower flows; these included reduced water quality for aquatic life, algae blooms caused by warmer conditions, and drinking water impacts. Currently, wastewater from the Town of Lake Cowichan is discharged to the upper river, while wastewater from the Municipality of North Cowichan, the City of Duncan, Cowichan Tribes, and Areas D and E of the CVRD is discharged to the lower river via the Joint Utility Board Sewage Treatment Plant (JUB STP) outfall. There is a need to ensure adequate flows to dilute wastewater effluent discharges in the upper and lower river at low flow periods while accounting for population growth into future waste water dilution requirement estimates. Note: While the JUB STP outfall is expected to be relocated to Cowichan Bay (~4 years in future), the intent is to maintain the existing outfall as an overflow/emergency outfall (as an emergency measure). This issue would be assessed independently during that EA.	Led to an objective and development of PMs.

Table F-6: Recreation and Tourism

Issue	Description	Cowichan WUP Relevance
LAKE: Aesthetics	Lower (or more variable) lake levels could potentially result in visual and aesthetic impacts. Concerns from visual quality perspective include a "bathtub ring" associated with lake levels dropping below historical levels in summer/early fall.	Led to an objective and development of a PM.
LAKE: Recreation Beach Use Areas	Higher (and possibly lower) summertime lake levels affecting the access and usability of beach areas for recreation purposes (both private and public).	Led to an objective and development of a PM.
LAKE: Boat Access / Navigation	Lower lake levels could adversely impact water-based recreation / boating (i.e., safety and navigation) and maintaining the usability of docks/wharves for boating and swimming	Led to an objective and development of a PM.
RIVER: Water based recreation	Tubing and boat use (kayak, canoe) are popular recreation activities on Cowichan river and are limited by low summer flows. Drift boating is also a popular activity, however very rarely is this activity done for reasons other than fishing.	Led to an objective and development of PMs for recreational boating and tubing activities.

Issue	Description	Cowichan WUP Relevance
	Concerns were also raised regarding potential impacts to recreational fishing/angling. Maintaining spring river flows for fish (15-25cms from April-July) also supports recreational fishing opportunities, which in turn provides value to the BC economy. The fish PMs served as a proxy to assess impacts on recreation fishing/angling opportunities.	Fish PMs will be used as a proxy to assess impacts on recreation fishing / angling opportunities.
RIVER: Beach health advisories	Water quality is important in the river for public health and recreational purposes. Low flows are linked to warmer water and more people using the beaches, and beaches have been closed to swimmers/tubers due to fecal coliform issues. Health advisories for Cowichan River beaches were reviewed and no relationship with river flow data was found. There are likely many other variables contributing to river beach water quality (e.g. air temp, number of visitors, pets and wildlife etc.).	This issue was documented during the Cowichan WUP.

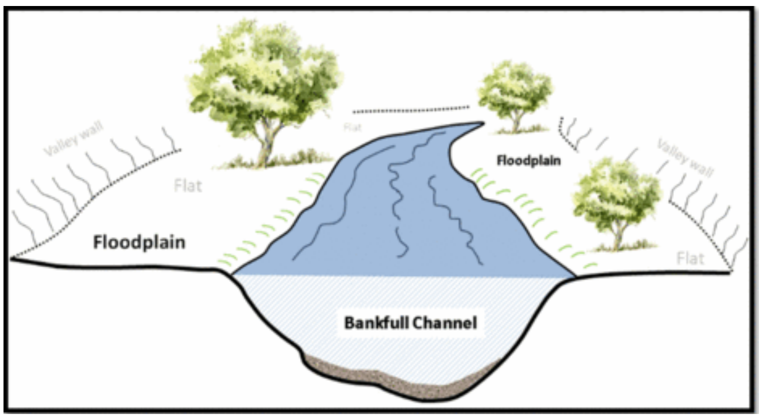
Table F-7: Water Management

Issue	Description	Cowichan WUP Relevance
Infrastructure Capital and Operating Costs	There are capital costs associated with improving or replacing the existing water management infrastructure and the costs associated with weir operations, pump operations, and river monitoring. Concerns were expressed over the potential costs to tax payers, including the potential for increased taxes with new infrastructure.	Led to an objective and development of PMs.

PERFORMANCE MEASURE INFO SHEET: CONNECTIVITY PMS[1]

Component	Performance Measure	Units	Description	MSIC[2]
Connectivity: Lateral connectivity (river)	**PM1: Side channel connectivity**	%	Estimated proportion of side channels that are connected to the mainstem at a specific flow, based on surveys	10%
	PM2: Relative side channel discharge	%	Estimated average discharge in side channels, relative to when mainstem discharge approximates mean annual conditions and all side channels are connected	10%

Figure 1. Schematic to illustrate the concept of lateral connectivity. Floodplain, side channel and tributary habitats become disconnected from the river mainstem below threshold flows.



[1] Longitudinal connectivity for fish is captured in a separate Fish Passage PM info sheet.

[2] Minimum Significant Increment of Change. This is a user-defined value that represents the minimum increment of difference in the performance of two alternatives thought to be significant for decision making. It reflects technical judgments about the precision of modeling as well as value judgments about the magnitude of change that merits decision maker attention when choosing among alternatives. This value is used in the presentation of colour-coded consequence tables to focus attention on significant differences between alternatives.

Performance Measure

This performance measure (PM) group evaluates the potential for management actions to cause lateral channel units (side channels) to become hydrologically disconnected from the mainstem. Such areas provide important rearing and overwintering habitat for salmonids. Lateral connection with tributaries is also necessary for fish to access spawning habitats.

PMs have been developed based on a periodicity table developed for the Cowichan River (McCulloch 2017). This table defines an “active rearing season” of March 1 to December 31 based on the period when mainstem water temperatures are above 7°C on average.

Two sets of PMs have been developed.

PM1: Side channel connectivity

This PM is based on side channel and tributary connectivity analysis (Figure 2) completed by Baillie (2017), based on data collected by Burns et al. (1988). These data were collected by visiting 35 side channels during a range of flows and recording whether each site was connected to the mainstem. The PM is the estimated proportion of side channels that are connected to the mainstem at different flows (Figure 2). The PM is calculated for two separate periods:

PM1a: Side channel connectivity during smolt outmigration

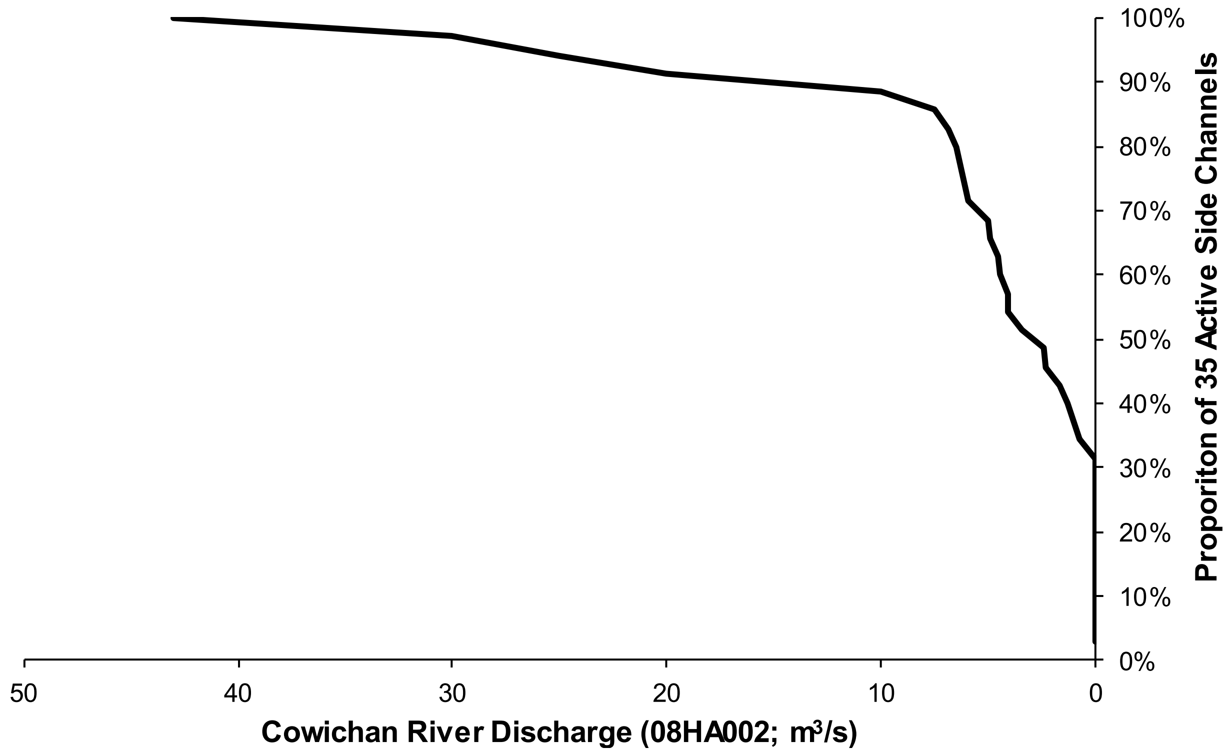
This PM relates to the requirement for side channel connectivity during Chinook Salmon and Coho Salmon smolt outmigration in the spring. During this period, emergent Chinook Salmon fry are rearing in lateral habitats and Coho Salmon smolts are migrating from lateral habitats to the mainstem.

This PM is calculated for the period April 1 to June 15. This is the period when lateral connectivity for these life stages has been identified as particularly important in the Cowichan River (Ayers et al. 2017).

PM1b: Side channel connectivity during salmonid rearing

This PM relates to the requirement for side channel connectivity during the growing season for rearing salmonids such as juvenile Coho Salmon. This PM is calculated for the period March 1 to December 31. This spans the active rearing period.

Figure 2. PM1 is based on lateral connectivity data collected by Burns et al. (1988) and analyzed by Baillie (2017).



PM2: Relative side channel discharge

This PM is based on side channel and tributary connectivity analysis (Figure 2) completed by Baillie (2017), using data collected by Wright and Pellett (2006). These data were collected by visiting 12 of the 35 side channels that were sampled by Burns et al. (1988) and measuring side channel discharge when discharge in the mainstem was: 50.5 m^3/s, 26.5 m^3/s, 21.5 m^3/s and 15.8 m^3/s. For each of the four conditions, discharge in each side channel was expressed as a proportion (%) of the discharge measured in the side channel during the highest flow (mainstem discharge = 50.5 m^3/s). The PM has been developed by fitting a relationship between mainstem discharge and the average of these proportions for the 12 sites. Thus, PM2 provides a more nuanced measure of side channel connectivity than PM1 because it evaluates the potential for changes in mainstem discharge to affect side channel discharge (which is correlated with the area of available habitat), rather than only side channel connectivity.

Consistent with PM1, this PM is calculated for two separate periods:

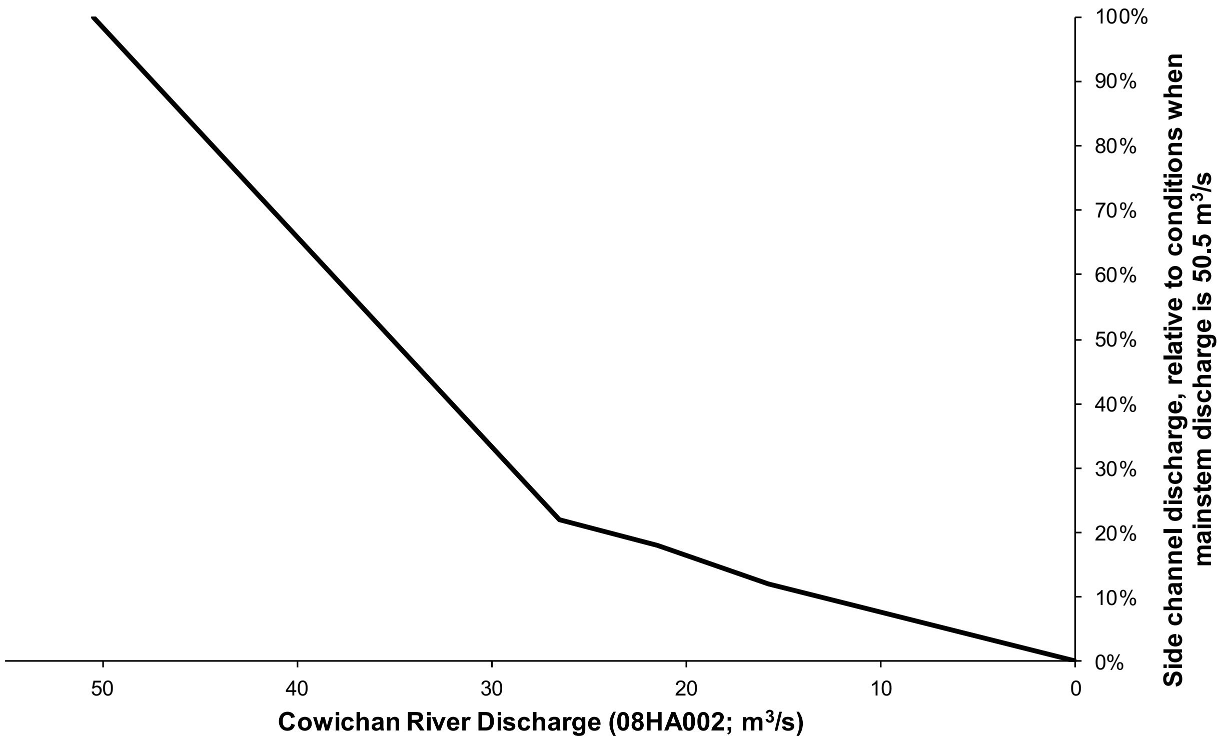
PM2a: Side channel discharge during smolt outmigration

This PM is calculated for the period April 1 to June 15.

PM2b: Side channel discharge during salmonid rearing

This PM is calculated for the period March 1 to December 31.

Figure 3. PM2 is based on lateral connectivity data collected by Wright and Pellett (2006) and analyzed by Baillie (2017).



Interpretation

The output for PM1 is the estimated proportion of side channels that remain connected to the mainstem. The output for PM2 is the estimated average discharge in side channels, expressed as a proportion of side channel discharge when discharge in the mainstem approximates mean annual conditions, and all side channels are flowing. Thus, PM1 provides a measure of connectivity, while PM2 provides a broader measure of habitat availability and reflects that, when mainstem flow declines, flow in lateral habitats decreases at a greater rate. Both PMs should be interpreted relative to the baseline flow regime.

Calculations

This PM group is calculated using several years of mean daily discharge data recorded at the upstream gauge (08HA002), or modelled for that location. Accuracy will be higher with a longer flow series.

The steps to calculate each PM are:

1. trim the flow series to the applicable period
2. calculate the PM value for each day based on mainstem discharge and the relationships presented in Figure 2 and Figure 3
3. calculate the 10th percentile of the values for each year to characterize lateral connectivity during relatively low flow conditions for that period of the year
4. summarize the range of 10th percentile values for each alternative using appropriate statistics, e.g., 10th and 50th percentiles.

Key Assumptions and Uncertainties

Key assumptions and uncertainties in the calculation of this performance measure include:

- **Applicability of historical data:** These PMs are based on fieldwork in 1987 (Burns et al. 1988). There is uncertainty about the extent to which these data are representative of current conditions. Similarly, it is assumed that the side channels that were sampled are representative of side channel habitats in the river generally, although this is uncertain.
- **Conditions in disconnected side channels**: No consideration is currently given to the potential for disconnected side-channels to provide habitat values, although it is recognized that fish can occupy these habitats for a period until they become completely dewatered.
- **Spatial variability in habitat values:** This performance measure does not reflect that some lateral habitats have higher biological values than others.
- **Active growing season:** This was assumed to span the period when mainstem temperatures exceed 7°C on average. This does not account for periods when high temperatures in the summer may constrain growth, or temperature differences between mainstem and lateral habitats.

References

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PERFORMANCE MEASURE INFO SHEET: FISH PASSAGE PMs[3]

Component	Performance Measure	Life Stage	Applicable Timing	MSIC
Fish Passage (Chinook)	PM1a	Chinook Salmon smolt outmigration	May 1–July 15	10%
	PM1b	Adult summer-run Chinook Salmon migration	April 1–July 31	10%
	PM1c	Adult fall-run Chinook Salmon migration	Sept 1–Nov 30	10%
Fish Passage (Coho)	PM2a	Coho Salmon smolt outmigration	April 1–May 30	10%
	PM2b	Coho Salmon adult migration	Oct 1– Dec 31	10%
Fish Passage (Chum)	PM3a	Chum Salmon fry outmigration	March 1–April 30	10%
	PM3b	Chum Salmon adult migration	Oct 1–Dec 15	10%

Performance Measure

Some migration barriers in the Cowichan River are flow dependent, meaning that upstream or downstream migration of fish is hindered or prevented at low or high flows. The potential for a fish to pass a barrier at a specific flow varies among species and life stages.

This performance measure (PM) group quantifies effects on fish passage from management actions that alter flows. The PMs have been developed based on expert evaluation of periodicity information for the Cowichan River (McCulloch 2017) and observations of fish passage success at a range of flows (see Ayers et al. 2017). Performance measures are quantified using suitability scores that range from 0

[3] This PM Information Sheet relates to upstream and downstream fish passage. Lateral connectivity with habitats such as side channels is addressed in the Connectivity PM Information Sheet.

(passage is potentially limiting) to 1 (no passage constraints)[4]. A suitability score value of 0.5 is proposed as a minimum target, with values less than 0.5 of biological concern.

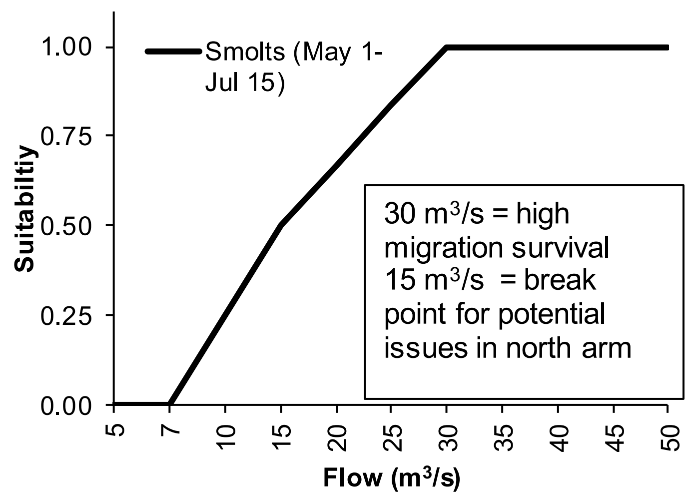
PMs have been developed for three priority species that may be susceptible to passage issues. These are as follows, listed in order of priority: Chinook Salmon (PM1a, 1b, 1c), Coho Salmon (PM2a, 2b), and Chum Salmon (PM3a, 3b).

Seven PMs have been developed.

PM1a: Chinook Salmon smolt outmigration

This PM relates to fish passage constraints to outmigrating Chinook Salmon smolts. A primary concern is low flows in a braided section of the lower river, although low flows are understood to constrain passage throughout the river in general. This PM is calculated for the period May 1 to July 15 (Figure 4).

Figure 4. PM1a: Chinook Salmon smolt outmigration



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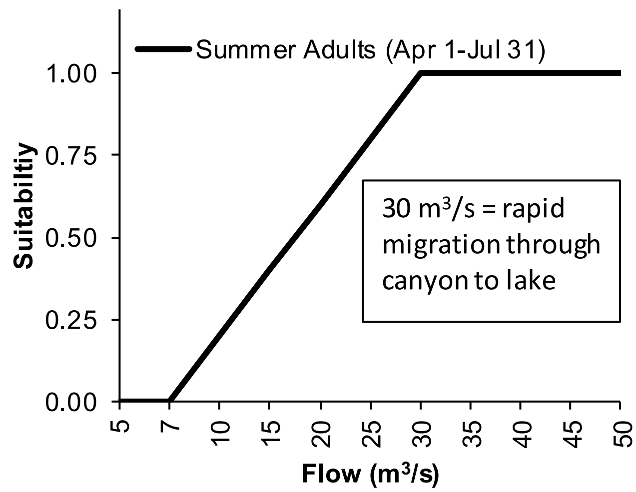
[4] The resulting PM values cannot be interpreted using these criteria because the suitability scores are modified during PM calculation as part of a weighting procedure to reflect run-timing distribution (see 'Calculations' section).

PM1b: Adult summer-run Chinook Salmon migration

This PM relates to fish passage constraints to adult summer-run Chinook Salmon caused by low flows in Marie Canyon. This PM is calculated for the period April 1 to July 31 (Figure 5). Relative to the corresponding PM for fall-run fish (PM1c), this PM yields lower suitability at low flows. This is because summer-run fish enter the river in mid-spring/early-summer when flows are generally declining. These fish therefore need to migrate relatively rapidly through Marie Canyon (a low flow barrier) to avoid being isolated downstream.

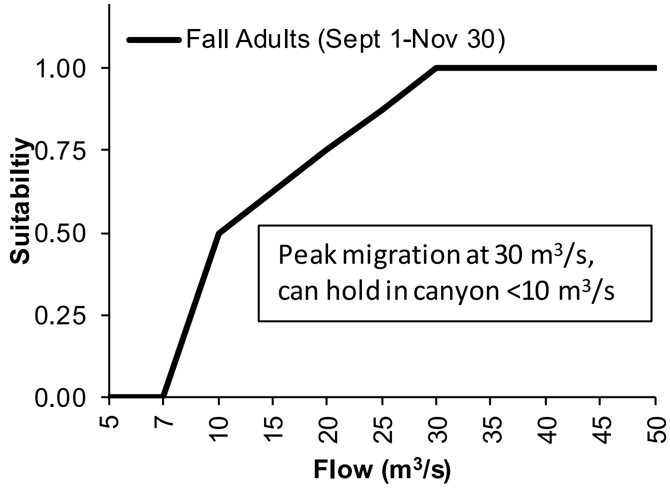
Figure 5. PM1b: Adult summer-run Chinook Salmon migration



PM1c: Adult fall-run Chinook Salmon migration

This PM relates to fish passage constraints to adult fall-run Chinook Salmon caused by low flows in Marie Canyon. This PM is calculated for the period September 1 to November 30 (Figure 6).

