Columbia River Treaty Review Technical Studies [DRAFT]

Prepared by BC Hydro and Power Authority

March 11, 2013

Note:
This draft report is made available for the public technical sessions in Golden and Castlegar on March 20 and 22 and for public comment. Please provide comments by April 30, 2013 to columbiarivertreaty@gov.bc.ca

Table of Contents

Chapter 1: Introduction

1.1 Background

The Columbia River Treaty (the Treaty) is an agreement between the United States and Canada to develop and operate dams and reservoirs to provide regulated flows on the Columbia and Kootenay rivers to optimize flood control and power generation in both countries. Most of the benefits and obligations under the Treaty were transferred to BC in the separate 1963 Canada-BC Agreement. BC Hydro was appointed as the Canadian Entity under the Treaty and the US Entity is Bonneville Power Administration and the U.S. Army Corps of Engineers. Under the terms of the Treaty, BC Hydro built and now operates 15.5 million acre-feet (MAF) (19.1 km^3) of storage at the Mica (7.0 MAF/8.6 km^3), Hugh Keenleyside (7.1 MAF/8.8 km^3) and Duncan (1.4 MAF/1.7 km^3) projects. The Treaty also permitted the U.S. to construct Libby dam and associated Koocanusa reservoir, which extends approximately 70 kilometres into BC. In return, Canada received an up-front payment[1] for the flood control benefits as well as one-half of the annual additional power generation benefits the U.S. could realize at the downstream U.S. projects on an on-going basis. This “Canadian Entitlement” is returned to the BC border and the proceeds are received by the Province of BC.

The Treaty has no termination date, but either Canada or the U.S. can unilaterally terminate most of the provisions of the Columbia River Treaty any time after September 16, 2024, providing at least ten years’ notice is given. The latest date to provide termination notice for September 2024 is September 2014. Both countries are currently undertaking domestic consultations to explore the question of whether to initiate termination of the Columbia River Treaty at the earliest opportunity, or instead to continue the Treaty in some form. In BC, the provincial Columbia River Treaty team is mandated to make recommendations to the provincial Cabinet in September 2013 on the ‘strategic decision’ of whether the Columbia River Treaty should be terminated, continued, or modified in some way.

If the Treaty is terminated, BC will lose the Canadian Entitlement but will gain additional operating flexibility at the Canadian reservoirs, since the Treaty operating constraints would no longer apply. This operating flexibility could potentially be used to generate more electrical energy (or more valuable electrical energy) or could be used to improve other social/environmental interests such as fisheries, vegetation and wildlife, or recreation. Regardless of whether the Treaty continues or is terminated, the assured operation by Canada for US flood control ends in 2024 and changes to ‘Called Upon’ flood control.

1.2 Approach to Treaty Strategic Decision

The purpose of this report is to evaluate how environmental and social values in BC may be affected by the potential strategic decision on the future of the Treaty. To accomplish this, the report focuses on exploring how environmental and social interests could be affected, both positively and negatively, in Treaty Terminate versus Treaty Continue ‘scenarios’. Moreover, it is possible that Canada and the US may agree to changes in current operational rules governing water management in the Columbia and Kootenay Rivers that would be of mutual benefit. Any changes to the current

[1] Upfront payment included $64 million for 60 years of assured flood control and $254 million for the sale of the first 30 years of the Canadian Entitlement to a consortium of utilities in the United States. The Canadian Entitlement is now returned to BC and is worth $120-300M annually.

range of operations affecting *border flows*[2] will, of course, also require the agreement of the United States

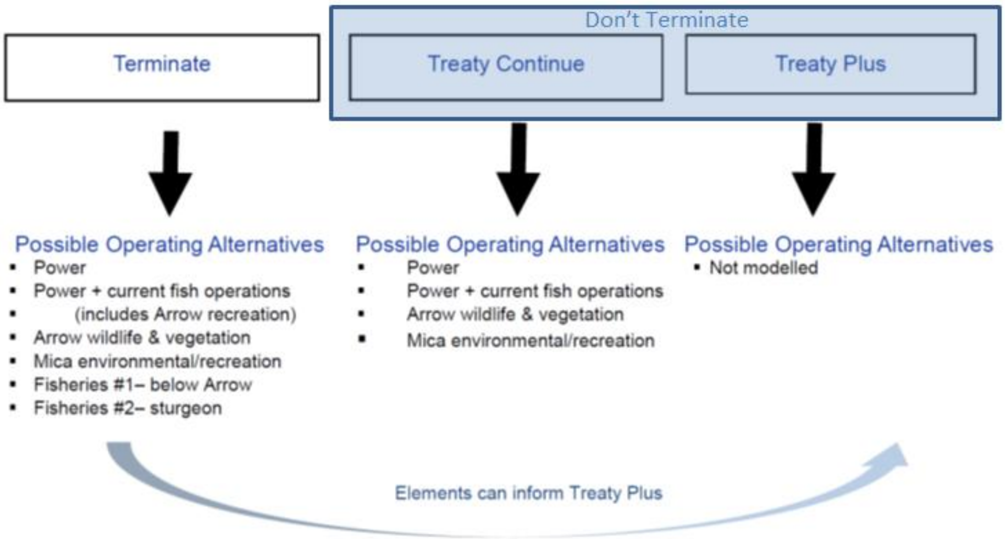

Figure 1 presents the three high level scenarios that are being considered: Treaty Terminate (TT), Treaty Continue (TC), and Treaty Plus (TP). These strategic scenarios can be thought of as concerning different "suites of constraint and opportunity" for water management alternatives in BC.

The purpose of the Treaty review is *not to determine how to best operate the reservoirs under each of the strategic scenarios*. Instead, the purpose is to provide decision makers with an understanding of the *range of physically possible operations* under each of the scenarios, and how social and environmental values might differently be affected by them, in order that the scenarios themselves may be evaluated.

Since terminating the Treaty provides more flexibility for Canada to make domestic decisions, one way of approaching the initial strategic decision is to ask whether there are social/environmental benefits that could be achieved by terminating the Treaty that outweigh the benefit to the Province of the Canadian Entitlement.

Once the strategic decision is made, detailed operating alternatives under the chosen scenario can be further developed at the appropriate time and in an appropriate setting. For example, if the Treaty is terminated by either Canada or the US, any changes to the current operating regime for the Columbia River would be explored in the next Water Use Plan (WUP) review in approximately 2020. If the Treaty continues, any modification to the existing Treaty operation that would change border flows requires mutual agreement with the United States. The process for implementing any changes under a Treaty Continue scenario will not be decided until after the strategic decision is made.

The situation on the Kootenay system is different than the Columbia as coordination of Libby operations continues whether or not the Treaty is terminated. Operations on the Kootenay system

[2] The term '*Border Flow*' is used throughout the document to refer to the regulated flow out of Canada (i.e. Arrow + Duncan discharge). Physical water flow at the border also depends on Libby operation, Kootenay Lake regulation, the unregulated Slocan River, flows from the Pend d' Oreille River that joins the Columbia just upstream of the border, and other local inflow that enters the Columbia River in Canada.

are not directly linked to the strategic decision to terminate or continue the Treaty. Instead the focus will be on evaluating the effects of post 2024 flood control operations at Libby and the potential to use discussions with the US on the Columbia River Treaty Review to influence Libby operations in a 'Treaty Plus' scenario. The approach on the Kootenay system is discussed in more detail in section 3.2.

The broad range of water management alternatives created and modelled for both the Columbia River and the Kootenay River to inform the strategic decision are described in Chapter 3.

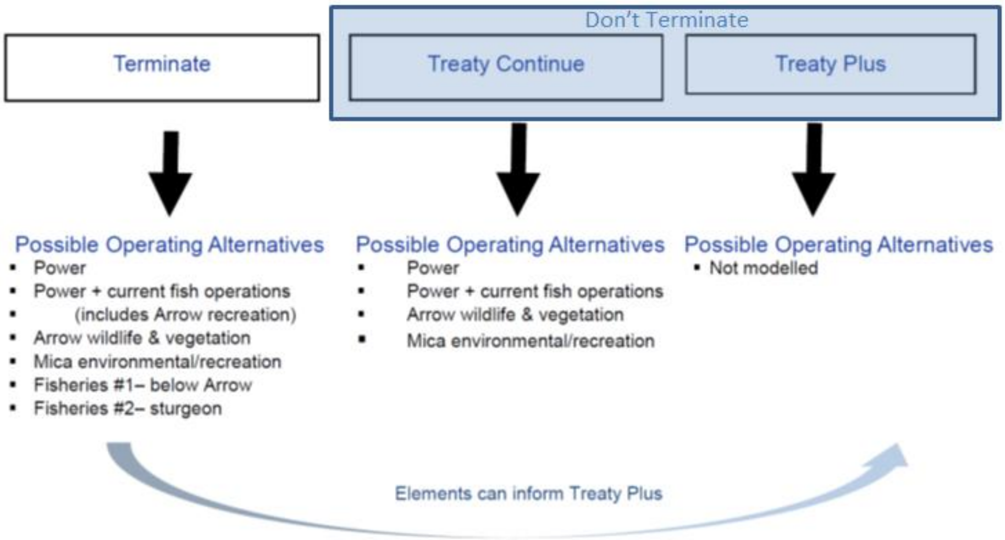

Figure 1: Strategic Decision Scenarios

1.3 Process and Scope of Analysis

The technical analysis in this report was limited to Canadian interests that have the potential to be affected by operations at Columbia River Treaty dams (Mica, Arrow, Duncan and Libby). This limited the geographic study area to the reservoirs and downstream river (and lake) segments on the Kootenay and Columbia rivers to the US border. Okanagan salmon that migrate through the lower Columbia River in the US to the confluence with the Okanagan River and up into Canada are also of interest and are being assessed in a separate report.

The Ministry of Energy, Mines and Natural Gas Columbia River Treaty Review team has overall responsibility for the Treaty Review process. Working with BC Hydro and a team of independent facilitators and consultants, their tasks include technical modelling and analyses, stakeholder engagement, First Nations consultation, and making the recommendations to provincial Cabinet.