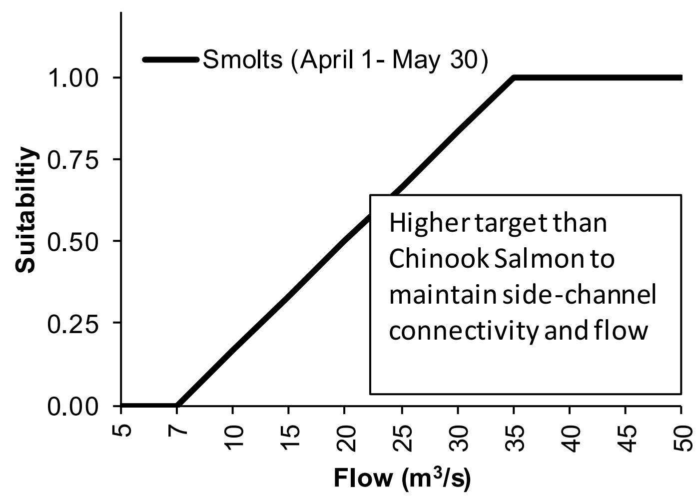
Figure 6. PM1c: Adult fall-run Chinook Salmon migration



PM2a: Coho Salmon smolt outmigration

This PM relates to fish passage constraints to outmigrating Coho Salmon smolts caused by low flows. The PM partly reflects the need for lateral connectivity, which is also considered in a separate Connectivity PM. This PM is calculated for the period April 1 to May 30 (Figure 7).

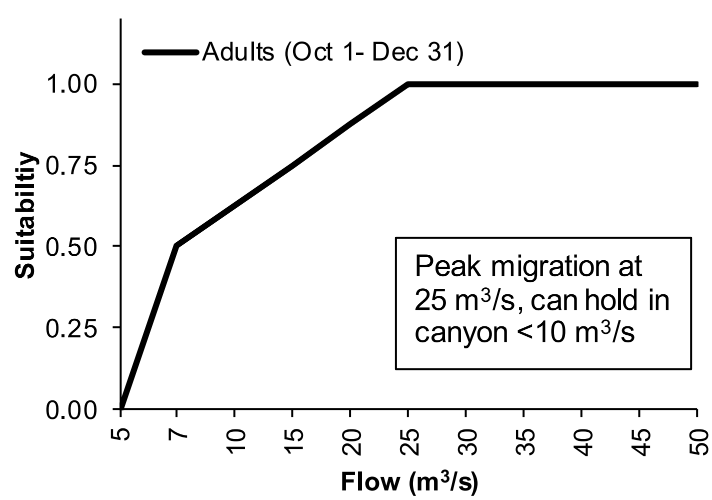
Figure 7. PM2a: Coho Salmon smolt outmigration



PM2b: Adult Coho Salmon migration

This PM relates to fish passage constraints to adult Coho Salmon caused by low flows in Marie Canyon. This PM is calculated for the period October 1 to December 31 (Figure 8).

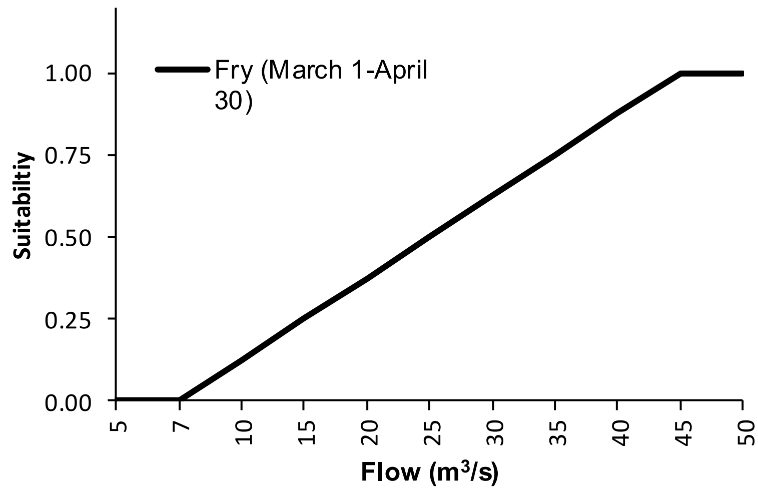
Figure 8. PM2b: Adult Coho Salmon migration



PM3a: Chum Salmon fry outmigration

This PM relates to fish passage constraints to outmigrating Chum Salmon fry caused by low flows. This PM is calculated for the period March 1 to April 30 (Figure 9).

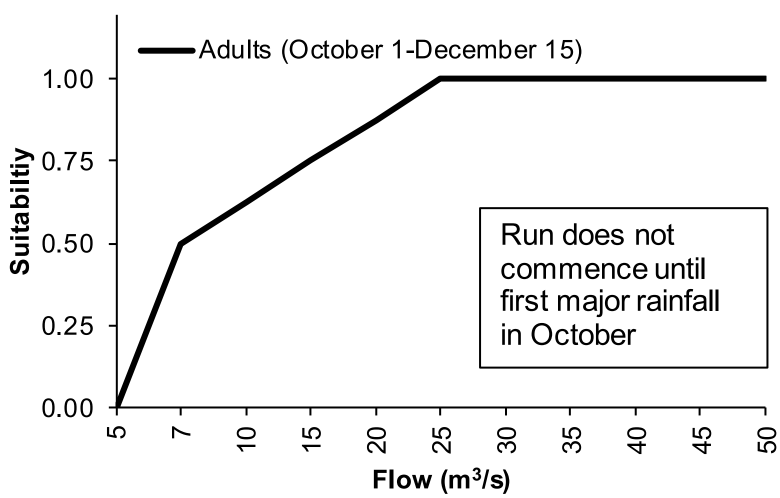
Figure 9: Chum Salmon fry outmigration



PM3b: Adult Chum Salmon migration

This PM relates to fish passage constraints to adult Chum Salmon caused by low flows in Marie Canyon. This PM is calculated for the period October 1 to December 15.

Figure 10. PM 3b: Adult Chum Salmon



Interpretation

The PMs provide an index of suitability ranging from 0 (low) to 1 (high). At this stage weightings have not been applied to reflect an order of priority among fish passage PMs; however, this may be done at a later stage.

Calculations

The PMs are calculated using several years of mean daily discharge data recorded at the upstream gauge (08HA002). Accuracy will be higher with a longer flow series.

The steps to calculate each PM are:

5. trim the data to the applicable period
6. calculate the suitability index value for each day based on the suitability~flow relationship specific to each PM
7. apply a weighting factor to each daily value, based on the assumption that the number of fish that migrate each day is normally distributed through the migration period. This recognizes that there is expected to be a peak during the run when the provision of suitable fish passage is of greater ecological importance than during the tail ends of the run. This weighting factor is calculated as follows:

$$Y_i = 1\frac{1}{\sigma\sqrt{2\prod}}e^{-\frac{(X_i-\mu)^2}{2\sigma^2}}$$

where,

Y_i = weighting factor for day *i*,

X = days represented as a sequence through the full migration period[5], based on the periodicity table established by the ARTSG,

μ = the mid point of migration period, as a value for X,

σ = standard deviation (6σ ≈ # days in migration period),

[5] Note that the migration periods used to develop some of the PMs do not encompass the full periods described by the periodicity table because the PMs focus on the period April to November. Therefore, the migration periods described by the periodicity table should be used for this calculation to accurately reflect run timing distributions.

e = 2.7183,

π = 3.1416.

8. calculate the 10th percentile of the weighted suitability index value for each year
9. summarize the range of annual 10th percentile values for each alternative using appropriate statistics, e.g., 10th and 50th percentiles
10. values are then standardized to the mean value for Alternative 1 (current operations) for the historical dataset. This step is required because the weighting procedure results in small values that are approximately in the range 0.001 to 0.00001. Standardizing in this way therefore provides a metric that is more intuitive to interpret.

Key Assumptions and Uncertainties

Key assumptions and uncertainties in the calculation of this performance measure include:

- **Migration timing is normally distributed:** The PMs assume that run timing is normally distributed throughout each period. This reflects that the abundance of migrating fish is generally not evenly distributed across a migration period, but instead has a peak and tails. It is uncertain whether the distribution in time is normally distributed (or approximately so) but this is considered a reasonable assumption.
- **Fish passage dependence on flow:** The relationships of fish passage vs. flow represent estimates based on the best information currently available. The relationships are assumed to be constant among years although this is a simplification in the case of low flow barriers to outmigration, which may be influenced by annual changes in channel geomorphology.

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PERFORMANCE MEASURE INFO SHEET: GEOMORPHOLOGY PM1 AND PM2

Component	Performance Measure	Units	Description	MSIC[6]
Geomorphology: Channel Maintenance	**PM1a: # Years exceeding median annual peak flow**	#	Number of years with flows exceeding the median annual peak flow	10%
	PM1b: Mean # of days per year exceeding median annual peak flow	#	Average number of days per year with flows exceeding the median annual peak flow	10%
Geomorphology: Flushing Flow Frequency	**PM2: Mean # of days per year ≥ 200% MAD**	#	Average number of days per year in which flows meet or exceed 200% MAD	10%

Performance Measure

These performance measures reflect the effects of management actions on the frequency and duration of high flows that may be effective for channel maintenance, and the frequency of high flows for flushing fine sediments; these are relevant to the maintenance of fish habitat.

PM 1 reflects the effects of management actions on the frequency and duration of high flows that may be effective for channel connectivity to lateral channel units and floodplain. This PM is divided into two parts: PM1a describes the frequency, and PM1b describes the duration. High magnitude flows maintain gravel quality, sediment dynamics, connectivity with off-channel habitat, and riparian communities (Annear et al., 2004). Bankfull discharge is used in this performance measure to represent these channel-forming flows; bankfull discharge can typically be estimated by determining annual peak flow with a recurrence interval of 1.5 years (Leopold, 1994). If discharge data are relatively low resolution (e.g., daily rather than hourly), the recurrence interval can be adjusted upward (e.g., 2 years; i.e., 50% chance of occurrence in any

[6] Minimum Significant Increment of Change. This is a user-defined value that represents the minimum increment of difference in the performance of two alternatives thought to be significant for decision making. It reflects technical judgments about the precision of modeling as well as value judgments about the magnitude of change that merits decision maker attention when choosing among alternatives. This value is used in the presentation of colour-coded consequence tables to focus attention on significant differences between alternatives.

given year). This approach allows for lower resolution data; the adjustment can be modified depending on the resolution of data

PM 2 is based on the Tennant method (Tennant 1976) provided a widely used method for determining the relationship between flow and habitat quality. Hydraulic data taken at different transects were combined with subjective habitat quality ratings to create this relationship. The result is a scale of flows – expressed as a percentage of mean annual discharge (MAD) – that is coded by qualitative ratings of aquatic habitat quality. Flushing flows were defined as discharge values of ≥200% MAD.

Flushing flows can serve numerous beneficial purposes for a stream (Reiser et al. 1990). Specific examples of these benefits include gravel conditions and concomitant effects on fish egg and alevin survival, and prevention of vegetative encroachment (Reiser et al. 1990).

Interpretation

The output for PM1a provides the number of years with flows exceeding the median annual peak flow. PM1b provides the average number of days per year with flows exceeding the median annual peak flow. Interpretation of these outputs should be made relative to the natural flow regime. Alternatives that produce PM scores higher or lower than the natural flow scenario should be interpreted as providing excessive or insufficient flood regimes, respectively.

The output of Geomorphology PM2 provides the average number of days per year with flows equal to or exceeding 200% MAD of the stream. Interpretation of this output should be made relative to the natural flow regime. A higher PM score for a particular alternative indicates a greater frequency of flushing flows.

Depending on the alternatives under consideration, the output from both PMs could be explicitly scored relative to the natural flow regime (e.g., as an absolute difference); however, the need for this adjustment can be reviewed when the range of alternatives are better understood.

Calculations

Geomorphology PM1

Geomorphology PM1 is calculated using several years' worth of discharge data recorded at the upstream gauge (Cowichan River at Lake Cowichan, 08HA002) or modelled for that location. Accuracy will improve with length of the flow series used.

The steps to calculate the PM are:

11. **Annual Peak Flow:** Determine the annual peak flow for each year in the data record, assuming no diversion of water. The annual peak flow is equal to the maximum flow during a given year.

12. **Median Annual Peak Flow (MAPF):** Determine the median annual peak flow. The MAPF is equal to the 50th percentile of the annual peak flow values. This is representative of bankfull discharge as it is the annual peak flow with a recurrence interval of 2 years.

PM1a (Frequency):

3a. **Years Exceeding Median Annual Peak Flow:** Determine the number of years in the data record with flows that exceed the MAPF.

PM1b (Duration):

3b. **Days Exceeding Median Annual Peak Flow:** Create a series consisting of the number of days within each year in the data record with flows that exceed the MAPF.

4b. **Mean Days Per Year Exceeding Median Annual Peak Flow:** Determine the mean days per year that exceed the MAPF by taking the mean of the series from #3b.

Geomorphology PM2

Geomorphology PM2 is determined using several years' worth of discharge data recorded at the upstream gauge (Cowichan River at Lake Cowichan, 08HA002) or modelled for that location.

The steps to calculate the PM are:

1. **Mean Annual Discharge (MAD):** Determine the mean annual discharge. The MAD is calculated by taking the mean discharge across all years in the data record.
2. **Days Per Year Equal to or Exceeding 200% MAD:** Determine the number of days for each year that have flows equal to or greater than double the MAD.
3. **Mean Days Per Year Equal to or Exceeding 200% MAD:** Determine the average across all values calculated in Step 2.

Key Assumptions and Uncertainties

Key assumptions and uncertainties in the calculation of this performance measure include:

- **Bankfull Discharge**: Geomorphology PM1 uses a representation of bankfull discharge (the median annual peak flow) as a threshold. It is assumed that bankfull discharge is sufficient for sustaining habitat quality in the ways discussed above. Furthermore, it is also assumed that the MAPF is a valid proxy for bankfull discharge, although this is likely dependent on the sampling frequency of the discharge data being used.

- **Magnitude of Annual Peak Flows** Geomorphology PM1 is a threshold-based metric, which gives equal weighting to all data not exceeding the MAPF. Two scenarios with the same or similar PM results may actually differ in the magnitude of their respective annual peak flows and therefore their ability to sustain habitat quality.

- **Definition of Flushing Flows**: Geomorphology PM2 uses a representation of flushing flows (200% MAD) as a threshold. It is assumed that this definition is representative of the flows required to provide the potential benefits described above. For example, 200% MAD may be suitable to flush fine sediments of various sizes, but only down to a specific size limit.

- **Benefits of Flushing Flows**: The potential benefits of flushing flows described above depend on numerous factors. The effects of flushing flows are stream-specific and condition-specific, and this PM must be assessed critically in the context of the stream being studied. Furthermore, the timing of flushing flows is not considered by this PM; for example, flushing flows occurring after fish spawning may dislodge eggs and limit recruitment (Reiser et al. 1990).

- **Magnitude of Flows:** This performance measure is a threshold-based metric, which gives equal weighting to all instances where flows do not meet or exceed 200% MAD. An alternative with a low value for this PM may nevertheless have flows close to the threshold that are sufficient as flushing flows.

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PERFORMANCE MEASURE INFO SHEET: LITTORAL REARING HABITAT PMS

Component	Performance Measure	Metric	Description	MSIC[7]
Cowichan Lake – littoral rearing habitat for fish	**PM1a: availability of littoral rearing habitat**	Minimum value during control period	Calculated based on a Habitat Score that provides an index of habitat area based on lake elevation	10%
	PM1b: availability of littoral rearing habitat	Average value during control period		10%
Cowichan Lake – littoral rearing habitat for fish	**PM2a: productivity of littoral rearing habitat**	Minimum value during control period	Calculated based on a Relative Productivity score that provides an index of littoral habitat productivity based on lake elevation	10%
	PM2b: productivity of littoral rearing habitat	Average value during control period		10%

Performance Measure

Littoral habitats provide productive feeding and cover habitats for fish, and total fish production is often related to area of littoral habitat in lakes (Hecky and Hesslein 1995, Randall et al. 1996). Energy sources in littoral zones come from in situ production (e.g., rooted littoral plant growth) as well as energy subsidies from the surrounding land (e.g., dissolved carbon, leaf litter, insect fall) (Hocking et al. 2017). Productivity of littoral areas is determined by physical and biological factors that include: riparian and littoral vegetation abundance, depth of the euphotic zone, sediment types, shoreline slope and aspect, nutrient levels, and interactions among species (Furey et al. 2004, 2006). Depending on timing and magnitude, water level fluctuations may reduce primary and secondary production within littoral areas (Furey et al. 2004, 2006) and restrict access to food and cover within this zone, particularly for juvenile fish.

Two PMs are proposed for shallow littoral areas within Cowichan Lake to compare the availability of productive juvenile salmonid habitat among alternatives. Species of concern include Cutthroat Trout and Coho Salmon. The PMs are calculated for each scenario using multiple years of modelled lake level, expressed as mean daily elevation in m GSC (Geodetic Survey of Canada). The PMs have been developed based on relationships between lake elevation (m) and habitat

[7] Minimum Significant Increment of Change. This is a user-defined value that represents the minimum increment of difference in the performance of two alternatives thought to be significant for decision making. It reflects technical judgments about the precision of modeling as well as value judgments about the magnitude of change that merits decision maker attention when choosing among alternatives. This value is used in the presentation of colour-coded consequence tables to focus attention on significant differences between alternatives.

suitability values that range from 0 (potentially limiting) to 1 (optimal). PM1 is calculated based on a relationship between lake elevation and a Habitat Score, which is a proxy for the area of available littoral habitat (Figure 11). PM2 is calculated based on a relationship between lake elevation and a Relative Productivity value. PM2 is similar to PM1, except lake elevations that are between full pool (El. 162.4 m) and zero storage (El. 161.4 m) are assigned higher values to reflect that these areas of the lake are relatively close to the shoreline, and are therefore expected to receive disproportionately higher inputs of nutrients from terrestrial and riparian habitats. The curves used to calculate both PMs were developed based on expert judgement, with qualitative consideration of available lake bathymetry information. The PMs are assumed to be correlated with overall fish production in Cowichan Lake and are intended to allow assessment of alternatives that reduce the lake level below the existing zero storage elevation (i.e., drawdown).

Figure 11. Littoral Habitat Score curve used to calculate PM1.

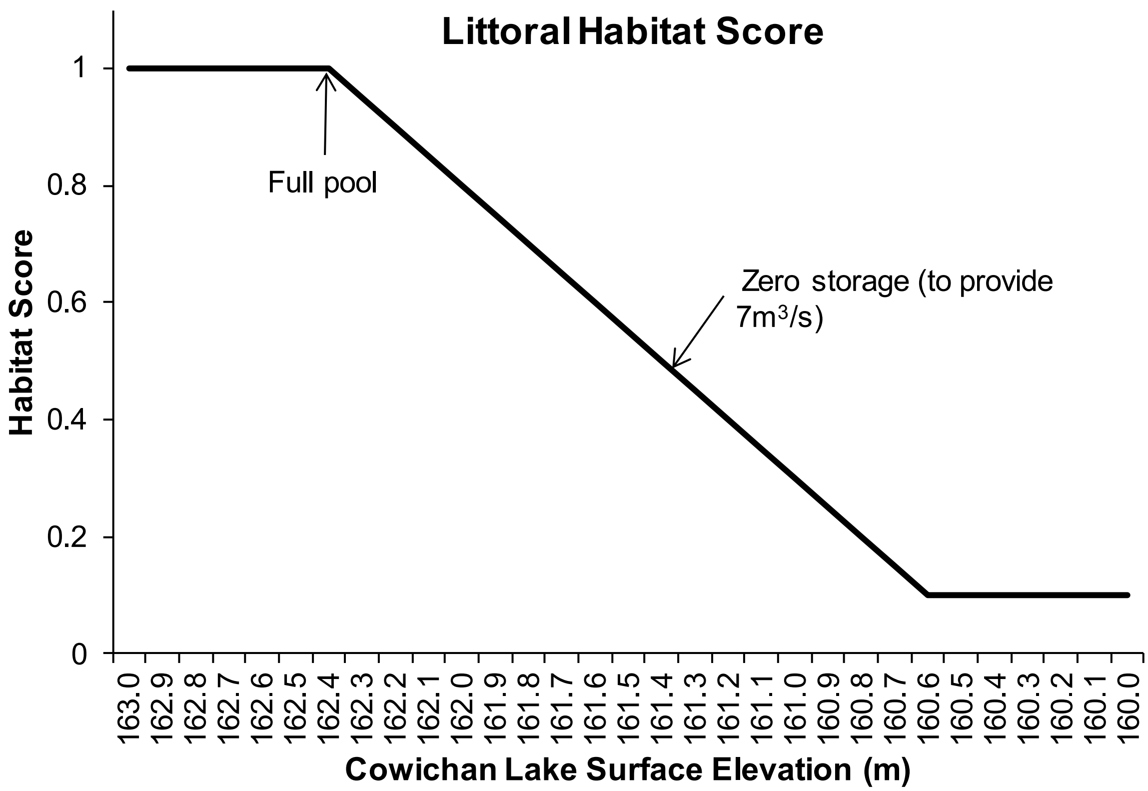
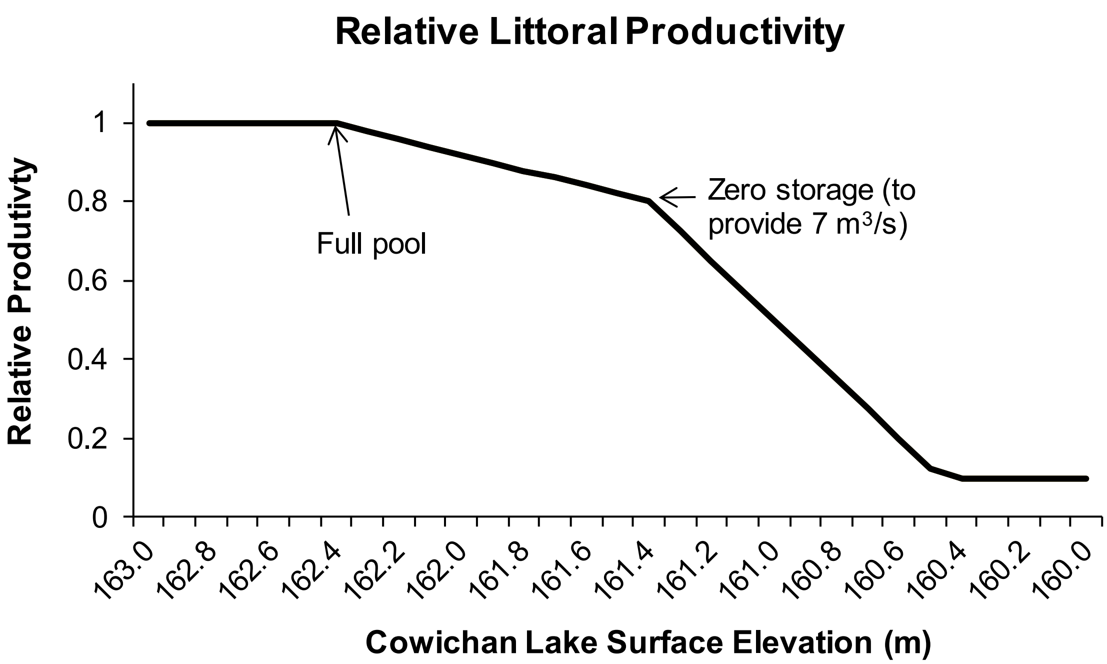


Figure 12. Relative Productivity curve used to calculate PM2.



Interpretation

Calculations

1. trim the lake level data to the current control period, which is April 1 to November 5
2. calculate the habitat suitability value for each day based on the relationship specific to each PM
3. calculate the minimum (PM1a, PM2a) and average (PM1b, PM2b) values for each year. The minimum value provides a measure of the ecologically poorest conditions that occur each year. The average value provides a more representative measure of conditions throughout the control period.
4. calculate the 10^{th} and 50^{th} percentiles of each value across all years to represent littoral productivity in a “poor" year and an “average” year, respectively, for each alternative.

Key Assumptions and Uncertainties

A number of assumptions are required for this PM, including:

1. suitability of littoral areas as rearing areas
2. assumption that littoral rearing areas for juvenile salmonids are limiting the salmonid population

3. for PM2, it is assumed that the current typical minimum potential lake elevation (the zero storage elevation) represents a break point in habitat quality, below which there is a greater decoupling from riparian habitats, and a reduction of terrestrial nutrient inputs.

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PERFORMANCE MEASURE INFO SHEET: LAKE WATER QUALITY

Component	Performance Measure	Units	Description	MSIC[8]
Lake water quality (drawdown)	**PM1a: # years with drawdown**	#	Number of years when lake elevation declines below zero storage elevation	5%
	PM1b: Annual mean *water quality risk score*	m·d	Annual mean value of a *water quality risk score* calculated as the product of drawdown magnitude and duration	10%

Performance Measure

Facility changes or operations that cause Cowichan Lake level to fluctuate below the annual minimum level (i.e., lake drawdown below the zero-storage elevation) can influence water quality, most notably by causing erosion of fine unconsolidated sediments deposited along the shoreline (e.g., Effler et al. 2004). These effects can influence water quality (e.g., turbidity), which can influence fisheries (Zohary and Ostrovsky 2011), drinking water, and aesthetic values. The characteristics of any such effects would depend on numerous factors such as substrate characteristics and weather. However, the risk to water quality is broadly expected to increase in proportion to the *duration* and *magnitude* of drawdown. These two factors will act synergistically, i.e., there is considerably higher risk of erosion associated with a large drawdown of long duration than a small and brief drawdown. Thus, this performance measure is calculated as the product of duration (days) and magnitude (m), with higher values indicating higher risk. Data collection and modelling would be required to develop a PM that provides a quantitative measure of water quality outcomes (e.g., precise changes to water clarity). This additional work is not proposed at this time.

Additionally, the task group recognizes that facility changes or operations that cause Cowichan Lake level to increase above the current annual maximum level (i.e., to flood riparian areas) have the potential to cause changes to water quality due to: 1)

[8] Minimum Significant Increment of Change. This is a user-defined value that represents the minimum increment of difference in the performance of two alternatives thought to be significant for decision making. It reflects technical judgments about the precision of modeling as well as value judgments about the magnitude of change that merits decision maker attention when choosing among alternatives. This value is used in the presentation of colour-coded consequence tables to focus attention on significant differences between alternatives.

erosion of riparian soils; 2) flooding potential pollution sources (e.g., septic tanks or log storage areas), or; 3) mercury methylation in organic terrestrial soils (Kelly *et al.* 1997). Currently, changes to weir operations that cause the lake level to extend above the current annual range are not proposed as alternatives in the Cowichan WUP. However, if such alternatives are considered during the WUP, then this effect pathway will be explored further.

Further, the Aquatic and Riparian Task Sub-Group considered the need to develop a separate performance measure relating to the potential influence of weir operations on pelagic productivity in the lake due to changes to water residence time. However, this potential effect was scoped out for further consideration, based on analysis of the lake water residence time (see Appendix for further rationale).

Interpretation

The output of Lake Water Quality PM1a provides the number of years when drawdown occurs. A value of zero indicates that there is no risk. A value > 0 indicates that there is a potential for adverse water quality effects due to this pathway in some years.

The output of Lake Water Quality PM1b will be > 0 if the alternative involves drawdown. The risk of water quality effects will increase in proportion to this PM.

A value > 0 for either indicator means that a risk is present, but not necessarily that detectible and biologically significant effects will occur.

Calculations

Lake Water Quality PMs are calculated for each scenario using multiple years of modelled lake level, expressed as mean daily elevation in m GSC (Geodetic Survey of Canada).

PM1a is calculated based on the occurrence of lake surface elevation below the zero-storage elevation, which is considered to be 161.4 m GSC (Preikshot and Willmott 2016).

PM1b is based on a *water quality risk score*, which is the product of mean drawdown magnitude (m) and the number of days when drawdown occurred. That is:

$$Water\ quality\ risk\ score = \bar{M}_i \cdot D_i$$

where $\bar{M}_i$ is the average magnitude of drawdown during year *i* and D_i is the number of days during year *i* when drawdown occurred. $\bar{M}_i$ is calculated as the mean drawdown magnitude, based on vertical distance below zero storage elevation[9]. Only days when drawdown occurred are considered in the calculation of $\bar{M}_i$.

[9] The *area* of exposed shoreline is an alternative measure of the magnitude of drawdown that more accurately represents the amount of shoreline exposed to erosion. This would require a precise stage–area relationship for nearshore habitats. At this time, the task group understands that the maximum

PM1b is then calculated as the annual mean *water quality risk score*.

Other PMs may be developed that require calculation of different summary statistics (e.g., percentile values) using the *water quality risk scores.*

Key Assumptions and Uncertainties

The precise nature of water quality effects associated with different water quality risk scores is uncertain. These will depend on a range of site-specific factors such as substrate characteristics and wave action. Further investigation would be required to resolve this.

Risk is dependent on the timing of drawdown, with higher risk during higher rainfall periods (fall to spring) relative to lower rainfall periods (summer). This reflects the potential for sheet wash and rill erosion to mobilize fine sediments along the shoreline following rainfall. This risk factor has not been considered at this stage due to the assumption that alternatives involving drawdown will entail drawdown during similar times of the year.

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proposed drawdown is ~1 m vertical change. Effort is not proposed to model changes in the area of exposed shoreline at this stage; instead, stage change is used as a proxy.

APPENDIX – POTENTIAL FOR CHANGES TO LAKE WATER RESIDENCE TIME TO AFFECT PELAGIC PRODUCTIVITY

Increasing the outflow from Cowichan Lake to provide higher flows in Cowichan River will decrease the lake water residence time. Theoretically, this change has potential to reduce pelagic productivity of plankton by increasing “transport losses” (Lucas et al. 2009), i.e., increasing the outflow will increase the rate at which plankton cells are flushed from the lake. Generally, this effect pathway has potential to adversely affect fisheries.

Phytoplankton (suspended algae) form the base of the pelagic food web in the lake. Phytoplankton is grazed by zooplankton (suspended invertebrates), which provides forage for planktivorous fish such as Kokanee. Reduced plankton productivity could therefore adversely affect fisheries in the lake. In particular, phytoplankton production is expected to be high in the spring (the “spring bloom”)[10] and high flushing rates during this period could theoretically depress pelagic productivity for the remainder of the growing season. High flushing rates have been shown to depress plankton productivity in small lakes in BC (Dickman 1969) and the effect of altered water residence time on fisheries is an issue of management interest elsewhere, e.g., for diversion lakes in the Campbell River watershed (Hocking et al. 2017).

A key point is that this effect pathway is only relevant if flushing is sufficiently high to reduce water residence time to low values that are comparable with the intrinsic growth rates of plankton. It is necessary to consider phytoplankton and zooplankton in the effect pathway.

The maximum intrinsic growth rates of phytoplankton in natural environments (i.e. accounting for losses) are typically of the order of 0.1–1 d^{-1} (Reynolds, 2006 and references therein). This means that increased flushing is not expected to significantly affect phytoplankton productivity unless water residence time is reduced to the order of days to weeks. Based on this, a water residence time of 20 days has been proposed as an appropriate threshold below which flushing has potential to exert a substantial effect on phytoplankton biomass (Hamilton and Dada 2016).

Zooplankton taxa have longer generation times and therefore they are more sensitive to flushing effects. The effect of flushing on zooplankton production is variable but it is known to exert a significant effect in some systems such as rapidly flushed impoundments. For example, zooplankton biomass increased approximately 19-fold when water residence time was increased from 4 to 338 days in a Newfoundland reservoir (Campbell *et al*. 1997). The relationship between zooplankton production and water residence time is expected to be non-linear, with the effect declining as water residence time increases. Walz and Melker (1998) proposed that lentic plankton communities do not develop at all below water residence times of ~3 days. The authors report relationships between the biomass of zooplankton taxa and water

[10] Supported for Cowichan Lake by limited data presented in Epps and Phippen (2011).

residence time in the range of ~1 day to 53 days for a single lake. Based on these relationships, maximum biomass was achieved at a water residence time of less than 53 days for the majority of taxa, indicating that the biomass of these taxa was insensitive to changes to water residence time when water residence time exceeds 53 days. Exceptions were some copepods, which are important prey for zooplanktivorous fish. A study of 11 waterbodies near Campbell River (BC) showed no positive relationship between zooplankton biomass and growing season water residence time (range = 0.5 to 874 days), with the highest zooplankton biomass measured in small productive lakes with short water residence time (Hocking *et al*. 2017). This result is instructive, although the study made comparisons among (not within) lakes and therefore other limiting factors were not controlled. A similar study in a montane lake in Italy showed that the zooplankton community switched from being dominated by rotifers, to being dominated by crustacea above a threshold water residence time of 193 days (Obertegger *et al*. 2007). Crustacean zooplankton taxa are preferred prey for fish and therefore such changes in community composition are relevant to fish productivity.

Accordingly, the following general inferences can be made:

- Decreasing water residence time to less that ~3 weeks could reduce phytoplankton production;
- Decreasing water residence time to less than several months could reduce production of crustacean zooplankton with long generation times. Biologically significant declines in zooplankton biomass are most likely to occur when water residence time is less than ~ 2 months;
- Decreasing water residence time to less than ~200 days could cause a shift in the zooplankton community that would adversely affect fish production.

In light of the above, it is relevant to now consider that the mean water residence time of Cowichan Lake is approximately 2.2 years (802 days)[11]. Water residence time is considerably greater in the summer when outflow declines. A water residence time of 200 days (the upper threshold identified above) would equate to a lake outflow of ~180 m^3/s. This flow approximates winter flood conditions in Cowichan River and greatly exceeds the flows that are expected in spring to fall as part of alternatives being considered in the Cowichan WUP. Accordingly, this impact pathway has been scoped out for further consideration.

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PERFORMANCE MEASURE INFO SHEET: REARING PMS

Component	Performance Measure	Life Stage	Applicable Timing	MSIC[12]
Rearing habitat (steelhead)	PM1a	Steelhead fry	May 1–Dec 31	10%
	PM1b	Steelhead parr	March 1–Dec 31	10%
Rearing habitat (Chinook)	PM2	Chinook Salmon fry	March 1 – April 30	10%
Rearing habitat (Coho)	PM3a	Coho Salmon emergent fry	March 1– April 30	10%
	PM3b	Coho Salmon rearing fry	May 1 – Dec 31	10%
Rearing habitat (swiftwater invertebrates)	PM4	Predominantly larval	March 1 to Dec 31	10%

Performance Measure

The availability of rearing habitat for fish in the Cowichan River varies depending on flow. Conditions that maximize the area of suitable rearing habitat typically occur over a narrow range of flows that are specific to a given species and life history stage. Outside of this optimum flow range, habitat availability can decline rapidly, particularly as flows decline towards zero.

This performance measure (PM) group quantifies effects on rearing habitat due to management actions that alter flow. The PMs have been developed based on relationships between flow (m^3/s) and species- and life-stage-specific habitat suitability index (HSI) values that range from 0 (potentially limiting) to 1 (optimal). These HSI relationships are based on weighted usable area vs. flow relationships developed using field measurements (LGL Limited 2013, 2015), with adjustments

[12] Minimum Significant Increment of Change. This is a user-defined value that represents the minimum increment of difference in the performance of two alternatives thought to be significant for decision making. It reflects technical judgments about the precision of modeling as well as value judgments about the magnitude of change that merits decision maker attention when choosing among alternatives. This value is used in the presentation of colour-coded consequence tables to focus attention on significant differences between alternatives.

based on expert evaluation (Ayers et al. 2017). PMs have been developed based on a periodicity table developed for the Cowichan River (McCulloch 2017). This table defines an “active rearing season” of March 1 to December 31 based on the period when water temperatures are above 7°C on average. All salmonid species that have a freshwater rearing stage have been considered when developing these PMs; however, the working suite of PMs relates to a subset of these species. This is because there is considerable overlap in the habitat requirements for several species/life stages and, therefore, it is appropriate to reduce the number of PMs to minimize redundancy.

PMs have been developed for three priority fish species that are susceptible to flow-related constraints on rearing habitat availability. These priority fish species are: steelhead (PM1a, b), Chinook Salmon (PM2) and Coho Salmon (PM3a, b). A separate PM (PM4) relates to the availability of habitat for swiftwater invertebrate taxa (e.g., Plecoptera spp.). It is recognized that healthy invertebrate communities are required to sustain rearing salmonids; therefore, it is appropriate to consider invertebrate requirements separately to protect fisheries values. The Aquatic and Riparian Task Sub-Group also recognizes that healthy invertebrate communities have inherent value in their own right.

Six PMs have been developed:

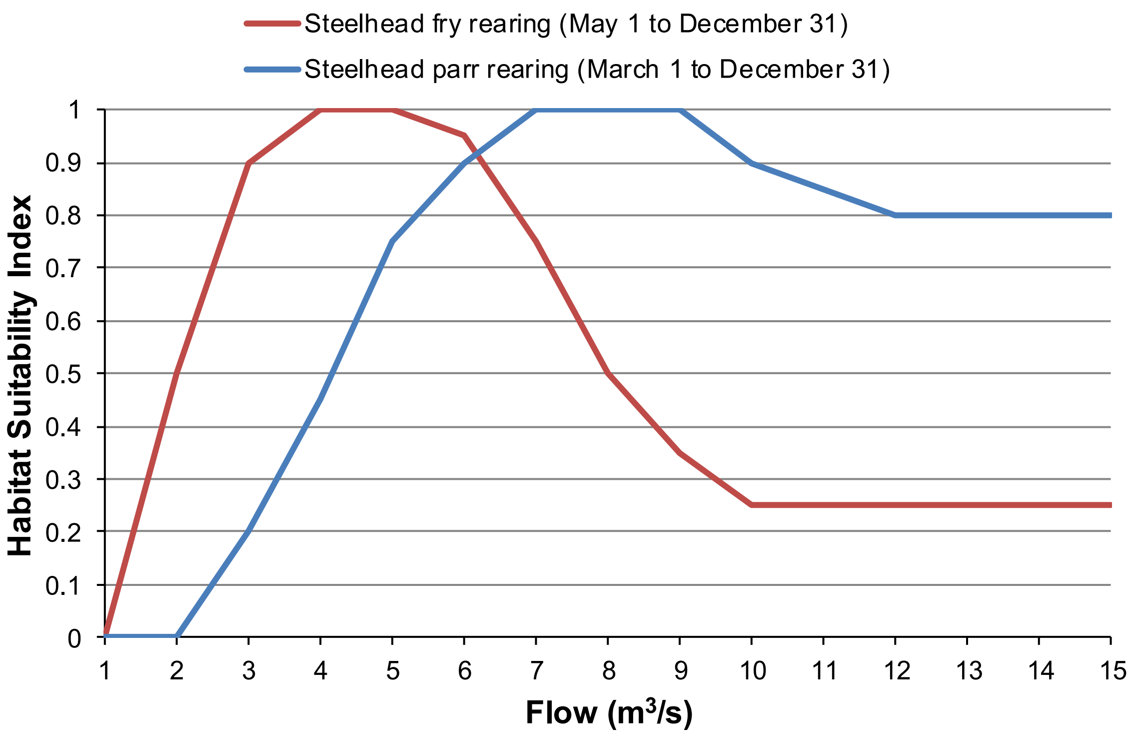
PM1a: Steelhead fry rearing

This PM relates to rearing habitat constraints to steelhead fry. This PM is calculated for the period May 1 to December 31 (Figure 4).

PM1b: Steelhead parr rearing

This PM relates to rearing habitat constraints to steelhead parr. This PM is calculated for the period March 1 to December 31 (Figure 4).

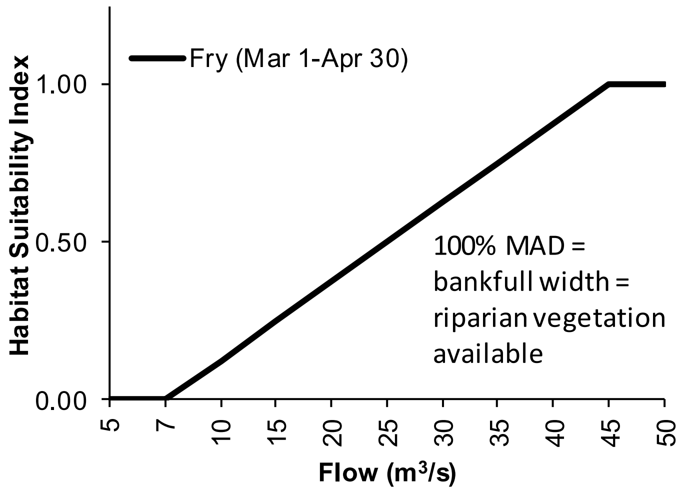
Figure 13. PM1a (steelhead fry rearing) and PM1b (steelhead parr rearing)



PM2: Chinook Salmon fry rearing

This PM relates to rearing habitat suitability for Chinook Salmon fry. Specifically, this PM relates to the inundation of riparian vegetation in shallow habitats, e.g., willows (*Salix* spp.) on gravel bars. This has been identified as important for rearing Chinook Salmon fry because submerged vegetation provides cover and food. This PM is calculated for the period March 1 to April 30 (Figure 7).

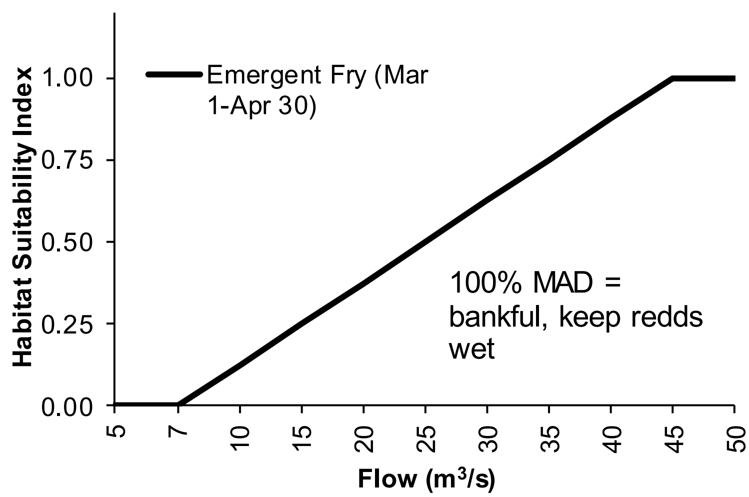
Figure 14. PM2a: Chinook Salmon fry rearing habitat suitability



PM3a: Coho Salmon emergent fry

This PM relates to rearing habitat suitability for emergent Coho Salmon fry. Specifically, this PM relates to the need for redds to remain wetted during the spring when flows generally recede yet emergent fry or alevins have limited mobility and are susceptible to stranding in the vicinity of redds. This PM is calculated for the period March 1 to April 30 (Figure 8).

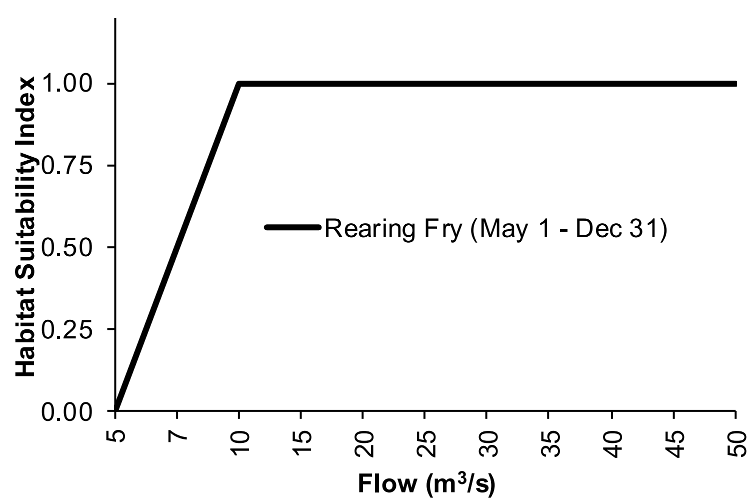
Figure 15. PM3a: Coho Salmon emergent fry



PM3b: Coho Salmon rearing fry

This PM relates to rearing habitat suitability for Coho Salmon fry during the active growing season. This PM is calculated for the period May 1 to December 31 (Figure 9).