1.3.1 Environmental Advisory Committee and Fish and Wildlife Technical Committee

The Columbia River Treaty Environmental Advisory Committee (EAC) was formed to advise and provide policy and technical input to design, evaluation and implementation of the outcomes of the environmental studies for the Treaty Review. The EAC has representatives from the provincial Ministry of Energy, Mines and Natural Gas, the Ministry of Environment, the Ministry of Forests, Lands and Natural Resource Operations, the federal departments of Natural Resources Canada, Environment Canada, Fisheries and Oceans Canada, and BC Hydro. The EAC focused on exploring opportunities to further enhance environmental values under the Treaty Review.

The Columbia River Treaty Fish and Wildlife Technical Committee (FWTC) was assembled to provide technical support and advice to the project. It is made up of technical advisors with expert knowledge of fish and wildlife issues in the Columbia and Kootenay River systems and includes representatives from Environment Canada, Fisheries and Oceans Canada, BC Hydro, Ministry of Forests, Lands and Natural Resource Operations, Ministry of Environment, the Canadian Columbia River Inter-Tribal Fish Commission, the Ktunaxa First Nation and Sexqeltkemc te Sewepemc First Nation.

The FWTC worked with the provincial review team to develop different flow alternatives for the Columbia and Kootenay operations as well as objectives and performance measures that could be used to compare and contrast those alternatives. More specifically, the FWTC focused on the following tasks:

- Developing performance measures for the Kootenay system
- Reviewing existing performance measures from previous planning processes on the Columbia River and Duncan River
- Developing hypothesis of beneficial flow management regimes in the Columbia River below Arrow
- Reviewing alternative modelling results
- Reviewing this report

Appendix A contains the Terms of Reference, meeting schedule and topics discussed.

1.3.2 Water Use Plan and Structured Decision Making Process

In the late 1990s the province of British Columbia ordered BC Hydro to undertake a program of Water Use Plans (WUPs) at its hydroelectric facilities. The consultative planning process involved participants from provincial and federal government agencies, First Nations, local citizens and other interest groups. For the most part, WUPs employed a structured decision making approach to explore the impacts of water management alternatives on environmental, social and economic interests.

Structured decision making involves a systematic analysis of how various interests are affected by possible management alternatives. In this case, interests were expressed where possible as fundamental objectives (e.g. cost, fish and fish habitat protection, wetland protection, recreation opportunity, etc.) and performance measures were created to compare how the different water management alternatives meet these objectives. This enabled a values-based discussion on the trade-offs presented by the different alternatives. As a result of the WUP, BC Hydro undertook operational changes and physical works on the Columbia system that benefited fish, wildlife, cultural heritage, recreation and other interests, while still being able to maintain power generation.

After the development of a consensus decision for the Columbia WUP, several other BC Hydro planning processes, while different, built on this evaluative framework, including the Revelstoke

Unit 5 and Mica Units 5&6 capacity expansions projects and, most recently in 2010, the process for the Non-Treaty Storage Agreement renegotiation with the United States. Links between the Columbia River Treaty, Non-Treaty Storage Agreement, and Water Use Plan are described in Chapter 2.

The evaluative framework and knowledge from previous planning work on the Columbia River is helpful in understanding the potential implications of the Columbia River Treaty strategic decision on social and environmental interests.

Much less is known about the potential impacts of water management alternatives on values in the Kootenay River system, however, since no such comparable planning process has taken place on the Kootenay River system to date other than the Duncan WUP. A Kootenay Lake Water Use plan has not been conducted because BC Hydro is not the owner of the storage water license. As part of the Columbia River Treaty Review process, the project team undertook studies to fill in some of the information gaps on the Kootenay system.

Chapter 2: Columbia and Kootenay Hydroelectric System Summary

The complex geography of the Columbia and Kootenay watersheds creates an interesting drainage pattern for the rivers. The headwaters for the Columbia River are at Columbia Lake near Canal Flats, and the river flows north to Mica dam before turning south. The Kootenay River originates in the Rocky Mountains to the east between Golden and Invermere, and flows south into the US before re-entering BC near Creston and entering into Kootenay Lake. Duncan River is also part of the Kootenay drainage basin and enters Kootenay Lake from the north. The Kootenay River joins the Columbia River at Castlegar, and then the Columbia flows south into the US. A map of the Columbia and Kootenay Region showing locations of all the dams is provided in Figure 2, and a schematic showing the flow of water through the system of dams is provided in Figure 3.