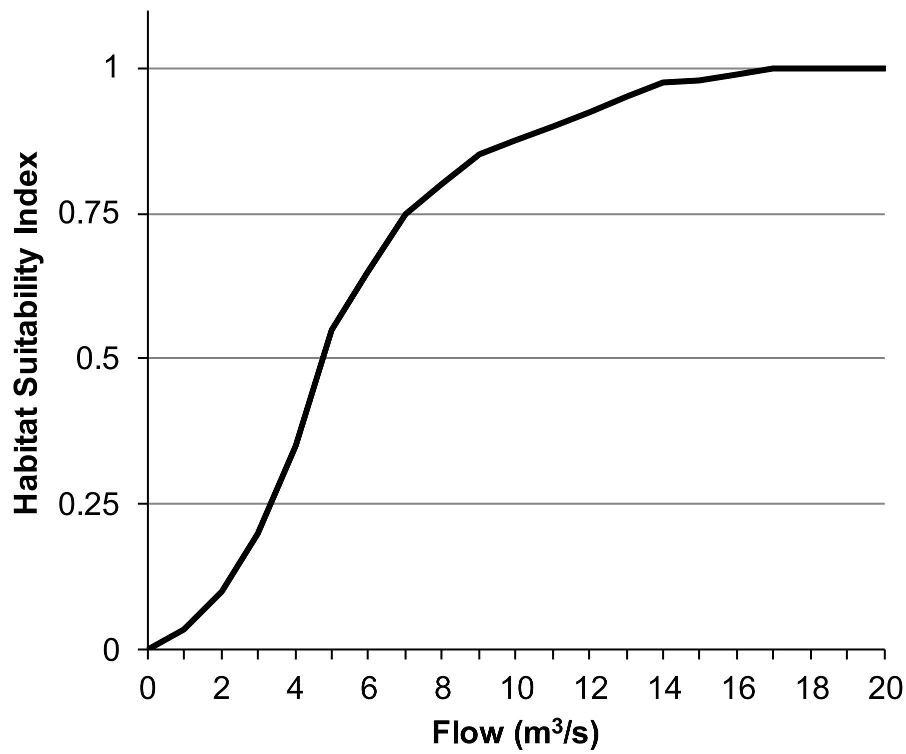
Figure 16: Coho Salmon rearing fry



PM4: Swiftwater invertebrates

This PM relates to rearing habitat suitability for swiftwater invertebrates during the growing season This PM is calculated for the active growing season (Figure 17), which is March 1 to December 31 based on average water temperatures.

Figure 17. PM 4: Swiftwater invertebrates



Interpretation

The PMs provide an index of suitability ranging from 0 (low) to 1 (high). Weightings have not been applied to reflect an order of priority among rearing PMs; however, this may be done later.

Calculations

The PMs are calculated using several years of mean daily discharge data recorded at the upstream gauge (08HA002), or modelled at that location. Accuracy will be higher with a longer flow series.

The steps to calculate each PM are:

13. trim the flow series to the applicable period

14. calculate the HSI value for each day based on the HSI vs. flow relationship specific to each PM

15. calculate the 10th percentile of the HSI values for each year

16. summarize the range of annual 10th percentile values for each alternative using appropriate statistics, e.g., 10th and 50th percentiles.

Key Assumptions and Uncertainties

Key assumptions and uncertainties in the calculation of this performance measure include:

- **Rearing habitat limits fish production:** The PMs assume that rearing habitat constrains fish production and that the ecological significance of rearing habitat is constant throughout each applicable period.

- **Rearing habitat suitability dependence on flow:** The relationships between HSI values and flow represent estimates based on the best information currently available. The relationships are assumed to be constant among years.

- **The 10th percentile of HSI values is a reliable metric:** Daily HSI values are summarized based on the 10th percentile. This provides a focus on periods when habitat is likely to be limiting; however, fish are expected to tolerate short periods of more restricted rearing habitat availability.

- **Temperature effects on rearing:** The active rearing period is defined as the period when average water temperatures exceed 7°C. However, no adjustments have been made to reflect periods during the summer when high (>20°C) temperatures can occur that may restrict salmonid growth. This is because it is assumed that rearing fish are able to access temperature refuges. This assumption is uncertain, as is the potential effect of warmer summer temperatures on rearing conditions in the future.

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McCulloch, M. 2017. Cowichan River and Cowichan Lake periodicity chart. Developed in consultation with the Aquatic and Riparian Task Sub-Group. Revised version prepared on January 16, 2018.

Performance Measure Info Sheet: Spawning and Incubation PMs

Component	Performance Measure	Life Stage	Applicable Timing	MSIC[13]
Spawning and incubation (steelhead)	PM1a	Early spawning	January 15–March 31	10%
	PM1b	Early incubation	January 15–March 31	10%
	PM2a	Late spawning	April 1–May 7	10%
	PM2b	Late incubation	April 1–June 7	10%

Performance Measure

The availability of spawning and incubation habitat for fish in the Cowichan River varies depending on flow. By changing flow, the alternatives have the capacity to influence wetted area, water depth, and water velocity, thereby altering the abundance, distribution, and quality of spawning and incubation habitat.

This performance measure (PM) group quantifies effects on spawning and incubation habitat due to management actions that alter flow. The PMs have been developed based on relationships between flow (m^3/s) and species-specific habitat suitability index (HSI) values that range from 0 (potentially limiting) to 1 (optimal), with 0.5 approximating a minimum target. These HSI relationships are based on weighted usable area vs. flow relationships developed using field measurements (LGL Limited 2013, 2015), with adjustments based on expert evaluation (Ayers et al. 2017). PMs have been developed using a periodicity table developed for the Cowichan River (McCulloch 2017). All salmonid species present in the river have been considered when developing these PMs; however, PMs have only been developed for steelhead, i.e., the anadromous life history form of Rainbow Trout. The Aquatic and Riparian Task Sub Group recognizes that some alternatives may have the potential to affect fall-spawning species (e.g., Pacific salmon); however, the group considers that these

[13] Minimum Significant Increment of Change. This is a user-defined value that represents the minimum increment of difference in the performance of two alternatives thought to be significant for decision making. It reflects technical judgments about the precision of modeling as well as value judgments about the magnitude of change that merits decision maker attention when choosing among alternatives. This value is used in the presentation of colour-coded consequence tables to focus attention on significant differences between alternatives.

issues are already captured by the separate fish passage PMs[14]. Similarly, the spawning PMs presented here encompass spawning constraints associated with other spring-spawning species/life history forms (principally resident Rainbow Trout) so separate PMs have not been developed for these fishes.

Two sets of PMs have been developed, with separate PMs developed for early and late spawning steelhead.

PM1a: Early steelhead spawning

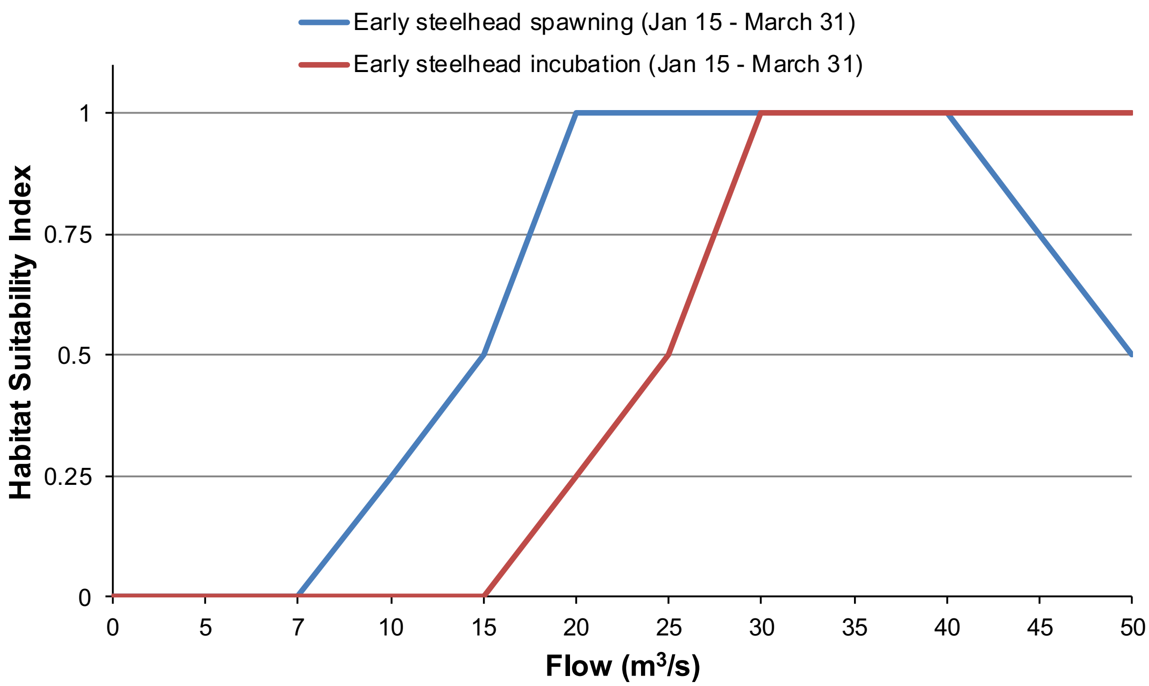
This PM relates to spawning habitat constraints to early-spawning steelhead. The PM has been developed based on the optimum hydraulic habitat characteristics (depth, velocity) that characterize steelhead spawning habitat. This PM is calculated for the period January 15 to March 31 (Figure 4).

PM1b: Early steelhead incubation

This PM relates to incubation habitat constraints to the progeny of early-spawning steelhead. This curve spans flows that are sufficiently high for redds to remain wetted and maintain suitable hydraulic habitat characteristics. This PM is calculated for the period January 15 to March 31 (Figure 4).

[14] Further, the group recognizes that managing operations to achieve a target flow to optimize fall spawning habitat availability entails risk because that flow must be met as a minimum throughout the duration of the spawning and incubation periods to avoid dewatering redds. This may be challenging in some years if lake storage is insufficient.

Figure 18. PM1a (early steelhead spawning) and PM1b (early steelhead incubation).



PM2a: Late steelhead spawning

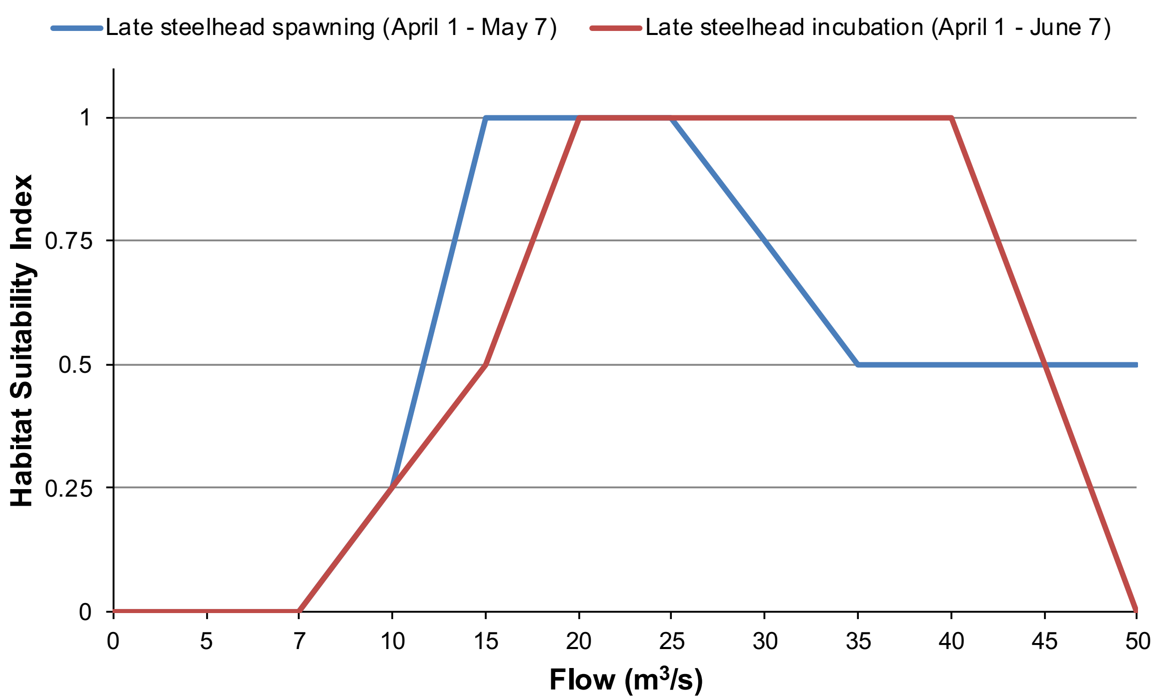
This PM relates to spawning habitat constraints to late-spawning steelhead. The range of optimum flows is lower than for early-spawning steelhead. This is because flows typically decline through the spring period and it is therefore desirable that fish spawn at lower flows during the late spawning period to minimize the risk of desiccation of redds. Thus, this PM reflects a trade-off between maximizing spawning habitat availability and also maximizing the likelihood that steelhead spawn in effective habitat that remains wetted through the incubation period.

This PM is calculated for the period April 1 to May 7 (Figure 19).

PM2b: Late steelhead incubation

This PM relates to incubation habitat constraints to the progeny of late spawning steelhead. This PM is calculated for the period April 1 to June 7 (Figure 19).

Figure 19. PM2a (late steelhead spawning) and PM2b (late steelhead incubation)



Interpretation

The PMs provide an index of suitability ranging from 0 (potentially limiting) to 1 (optimal). At this stage weightings have not been applied to reflect an order of priority among PMs; however, this may be done at a later time.

Calculations

The PMs are calculated using several years of mean daily discharge data recorded at the upstream gauge (08HA002), or modelled for that location. Accuracy will be higher with a longer flow series.

The steps to calculate each PM are:

17. trim the data to the applicable period
18. calculate the HSI value for each day based on the HSI vs. flow relationship specific to each PM
19. calculate the 10^{th} percentile of the HSI values for each year
20. summarize the range of annual 10^{th} percentile values for each alternative using appropriate statistics, e.g., 10^{th} and 50^{th} percentiles.

Key Assumptions and Uncertainties

Key assumptions and uncertainties in the calculation of these PMs include:

- **Spawning habitat suitability dependence on flow:** The relationships between HSI values and flow represent estimates based on the best information currently available. The relationships are assumed to be constant among years.
- **The PMs adequately capture the concept of "effective spawning habitat":** Effective spawning habitat requires suitable hydraulic conditions during spawning, but also suitable and continuously wetted conditions during incubation. These requirements have been considered, and the PMs are considered appropriate to assess the alternatives that have been proposed. However, if new alternatives are proposed that entail dynamic stage changes, then revised PMs may be necessary that explicitly track whether incubation habitat remains continuously wetted.
- **The 10^{th} percentile of HSI values is the optimum metric.**

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McCulloch, M. 2017. Cowichan River and Cowichan Lake periodicity chart. Developed in consultation with the Aquatic and Riparian Task Sub-Group. Revised version prepared on January 16, 2018.

Socio-economic Performance Measures

1 Performance Measure Info Sheet: Industry and Commercial

Sub-Objective	PM	Units	Description	MSIC[1]
Catalyst Paper	PM1: Impacted operations days	days/yr	Average number of days where industrial operations may potentially be impacted.	10%

1.1 Overview

This performance measure reflects the effects of management actions on Cowichan Lake and Cowichan River industrial activities. The Cowichan River is the source of the water used at Crofton Division, including for the operation of the Crofter Pulp Mill. The extent, timing and duration of river flows impact the amount of water available for industrial purposes.

1.2 Performance Measure

PM1: Catalyst Paper – Impacted Operation Days

This PM represents an interest in maintaining river flows to enable Catalyst to withdraw water for mill operations. It reports the average number of days per year where river flows are less than 4.5cms flow threshold, the required flow to provide the 1.7cms average daily withdrawal by the mill and the 2.8cms minimum environmental thresholds set for the lower river.

1.3 Calculations

The PM is estimated using the Cowichan Lake Operational Model, which reports the predicted river flow as a daily time series for a 10-year period based on inflow data projected for the 2051 to 2060. The PM is estimated using a historical 63-year dataset from 1953 to 2016.

The PM reports the number of days the river flows are less than 4.5cms and is calculated as a single value for each year of the modeled dataset and summarized across all yeas for the 2050s and historical datasets (n = 10 years and n = 64 years) using the minimum, maximum, and 10th, 50th, and 90th percentile statistics to reflect the degree to which these PM data can vary from year to year.

1.4 Key Assumptions and Uncertainties

- Assuming a withdrawal of 1.7cms by Catalyst Paper, below threshold withdrawals would need to be cut back or stopped in order to maintain adequate flows in the lower river to meet environmental and community water supply needs.

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[1] Minimum Significant Increment of Change. This is a user-defined value that represents the minimum increment of difference in the performance of two alternatives thought to be significant for decision making. It reflects technical judgments about the precision of modeling as well as value judgments about the magnitude of change that merits decision maker attention when choosing among alternatives. This value is used in the presentation of color-coded consequence tables to focus attention on significant differences between alternatives.

- This assumes that any license priority would be given up in order to avoid impacts to community water supply.
- Assumes flow rate released from Cowichan Lake is maintained along length of Cowichan River to the Catalyst Pump station upstream of Duncan.

2 Performance Measure Info Sheet: Recreation & Tourism

Sub-Objective	PM	Units	Description	MSIC
Lake Beach Use Areas	PM1: Beach User Days	days	Average number of weighted beach user days during the recreational season	10%
Lake Boat Access / Navigation	PM2a: Decrease in dock use days	days	Average number of dock use days during the recreational season	10%
	PM2b: Impacted boat ramp use days	days	Average number of dock use days during the year	10%
Boating and Tubing - River	PM3a: Decrease in summer tubing days	days	Average number of tubing days during the recreational season	10%
	PM3b: Decrease in river boating days	days	Average number of paddling days during the year	10%

2.1 Overview

These performance measures reflect the effects of management actions on Cowichan Lake and Cowichan River recreational activities. Recreation was identified as an important value and interest for water use planning. Lake and lakefront recreational values include beach and dock use, swimming, and boating; river recreational values include tubing, small boating, swimming and beach use. The magnitude, timing and duration of both elevated and lowered lake levels impact the opportunity for and quality of experience of recreational activities in Cowichan Lake. Likewise, the extent, timing and duration of river flows impact the opportunity for and quality of experience of recreational activities in Cowichan River.

2.2 Performance Measures

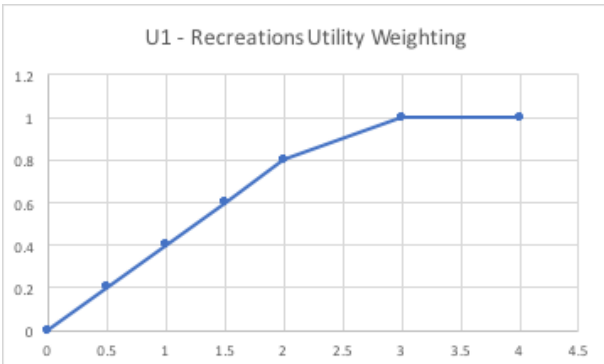
PM1: Lake Beach Use Areas

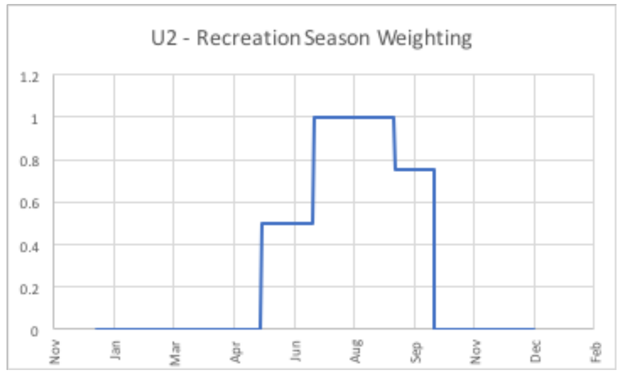
This PM represents an interest in maintaining usable lakefront and beach areas for access and use for recreational purposes, for both private and public lakefront areas. It reports the average number of weighted beach user days during the recreational season, using a preferred beach slope length of 3m (from the water's edge to the crest of the beach slope), which was considered the optimal beach length for beach access and recreational use.

Inputs on the preferred beach size for recreational activities, key issues and concerns, and period and dates of use were provided by the Cowichan Water Use Plan Lakefront Technical Sub-Group (LTSG). The LTSG identified the peak recreation season to occur from Canada Day weekend to the Labour Day weekend. There are two short shoulder periods, the first occurring in the spring beginning the May Long weekend, and the second occurring in the fall lasting until the Thanksgiving weekend. The fall season is believed to be more important than the spring season. To capture this difference in relative importance, a seasonal weighted index was developed that ranked: the peak recreation season from Canada Day weekend to the Labour Day weekend as 1; the spring shoulder seasons from May Long weekend to

Canada Day weekend as 0.5; and, the fall shoulder season from Labour Day weekend to Thanksgiving weekend as 0.75.

Beach utility is considered to be linked to the amount of available beach area which varies by lake level. Beach slope length (BSL), measured as the distance from the water's edge to the crest of the beach slope, was used as a proxy for beach area. Increasing the length of the beach beyond 3m did not change the utility of the beach. There is considered to be some utility of the beach at less than 3m, which decreases with decreasing length of the beach. To capture the variation in usability, a second weighting index was developed that ranked: days with beach slope length of 0m as 0, days with beach slope length >3m as 1; and, days with beach slope length between 0 and 3m were linearly weighted between 0 and 1.





The PM was calculated for a representative selection of beach types with varying slope steepness and vegetated/non-developed or non-vegetated/developed shorelines, including the following beach slope type categories:

- Gordon Bay Provincial Park: vegetated/moderate slope
- Youbou/Sass Pt: un-vegetated/steep slope
- Honeymoon Bay: vegetated/shallow slope

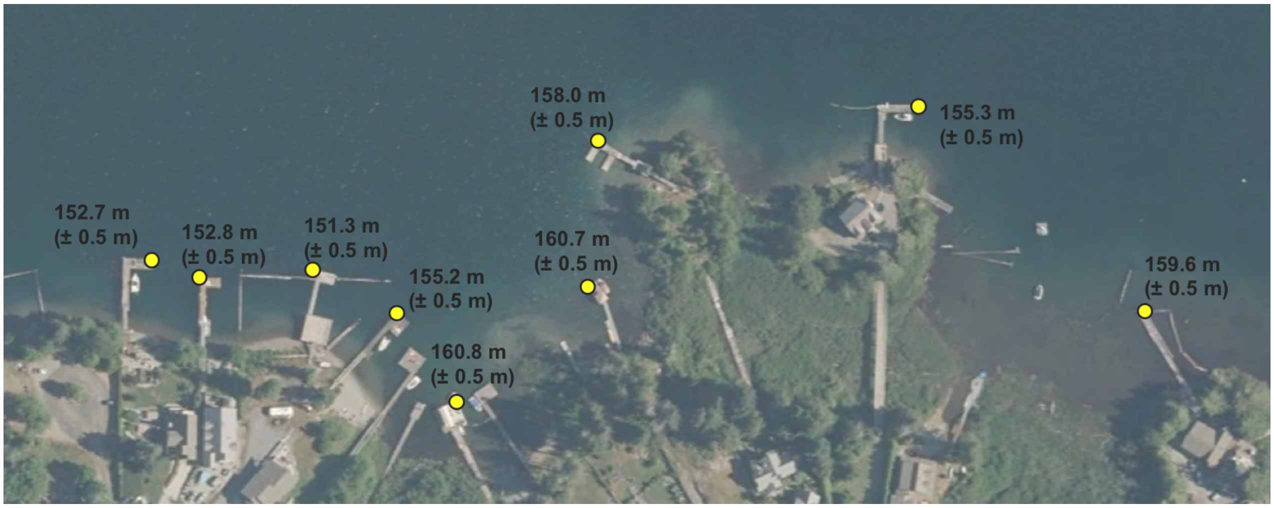
Cross sections of the different beach slope categories were provided were determined from a shoreline visualization model developed for the CVRD and provided by Nathan Vadeboncoeur (Vadeboncoeur Consulting). The daily lake elevation was indexed against the vertical axis of the cross section to provide the corresponding length of available beach slope length for each day of the recreational period. The daily beach slope length was then indexed against the seasonal and beach utility weights, the product of which is the value for the weighted beach user day.

PM2: Lake Boat Access / Navigation

PM2 represents an interest in maintaining suitable lake levels to support safe water-based recreation. It includes access to and usability of docks/wharves and other boating infrastructure, swimming infrastructure, navigation issues associated with lower levels. The PM is divided into two parts:

PM2a: Dock use days

PM2a describes the average number of days during the recreational season where the water depth at private docks is less than 1m at the lakebed elevations at two different locations around Cowichan Lake. LTSG identified and agreed to use 1m as a depth of water that would provide for sufficient boat draft for an average boat used for recreational purposes. Lakebed elevation at dock locations were determined by CVRD through GIS analysis using bathymetry data. The LTSG identified and agreed to use two known shallow lake areas as two representative sites known to be sensitive to low lake levels as observed in recent dryer years for assessing the dock use PM: Point Ideal and Pine Point. While the Pine Point Site was the most sensitive of the two sites, an average of the lake elevation to provide a 1m draft at the most shallow docks at Point Ideal (161.8m) were used as the lakebed elevation data was known to be of better quality at this location. The LTSG identified dock use to the peak recreation season to occur from Canada Day weekend to the Labour Day weekend.



PM2b: Impacted boat ramp use days

A potential PM was explored to characterize the impacts of lake levels on the use of boat ramps around Cowichan Lake. This PM is intended to capture limitations in existing boat infrastructure only at low lake elevations. The LTSG identified that higher lake elevations were not an issues to capture in the PM as people continue to launch their boats in high lake conditions, and that boat ramps are used year round (not just during the recreational period).

The PM was explored based on the average number of days during the year where the water depth at the offshore limit of the Town of Cowichan Lake boat ramp is less than 1m at different lake elevations. The 1m depth is used based on Provincial best management practices for boat launch construction (BC MOE, 2006) that no less than 1m below the 100 year low water level during the proposed season(s) of use to provide adequate water depth to float an average boat from its trailer. A 2018 field survey reported the lakebed elevation for the offshore limit of the boat ramp at 160.5m (Island Land Surveying Ltd. 2018), such that a lake elevation of 161.5m or greater is required to provided a 1m water depth. As the minimum lake elevation was determined to be less than that used for the dock boat draft, impacts to boat ramp use were considered to be captured in PM2a characterizing impacted to dock user days.

PM3: Boating and Tubing – River

PM3 represents an interest in maintaining suitable river flows to support water-based recreation down the river. (i.e., tubing and boating).

PM3a: Summer tubing days

PM3a reports the average number of days during the summer recreation season when river flows are less than 5cms. A local tubing company operating on the Cowichan River indicated that while the experience is more enjoyable when the river is flowing at levels closer to 7-8cms, they can operate the river's lowest levels (estimated to be 4.5cms) (Aaron Frisby The Tube Shack, pers. comm.). 5cms was used as a minimum flow below which recreational tubing would begin to be impacted. The summer tubing season is defined for the summer period from Canada Day weekend to the Labour Day weekend when temperatures are warmer and tubing activities take place on the river, which corresponds to the tubing company's booking period for 2018 (http://www.cowichanriver.com/).

PM3b: River boating days

PM3b was developed as a draft PM to calculate and report on the average number of days the year when river flows impact the use of small boat use on the river (kayak, canoe, drift boats). The PM used a minimum river flow of 7cms based on original suggestion by the consulting team. Further investigation into specific flows for small boat use found that the 5cms threshold used for recreation tubing activities (PM3a) was appropriate for all river boating recreation activities, based on the following:

- In a presentation to the Cowichan Watershed Board by representatives of the Recreational Canoeing Association of BC and Vancouver Island Whitewater Paddling Society the Cowichan Watershed Board, 10cms was indicated as the minimum river flow preferred by the paddling community, however the river has been paddled as low as 3.5cms; above 120cms, paddling is less safe of enjoyable due to strong currents, washed/flooded out rapids, and hazards (Bryan and Duggan, 2017).
- A drift boater on the river identified that the low flow cut-off for drift boats as 10cms (Joe Saysell, personal communication, April 23 2018), however it was relayed that preferred flows are driven by flows for fish and that very rarely is this activity done for reasons other than fishing, and as such is covered by the environmental PMs.

2.3 Calculations

The PMs are estimated using the Cowichan Lake Operational Model which reports the predicted lake elevation and river flow as a daily time series for a 10-year period based on inflow data projected for the 2051 to 2060. The PMs are also estimated using a historical 63-year dataset from 1953 to 2016. All PMs are calculated as a single value for each year of the modeled dataset and summarized across all yeas for the 2050s and historical datasets (n = 10 years and n = 64 years) using the minimum, maximum, and 10th, 50th, and 90th percentile statistics to reflect the degree to which these PM data can vary from year to year.

PM1: Beach User Days

The steps to calculate the PM are:

1. Determine the beach slope length at the lake elevation
2. Sum the products of seasonal weight and beach slope length weight for every day of the year

PM2: Lake Boat Access / Navigation

The steps to calculate the PM are:

PM2a:

1. Determine the number of days the lake elevation is less than 161.8m for each day of the recreation season.

PM2b:

1. Determine the number of days the lake elevation is less than 161.5m for each day of the year.

PM3: Boating and Tubing - River

The steps to calculate the PM are:

PM3a:

1. Determine the number of days river flows are less than 5cms for each day of the recreation season.

PM3b:

1. Determine the number of days river flows are less than 7cms for each day of the year.

2.4 Key Assumptions and Uncertainties

Key assumptions and uncertainties in the calculation of this performance measure include:

- The lower limit of the beach slope cross sections were surveyed to the water's edge. It was assumed a consistent beach slope as for the exposed beach areas when calculating beach slope length during lake drawdowns.
- The confidence in the accuracy of the lakebed elevations at dock locations is ±0.5m as a result of using blended data from two different bathymetric datasets; because there is a gap between the depths which the datasets cover, the 150 to 160m is extrapolated. The distance between the nearshore survey lines also varies (40 to 650 m) adding to the uncertainty.
- The PMs are calculated using representative sites around Cowichan Lake. The Town of Lake Cowichan boat ramp is used as a proxy for other sites around the lake, including private and public boat launches.

2.5 References

British Columbia Ministry of Environment (BC MOE). 2006. Best Management Practices for Boat Launch Construction & Maintenance on Lakes. Available online: http://www.env.gov.bc.ca/okanagan/documents/BMPBoat_LaunchDraft.pdf

Bryan, Rick and Duggan, Edmond. 2017. Paddling on the Cowichan River. Presentation delivered by representatives of Recreational Canoeing Association of BC and Vancouver Island Whitewater Paddling Society to the Cowichan Watershed Board on the 31st of July, 2017.

Island Land Surveying Ltd. 2018. Site Plan of Boat Ramp at Norther Shore Road Town of Lake Cowichan. Field survey dated February 28, 2018.

3 Performance Measure Info Sheet: Lakefront Private Properties

Sub-Objective	PM	Units	Description	MSIC
Flooding and inundation	PM1: Maximum high water event	meters	Maximum lake levels during the control period	0.15m
Private property lakefront areas	PM2: Frontage length	meters	Daily average length from high-water mark to lake's edge for representative lakefront areas	10%

3.1 Overview

These performance measure reflects the effects of management actions on Cowichan Lake on lakefront properties. Impacts to private lakefront properties was identified as an important value and interest for water use planning. The magnitude, timing and duration of elevated lake levels could result in flooding and/or inundation of lakefront properties, with impacts including property damage (e.g., septic fields, homes, secondary structures), loss of property use, and infringement of property rights.

An earlier control period and an increased weir height could increase the maximum level in the lake during potential spring flooding events. Lake levels at the end of control period could influence the first fall peak and increase flood risk associated with fall storms. Changes to the weir height and operations could result in higher spring and summer lake levels could store water over a larger inundation area and longer duration of time.

3.2 Performance Measure

PM1: Maximum high water event

This PM represents an interest in minimizing peak lake levels to avoid potential flooding impacts associated with higher lake levels that may cause loss of property use and/or property damage. It reports the maximum daily lake elevation over the entire dataset (2050s, and 1953-2016) during:

a) the early spring control period from March 1 to April 30,
b) the late winter portion of the control people from February 1 to February 28, and
c) the early fall portion of the control period from October 1 to November 5

The different time periods used for this PM were selected based on a review of the alternatives and in order to capture variation across the different alternatives. The maximum daily lake elevation was used based on feedback from the LTSG and the PAG that minimizing the magnitude of flooding events during the control was more important than the number of flooding events above an arbitrary threshold such as the average high water mark.

PM2: Frontage length

This PM represents an interest in maintaining existing exposed lakefront areas for aesthetic and property value considerations, including lakefront areas within or adjacent to private properties. The Lakefront Technical Sub-Group (LTSG) identified that the potential loss of lakefront areas was important regardless of how or when (i.e. time of year) that area was being used. Frontage length is considered to be linked to the amount of available lakefront area which varies by lake level.

The PM reports the average daily frontage length for a selection of representative sites around Cowichan Lake with varying slope steepness and vegetated/non-developed or non-vegetated/developed shorelines, (see Recreation Beach Use for representative sites). Frontage length was measured as the distance from the water's edge to the normal high-water mark (164m) as a proxy for the private property boundary elevation, given the variation in property boundaries around the lake.

3.3 Calculations

The PMs are estimated using the Cowichan Lake Operational Model which reports the predicted lake elevation as a daily time series for a 10-year period based on inflow data projected for the 2051 to 2060. The PMs are also estimated using a historical 63-year dataset from 1953 to 2016. All PMs are calculated as a single value for each year of the modeled dataset and summarized across all yeas for the 2050s and historical datasets (n = 10 years and n = 64 years) using the minimum, maximum, and 10th, 50th, and 90th percentile statistics to reflect the degree to which these PM data can vary from year to year.

PM1: Maximum high water event

The steps to calculate the PM are:

1. For each different portion of the control period (February 1 to 28, March 1 to April 30, October 1 to November 5), determine the maximum lake elevation for each day of the control period.

PM2: Frontage length

The steps to calculate the PM are:

1. For each representative site, determine the daily frontage slope length at the lake elevation.

3.4 Key Assumptions and Uncertainties

- 10-year projected climate time series does not incorporate the full range of potential climate conditions that can lead to extreme high water events. Therefore, PM should be used as relative comparison of performance of different management alternatives, not absolute value of maximum peak water levels.
- Peak water levels based on average daily records not instantaneous peak levels (ie: the highest water level during the day with the highest average water level).

4 Performance Measure Info Sheet: Municipal

Sub-Objective	PM	Units	Description	MSIC
Waste water dilution	PM1a: Effluent dilution ratio objective (200:1) – Upper River	days/yr	Average number of days effluent dilution ratio objective is not met	10%
	PM1b: Effluent dilution ratio guidelines (40:1) – Lower River	days/yr	Average number of days effluent dilution ratio guidelines is not met	10%
Community water supply	PM2a: Intake pumping capacity – Town of Lake Cowichan	days/yr	Average number of days water pumping capacity is not met	10%
	PM2b: Intake invert elevation - Town of Lake Cowichan	days/yr	Average number of days water intake invert is	10%

4.1 Overview

These performance measure reflects the effects of management actions on Cowichan Lake and Cowichan River on municipal water supply and waste water dilution. The Cowichan watershed supplies 30% of region's fresh water needs for drinking, irrigation, sewage dilution and other uses, including drinking water for around 25,000 people in three municipalities, five electoral areas, and two First Nations. Currently, waste water from the Town of Lake Cowichan is discharged to the upper river, and from the Municipality of North Cowichan, the City of Duncan, Cowichan Tribes, and Areas D and E of the CVRD are discharged to the lower river via the Joint Utility Board Sewage Treatment Plant (JUB STP) outfall. There is a need to ensure adequate flows to dilute waste water effluent discharges in the upper and lower river at low flow periods while accounting for population growth into future waste water dilution requirement estimates.

4.2 Performance Measure Summary

PM1: Effluent dilution ratios

These PMs represent an interest in maintaining suitable river flows to meet waste water dilution requirements for Town of Lake Cowichan discharges to the upper river and for JUB STP outfall discharges to the lower river.

PM1a reports the average number of days river flows are below the minimum threshold needed to meet the effluent dilution ratio objective (of 200:1) for the Town of Lake Cowichan. The PM is calculated using the projected 2050s minimum effluent river flows based on average monthly flow.

Month	Minimum River Flow Required for Dilution (2016 Treatment Plant Effluent Flows) (cms)	Minimum River Flow Required for Dilution (Projected 2050s Effluent Flows) (cm)
January	4.6	6.4
February	4.2	6.0
March	4.9	6.7
April	2.0	3.8
May	1.8	3.6
June	1.5	3.3
July	2.2	4.0
August	2.4	4.2

Month	Minimum River Flow Required for Dilution (2016 Treatment Plant Effluent Flows) (cms)	Minimum River Flow Required for Dilution (Projected 2050s Effluent Flows) (cm)
September	2.2	4.0
October	4.7	6.6
November	4.4	6.2
December	3.6	4.5

PM1b reports the average number of days river flows are below the minimum threshold needed to meet the effluent dilution ratio (40:1) guidelines for treated effluent discharged from the existing Joint Utility Board Sewage Treatment Plant (JUB STP) outfall. Average Dry Weather Flows (ADWF) for the JUB STP are 8,145 m^3/day (0.094 m^3/s), based on the average of the lowest five years of recorded treatment plant flows from July 1 to September 30 for the period from 2007 to 2016. The minimum dilution flow is roughly equal to the environmental flow target of 2.8cms. For the 2050s, the JUB plant flow is projected to increase to about 14,000 m^3/day (0.16 m^3/s) which would significantly increase the minimum required dilution flow. However, plans are being prepared to divert effluent discharge from the river and to pump to an outfall in Cowichan Bay.

PM2: Intake pumping capacity and invert elevation

These PMs represents an interest in maintaining suitable lake levels to avoid impacts to the municipal water supply. These PMs are calculated based on the infrastructure and operating constraints provided for the current community water pump station for the Town of Lake Cowichan (Nagi Rizk, personal communication, November 24 2017).

PM2a reports the average number of days lake levels are below the 161.15m, the minimum elevation for the Town of Lake Cowichan pump station to function. The minimum pumping rate is met when intake pipe at the wet well is at least half full. At lake elevations below 161.15m, the Town of Lake Cowichan will not meet its minimum pumping capacity.

PM2b reports the average number of days lake levels are below 160.80m, the elevation of the Town of Lake Cowichan water pump station intake invert (inlet pipe to pump station). If the lake level drops to 160.80m the pump station would not be able to function without significant upgrades to the pump station (i.e. installing a new intake at a lower elevation). Given that the Cowichan Lake water intake is the only source of water for the Town, this is a critical elevation that the lake could not go below without significant detrimental impacts to the town.

4.3 Calculations

The PMs are estimated using the Cowichan Lake Operational Model which reports the predicted lake elevation as a daily time series for a 10-year period based on inflow data projected for the 2051 to 2060. The PMs are also estimated using a historical 63-year dataset from 1953 to 2016. All PMs are calculated as a single value for each year of the modeled dataset and summarized across all yeas for the 2050s and historical datasets (n = 10 years and n = 64 years) using the minimum, maximum, and 10th, 50th, and 90th percentile statistics to reflect the degree to which these PM data can vary from year to year.

PM1: Effluent dilution ratios

1. Determine the number of days for each year that river flows are less the minimum required flow.

PM2: Intake pumping and invert elevation

The steps to calculate the PM are:

1. Determine the number of days for each year that lake elevations are less than the water supply infrastructure minimum levels.

4.4 Key Assumptions and Uncertainties

- 2050s Average Dry Weather Flows are based on annual growth rates of 1.5% and 1.28%, for Town of Lake Cowichan and North Cowichan Respectively
- For the upper river effluent dilution requirements, the required minimum monthly flow for October was assumed to be the same as for August in order to represent a dryer year (when the river is still being controlled by the weir).

4.5 References

Town of Lake Cowichan Water Demand Projections, prepared by Nagi Rizk November 2017

North Cowichan Water Demand and Sewer Flow Projections, prepared by Clay Reistma November 2017

5 Performance Measure Info Sheet: Water Management

Sun-Objective	PM	Units	Description	MSIC
Infrastructure Capital and Operating Costs	PM1: Capital Costs	Million $	Capital costs associate with new infrastructure	10%
	PM2: Operating Costs	Million $	Average operational costs (over 10 years)	10%

5.1 Overview

These performance measure reflects the financial costs associated with building and operating new water management infrastructure for the Cowichan water management system.

5.2 Performance Measures

These PMs represents an interest in minimizing costs associated any new capital costs or any increases in ongoing operating costs required for new water management infrastructure.

PM1 reports the approximate capital costs (estimated to an order of magnitude) to build new or modify existing water management infrastructure, including to raise the weir or install a permanent pump house. These cost estimates were based on a 2015 Cowichan Lake Storage Options Review (KWL, 2015) and on estimates from Catalyst to design and build a new weir (raised by 1m), based on previous studies (personal communication, Graham Kissack, January 24 2018), as follows:

- $6M - permanent pumphouse
- $20M - raise weir 1m (less for a lower height increase)

PM2 reports the approximate operational costs (estimated to an order of magnitude) to operate any new or modified water management infrastructure. Operational costs include costs to operate a permanent pump station and costs to mobilize temporary pumps one time per year, and were estimated based on the assembly of emergency pumps in 2016 (personal communication, Graham Kissack, January 24 2018), as follows:

- $500K / mobilization of temporary pumps (once per year)
- $100K / year for operation of permanent pump house

5.3 Key Assumptions and Uncertainties

Cost estimates are considered conceptual/indicative (accuracy of +/- 50%) and are appropriate for comparison of alternatives. Costs will be revised and refined as detailed designs and plans are prepared.

5.4 References

Kerr Wood Leidal, 2015. Cowichan Lake Storage Options Review. Prepared for the Cowichan Valley Regional District.

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Technical Memorandum

DATE: December 22, 2017

TO: Michael Harstone
Compass Resource Management

FROM: Craig Sutherland, M.Sc., P.Eng.

RE: **COWICHAN WATER USE MANAGEMENT PLAN**
Cowichan Lake Operational Model
Our File 2860.009

The Cowichan Lake Operational Model simulates how the weir as well as operation of the gates and boat lock at the outlet of Cowichan Lake impacts lake levels and discharges throughout the year. It can be used to assess how lake levels and river flows change as a result of:

1. changes in weir operation and prescribed outflow schedule;
2. increasing storage by either raising weir structure and/or pumping; and
3. projected future changes in inflow to the lake.

Daily Water Balance

The model is a spreadsheet (MS-Excel) based model which calculates daily water balance through the lake using the simple mass balance equation:

$$I - O = \_S / \_t$$

Where:
Δt is the model time step
I is the average net-inflow over Δt
O is the average outflow over Δt
ΔS is the change in storage in the lake over Δt

Net-inflow is defined as the volume of surface and groundwater runoff from the watershed plus volume of direct rainfall on the lake surface minus volume of evaporation from the lake surface during time step _t. This means that at certain times in the summer the net-inflow is negative when runoff and precipitation to the lake are less than evaporation.

Historical and Future Projected Daily Net-inflow

An average daily net-inflow time series has been back-calculated from daily discharge and lake level records collected since 1953 by the Water Survey of Canada. This record provides a continuous estimate of net-inflow to the lake for a 64-year period up to the end of 2016. The back-calculation is also based on the mass balance equation.

In addition to net-inflow time-series based on historical record, a net-inflow record based on projected changes in climate for the 2050s period can also be used in the analysis. This future projected net-inflow time-series is based on hydrological modelling completed by Simon Fraser University (Foster & Allen, 2015). The climate time series used for the future 2050s period is based on downscaled global circulation model (GCM) projections using the Pacific Climate Impacts Consortium (PCIC) BC Regional Analysis Tool. Specifically, the results of the GCMs used in the TreeGen Ensemble (Cannon, 2008) and the SRES AR4 emissions scenario which represents future emissions for business as usual case. The ten years of projected 2050s inflows for Cowichan Lake are shown in the attached Figure 1 including a comparison of the median daily flows for 2050s and the historical 1981 to 2010 climate normal period.