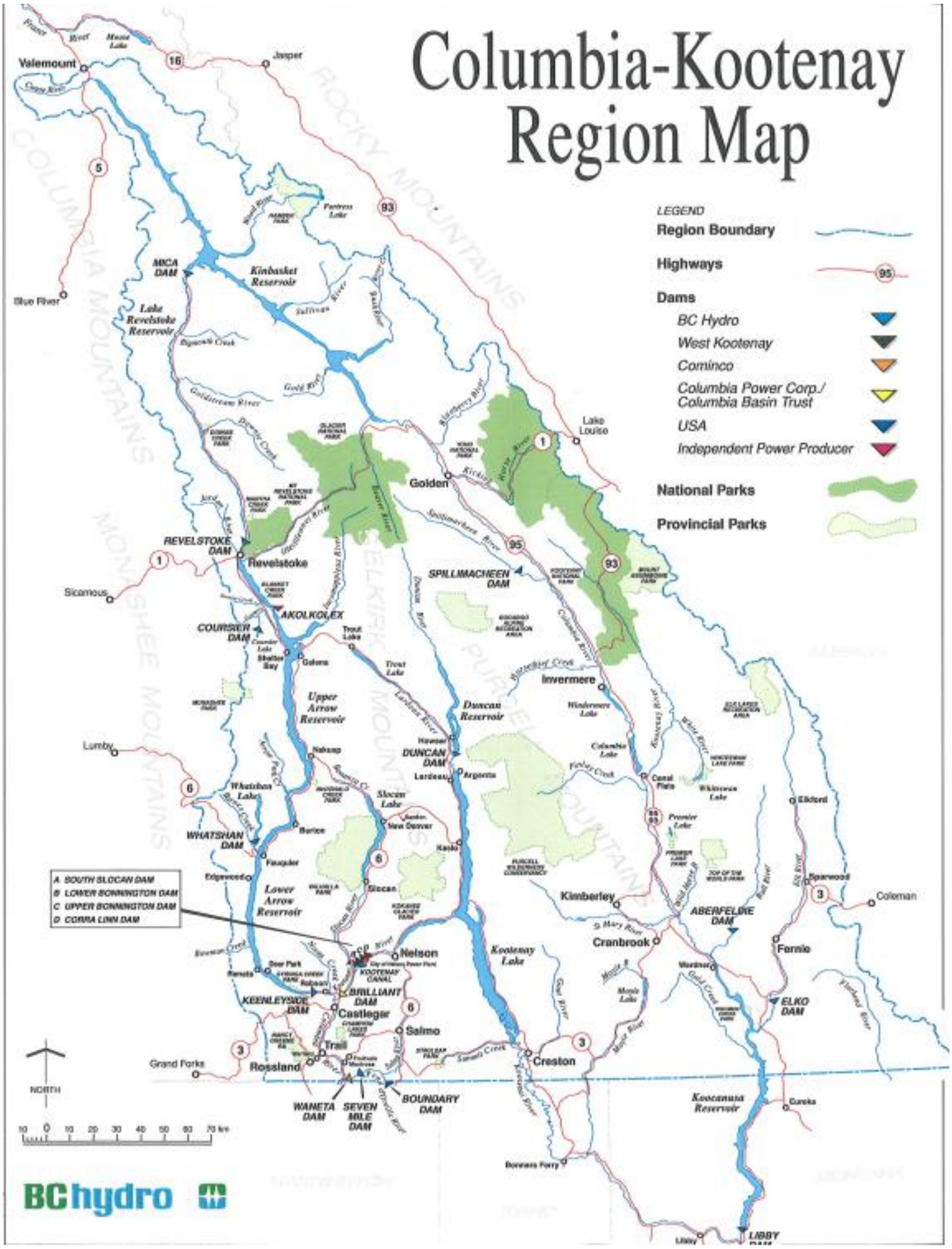

Figure 2: Columbia and Kootenay Regional Map

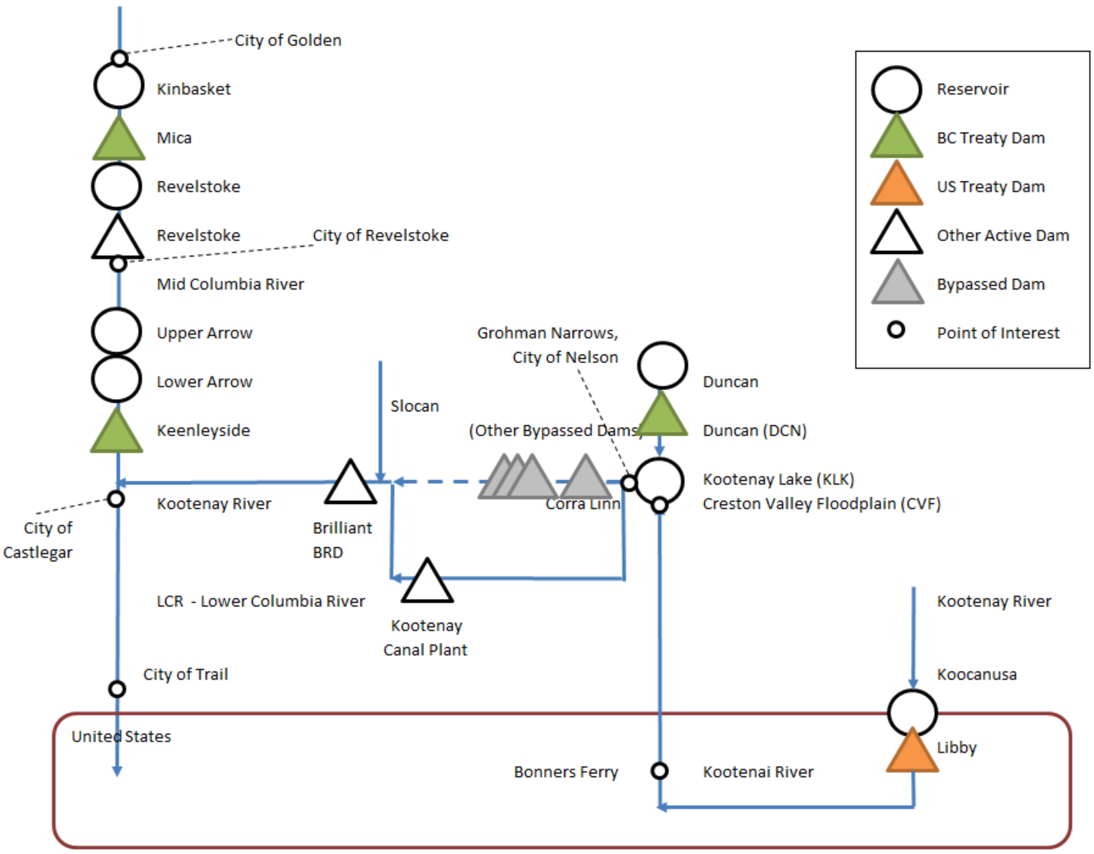

Figure 3: Schematic of the Columbia and Kootenay Hydroelectric Systems

2.1 Operations on the Columbia River - Relationship between Columbia River Treaty, Non Treaty Storage Agreement, and Water Use Plans

The hydroelectric system on the Columbia River includes three dams whose operation is affected by the Columbia River Treaty, Non-Treaty Storage Agreement, and the Columbia Water Use Plan. The components of the system are briefly described:

Mica Dam (owned by BC Hydro) impounds Kinbasket Reservoir, the largest storage reservoir in the entire Columbia system, with a drawdown range of approximately 150 ft (45.7 m). With an installed capacity of approximately 2700 MW (after the addition of units 5 and 6), Mica is a key project in meeting BC's domestic electricity load. Mica is a Columbia River Treaty dam.

Revelstoke Dam (owned by BC Hydro) takes advantage of the storage provided by the upstream Mica Dam and with an installed capacity of approximately 3000 MW (after the addition of unit 6), is also an important project in meeting BC's domestic electricity load. The Revelstoke reservoir is typically operated within the top 5 ft (1.5 m) of its operating range, but can be drafted below this range under unusual conditions (high system loads, unit outages). Under emergency system conditions, it is possible that the Revelstoke reservoir could be drafted down to its water licence limit, 60 ft (18.3 m) below normal full pool.

Hugh Keenlyside Dam (Arrow) (owned by BC Hydro) is a Columbia River Treaty dam that provides significant storage primarily for downstream benefits in the US. BC benefits from the dam through additional flood protection to Castlegar/Trail, the return of the Canadian Entitlement, and the 185 MW of installed capacity at Arrow Lakes Generation Station. The Arrow Lakes Generating Station, completed in 2002, is owned by a joint venture between the Columbia Basin Trust and Columbia Power Corporation, both BC Crown corporations. Arrow reservoir has a similar volume to Grand Coulee in the US, and has a drawdown range of approximately 66 ft (20.1 m). BC Hydro typically operates Arrow in the top 40 to 50 ft (12.2 – 15.2 m).

The actual physical operations of the Canadian dams on the Columbia River are a result of a combination, or layering, of different agreements that fall within the Columbia River Treaty framework, plus some limited unilateral flexibility that Canada has to meet system and non-power needs. The Columbia River Treaty itself is highly prescriptive to meet detailed requirements for flood control and power generation. Other agreements are used by the Canadian and US Entities to achieve a more advantageous operation and address other interests such as fisheries or recreation interests.

These other agreements fall into two categories:

- Those that alter the operation of the 15.5 million acre feet (19.1 km^3) of Treaty Storage
- Those that change the operation of the additional storage built in Canada, referred to as Non-Treaty Storage

When Mica Dam was constructed, it was built with an additional 5 million acre-feet (6.2 km^3) of live storage capacity beyond that required under the terms of the Columbia River Treaty. It was economic to build this extra storage due to the increased power generation at Mica from the higher head and the improved ability to regulate reservoir discharges. This additional reservoir storage cannot be fully utilized without agreement from the US Entity as doing so could conflict with reservoir discharge requirements under the Columbia River Treaty. This additional storage is managed under the Non Treaty Storage Agreement (NTSA). Similarly, an additional 0.25 MAF (0.31 km^3) of storage was built at Arrow (El. 1444 – 1446 ft/440.1 – 440.7 m); however, this storage is only available when required for flood control.

The combination of operations of the Treaty Storage and Non-Treaty Storage managed under the different agreements determines the total flow released from Canadian reservoirs. However, BC Hydro has flexibility to operate the individual dams for Canadian benefits provided i) the flood control draft requirements at each reservoir are maintained, and, ii) the total discharge from Canadian reservoirs remains unchanged. This *Canadian flexibility* allows BC Hydro to ‘move water’ between Mica, Revelstoke, Arrow, and Duncan (within project operating constraints) in response to various power, social and environmental interests.

It was primarily through use of this Canadian flexibility and use of BC Hydro’s portion of the Non-Treaty storage that beneficial changes to operations on the Columbia were investigated in the Columbia Water Use Plan. The Columbia and Duncan WUP consultative planning process was conducted from 2000 to 2004 and resulted in a number of constraints (hard and soft) within which operations were generally acceptable to the consultative committees.

The Water Use Plan and BC Hydro’s water licences, which are consistent with the Columbia River Treaty requirements, provide the overall framework for system operations. Any operational changes considered by BC Hydro with respect to Non-Treaty storage utilization or agreements for mutual benefit on the use of Treaty storage must adhere to these overall operational conditions.

Appendix B describes the different agreements that are used to manage the Treaty and Non-Treaty storage and also provides further detail on the Columbia Water Use Plan.

2.2 Operations on the Kootenay River - Relationship between Columbia River Treaty, Duncan Water Use Plan, International Joint Commission Order, and Canal Plant Agreement

Operation of the Kootenay River system is more complicated as it is administered by several different jurisdictions, and the hydroelectric facilities are owned by different agencies/corporations. The operations of the Kootenay River system and a description of the various agreements are provided in Appendix C. The components of the system and agreements/orders that affect each component are summarized as follows:

Duncan Dam (owned by BC Hydro): Regulates flows on the Duncan River flowing into Kootenay Lake. As a Columbia River Treaty Dam, it is operated to meet Treaty requirements; however, Canadian flexibility is used to generally operate Duncan for Canadian interests independent from the Treaty. Discussion and alternatives evaluated as part of the Duncan WUP were not constrained by the Treaty operations, and the Treaty did not have a significant influence on the results of the Duncan WUP. Minor impacts on Arrow reservoir due to the Treaty were accounted for in the Duncan WUP. As a result, different alternatives for Duncan were not investigated further in the Columbia River Treaty Review.

Libby Dam (owned by US Army Corp of Engineers): Libby Dam is located in Montana and Koocanusa Reservoir inundates approximately 70 kilometers back into Canada. Libby Dam regulates flows on the Kootenai River flowing into Kootenay Lake. Under the Columbia River Treaty, the US must coordinate with Canada on Libby's operations. This obligation continues whether the Treaty continues or is terminated. The Canadian and US Entities have an outstanding dispute on the interpretation of this coordination obligation although currently the dispute is partly resolved through the Libby Coordination Agreement (there is still disagreement over the U.S. Libby VarQ operation). The US operation of Libby Dam is highly constrained by US fish operations that are required by US federal law. Libby's operations and the Libby Coordination Agreement are described in Appendix C.

Kootenay Lake Reservoir (controlled by Corra Linn Dam owned by FortisBC): Kootenay Lake reservoir is operated under an International Joint Commission (IJC) order that is held by FortisBC. The order specifies maximum reservoir levels throughout the year. A hydraulic constriction at Grohman Narrows, downstream of the city of Nelson, limits the discharge from the lake. In spring and early summer the Corra Linn forebay is typically lowered to maximize the discharge from the reservoir.

Kootenay Canal (owned by BC Hydro) and the **Kootenay River Plants** (owned by City of Nelson, Fortis BC): Water exiting Kootenay Lake Reservoir is preferentially diverted to the Kootenay Canal plant instead of the less efficient river plants (Corra Linn, Upper Bonnington, Lower Bonnington and South Slocan). At all times a minimum flow of 5 kcfs (141.6 cms) is maintained in the Kootenay River and through the river plants.

Brilliant Dam (owned by Columbia Power Corporation and Columbia Basin Trust): Brilliant Dam is located downstream of Kootenay Canal and the river plants. It has a small head pond that is used for daily shaping of the generation.

For the purpose of these studies, the two systems – Columbia River and Kootenay River – are generally modelled and analysed separately as discussed in section 4.1 and 4.2 of this report. Links between the two systems are assessed when needed.

Chapter 3: Selection of Alternatives to Model

The purpose of modelling different alternatives under the Treaty Terminate and Treaty Continue scenarios is to inform the strategic decision on the future of the Treaty. The intent was not to revisit decisions and trade-offs previously decided in the WUP. Instead the focus was to highlight trade-offs that would have been different without the constraints of the Treaty and to analyse operating alternatives that were not possible in the WUP due to the Treaty constraints. Many different operating alternatives can be accommodated within the Treaty, and one goal was to differentiate between what interests can be accommodated purely by domestic choices and which are limited by Treaty constraints.

Although the model alternatives were limited to those under the scenarios of Treaty Continue and Treaty Terminate, the results also indirectly inform what modifications to operations might be desired under a Treaty Plus scenario.