Cowichan Lake Operational Model Logic

Average daily outflow from the lake is simulated to account for both the proposed weir operation set for the alternative and the physical hydraulic constraints of the system.

The physical constraints that can be adjusted in the model include:

1. Increasing or decreasing the top elevation of available lake storage which would be achieved by raising the weir, increasing the height of the gates and making physical modifications to the boat-lock;
2. Decreasing the bottom elevation of available lake storage by using "negative storage" which would require installation of pumps to lift water from the lake into the river;

The operational constraints that can be adjusted in the model include:

1. the start and end date of the control period for the weir and gates control lake levels and flow in the river,
2. setting preferred minimum flows and absolute minimum flows to control how discharge in the river is adjusted during the control period,
3. setting rule curve that dictate when the modelled river discharges need to be increased to lower lake levels below the control curve;
4. trigger lake levels (rule bands) that dictate when discharge should be decreased to the absolute minimum flows;
5. set of flow ramping rates that dictate how quickly river discharges can change from one day to the next; and
6. the maximum pumping rate for those alternatives requiring negative storage.

The physical constraints that cannot be adjusted in the model are:

1. the lake level vs river discharge rating curve which defines the minimum lake level at which a specified discharge can be released from the lake or the natural outflow limit which is defined by the natural river channel downstream; and
2. the weir/gates rating curve which defines the maximum lake level at which a specified discharge can be released from the lake, this curve is shifted up or down depending on the weir crest elevation set in the model.

Figure 2 shows the rating curves including weir/gate rating curves over a range of potential increases in weir and gate elevation.

The model sets outflow on a daily time-step using a series of following logical statements.

1. Are the weir, gates, and boat lock in operation and controlling the flow (currently control period is from April 1 to Nov 7 or return of fall rains whichever occurs first).
2. Are lake levels greater than and less than the defined control lake level (rating curve) for the proposed alternative?
3. Increase or decrease controlled outflow based on the prescribed ramping rate depending on if lake levels are above or below the control curve.
4. If controlled outflow based on prescribed ramping rate is less than preferred or absolute minimum river flows, then set outflow to minimum flow.
5. If outflow from step 4 above is greater than the natural outflow limit (set by the lake level vs river discharge rating curve) then set outflow to natural outflow limit otherwise use the controlled outflow.

A flow diagram showing the model logic is included in Figure 3.

Model Output

The model output includes time-series of daily average water levels for Cowichan Lake and discharges in Cowichan River immediately downstream of the weir. The model runs continuously such that it calculates water levels and river discharges throughout the year. Currently, the model does not calculate discharge along the length of the Cowichan River.

Model Assumptions and Limitations

The model assumptions and limitations include the following.

1. Net-inflow time-series used as input to the model have been derived from recorded lake levels and river discharges. Therefore, the uncertainty in the net-inflow record is reflective of any errors in the historical lake level or river discharge record.
2. The results of the Cowichan Lake Operation Model represent how lake levels and river discharges would fluctuate based on a set of prescribed rules. The model can only use lake levels and prescribed discharge rates on specific dates for the modelled storage alternative. This constraint in the model may not reflect exactly how the weir may be operated given specific

conditions and management decisions. For instance, using seasonal and short-term weather forecast to provide guidance for river flow and lake water level management decisions.

Closing

Should you have any questions related to the Cowichan Lake Operational Model, please contact the undersigned at 250-595-4223.

KERR WOOD LEIDAL ASSOCIATES LTD.

Prepared by:

Craig Sutherland, M.Sc., P.Eng.
Water Resources Engineer

CS

Encl.: Figure 1 Net-inflow Time-series and Figure 2 Model Logic Diagram

Statement of Limitations

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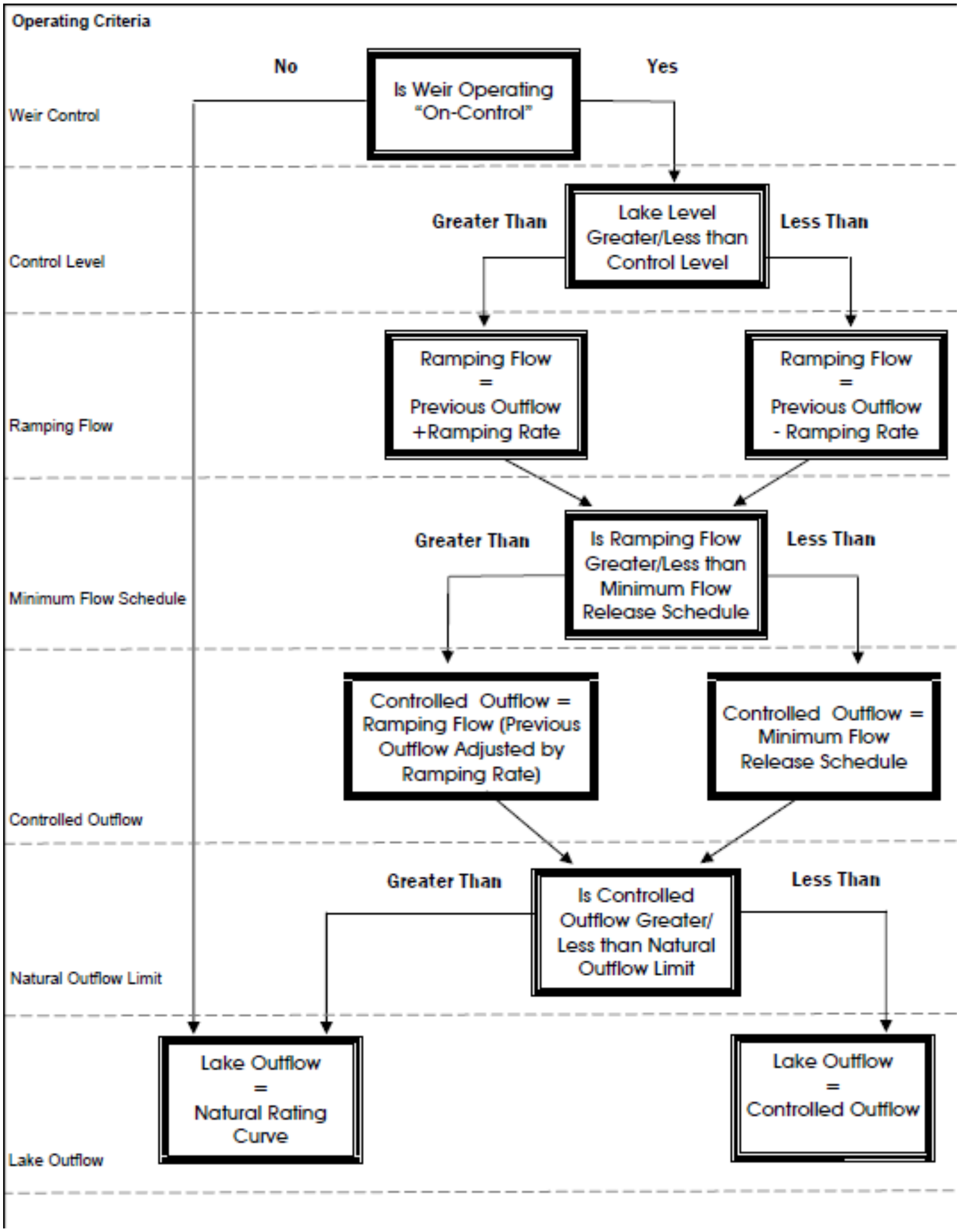
Revision History

Revision #	Date	Status	Revision Description	Author
A	December 22, 2017	DRAFT	Issued as draft	CS

Works Cited

Cannon, A. J. (2008). Probabilistic multisite precipitation downscaling by an expanded Bernoulli-Gamma density network. *Journal of Hydrometeorology, 9*(6), 1284-1300.

Foster, S. B., & Allen, D. M. (2015). *Results of Coupled Groundwater-Surface Water Model of the Cowichan Valley Watershed.* Burnaby: Department of Earth Sciences Simon Fraser University.


Operating Criteria
Weir Control
Control Level
Ramping Flow
Minimum Flow Schedule
Controlled Outflow
Natural Outflow Limit
Lake Outflow
No
Is Weir Operating "On-Control"
Yes
Greater Than
Lake Level Greater/Less than Control Level
Less Than
Ramping Flow = Previous Outflow +Ramping Rate
Ramping Flow = Previous Outflow - Ramping Rate
Greater Than
Is Ramping Flow Greater/Less than Minimum Flow Release Schedule
Less Than
Controlled Outflow = Ramping Flow (Previous Outflow Adjusted by Ramping Rate)
Controlled Outflow = Minimum Flow Release Schedule
Greater Than
Is Controlled Outflow Greater/ Less than Natural Outflow Limit
Less Than
Lake Outflow = Natural Rating Curve
Lake Outflow = Controlled Outflow

Appendix I. Characterizing Potential Effects on Lakefront Properties

This section responds to the request at the last meeting to better characterize potential impacts on lakefront properties and, in particular, the degree to which higher lake levels (as a result of a higher weir) may be related to the natural boundary and where property rights may be starting to get affected. Anyone who has been involved with this discussion in the past recognizes the challenges with undertaking an assessment like this, and so our preliminary review of the natural boundary definition should be considered as an input into a fuller assessment that may be needed after the Cowichan WUP, depending on the recommendations coming out of our meeting. In addition, we also took a closer look at the potential for increased flooding and erosion risks to lakefront areas.

This section provides a summary of our review and offers some observations and recommendations that were built into the new alternatives to reduce and mitigate the potential of adverse effects on lakefront properties. In addition, we have identified recommendations for further analysis and field work depending on what the PAG decides at the upcoming meeting.

1.1 Characterizing Potential Flooding Risks to Lakefront Homes

Description for Cowichan WUP

Many lakefront structures and homes are and will continue to be vulnerable and susceptible to flooding regardless of whether any changes are made to the existing weir or to the water management operations at the outlet of Cowichan Lake. There are two main reasons for this: a) many homes and lakefront structures were built below the natural floodplain level of the lake (i.e., defined as EL. 167m); and b) during large inflow events, high lake levels are controlled by the natural constriction in the river (by the trestle bridge) and not governed by the weir or its operation which is submerged during these events. The key issue for the Cowichan WUP is whether any of the water use alternatives would result in a greater incremental risk of flooding either through a higher weir; an earlier control date for storing water in the lake; a change in timing and magnitude of flow releases to the river; or some combination of changes to the weir or operations. This section looks more closely at any incremental increase in flooding risk associated with the water use alternatives being considered for the Cowichan WUP.

Over the past few months, the focus of review for potential increased incremental flood risk has been during higher lake levels in the late winter and early spring period, as this is where there has been the most difference across the alternatives. The hydrograph below shows the highest lake level event (according to the 2050s dataset) occurred in the late fall in November where lake levels reached 165m. However, this flooding event was not associated with any noticeable differences across the alternatives (because the highest inflow / flooding events occur during the off control period when the gates and boat lock are left fully open; and lake levels are governed by the capacity of the river to pass flows about a kilometer or so downstream by the trestle bridge).

Having said this, there were differences observed in the largest spring inflow event across the alternatives even though these lake levels were lower than the highest flooding in the winter (i.e., where lake levels rose to 165.0m). During the Round 2 alternatives (i.e., Alternatives 10 to 13) that were reviewed during PAG meeting 3, the incremental increase in lake levels ranged from +10cm (i.e., 163.40m) to +40cm (i.e., 163.70m). See Figure 1 showing the modeled differences in lake levels during the highest inflow events in the 10 year dataset (2050s).

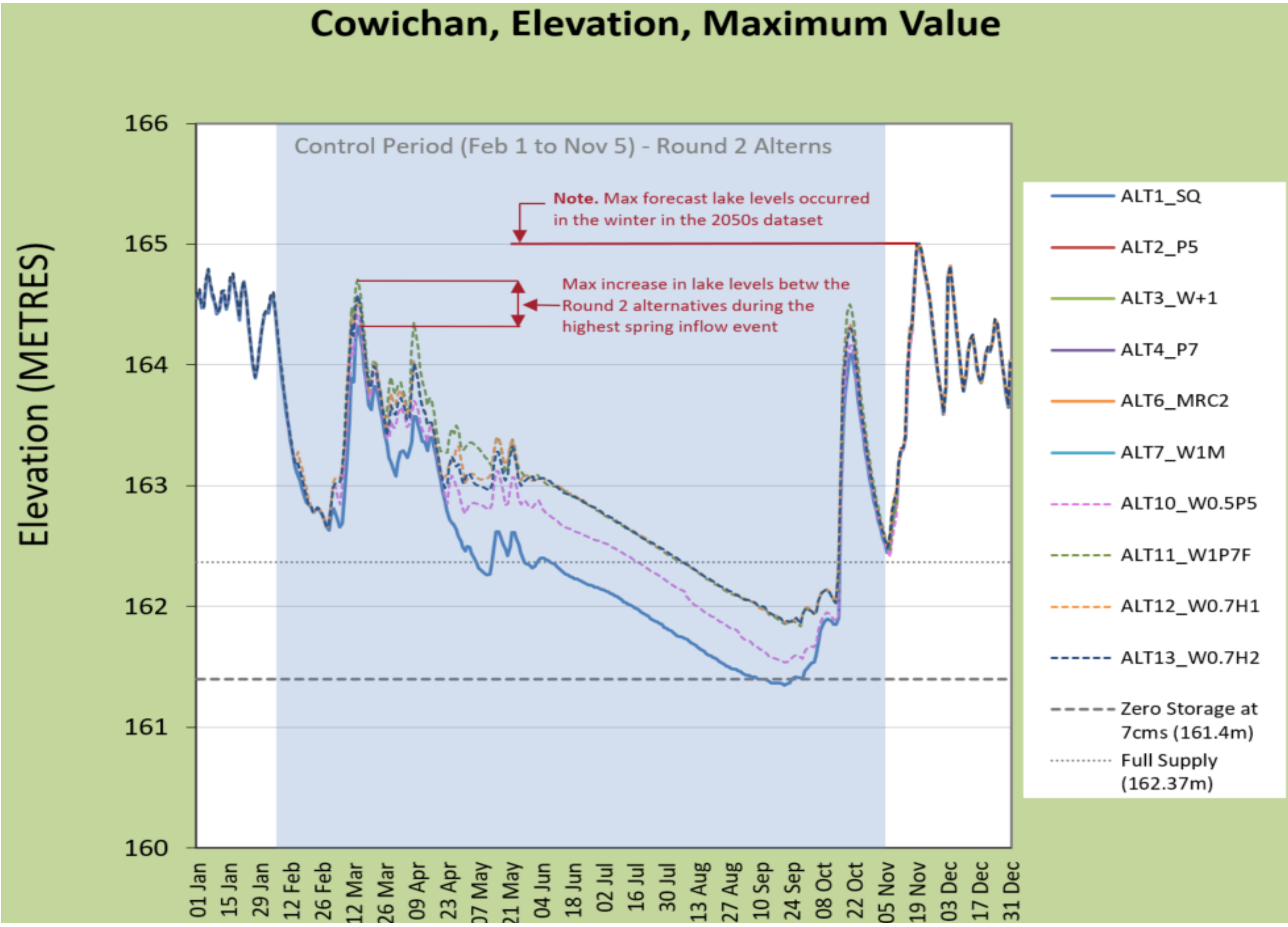


Figure 1. Maximum lake levels modeled using the future 2050s dataset for the Round 2 alternatives (ALT_10 to ALT_13) from PAG Meeting 3. The graph shows the highest lake levels occur in the winter (mid-Nov), although there was no net increase in lake levels during this event compared with the existing weir and operations (ALT1_SQ indicated in blue). However, smaller inflow events in the spring did show differences across alternatives increasing lake levels by as much as 40cm for one of the alternatives where lake levels reached 164.70m.

So a key question during the review of the Round 2 Alternatives was whether the incremental increases in lake levels during the maximum spring inflow event to Lake Cowichan in the 2050s was whether this was likely to cause any incremental damage to homes or structures (recognizing that lake levels were often higher during other events during the off-control period)?

Characterizing Potential Incremental Flooding Effects – During the Control Period

To answer the question whether there could be incremental increases in flood risk during the control period, we needed to have a better understanding of when homes and structures may be at risk of flooding. As a preliminary assessment, we undertook a geospatial review of when outlines of homes would intersect with different elevation contours around the lake in order to develop a profile for the elevations of lakefront homes using 0.5m increments.

We used CVRD's spatial elevation dataset to generate 0.5m contours around the lake and counted when a contour touched or crossed what appeared to be the principal residence building using Google Earth satellite maps. A total of 490 structures / homes were clearly identified and assessed. There were weaknesses with this method because an intersection point does not mean that there will necessarily be flooding damage to a home, as the foundations may be elevated or on pilings or the basement/first floor of the house may be open or designed to avoid damage. Having said this, the assessment does provide helpful context for getting a better sense of the number of homes that may be at risk at increasing lake levels. Figure 2 provides an illustration for the results of a few lakefront properties and where their homes intersect with the contour elevations.

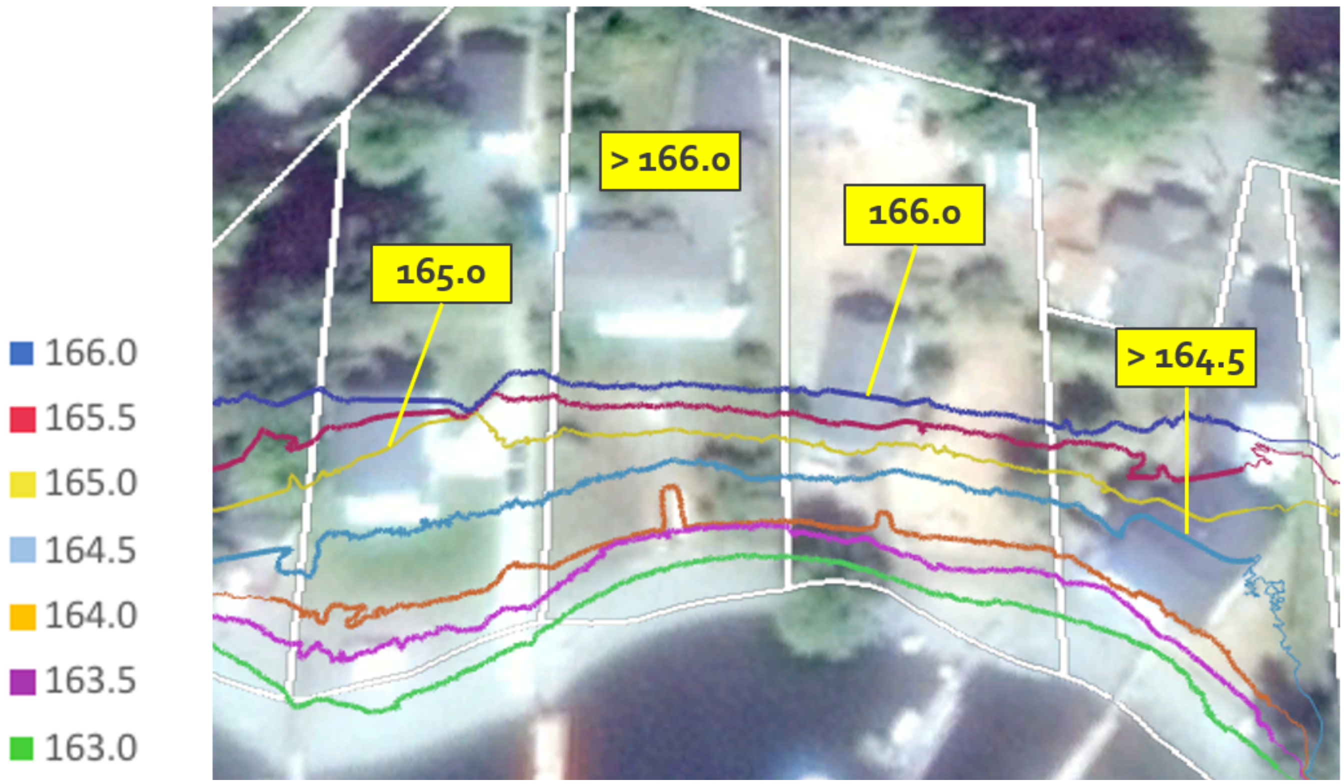


Figure 2. Cowichan Lake level contours overlaid on Google Earth to show the intersection point with lakefront homes at risk of flooding. Note that the 1 in 200-year flood elevation for Cowichan Lake is 167.0m. The yellow boxes indicate the approximate elevation contour where the building would be at risk of flooding.

The results from this preliminary assessment are summarized in the following graph in Figure 3.

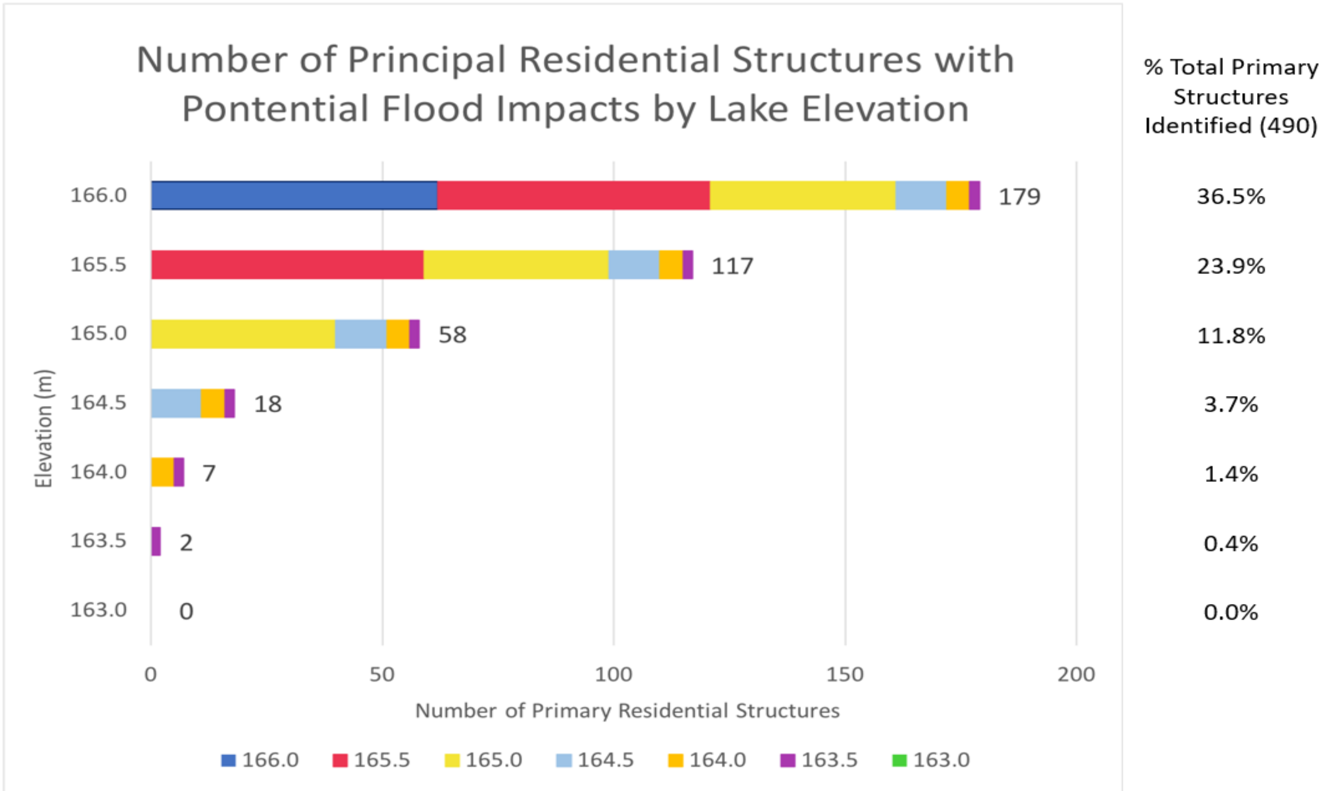


Figure 3. Summary of number of primary residences potentially at risk of flooding by 0.5m contour.

A couple of points to emphasize in this preliminary assessment. First is that the 1 in 200-year flood level for Cowichan Lake is 167.0m and it appears that a significant proportion and number of homes are lower than this level (36.5% of the 490 homes assessed were at risk of flooding at the 166m contour). The average winter high water level is 164m and given that there are 2 homes which intersect the 163.5m contour and a further 5 homes which intersect the 164m contour, it is unlikely that the habitable floors of these low-lying homes are regularly and damaged on an annual (or more frequent basis) given that the average high water level of 164m has been fairly constant over the past 65 years. It is also noted that some (if not all) of these low-lying homes are known to be built on raised foundations, which our assessment would not have been able to take into account.

Another observation is that there appears to be a break point where flooding risk seems to increase based on the number of potentially affected homes somewhere between the 164.5m and 165m contours when the number of homes increases from 18 to 58. To get a better sense of the frequency for when lake levels reach these contour levels, we reviewed the number of times that lake levels exceeded various elevations on Cowichan Lake over the past 65 years (from 1952 to 2018) and we summarized these by month in the following table.

Month	El. 163.5	El. 164	EL. 164.5	EL. 165	EL. 165.3
Jan	32	15	3	2	1
Feb	24	5	1	1	0
Mar	15	3	0	0	0
Apr	0	0	0	0	0
May	0	0	0	0	0
Jun	0	0	0	0	0
Jul	0	0	0	0	0
Aug	0	0	0	0	0
Sep	0	0	0	0	0
Oct	1	1	0	0	0
Nov	16	10	5	0	0
Dec	37	16	4	2	0

The adjacent graph shows that the maximum level that lake levels have reached over the past 65 years was 165.3m (well below the 1 in 200 yr flood level of 167m). Lake levels regularly reach 163.5m (about twice a year on average) and reach 164m (about every year) and 164.5m (about every 5 years) and 165m (about every 13 years or so). As well, it is also interesting to note that peak lake levels are concentrated in late fall and winter months and generally fall off sharply by the end of March.

The future 10 year hydrology dataset (in the 2050s) being used to assess the water use alternatives has a maximum flooding event where lake levels rise up to about 165m and this would be equivalent to about a one in 13 year event (based on a comparison with the 65 year historical set).

Preliminary Results and Recommendations

The highest inflow event during the control period (Feb 1 to Nov 5) being used to assess differences in the Round 2 Alternatives (and using the 10-yr 2050s dataset) showed that lake levels would increase from 164.3m to as much as 164.7m* depending on the alternative. The net increase in lake levels by as much as 40cm would increase the number of homes at potential risk of flooding from maybe 10 or so to maybe about 30 or 40 (according to a linear interpretation of the 0.5m contour summaries in Figure 3 above). The significance of this incremental increase in flood risk and whether more damage would occur to these homes is unknown. But it is probably fair to say that there would be increased risk.

*** Note.** It is important to stress that these levels are still lower than the peak flood levels that will occur during the off control period (Nov 6 to Jan 31) where lake levels were modeled to rise to 165m.

Accordingly, the consulting team has recommended the following strategies to mitigate and reduce these risks in the new alternatives.

#	Recommendation	Comment
Rec O1	**All new water use alternatives will be designed to limit increases in the peak lake levels of no more than 10cm <u>during thecontrol period</u>.**	The new alternatives were designed to limit incremental increases in peak lake levels during the control period through one or a combination of: • Lower weir height increases • Varying the control period (i.e., starting later than Feb 1) • Building mandatory pre-spilling into the operations Note. The 10cm threshold was selected because the consulting team was confident that a modeled increase in lake levels could be avoided through in-season management by taking into account snow pack levels, weather forecasting and potentially new increased capacity to pre-spill through the control gates, if they were redesigned with a higher weir.

Rec S1	**Post WUP – carry out a more detailed flooding risk assessment of lakefront homes and any corresponding field surveys that may be required**	This may or may not be required depending on the alternative that is agreed to.

1.2 Characterizing Inundation of Lakefront Properties and the Natural Boundary

Description for Cowichan WUP

Defining the degree of inundation of lakefront areas in relation to higher lake levels (associated with a higher weir) is relatively straightforward. Defining the natural boundary for determining where lakefront property rights begin – *and compensation may be warranted if water were to be stored above this point* – is particularly complicated for properties around Cowichan Lake. Some of these challenges relate to:

- The natural boundary is not static and varies according to soil type, vegetation, exposure, gradient, erosion, etc.
- Many regulated lakes have a consistent and stable high water mark that correlates to more directly to the natural boundary (for example, the natural boundary typically is associated with the normal winter high water mark, which is defined by the top of a weir or dam). But for Cowichan Lake this is not the case as the top of the weir is 162.37m and winter high water levels are often considerably higher than this as levels are controlled by the river downstream and not the weir.
- There have been different interpretations of the natural boundary over the past 60 years or more and many land title surveys have identified the natural boundary but these have highlighted some inconsistencies in elevations and interpretations for how they must have been derived.
- Given the variation of the natural boundary over time, natural boundaries defined on older land title surveys may not be representative any more given erosion or changes as a result of other causes.
- Moreover, lakefront property surveys have revealed considerable variance for where the legal property line is in relation to lake levels: sometimes the legal property is well below the top of the existing weir elevation of 162.37m and in other cases the property line is well above the normal high water mark defined by the 164m contour.
- Etc.

Given some of these challenges, we have made some assumptions to better carry out a review and provide context for assessing the magnitude and significance of possible inundation effects in order to better compare and select a preferred alternative. Our starting assumption is that property rights start above the natural boundary line regardless of whether a land title survey identifies a property line that extends below this point or not. Depending on the outcome of the recommendations of the WUP, this assumption may need to be more fully assessed and tested. But we believe the recent Environmental Appeal Board (EAB) ruling supports this interpretation, which stated:

> [110] *"[…] property rights end at the "natural boundary" of the lake, which is close to the high water mark of the lake. Below the natural boundary, the property belongs to others."*

[202] *"The Panel notes that the high water mark around Cowichan Lake is above the full storage level of 162.37 metres. The Panel concludes that the high water mark, or natural boundary, of Cowichan Lake is the result of natural causes. The Panel finds that, applying the legal definition of "natural boundary" in the Land Act (as required by the Act), the present natural boundary of the lake […] is higher than 162.37 metres."*

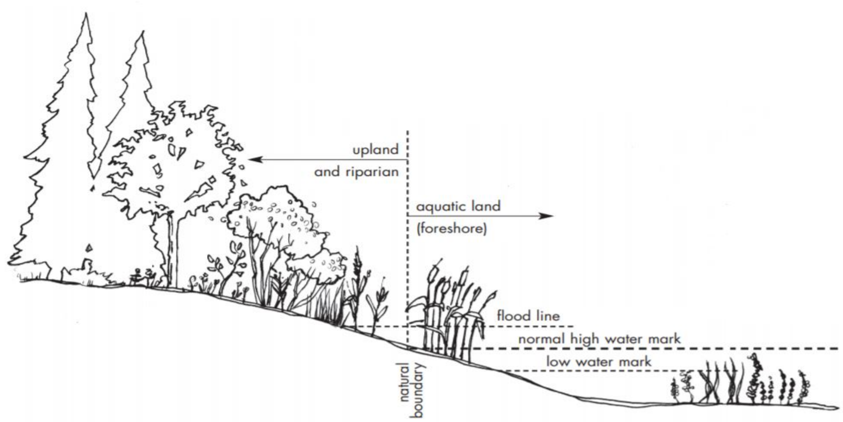
EAB Decision Nos. 2013-WAT-013(b), 015(c), 016(b), 017(c), 018(c) and 019(c)

The main focus for characterizing potential inundation effects of lakefront areas for the Cowichan WUP was on estimating higher spring and summer lake levels (i.e., associated with an increased weir height) in relation to the degree and duration of inundated lakefront properties around the lake for the different alternatives. Once this inundation profile of lakefront properties was completed it could be referenced in relation to the elevation range of where the natural boundary may lie to help put these effects into context.

Estimating an approximate range for where the natural boundary is?

The adjacent sketch provides a fictionalized representation showing the natural boundary in relation to typical water levels and vegetation types.

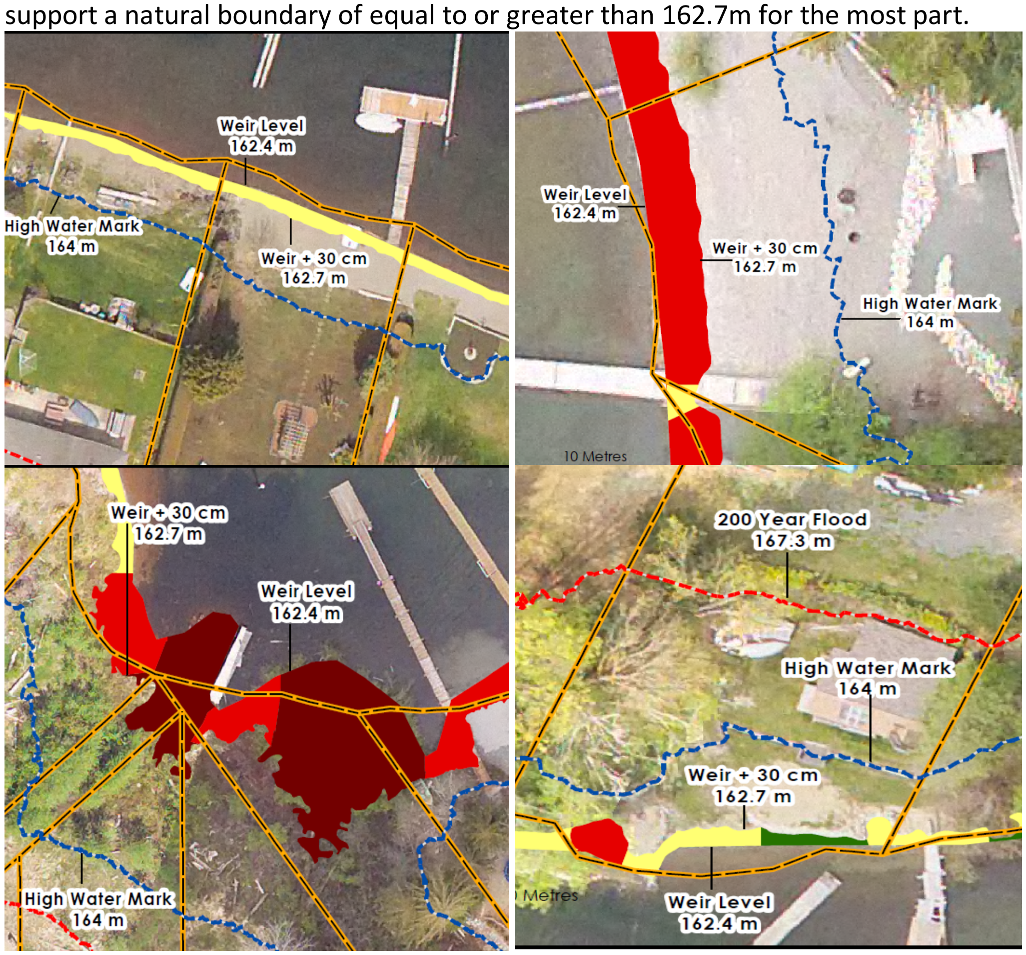
Reference: http://www.bcnature.ca/wp-content/uploads/2015/03/Section4-17.pdf

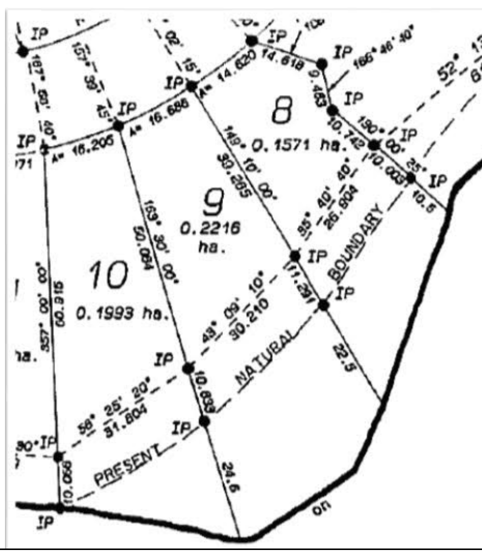
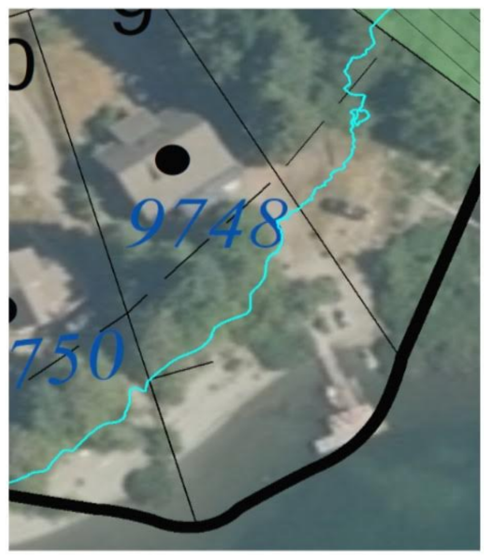


According to the *Land Act*, the natural boundary is defined:

"the visible high water mark of any lake, river, stream or other body of water where the presence and action of the water are so common and usual, and so long continued in all ordinary years, as to mark on the soil of the bed of the body of water a character distinct from that of its banks, in vegetation, as well as in the nature of the soil itself."

For Cowichan Lake a detailed field assessment would need to be undertaken to determine an elevation for the natural boundary using this definition. And quite likely the resulting assessment would lead to an elevation range and not a specific elevation given the site-specific nature of the soils, vegetation, bathymetry, exposure, etc., and other characteristics which vary around the lake. These challenges are part of the reason why it is more common to relate the natural boundary to water levels. We researched a variety of different water elevations and other sources of information to build a weighted evidence approach for an elevation range where the natural boundary line is probably located, as summarized in the following table (organized from lowest to highest elevation):

<table>
<tr><th>Natural Boundary Reference Points</th><th>Discussion and rationale</th></tr>
<tr><td>> 162.37m</td><td>During the 2013 EAB hearing the panel concluded the high water mark, or natural boundary, of Cowichan Lake is above the full storage level of 162.37m and is the result of natural causes [202]. They did not provide an opinion however on how much higher the natural boundary may be above the top of the weir although expert testimony was heard that the level could be considerably higher in places.</td></tr>
<tr><td>Between
162.4 - 163m</td><td>This was the elevation range for exposed tree roots that were surveyed by eye in relation to the top of the weir elevation. The study was carried out by Kerr Wood Liedal in 2014 as part of an erosion study and the tree roots represented the lower point of exposed roots that were assessed on undeveloped properties.</td></tr>
<tr><td>162.7m +</td><td>We carried out a cursory review of ortho photos with contours line representing an elevation of 162.7m (redline photos prepared a few years back). Our review was focused on assessing approximately where the natural boundary may lie in relation to native riparian vegetation that was evident in the photos. This review seemed to support a natural boundary of equal to or greater than 162.7m for the most part.

</td></tr>
<tr><td>162.8m</td><td>Average (and median) winter lake elevation calculated from Nov 1 to Feb 28 from 1953 to 2018 lake level survey information. Average winter lake elevations raise to 162.9m if the period of calculation is from Dec 1 to Feb 28. Also note that there were no trends in this average varying significantly over the past six decades.</td></tr>
</table>

162.87m	For guidance in estimating the natural boundary in relation to water levels, the Provincial Riparian Area Regulation Schedule (RAR Assessment Methods) provides some discussion on definitions for the high-water mark on ungauged and gauged lakes and reservoirs. It is noted that these definitions sometimes can vary substantially from the natural boundary however. The **MFLNRO developed some further guidance**[1] specific to the Okanagan region to provide assistance to professionals in defining the natural boundary in relation to the highwater mark, which provides some context for the Cowichan system. They define the HWM for gauged lakes as the highest target lake level plus 0.5m to take into account wave action. Qualified professionals can vary the highest target lake level if there is a strong rationale based on natural indicators along the shoreline (e.g., change in soil, change in vegetation). A conservative lower bound for the natural boundary on Cowichan Lake using this method would consist of taking the weir height as the highest target lake level and adding 0.5m on it. Therefore, 162.37 + 0.5m = ~ 162.87m.
164.0m	This is the elevation used by CVRD for the **riparian area regulation** by-law.
164.0m	This is the **normal high water level** for Cowichan Lake. Based on the average annual high water levels.
164.1m	CVRD did an assessment to estimate the elevation of the present natural boundary (PNB) that was identified on a **land title survey** carried out in 1990 (Lot 9 of VIP51348) that was available. The PNB line correlated directly to an elevation of 164.1m. The blue line on the orthophoto below represents the 164.1m contour.  

So while there is no definitive single elevation for the natural boundary on Cowichan Lake, **there is probably a fairly strong argument that it is in the range of somewhere between 162.7m and 163m** based on the average winter water levels assessment and a review of the riparian vegetation using the redline photos that were developed. Therefore, a reasonable lower end elevation for the natural boundary in order to help assess

[1] MFLNRO. Guidance for Determining High Water Marks for Lakes in the Okanagan under the Riparian Areas Regulation. March 18, 2014. http://a100.gov.bc.ca/pub/eirs/finishDownloadDocument.do?subdocumentId=9721

inundation effects in relation to property rights for the Cowichan WUP would be the elevation of the existing weir plus maybe 30 or 40cm.

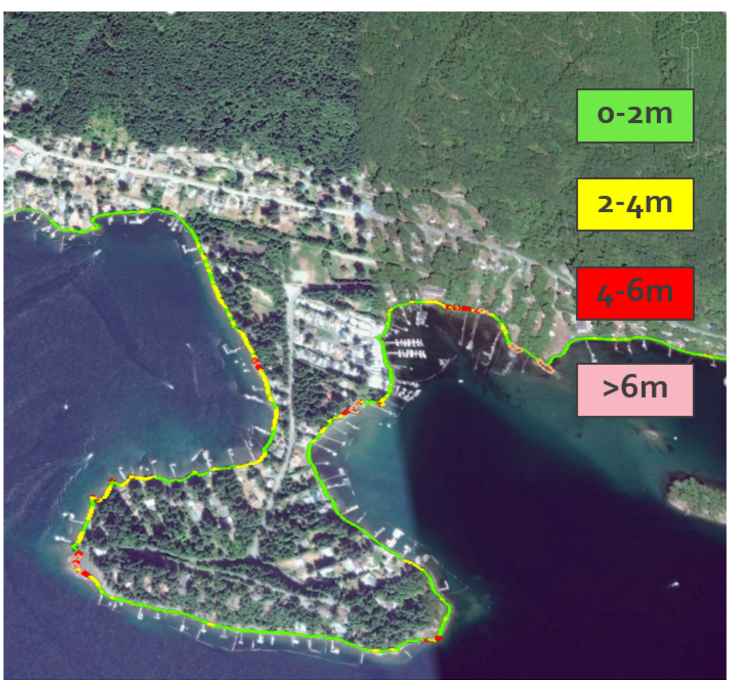
Characterizing Potential Inundation Effects associated with a higher weir – During the Control Period

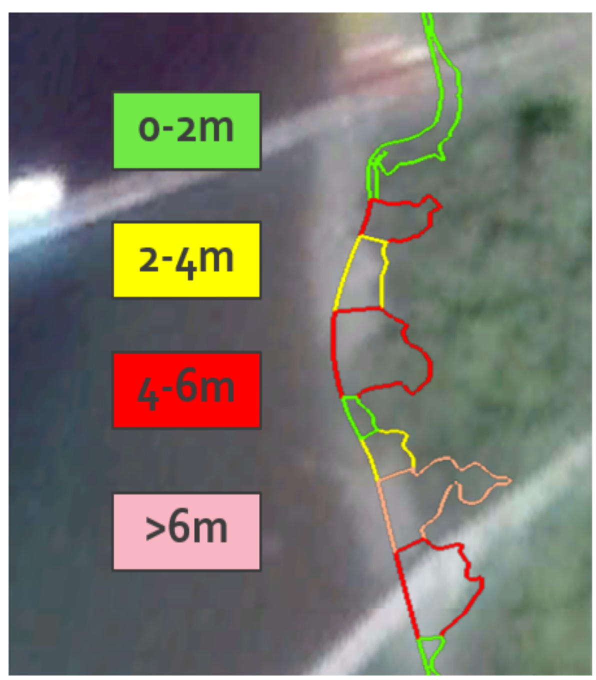
We carried out a preliminary assessment of the degree of inundation of each lakefront property assuming an increase in the weir height of 30cm. This led to the characterization of an inundation profile for the # of lakefront properties and the horizontal length of inundation associated with a 30cm increase in the weir. It needs to be emphasized that the horizontal distances were not measured from property lines on land title surveys (as already discussed above), but from the existing lake level associated with the top of the weir (i.e., 162.37m).