3.1. Columbia River System Alternatives

Selection of alternatives to model on the Columbia River drew heavily from the Columbia WUP and subsequent planning processes. The WUP highlighted the following key linkages:

- **Kinbasket/Arrow Balance**: with required border flows (Arrow + Duncan outflows) primarily determined by the Treaty, operations that raise the water level in Kinbasket generally result in lower Arrow reservoir levels and vice versa.
- **Arrow Reservoir / Lower Columbia River Balance**: with border flows primarily determined by the Treaty, for practical purposes the investigation of different flow regimes downstream of Arrow was limited to those operations where BC Hydro could successfully negotiate alternative flows with the U.S. Entity (i.e. trout & white fish spawning flows). Lowering Arrow flow releases in January through March for spawning flows was achieved by storing more water in Arrow for US flow augmentation in June/July. Thus there was a trade-off between Arrow reservoir levels and Lower Columbia River flows.
- **Flow constraints at Revelstoke**: different flow alternatives were investigated that primarily showed a trade-off between fisheries benefits in the Mid-Columbia and lost electricity value. A minimum flow of 5 kcfs (141.6 cms) was agreed to.

The trade-offs in the first and second points above are expected to be different under the Treaty Continue and Treaty Terminate scenarios because under Treaty Terminate the decisions at each reservoir are less linked (i.e. border flows are not prescribed, having Kinbasket reservoir level high does not require having Arrow reservoir level low). To highlight this point, alternatives designed to achieve specific interests were modelled under both the Treaty Terminate and Treaty Continue scenarios. The flow constraints at Revelstoke investigated during the WUP are primarily a domestic issue as they were not constrained by the Treaty; as a result no further analysis was done in the Treaty Review on this topic.

The interests that drove the development of alternatives in the WUP around the Kinbasket/Arrow balance and the Arrow Reservoir/Lower Columbia balance remain the key areas to continue investigations in the Treaty Review:

- Mica: fish, navigation, dust and recreation all favour higher reservoir levels in Kinbasket.

- Upper Arrow Reservoir/ Mid-Columbia River: vegetation, wildlife, large river habitat, and shore based recreation all favour lower Arrow levels in the spring/early summer and lower levels in the fall.

- Arrow Reservoir: water-based recreation, navigation, resident fish and power benefits favour higher Arrow reservoir levels

- Lower Columbia River: different hypotheses exist for flow regimes that may provide fisheries and other ecosystem benefits. This was an area of focus for the Fish & Wildlife technical committee.

Figure 4 shows the alternatives modelled under the Treaty Continue and Treaty Terminate scenarios that were evaluated in support of the strategic decision. The alternatives were designed based on the interests discussed above and descriptions of the alternatives are provided in Table 1. Note that Alt 3 TC and Alt 4 TC are similar to Alt 11 and Alt 2 in the WUP.

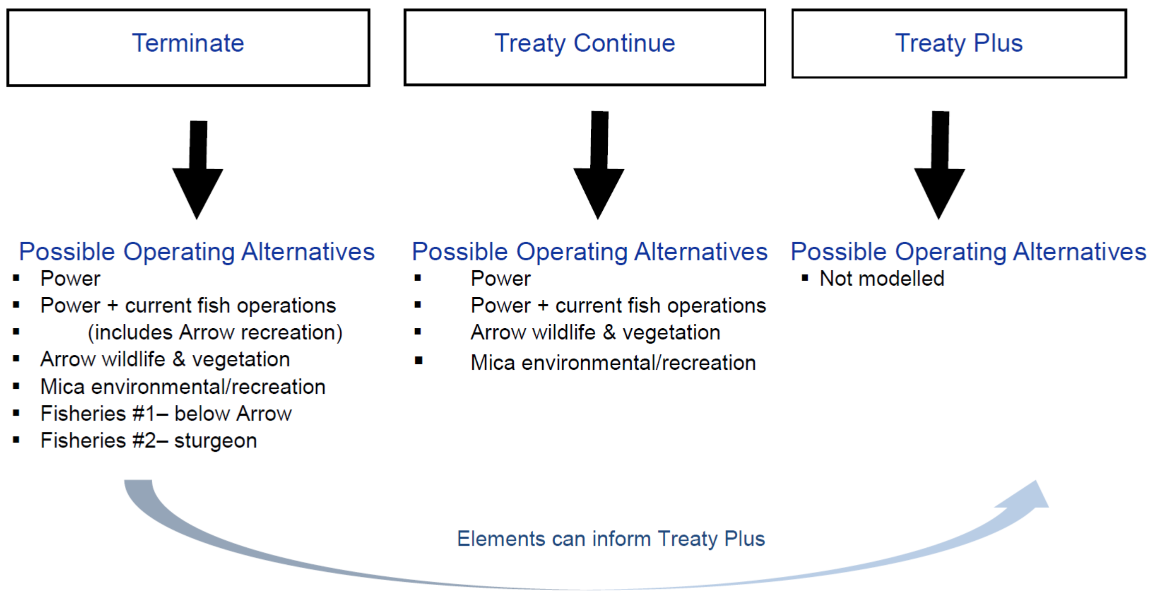

Figure 4: Alternatives Modelled

Table 1: Columbia River Alternatives

Alternative	Description
Ref- TC (reference)	**Current Operating Constraints (TC) –** This alternative includes all current hard operating constraints and the Treaty power operations. Flows below Arrow are adjusted to meet whitefish and rainbow trout spawning flows. For whitefish, Arrow discharge is reduced in Jan and then excessive flow reductions are managed through March. Rainbow trout require increasing flow April through June. Appendix D provides detailed description of constraints and assumptions.
Ref - TT (reference)	**Optimum Power (TT) –** This alternative includes all current hard operating constraints but is not constrained by the Treaty. To optimize power, Arrow reservoir is held close to full throughout the year. Trout spawning flows are met. Whitefish spawning flows are met in approximately 40% of years.
Alt 3 TC	**Arrow Wildlife/Vegetation (TC)** – This alternative holds Arrow Lakes Reservoir lower until mid-July to allow vegetation to extend into lower elevations, provides benefits to nesting birds, increases the length of flowing river, and provides shore based recreation in the Revelstoke reach. The following maximum month end elevations are used as constraints to model this alternative: April (1427.2 ft/435.0 m) , May (1427.2 ft/435.0 m), June (1427.2 ft/435.0 m), July (1433.8 ft/437.0 m), August (1433.8 ft/437.0 m)
Alt 3 TT	**Arrow Wildlife/Vegetation (TT)** – same as above except no Treaty constraints
Alt 4 TC	**Mica Environmental/Recreation** (TC) – This alternative generally supports fish, navigation and recreation on Kinbasket Reservoir. Its objective is to maintain a minimum elevation of 2395 ft (730 m) year round.
Alt 4 TT	**Mica Environmental/Recreation** (TT) - same as above except no Treaty constraints
Alt 5 TT	**Fisheries hydrograph #1- Flushing flow** (TT) – Provide flushing flows of 200 kcfs (5663.4 cms) at Birchbank for 5 days.
Alt 6 TT	**Fisheries hydrograph #2 – Sturgeon (TT)** – Provide flows of 185 kcfs (5238.6 cms) at Birchbank for 4 weeks starting ~ mid-June in at least 60 % of the years. The ramping up rate doubles the discharge in about 2 weeks, and the ramping down rate reduces flows to 55% of the peak flow in 4 weeks.

Notes:
1) TC = Treaty Continue; TT = Treaty Terminate
2) Alt 4 TC - There were 16 out of 70 yrs where maintaining the minimum was not possible and the reservoir was drafted deeper to meet domestic load.
3) Alt 6 TT – in years when the peak could not be sustained for 4 weeks the operation was the same as the reference case (Alt 2 TT) to minimize cost of the alternative.

During the various information sharing meetings with Kootenay residents and the First Nation Consultation meetings there was general support voiced for ecosystem values. An ecosystem alternative could consist of elements from Alternative 3, 4, 5, and 6. The approach taken during the modelling was to focus on the specific ecosystem values expressed for each geographic area instead of combining all the elements. In this manner, the impacts and benefits can be more easily demonstrated.

3.2. Kootenay River System Alternatives

As seen from the description of the Kootenay River system components in section 2.2, operations on the Kootenay system are not directly linked to the strategic decision to terminate or continue the Treaty as the discussion and alternatives investigated in the Duncan WUP were not materially constrained by the Treaty and Libby coordination continues whether or not the Treaty is terminated. However, there are two topics that may influence Kootenay River system operations that are related to the Columbia River Treaty Review:

- **Post 2024 Flood Control operation at Libby**: Under the default Called Upon flood control operation, the US must make effective use of their reservoirs for flood control prior to requesting use of storage in Canada. This will result in deeper drafts more often at US reservoirs, including Libby, and may also increase the risk that reservoirs don't refill each year.

- **Potential to use discussions with the US on the Columbia River Treaty Review to influence Libby operations**: Residents living near Koocanusa Reservoir expressed a desire for more Canadian influence of Libby operations during the public engagement process. If alternative operations of Libby can be found with benefits to both countries, it may be possible to come to some arrangement with the US on Libby operation. However, it should be noted that the US will not be able to agree to changes that are in conflict with their own domestic law.

Given the historical information disparity between the Kootenay and Columbia systems, the focus of the analysis for the Kootenay River system has been to develop new performance measures to make it possible to analyse effects on environmental and social interests in Koocanusa Reservoir, Kootenay Lake, and Kootenay River related to different potential operating alternatives at Libby. This information will be useful to evaluate impacts of different Post 2024 Flood Control arrangements should the US want to pursue different arrangements other than the default Called Upon operations. Further detailed studies on post 2024 flood control are not expected until after BC's strategic decision in 2013.

Before contemplating the second point regarding Canadian influence on Libby operations, it is important to understand the trade-offs related to Canadian interests from different Libby operations. Three different Libby operating alternatives were developed to test the new performance measures and highlight these trade-offs. These alternatives were selected based on issues raised from various information sharing meetings with Kootenay residents who desired an earlier refill at Libby and voiced opposition to the current Libby operations of VarQ flood control and sturgeon flow releases in spring.

Alternative 1 represents the current situation. Alternative 2 operates to Standard Flood Control and does not include the spring sturgeon and bull trout flow releases. It does not however truly represent an optimum power operation as it does include a 20 ft (6.1 m) draft by the end of August for salmon flow in the US. The current operation includes only a 10 ft (3.0m) draft by then end of September in most years while still drafting 20 ft (6.1 m) in low water years. Alternative 3a and 3b explore the consequences on the Kootenay system of allowing earlier refills of Koocanusa reservoir. Table 2 provides a summary of the Alternatives and more detail is provided in Appendix D.

Note that Alternatives 2, 3a and 3b are hypothetical and are intended simply to explore potential consequences across a wide range of interests and to stimulate discussion. Each would require the

American Libby Dam to be operated in violation of current domestic US law, which mandates certain regimes for fish protection.

Table 2: Kootenay River Alternatives

Alternative	Description
1	**Current Libby Operation** - VarQ flood control regime and discharges for fish based on latest U.S. Endangered Species Act objectives for sturgeon, bull trout, and salmon.
2	**Standard Flood Control and deep August draft** - Libby operates to standard flood control regime. Spring sturgeon and bull trout not included; however Libby drafts 20 ft (6.1 m) by the end of August for Salmon in US.
3a	**Early refill at Libby (1 Jun**) – Current Libby operating regime adjusted to target refill of Koocanusa by 1 June.
3b	**Early Refill at Libby (30 Jun)** – Current Libby operating regime adjusted to target refill of Koocanusa by 30 June .

Chapter 4: System Modelling and Hydrological Results

The Columbia River operation cannot be examined in isolation from the rest of the BC electrical system as Mica and Revelstoke generating stations meet roughly one third[3] of the Provincial electrical demand, as do G.M. Shrum and Peace Canyon generating stations in the Peace region. Changes to the operations of one river system and its reservoirs must be coordinated with those in the other. The modelling performed for the Columbia alternatives in this study coordinates the storage and release of water from the three largest reservoirs in the Province: Williston Reservoir, Kinbasket Reservoir, and the Arrow Lakes.

The Duncan Dam and the Kootenay system, on the other hand, can be modelled separately as was done to investigate the Kootenay alternatives in this study. The Columbia system models are described in section 4.1 and the Kootenay system modelling is described in section 4.2. Further information on both models and the modelling assumptions is provided in Appendix D.

For each operating alternative modelled on the Columbia and Kootenay, statistics for reservoir elevations, dam discharges, river flows and value of power generation for the years of simulated flow operation are produced as described in section 4.3. Section 4.4 and 4.5 summarize the hydrological outputs from the models, which served as inputs to environmental models to calculate performance measures for each alternative as discussed in Chapter #5.

4.1. Columbia System Modelling

For the system modelling on the Columbia River, the Kootenay system is fixed based on current conditions. The operation of other smaller BC Hydro generating systems and purchases from Independent Power Producers (IPPs) are also fixed for each of the historical water sequences.

Inputs to the models include reservoir inflows, market prices, and electrical demand. The models meet the required electrical demand in the most economic manner within prescribed operating constraints by: i) using the fixed generation from the Kootenay system, small BC Hydro generating systems, and IPPs ii) dispatching the BC Hydro large generation on the Columbia and Peace rivers; iii) dispatching gas-fired generation in the BC Hydro system, and; iV) imports and exports of electricity over transmission lines connecting British Columbia to Alberta and the U.S.

The system modelling methodologies are generally the same as those undertaken during the WUP and subsequent planning processes:

> The **HYSIM model (Hydroelectric Simulation Model)** simulates operation of the entire BC Hydro system using the historical 60 year record of inflow data. Operations are simulated on a monthly time-step producing results such as end-of-month reservoir elevations and mean monthly dam discharges. The HYSIM model was the primary model used in the WUP, and is the primary model used to simulate the alternatives assessed in this report.
>
> The **GOM model (General Optimization Model)**, using HYSIM results as a guide can simulate operations on a much finer resolution, producing bi-hourly results of reservoir elevations and dam discharges. The GOM model is better suited for site-specific studies that require finer scale impact modelling (e.g., Revelstoke Dam discharge effects on the Mid-Columbia

[3] This number varies from year to year as a function of many variables including inflows in each river basin, outages at generating stations and on the transmission system, electricity market prices, and electrical demand in the Province, among others.

River in WUP and Revelstoke Unit 5 analysis). Since this was not the focus of these studies the GOM model was not used to model the alternatives in this report.

An **Excel ™ spreadsheet model** is used to simulate operations at Hugh L. Keenleyside Dam that include both Non-Treaty Storage transactions, and critical Treaty supplemental agreements (e.g., rainbow trout flows, mountain whitefish flows). Non-Treaty transactions were made based primarily on forecasted market conditions. A "typical agreement profile" for critical supplemental agreements was applied to each year of the 60-year inflow data set, with the recognition that the change to river flows and reservoir storage may vary under each annual agreement depending on inflows. The resulting modified release from Arrow was delivered as an input to HYSIM.

The **CRTM model (Columbia River Treaty Model)**, is a new model developed by BC Hydro that includes both a simulation and an optimization (similar to GOM) module, and has the capability of modelling different time steps (monthly, daily, hourly etc.). When fully functioning, CRTM will replace the Excel spreadsheet model and could more easily be modified to accept different constraints. The CRTM was used to help inform changes to the HYSIM model and flow releases from Arrow.

4.2. Kootenay System Modelling

The Kootenay alternatives were modelled in three separate spreadsheet models for Libby, Duncan, and Kootenay Lake. These spreadsheet models simulate the operations using a prescribed set of rules. The projected outflows from the Libby and Duncan models, as well as local Kootenay lake inflow, are used as input to the Kootenay Lake model. Further detail about the assumptions in the spreadsheet models is provided in Appendix D.

4.3. Introduction to Hydrological Statistics

The Columbia and Kootenay simulation models produce reservoir levels and discharge data sets at different locations within the basin. Figure 4-1 illustrates the type of data produced, in this case for Koocanusa Reservoir. The top chart shows the simulated elevation for each year of inflow if future water inflows were to mirror the patterns of actual historic inflow. By considering multiple inflow years, it is possible to better understand and communicate the variability in year-to-year inflows and their potential impact on elevations and flows throughout the system. For these studies, the historical inflows have not been adjusted for potential effects of climate change.

Since comparing the results of many years of data for different alternatives is difficult, simple statistical measures are used to communicate variability. The bottom chart of **Error! Reference source not found.** presents the daily maximum, minimum, and 90th, 50th and 10th percentiles for the same underlying data. Consider, for any given day of the year:

- Elevations would be higher than the 90th percentile line in 10% of years.
- Elevations would be lower than the 10th percentile line in 10% of years.
- 80% of years have elevations between the 10th and 90th percentile lines.
- Elevations would equally likely be to be above or below the 50th percentile line in any year.

The 50th percentile line (also called the median average line) is the main basis for comparing alternatives in this report. However in some cases such as flooding, rarer events are more relevant than average years so other statistics are used. It is important to understand that these lines are statistical constructs and that actual within year variations could be larger than suggested by these lines.

4.4. Modelled Hydrological Outputs - Columbia

4.4.1 TC & TT ref cases

Error! Reference source not found. shows daily median hydrological outputs for two water management alternatives at four locations in the Columbia River:

- Kinbasket reservoir elevation;
- Mica dam discharge ("Mica Flow rate")
- Arrow Lakes reservoir elevation;
- Hugh Keenleyside dam discharge ("Arrow Flow rate")

The hydrological data generated by BC Hydro's HYSIM model is generated monthly using inflows from the 1929 to 1999 period. The monthly reservoir elevations are linearly interpolated and shown as smooth curves in the Figure 4-2 elevation graphs. In contrast, the monthly dam discharge flow rates are set to the same value for each day for each month, as shown by the step charts in Figure 4-2 flow rate graphs.

The Ref TC alternative ("reference case under a Treaty Continue scenario") operates to current operating constraints. It is optimized for the financial value of power generation, but provides for various fish flows as described in Table 1. This is the only alternative that meets the intent of the WUP soft constraints. The Ref TT alternative ("reference case under a Treaty Terminates scenario") is intended to meet the same goals as Ref TC, but without the constraints of the Treaty. Therefore, after providing for the Lower Columbia River fish flows[4], operations are optimized for the financial value of power generation in part by maintaining a higher Arrow elevation throughout the year.

Reviewing the charts in **Error! Reference source not found.**, it can be seen that Kinbasket reservoir is operated in a similar way in both alternatives (lowest draft point moves from end of March in Ref TC to end of April in Ref TT). However, Arrow Lakes reservoir is held at a narrower and more stable range under Ref TT. Median discharges from Hugh Keenleyside dam under Ref TT are more than double those of Ref TC in May and nearly three times as much in June but lower in July and August. In the fall and most of the winter, discharges from this dam are lower under Ref TT relative to Ref TC.

4.4.2 Alt 3

Error! Reference source not found. shows the hydrographs associated with Alternative 3 under Treaty Continues and Treaty Terminate scenarios. Ref TC and Ref TT are provided for comparison purposes.

Alternative 3 was designed to explore the consequences associated with holding Arrow Lakes Reservoir lower than optimal for power values from May through August to allow vegetation to extend into lower elevations, provide benefits to nesting birds, increase the length of flowing river, and provide shore based recreation in the Revelstoke reach.

[4]Ref TT was not smoothed out as much as it could be for whitefish flows. It meets whitefish flows in 31/72 years, while trout meets flows 70/72. The cost of 'smoothing' these flows in Dec/Jan/Feb is ~$0.3 million but doesn't have a significant effect on levels/flows throughout the year. In comparison, Ref TC meets whitefish flows in 68/72 years, and meets trout flows in 67/72 years.