The analysis consisted of:

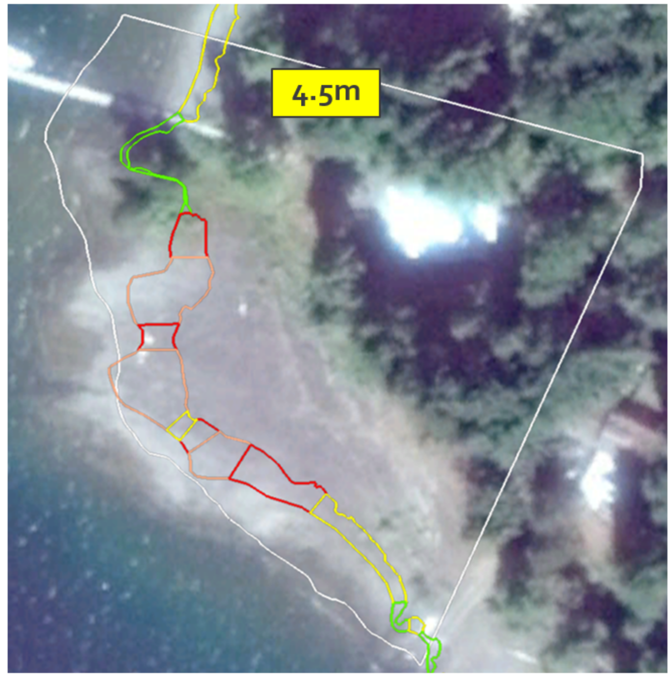
- Geospatial analysis provided by CVRD to map out 2m contours plotted out on Google Earth.
- Used land parcels (PIDs) as property boundaries and extended property lines to intersect the shoreline data.
- Assessed the average distance based on the relative proportions of each distance band to account for the natural shoreline variation of a given property.
- Assumed a linear relationship to extrapolate results to different increases in lake elevation (e.g. a 1m distance at +0.3m = 1.33m at +0.4m increase and 2m at a +0.6m increase).
- Results are summarized for 742 of 775 land parcels reviewed (33 parcels had no data or were not waterfront) at +0.3m to +0.7m and +1m increased in lake elevation.
- Did not distinguish between property use type (i.e. residential, park, industrial etc.).

The screen shots below shows a section of this preliminary assessment.

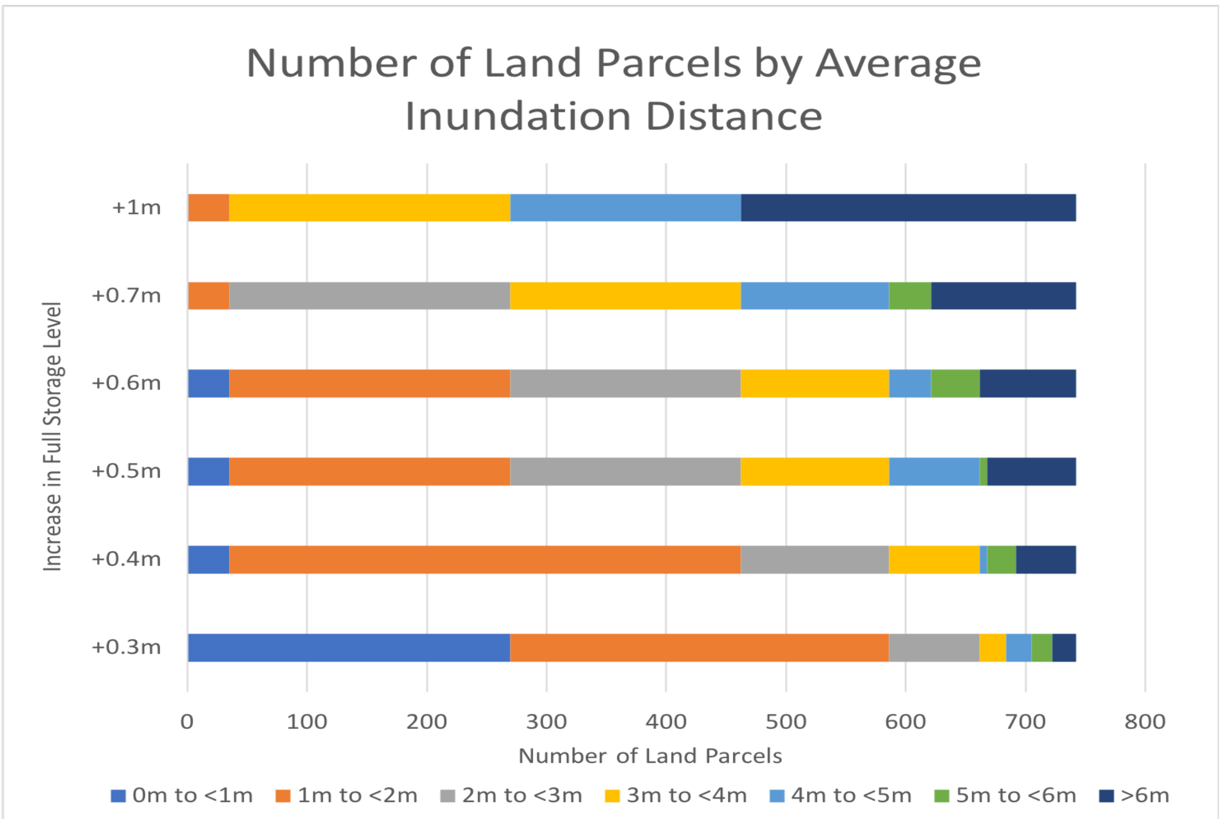




Horizontal inundation distances were averaged for each property and the screen shot below provides an illustrative of this for a few selected properties. The lengths in the yellow boxes represent an average inundation length for that property even though in some instances the length varied considerably across the property.



The results from this cursory assessment is summarized in the following graph. The graph shows that an increase in the weir height (y-axis) of 0.3m in the bottom bar plot results in about 270 properties have less than 1m of inundation; just over 300 properties having between 1m and 2m of inundation; and maybe 80 or so having between 2 to 3m of inundation; and the remaining properties varying between 3m or greater than 6m of inundation. As the weir height increases, the degree of inundation increases with a greater number of homes having greater horizontal distances of inundation. A one metre increase to the weir (top bar plot) results in at least a 3m horizontal inundation distance or more for all lakefront properties except those with a retaining wall that is at least one meter high. A point to emphasize is that these horizontal inundation distances are only when water levels are at the top of the weir and for the most part will only persist for relatively short in terms or days and weeks (generally in the May and early June period).



Preliminary Results and Recommendations

Characterizing the significance of potential inundation effects (in terms of magnitude and duration) will depend on the hydrology outputs modeled for each of the alternatives. If the PAG wanted to try and avoid potentially storing water above the natural boundary and where compensation may be warranted with lakefront properties, then choosing a lower weir height in the range of +30cm or +40cm would seem to make sense as an area to focus on for the Cowichan WUP at this point. A more detailed assessment and field surveys of the natural boundary to confirm this assumption and possibly refine the weir height further would be a recommendation based on this preliminary assessment. Alternatively, the PAG could choose to focus on alternatives that had a higher weir (i.e., >0.5m or more) with the recognition that there would be an increased likelihood that property rights could be affected through higher lake levels and further attention could be directed towards incorporating a potential compensation mechanism into these alternatives.

Later in this document, when we are reviewing the performance of the new alternatives, we provide more context on the magnitude and duration of potential inundation effects across the alternatives as lake levels often do not reach the full height of the top of the weir on many years and when lake levels do reach the top of the weir they often drop down to the height of the existing weir within a few weeks on many years.

Given this assessment the consulting team developed some new alternatives that had shorter increases to the height of the weir (0.3m, 0.4m).

1.3 Potential Risk of Increased Erosion – During the Control Period

Discussion for Cowichan WUP

In 2014, Kerr Wood Leidal carried out a shoreline erosion assessment for Cowichan Lake. The assessment was based on:

1. A field visit to developed and undeveloped sites around the lake to identify key erosion mechanisms,
2. A classification of shoreline types including slope, beach material, level of vegetation, level of shoreline development (including structures, etc.) and wave exposure; and
3. An assessment of the relative importance of the identified erosion mechanisms for each beach type.

The relative importance of the identified erosion mechanisms at key locations around the lake are shown in the graph below.

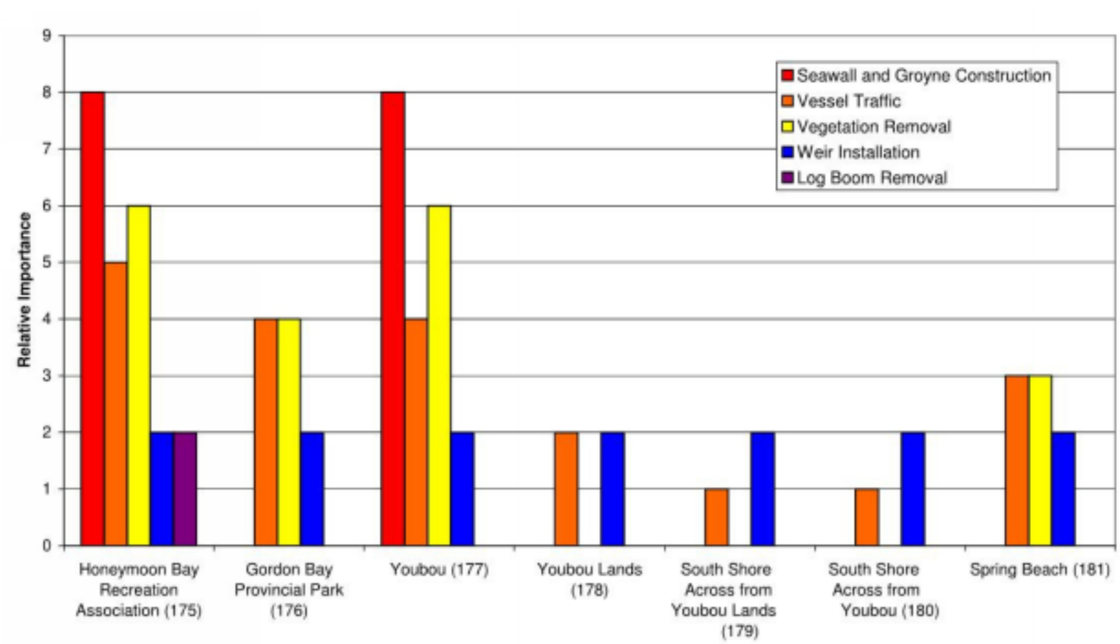


Figure 5-2: Relative Importance of Erosion Mechanisms at Each Site

The findings of the analysis were:

1. The most important erosion mechanism is the disruption of sediment transport due to seawall and groin construction, followed in relative order of importance by removal of shoreline vegetation, vessel wake waves, changes in water level regime as a result of operation of the Cowichan Lake weir and historical booming practices.
2. Changes in the height of the weir and the resulting changes in weir operations would change the of timing and duration of lake levels. This could focus more wave energy at higher elevations than the current weir. The study reviewed a hypothetic increase in the weir crest of 0.3 m and found an increased exposure to wave action for lake levels from about 162.4 m to 162.9 m. This change could result in shoreline reshaping over a period of several years. This change in the beach slope is unlikely to result in any recreational impacts but could have negative impacts to some structures and vegetation while having improved conditions at other structures.
3. Other on-going processes unrelated to the proposed increase in the weir crest elevation could also affect future shoreline erosion. These processes include increased frequency of boat wakes, removal of shoreline vegetation, construction of additional seawalls and groins as well as changes to frequency and magnitude of wind generated waves as a result of climate change.

Given these uncertainties, the PAG may want to consider a post WUP study to assess erosion risk and/or set up a compensation approach for lakefront properties who can demonstrate adverse erosion impacts as a result of any implemented changes associated with the Cowichan WUP.

Appendix J. Summary of Environmental Monitoring Studies

Study		Location	Species	Relevance	Purpose / Description	Duration	When	Capital Costs	Annual Costs	ARTSG Priority
COW1a	**Monitoring of Cowichan River flows**	2 current WSC locations	ALL	WUP Compliance	This monitoring study will collect continuous hydrometric data on releases from Cowichan Lake to monitor compliance.	life of project	current (ongoing WSC gauging)		$0 (assumed to be covered by WSC)	high
COW1b	**Monitoring of Cowichan Lake levels**	at weir	ALL	WUP Compliance	This monitoring study will collect continuous hydrometric data on Cowichan Lake levels to monitor compliance.	life of project	current (ongoing WSC gauging)		$0 (assumed to be covered by WSC)	high
COW1c	**Monitoring of major water withdrawals**	as needed (at present only Catalyst)	ALL	WUP Compliance / Water Use Compliance	This monitoring study will collect continuous data on industrial water withdrawals from Cowichan River and assess and report on compliance. Requirements are focused on withdrawals by Catalyst Paper, but this could conceivably change if water licences are redrafted.	life of water licences	current (ongoing gauging by Catalyst or other users)		$0 (assumed to be covered by ongoing program)	high
COW2	**Side channel connectivity**	Cowichan River	ALL	WUP information gap	The Cowichan River has a number of side channels that are considered important rearing habitats for fish, especially juvenile life stages. The current flow targets in the river have been influenced by data describing the proportion of side channels (and area) that are wetted at different flows (see Connectivity performance measure). This study would undertake a follow up study to Baillie (2017) and Burns et al. (1988) to confirm/revise information on side channel connectivity in relation to Cowichan River flows.	one-time study (<1 yr)	within 5 yrs		$50,000	high
COW3	**Ramping**	Cowichan River	ALL	WUP information gap	Ramping rates influence stranding probability in fish, with the general understanding that fast ramp down rates increase the probability of stranding. Ramping rates also influence the ability to store water in Cowichan Lake, as slow rates influence the amount of time, and therefore the amount of water, required to move from one flow to a lower flow target. Current ramping rates are considered precautionary, but considerable water savings may be realized if ramping requirements are relaxed to allow faster ramping. The increased storage would increase reliability of being able to deliver flows to the river in times of drought. A	one-time study (<2 yrs)	within 5 yrs		$75,000	high

Study		Location	Species	Relevance	Purpose / Description	Duration	When	Capital Costs	Annual Costs	ARTSG Priority
					ramping study would support evaluations of the trade-off between stranding risk and reliability of target flows. A quantitative study would likely need to be paired with an evaluation and deliberation by a technical group before any changes to ramping could be implemented.					
COW4	**Chinook rearing / downstream survival**	Cowichan River	Chinook	WUP information gap	Current evidence indicates that higher spring flows support higher chinook survival, especially during the downstream migration period. It is expected that spring flows will be under extreme pressure in drier years in the future and more work is needed to better understand the relationship between April/May flow levels and Chinook juvenile survival. This information will support better assessment of trade-offs between storage and benefits/risks.	one-time study (minimum 2 yrs)	within 5 yrs		$100,000	med
COW5	**summer Chinook run timing & migration behaviour**	Cowichan River & Lake	Chinook	WUP information gap	Summer-run Chinook salmon in the Cowichan River are rare and of high value, particularly to First Nations. There are considerable data gaps with respect to this life history form. There are a number of gaps, but of greatest importance are further understanding of genetic distinctiveness, timing of the run, and habitats used within the river. These studies would attempt to fill some or all of these gaps. Some work is in progress. For example, DFO and Cowichan Tribes are working on installing cameras in the Skutz Falls fishway. There is a chance a viable population may not exist, and this should be part of the assessment of additional work.	various studies (<5 yrs)	within 5 yrs		$100,000	high
COW6	**Bathymetry**	Cowichan Lake	ALL	WUP information gap	Development of environmental performance measures for Cowichan Lake was inhibited by availability of sufficiently detailed bathymetry. This information is especially important for quantifying littoral habitat availability for juvenile salmonids and Vancouver Lamprey. Bathymetry data collection should focus on key areas, such as tributary mouths and shallow embayments. Data will need to be collected for both upslope and within the wetted areas to allow development of a digital elevation model	one-time study (<2 yrs)	within 5 yrs		$75,000	high

Study		Location	Species	Relevance	Purpose / Description	Duration	When	Capital Costs	Annual Costs	ARTSG Priority
					for key areas. Methods (e.g., LIDAR vs. traditional survey) to be determined.					
COW7	**Lamprey habitat use**	Cowichan Lake	Vancouver Lamprey	WUP information gap	Development of an environmental performance measure for Vancouver Lamprey was inhibited by sufficient understanding of habitat use by the species. Additional understanding of habitat use is particularly important to support evaluation of negative storage (i.e., drawdown) scenarios. Of particular interest is understanding which habitats are used by lamprey ammocoetes and the extent to which this life stage moves/migrates in response to water level changes. This information would be used in combination with the lake bathymetry data to refine predictions on outcomes of drawdown scenarios.	one-time study (<3 yrs)	within 5 yrs		$75,000	high
COW8	**Lamprey life history**	Cowichan Lake	Vancouver Lamprey	WUP information gap	Development of an environmental performance measure for Vancouver Lamprey relied on existing information for spawning and incubation; however, there is reasonable uncertainty in this information. Better understanding of life history timing is important to support evaluation of negative storage (i.e., drawdown) scenarios.	one-time study (<3 yrs)	within 5 yrs		$75,000	high
COW9	**Amphibian and semi-aquatic wildlife**	Cowichan Lake	several	WUP information gap	Riparian PMs relied on generalized distribution maps of amphibian and semi-aquatic wildlife (e.g., water shrew) and assumed habitat preferences. There is a lack of knowledge about status and trends of these species. Some of them are Red or Blue listed and as such require special consideration in the regulatory process. A preliminary desktop or presence/absence study to identify actual habitat use would be helpful.	one-time study (<2 yrs)	within 5 yrs		$50,000	med

Study		Location	Species	Relevance	Purpose / Description	Duration	When	Capital Costs	Annual Costs	ARTSG Priority
COW10	**Status and trends of key fish species**	all	Steelhead, Coho, Chinook, Vancouver Lamprey, other fish	WUP information gaps	Response monitoring is challenging at the best of times but will be especially challenging in the Cowichan system where the outside influences are many (e.g., hatchery, salvage programs, marine survival, harvest, weir operations, etc.). There is widespread agreement that current programs (e.g., smolt enumeration, spawner counts, etc.) provide useful information on the status of some stocks and can also be used to understand trends. Details of the response monitoring program will need to be developed further but, at this stage, we have assumed that the existing monitoring undertaken by DFO, FNs and others provides some coverage for a program of annual enumeration of juvenile fish and spawner counts. Monitoring of juveniles does not currently happen on an annual basis. Fall electrofishing work is the most consistent data set but focuses on Steelhead and some Coho incidental observations. PIT tag programs focus on estimating downstream/adult survival but not population estimates. Adult data is good for Chinook and Chum; poor for Coho and Steelhead. Analysis would consider all available pre-WUP data and will be conducted after 5 years (interim analysis) and 10 years (final analysis)	2+ years baseline / 10 yrs post WUP	pre-WUP and post-WUP		$50,000 (analysis/reporting only; data collection expected to be covered by ongoing monitoring)	high
COW11	**Steelhead incubation***	Cowichan River	Steelhead	WUP impact monitoring	The recommended alternative involves starting the control period earlier on March 1, or an earlier date pending flood risk analysis. This may cause dewatering of steelhead redds due to reducing flow during the incubation period for early-spawning steelhead. The potential magnitude and biological significance of this effect are uncertain. To assess this, monitoring would involve surveying steelhead redds present when the weir is raised. Stage (to evaluate dewatering) and water temperature (to evaluate emergence time) would then be monitored at these sites for the duration of the incubation period to quantify the proportion of total redds that become	5 years	post WUP		$50,000	high

Study		Location	Species	Relevance	Purpose / Description	Duration	When	Capital Costs	Annual Costs	ARTSG Priority
					dewatered. Monitoring would be repeated over multiple years to sample a range of flow conditions. Analysis would estimate the mortality of steelhead eggs/alevins due to installing the weir. Flow and stage would be modelled at each site for a status quo scenario (control period starts on April 1) to assess the impact of moving the control period earlier. Results would be evaluated in the context of broader understanding about which life stage(s) limit steelhead in the Cowichan River.					

* Details of this proposed study were not presented to the PAG but the PAG was advised that this issue may need to be considered, pending confirmation of the details of the recommended alternative. These details were drafted after the final meeting and have not been reviewed by the ARTSG.

Note. Subsequent to the final PAG Meeting, two PAG members provided the following additional comments and questions on the proposed Environmental Monitoring and Studies:

- Suggest repeating side-channel study [COW2] every 10 years. This will help to understand any shifts in side-channel or inlet stream morphology. Also would be good to prioritize side-channels in-terms of fish habitat before analysis as not all side-channels have the same value. Rating flow influences on the least valuable ones may not give the most relevant information.
- It would be useful to combine the side-channel connectivity study [COW2] with the ramping rate study [COW3].
- Expand Lake connectivity study [COW2] to include salmonid access in and out of Lake tributaries. Do proposed lake elevations influence that?
- Is there a link between low flows in the fall in the Cowichan River and decreased access into tributaries for in-migrating adults. Or a relationship between out-migrating fry from lake tributaries (later than in mainstem) and low flows in the mainstem resulting in increased predation. Is there a relationship between declining chum/coho abundance in Robertson River or other tributaries and lower flows in the Cowichan River?
- Status and Trend of key fish species [COW10] - could use WSP metrics to be consistent. Need a better description of what the questions are in this study and how they will be answered. Currently, not clear.
- In addition to the proposed Environmental Monitoring and Studies, mitigations to reduce the risks to fish (stranding/predation) from low flows need to be identified with decision triggers of when to implement mitigation (e.g. gravel removal at head of north arm).