Under Alt 3- TC, the model meets the stated constraints, but drafts Arrow considerably further for much of the year. Arrow Lakes reservoir is drafted nearly empty to approximately 1380 ft (420.6 m) in the median elevation during the spring, more than 20 ft (6.1 m) deeper than under Ref TC, because Arrow must be drafted low enough to capture the local runoff (i.e. runoff that enters the Columbia downstream of Mica dam) and still remain below the spring elevation constraints. In TC, the discharge from Arrow remains similar across alternatives. Therefore to draft Arrow lower, Kinbasket elevation will be higher, as the same volume of inflow will be in storage. The deeper draft at Arrow Lakes Reservoir results in the Kinbasket reservoir draft being approximately 20 ft (6.1 m) higher relative to Ref TC.

Under the TT scenario, the model also meets the stated constraints for this Alternative, but Arrow Lakes reservoir is kept at a higher elevation for the rest of the year. Arrow releases are increased in April to draft the reservoir to the lower elevation target while releases are correspondingly decreased in July and September to refill the Arrow Lakes reservoir close to the maximum level for optimal power generation.

4.4.3 Alt 4

Error! Reference source not found. shows the hydrographs associated with Alternative 4 under Treaty Continues and Treaty Terminate scenarios. Alt Ref TC and Ref TT are also provided for comparison purposes.

Alternative 4 was designed to generally support fish, navigation, dust control and recreation on Kinbasket Reservoir. Its objective is to maintain a minimum elevation of 2395ft (730m) year round.

Alternative 4 has a similar impact on reservoir levels to Alternative 3 in the Treaty Continue scenario in that Kinbasket reservoir levels are higher and Arrow elevations are lower relative to the reference cases, even though the alternatives are driven by quite different constraints.

Under the TT scenario, the target Kinbasket elevation was maintained in the median year for Alternative 4 and Mica never had to draft below 2395 ft (730m) in the historic inflow sequences. A stable and full reservoir is maintained in Arrow, similar to the Ref-TT.

In Alt4-TC, the model was unable to maintain the 2395 ft (730m) constraint in all years; the median value for the end of April drops to 2390 ft (728.5m). In 47 of the 72 years, Mica had to draft below 2395 ft for one of the following reasons: i) to meet domestic load deficits (despite importing maximum amounts on the intertie), ii) to meet the required Treaty border flows, or iii) to meet the expected NTSA flows.

In Alternative 4, Kinbasket reservoir approaches full faster so Mica discharge in July is higher in comparison to the reference cases. Kinbasket reservoir can’t draft as deep so the fall and winter Mica discharge is lower than the reference cases.

4.4.4 Alt 5 and Alt 6

Error! Reference source not found. shows hydrographs associated with two alternatives that do not have TC scenario equivalents since they cannot be achieved within Treaty constraints.

Alt 5 TT, referred to in discussions as “Fisheries hydrograph #1”- provides flushing flows of 200 kcfs (5663.4 cms) at Birchbank for 5 days. A 15 kcfs/day (424.8 cms/day) ramping rate is used for increasing and decreasing the Arrow discharge.

Flushing flows are high peak flows that are designed to mobilize gravel to avoid clogging of the interstitial space by silt and sand to benefit fisheries. **Error! Reference source not found.** shows that the five day flushing flow alternative may be achievable with relatively minor adjustments throughout the system in Ref TT. The five day period peak discharge from Arrow is accounted for in the hydrological modelling, but the figure only shows the average monthly increase of approximately 8 kcfs (226.5 cms) in June. To provide the flow, Arrow reservoir was surcharged 2 ft (0.6 m) and then drafted 3.5 ft (1.1 m) followed by recovery within the month.

Alt 6 TT, referred to in discussions as "Fisheries hydrograph #2" was designed to provide flows of 185 kcfs (5238.6 cms) at Birchbank for four weeks starting around mid-June. The ascending limb doubles the discharge in about two weeks, and the descending limb reduces to 55% of the peak flow in four weeks. The target was to provide the flows in at least 60% of years.

Error! Reference source not found. shows the large volume of water discharged from Arrow Lakes reservoir during the specified time period for Alternative 6 TT (note that the ~100 kcfs (2831.7 cms) discharge at Arrow shown in **Error! Reference source not found.**-6 is added to Kootenay River inflows to reach the targeted flows at Birchbank). This operation would cause the draft of Arrow Lakes reservoir to 1380ft (420.6 m) in the 50% of the years, and would reduce discharges from the dam to below 10 kcfs (283.2 cms) from September through November inclusive. **Error! Reference source not found.** also shows that the impact to Kinbasket reservoir is minor as the flows are predominately provided by stored water at Arrow.

4.4.5 Summary

Error! Reference source not found. shows the median elevations for Kinbasket and Arrow Lakes reservoirs for all of the modelled alternatives. Figure 4-8 shows the flows in the Lower Columbia River, which are assumed to be the sum of the Arrow discharges and Alternative 1 from the Kootenay River modelling (see section 4.5).

4.5. Overview of Modelled Hydrological Results - Kootenay

Alternative 3a was not able to achieve its objective of refill by June 1 without exceeding the flood control draft requirement, or causing significant surcharge at Koocanusa reservoir in most years, or resulting in excessive flood levels at Bonners Ferry, Idaho and Kootenay Lake, BC. Having Koocanusa reservoir 5 ft (1.5 m) from full at the start of June with the highest inflows still to come in June soon causes the reservoir to fill. To achieve the refill target, Alt 3a regularly resulted in uncontrolled Libby discharges with Koocanusa reservoir at full pool, which is not an acceptable way to operate Libby dam. To avoid this, discharges had to be increased throughout most of June to reduce the rate of reservoir refill. This was attempted in the Kootenay model using perfect knowledge of the future inflows; however, the target refill objective could only be met in 17% of the years. As a result this alternative was dropped from further analysis and is not shown in the graphs.

4.5.1 Koocanusa

Error! Reference source not found.4-9 shows median (50th percentile) lines for Koocanusa reservoir elevations and **Error! Reference source not found.** shows the median (50th percentile) lines for Libby dam discharges for the four Kootenay alternatives (Alt1, Alt2, Alt3b).

Koocanusa Reservoir shows an annual pattern that is typical of interior reservoirs: the water elevation level declines through the fall and winter to create space for the high inflows spring freshet. The reservoir refills across the spring and then is generally held in the top 10 ft (3.0 m) for much of the summer.

Current Libby operations (Alt 1) endeavour to meet many fisheries requirements (as detailed in Appendix C) including VarQ flows and sturgeon pulses in spring, minimum bull trout flows through the summer, drafts in August/September for salmon flow augmentation, and the higher VarQ flood control elevations which require less draft than the standard flood control elevations (Alt 2) in the winter and spring.

The hydrographs (**Error! Reference source not found.**and **Error! Reference source not found.**) suggest that Alt 2 is the most different of the four alternatives as Koocanusa reservoir is drafted deeper in the winter due to the Standard Flood Control elevations. In addition, Alt 2 drafts 20 ft (6.1 m) in September for salmon flow in the US. The current operation (Alt 1) includes only a 10 ft draft by the end of September in most years while still drafting 20 ft (6.1 m) in low water years. In Alt 2, this results in high discharges during September, and corresponds to lower Koocanusa elevation levels for the fall and low discharges in November.

Alternative 3b was designed to refill to within 5 ft (1.5 m) of full pool (i.e. 2,454 ft/748 m) on the 30 June. In targeting this refill objective, winter (Jan-Apr) VarQ flood control drafts were maintained and fisheries constraints in the spring were relaxed as required. The VarQ flows, bull trout minimum flows (in May and June), and sturgeon operations are relaxed.

As seen in **Error! Reference source not found.**, the Jun 30 refill target (Alt 3a) is met in most years (87%). In some years the refill objectives was not met due to April flood control draft requirements combined with insufficient May-Jun inflows to refill by target refill date.

4.5.2 Kootenay Lake

Error! Reference source not found., shows median (50th percentile) lines for Kootenay Lake elevations for the four alternatives, while **Error! Reference source not found.** shows the Kootenay Lake discharges and **Error! Reference source not found.** shows spills at Corra Linn dam.

The figures indicate that the main difference between the alternatives for Kootenay Lake is during the spring freshet. During this period, Kootenay Lake levels are controlled by a natural hydraulic constriction at Grohman Narrows, which limits discharges from the lake depending on the Kootenay Lake level and inflows. In general, as inflows increase beyond the Grohman Narrows discharge capability, the lake level will rise. This, in turn, will increase the discharge capability, but not enough to prevent the lake from rising until the inflows recede below the discharge capability.Therefore, to understand the differences in Kootenay Lake elevations among the various alternatives, the discharge from Libby must be examined (**Error! Reference source not found.**).

Under the current operation (Alt 1), Libby releases a large volume of water for sturgeon operations beginning around June 1. This volume of water coincides and contributes to the peak inflows to Kootenay Lake, thereby resulting in a higher peak reservoir level, peak flow and longer duration. In Alt 2, Libby is drafted deeper under standard flood control, and with no sturgeon flow requirement, Libby discharges are generally lower as the reservoir refills towards the end of June to July. As a result, Kootenay Lake levels in Alt 2 are the lowest of the four alternatives.

In Alt 3b, the Libby operation is targeting refill to within 5 ft (1.5 m) of full by June 30. This target operation was assumed to have a higher priority over fisheries operations, so the May-June outflows were scaled down (to minimum flows in some years) to reach or to get as close as possible to the target elevation by June 30. This results in lower Libby outflows in June and defers the peak outflows into July, when Kootenay Lake levels have already peaked and have started to recede. With the deferred peak flows from Libby, peak Kootenay Lake levels and outflows are lower and for a shorter duration.

The other difference between the alternatives is the significantly higher Kootenay Lake outflow in September and the winter months (**Error! Reference source not found.**), which again is related to

Libby's 20 ft (6.1 m) draft in September and higher winter discharges form Libby due to the lower flood control curves under standard flood control.

Chapter 5: Interests, Objectives and Performance Measures

5.1 Introduction

In this chapter, objectives and performance measures that may be affected by the water management alternatives are presented for both the Columbia River and the Kootenay River.

5.1.1 Columbia River System

For the Columbia River, the majority of the objectives and performance measures in this chapter were developed initially in the WUP and then refined during subsequent planning processes, most recently the NTSA process in 2010/2011. The NTSA process updated the performance measures wherever possible by incorporating additional data or information from recent Water License Requirement monitoring programs.

Unless specifically noted as a change, it should be assumed that the measures used here are the same as used in the NTSA process. Several performance measures developed historically were designed to capture subtle changes in water management scenarios, and not all are useful for differentiating between these alternatives. In other cases the historic performance measure may not fully capture the interests inherent in these alternatives and the performance measures were modified based on feedback from the Fish and Wildlife Technical Committee, First Nations, and the public or were updated based on new information that has become available through the Water License Requirement monitoring programs.

5.1.2 Kootenay River System

In comparison to the Columbia River, the Kootenay River system has not had an extensive history of public planning processes to develop information about interests that may be affected by reservoir levels and flows. A Water Use Plan for Duncan was developed but there has not been a comparable process on the Kootenay system. Columbia Basin Trust (CBT) has conducted a process to investigate interests related to the VarQ operation at Libby Dam that documented some stated stakeholder preferences (CBT 2004). Columbia Power Corporation and FortisBC have also conducted processes or public information sessions related to their facilities on the Kootenay River. Information from these processes was used to inform the development of Kootenay River system performance measures.

Baseline scientific data is available from various sources. The Columbia Operations Fish Advisory Committee (COFAC) member agencies[5] have conducted fisheries studies on Kootenay Lake and the Kootenay River. Information is also available from the Fish and Wildlife Compensation Program's Kootenay Lake fertilization program. In addition, significant information is available on wildlife and wetland interests in the Creston Valley Wildlife Management Area. There is however, a general lack of data for Koocanusa reservoir.

Prior to the CRT Review, a systematic evaluation of all interests and the potential impacts of water management alternatives on those interests in the Kootenay River system had not been conducted.

[5] COFAC includes power producers (BC Hydro, Columbia Power Corporation, FortisBC, ?Tech-cominco) regulating agencies (Department of Fisheries and Oceans, Forestry Lands and Natural Resources) and First Nations (Canadian Columbia River Inter-Tribal Fish Commission, Sexqeltkemc te Sewepemc, and Okanagan Nation Alliance)

As a result, the project team undertook a number of studies to fill in some of the information gaps and develop performance measures for the Kootenay system. Information has been collected from:

- Public consultative sessions in spring and fall of 2012;
- Discussions with individual First Nations;
- Feedback provided by communities to BC Hydro, FortisBC, and Columbia Power Corporation on operations over a number of years;
- Reviewing available reports prepared for other planning processes;
- Drawing parallels with similar situations in other areas of British Columbia for which performance measures had already been developed; and
- The technical expertise of the Fish and Wildlife Committee members regarding environmental and wildlife interests.

Through the use of these methods, progress has been made on assessing how First Nation and public interests may be affected by water management alternatives in the Kootenay system. However, it is important to note that while this analysis uses a water use planning-like approach, the performance measures have not yet had the same level of scrutiny as those developed on the Columbia River, and have not benefited from monitoring studies specifically designed to provide information on these interests.

Note: The River between Libby Dam and Kootenay Lake is referred to as the Kootenay River in Canada and Kootenai River in the United States. In this report, the U.S. spelling is used for this specific reach both because this section of the river flows primarily in the U.S., and because this may help to distinguish references to the Kootenay River elsewhere in the system (e.g. above Koocanusa reservoir or below Corra Linn dam).

5.2 Objectives and Performance Measures

Table 3 provides a summary of the primary interests and fundamental objectives as originally developed during the Columbia River WUP as well as additional issues raised in subsequent processes. These fundamental objectives were also adopted for the Kootenay River, with additional Kootenay specific issues added.

Table 3: Columbia and Kootenay Water Use Interests and Fundamental Objectives

Interests	Fundamental Objectives
Flooding / Erosion Control	Minimize damage to property and injury to people
Navigation	Minimize disruptions to commercial navigation
Recreation	Maximize the community benefits from quality and diversity of recreation and tourism
Culture and Heritage	Minimize impacts of erosion and destructive human behaviour on potential archaeological zones Maintain the cultural, aesthetic and ecological context of important sites
Fish and Aquatic	Maximize the abundance of fish
Wildlife and Vegetation	Maximize the abundance and diversity of wildlife

Dust Generation	Minimize dust generation
Creston Valley Floodplain (Farming & wetland protection	Minimize the operating cost of maintaining the dykes and pumping system
Power Generation	Maximize power benefits
Greenhouse Gas	Minimize GHG emissions

Table 4 is a summary list of the Columbia River performance measures (PM) used for the CRT Review, and Table 5 provides the Kootenay River PMs . The PM Info Sheet Number refers to the filename of the document in Appendix F (Columbia) and G (Kootenay), which contains a description of the interest, calculation methodology, and the detailed results for each performance measure.

Both the Columbia River and Kootenay River are divided into four general areas, while the financial and greenhouse gas emission implications of the alternatives are evaluated for each system.

Kootenay River: Koocanusa reservoir, Kootenai River and the Creston Valley Floodplain, Kootenay Lake, and the Kootenay River downstream of Corra Linn dam.

Columbia River: Kinbasket reservoir, Mid-Columbia river (Revestoke dam to Arrow Lakes reservoir), Arrow Lakes reservoir, and the Lower Columbia River (Hugh Keenlyside dam to U.S. border**).**

Table 4: Columbia River Performance Measures for CRT Review Evaluation

PM Info Sheet #	Location	Topic
1	Kinbasket Reservoir	Navigation
2	Kinbasket Reservoir	Recreation
3	Kinbasket Reservoir	Heritage and Culture
4	Kinbasket Reservoir	Erosion
5	Kinbasket Reservoir	Vegetation
6	Kinbasket Reservoir	Dust Potential
7	Kinbasket Reservoir	Pelagic Productivity
10	Mid-Columbia River	Recreation
11	Mid-Columbia River	Vegetation
12	Mid-Columbia River	Fish Habitat
13	Mid-Columbia River	Wildlife
15	Arrow Lakes Reservoir	Navigation
16	Arrow Lakes Reservoir	Recreation
17	Arrow Lakes Reservoir	Heritage and Culture
18	Arrow Lakes Reservoir	Dust Potential
19	Arrow Lakes Reservoir	Recreation – Soft Constraint
20	Arrow Lakes Reservoir	Fish – Soft Constraint
21	Arrow Lakes Reservoir	Vegetation – Soft Constraint
22	Arrow Lakes Reservoir	Heritage – Soft Constraint
23	Arrow Lakes Reservoir	Erosion – Soft Constraints
24	Arrow Lakes Reservoir	Wildlife – Soft Constraint

25	Arrow Lakes Reservoir	Summary – Soft Constraint
26	Lower Columbia River	Recreation
27	Lower Columbia River	Flooding
28	Lower Columbia River	Total Gas Pressure [TBD]
30	System Wide - Columbia	Power Generation – Financial Value

Table 5: Kootenay River Performance Measures for CRT Review Evaluation

PM Info Sheet #	Location	Topic
50	Koocanusa Reservoir	Vegetation
51	Koocanusa Reservoir	Aquatic Ecosystem
52	Koocanusa Reservoir	Recreation
53	Creston Valley Floodplain	Dyke Operations
55	Kootenay Lake	Productivity
56	Kootenay Lake	Recreation
57	Kootenay Lake	Flooding
58	Kootenay River DS of Corra Linn dam	Vegetation & Wildlife
59	Kootenay River DS of Corra Linn dam	Fish and Aquatic Health
60	Kootenay Lake	Power Value

5.3 Interests in the Columbia and Kootenay Systems

In many cases, the First Nation and stakeholder interests cover the same range of issues across all the reservoirs and regulated rivers in the Columbia and Kootenay River systems, although the interests may manifest themselves in different ways in different locations. There are also some unique interests that are only of relevance to specific locations.

This section discusses the general interests and highlights some of the similarities and differences across the two systems. These are grouped under the headings of vegetation and wildlife, fish and aquatic ecosystem system health, recreation and tourism, and First Nations and Cultural Heritage. All the site specific information is found in the PM Info Sheets in Appendix F (Columbia) and G (Kootenay). Appendix H provides a summary of the development of the new Performance Measures for the Kootenay System.

An initial comparison of the reservoirs is provided before moving to the interests.

5.3.1 General Comparison of Reservoir Morphometry and Hydrology

Understanding differences in reservoir responses to water management alternatives begins with an understanding of underlying reservoir morphometry (the size and shape of reservoirs beneath the surface) and hydrology (patterns of water flow and storage).

Table 6 provides key data for each reservoir in the two systems. The key differences between the Koocanusa and Kootenay Lake reservoirs can be found in the drawdown regimes and residence times. The dams impounding Kootenay and Arrow reservoirs are constructed at the outlets of natural lakes and therefore have annual drawdowns that are much less than at Libby and Mica dams, which blocked free flowing rivers to create the Koocanusa and Kinbasket reservoirs.

Although Koocanusa Reservoir has the smallest watershed and lowest mean annual discharge (MAD), the water residence time for Kootenay Lake is more than double that of Koocanusa, with Arrow Lake intermediate between the two. Impoundment has increased the residence time of Arrow Lake modestly and at full pool, submerged a short section of riverine habitat ("the Narrows") between the separated the reservoir into Upper and Lower Arrow Lakes prior to impoundment.

Table 6: Morphology and Hydrology of Koocanusa, Kootenay, Kinbasket, and Arrow reservoirs

	Koocanusa[1]	Kootenay[2]	Arrow[3]	Kinbasket
Length at full pool (km)	145	107	240	
Length at low pool	87	106	205	
Area full pool (km2)	188	389	464	
Area low pool (km2)	61	388	445	
Volume full pool (km^3)	7.24	36.7	38.5	
Live Storage (km^3)	5.78	1.90	8.76	
Water residence time full pool (yr)	0.76	1.44	1.07	
Water residence time low pool (yr)	0.15	1.37	0.83	
Mean Depth (m)	39	94	83	
Max Depth (m)	107	154	287	
Mean Annual Discharge (m3/sec)	301	800	1143	

1 Dunnigan et al. 2009, Dalbey et al. 1998
2 Schindler et al. 2007
3 Schindler et al. 2010

5.3.2 Vegetation and wildlife

The depth, timing and duration of flooding can affect the composition and spatial extent of riparian vegetation (i.e., vegetation around reservoirs in the zone that is periodically inundated). This affects littoral productivity and changing vegetation composition may lead to different use of that land by wildlife or birds.

For example, reduction in flood peaks in the Duncan-Laredau wetland area of Kootenay Lake caused the vegetation comunity of sedge, grasses, and low density wood shrubs at lower elevations, and a cottonwood community at higher elevations to evolve into one dominated by dense stands of wood shrubs and reduced cottonwood recruitment, which is considered less valuable for wildlife.

Vegetation also improves aesthetic quality, helps to control dust, and may serve to protect cultural sites from erosion and human access. Rising reservoir levels in the spring can also have direct impacts on nesting birds, which is of particular concern in the Arrow Lakes reservoir.

Wetland areas are particularly sensitive areas and tend to be the focus of discussion regarding vegetation and wildlife. Important wetland areas include the Revelstoke reach in the north end of Arrow reservoir, the Crawford Bay and Duncan-Lardeau wetlands in Kootenay Lake, and some smaller wetlands on the Kootenay River (note the Creston Valley Wilde Management Area is discussed below).

5.3.3 Fish and Aquatic Ecosystem Health

The Columbia and Kootenay River systems are home to many different aquatic species. The primary fish that are monitored in the systems include rainbow trout, bull trout, whitefish, kokanee, burbot, and white sturgeon. While this section focuses on the common factors that affect fish and aquatic ecosystem health in the two river systems. More specific regional descriptions are documented in the Columbia WUP, Duncan WUP, and the CRT Review Environmental Discussion Paper, while detailed descriptions of the performance measures used for the CRT Review analysis is provided in Appendix F and G. Separate regional descriptions of developing the new performance measures for the Kootenay system and the Lower Columbia River are provided in Appendix E and Appendix ,H as the CRT Review process sponsored technical studies and new analyses in these regions.

Reservoirs

Changes in reservoir elevation and dam release patterns can affect the annual nutrient load and resultant pelagic productivity, which are the 'drivers' of annual phytoplankton carbon production cycles upon which kokanee populations (?and other reservoir fish?) are dependant. More productive lakes tend to be shallower, with higher water residence times as increased reservoir volume or area will lead to greater phosphorous retention. The productivity of upstream and downstream reservoirs and river segments are inversely linked as an increase in one will result in the decrease of another. Other issues that may be affected by reservoir levels are access to tributary habitat for spawning, shore spawning on Kootenay Lake, and fish entrainment (where fish upstream of dams are swept downstream).

Rivers

Regulated rivers tend to have some common interests such as the potential to strand fish if flow rates are decreased too quickly. This issue is typically managed by ramping protocols and minimum flows. Spilling too much water past dams can also create super saturation of air in water which can lead to gas bubble trauma in fish if exposed to gas pressures above 115% saturation. Regulated river systems tend to have lower peak flows, which can cause the gravel beds important to fisheries to get clogged with fine sands and silt.

Another interest is avoiding the dewatering of eggs once spawning has occurred. The different river segments examined in this analysis each have different priorities for water management. For example, in the Mid-Columbia reach, the priority is to increase the functional length of the river by maintaining lower Arrow reservoir levels.

5.3.4 Navigation

Commercial operations of forest companies at Kinbasket and Arrow reservoir can be affected by reservoir elevations. At Kinbasket reservoir, when water elevations are low the forest companies are not able to access certain sites. At Arrow reservoir, low water elevations affect Celgar's ability to transport log rafts, and operations north of Burton shut down when the reservoir falls below a certain level. Kootenay Lake ferries encounter navigation problems at really low lake levels.

5.3.5 Cultural Heritage Sites

There are known historical trails and archaeological sites within the drawdown zone of the reservoirs. These sites may be directly affected by water management alternatives to the extent that they endanger archeological sites through erosion, or help protect them through complete and constant inundation. BC Hydro's Reservoir Archaeology Program seeks to locate sites in the drawdown zones and develop plans for site protection. Koocanusa reservoir and Kootenay Lake are not part of this program.

5.3.6 Flooding and Erosion

One of the main drivers for building the dams on the Columbia and Kootenay rivers was to reduce flood peaks in both the U.S. and Canada. In Canada, Trail, and Kootenay Lake and Arrow Lake had experienced extensive damage in the 1948 and 1961 flood. Since construction of the Columbia and Kootenay River hydroelectric facilities, flood risk has been substantially reduced from historic levels.

There have been three inflow years comparable to 1948 without any impact on Trail. Onset of minor flooding issues in the Lower Columbia River starts when flows at Birchbank (Kootenay River plus total Arrow flows) exceed 165 kcfs (4672.3 cms). At flows of above 180 kcfs (5097.0 cms), there are access restrictions to Zuckerberg Island causeway (Castlegar), Millennium Park (Castlegar) and Gyro Park (Trail) and increasing issues with Trail sewage processing. At flows above 190 kcfs (5380.2 cms) there are erosion issues of the Robinson sewage lagoon (Castlegar) and river front backyards in Castlegar are flooded. On Kootenay Lake, the high lake alert elevation is 1751 ft (533.7 m), and incidental flooding begins around 1752 ft (534.0m). While the regional district (RDCK) flood construction level for Kootenay Lake is 1760 ft(536.4 m), encroachment into the flood plain has occurred and more properties are now exposed to flooding risks.

Concern has also been expressed for surcharging reservoirs (Kinbasket, Arrow, and Koocanusa) as surcharging may cause erosion from wave action and bank slumping, affecting properties and roads adjacent to the reservoirs. Surcharging may also mobilize debris that has accumulated along the shorelines. On Koocanusa reservoir, there may be an impact on grazing land.

Higher peak flows followed by rapid flow reductions in the Kootenai River can also erode dyke infrastructure in the Creston valley. The CRT Review project team commissioned a study (BGC Engineering , 2012) to investigate whether VarQ operations are responsible for increased dyke erosion rates. The report concludes that while current VarQ operations do have a somewhat higher peak flow than the pre 1990's 'power & flood control' operation, the peak is still much reduced relative to pre-Libby levels and VarQ has not had a significant negative impact on dyke infrastructure.

5.3.7 Recreation and Tourism

Recreation and tourism are important to many of the communities around reservoirs. Local communities benefit from improvements to the quality and diversity of recreation and tourism experiences through a greater quality of life, as well as through local economic development benefits that result from increased usage. Sport fishing is one of the main recreational activities on the reservoirs and rivers.

Community members have proposed objectives that provide for water access for boating and fishing, and that generally improved the quality and diversity of recreational activities. Preferred reservoir ranges tend to be from 5 - 15 ft (1.5 – 4.6 m) from the top of the reservoir (although they do vary across the system), except in the Mid-Columbia (Revelstoke reach) area that prefers lower Arrow Lakes reservoir levels to access the river. If reservoirs are too high, beaches are submerged and there is reduced shoreline access. The key period for recreation is July and August, although the shoulder months of April/May and Sep/Oct still provide recreational activities on the reservoirs.

In the Lower Columbia River, where flows are a function of both flows out of Arrow Reservoir and past Brilliant dam on the Kootenay River, sudden changes in river flow have been noted to have detrimental effects on recreational interests, such as boat navigation and stranding, and safe access to shorelines.

5.3.8 Creston Valley Floodplain – Wetlands and Farming

This region has a large system of dykes, predominately for agriculture but also for transportation corridors as well as residential and commercial developments. Agriculture has been an economic driver in the region since dyke infrastructure was installed beginning in the 1930s. The Creston Valley Wildlife Management Area (CVWMA), a 7,000-hectare area managed for wildlife and waterfowl habitat, is also protected by the dykes. Vegetation and wildlife interests are a major concern in this area and there is a strong local interest in maintaining or expanding the biodiversity in the CVWMA.

Although farming and wetland protection may appear to have little in common, both activities have developed over time with the present complex infrastructure on which they are now dependent. Because of the system of dykes and pumps, any water management alternative would not have a significant impact on the impounded areas except for the most extreme circumstances. Most if not all of the technical issues associated with maintaining wetland and farming values in the valley may be addressed through infrastructure investments rather than hydrological operations. For this reason, a performance measure was developed for pumping costs. An additional issue specific to certain farming areas concerns the need for relatively dry farmland during March and April.

Chapter 6: Alternative Assessment Results – Columbia

This section summarizes how environmental and social interests in Canada may be affected by different possible water management objectives under a Treaty Continue or Treaty Terminate scenario. Results are provided by geographic area, and then a summary of the system trade-offs is presented.

Notes: The statistical summaries of each performance measure for the water management alternatives are provided in PM Info sheets in Appendix F. The results presented in this section focus on the mean annual values unless otherwise stated. The effects of post-2024 flood management (i.e. called upon operations) have not been modelled.

In a manner consistent with Gregory et al, (2012), a systematic comparative analysis was undertaken to structure the consideration of alternatives. The tables in this section compare the different water management alternatives (Alts 3TC, 4TC, Ref TT, 3TT, 4TT, 5TT and 6TT) to the Treaty Continue reference case (Ref-TC). The interests for the different alternatives are shaded orange (dark text) if the difference is in a preferred direction (i.e. 'better') by an amount detailed in Appendix F (referred to as the Minimum Significant Increment of Change (MSIC)). A blue shaded (white text) value is 'worse' than the reference column by an amount greater than the MSIC. Changes that are within the MSIC in either direction are not shaded. The column labelled 'Dir' indicates the preferred direction of change (H=Higher, L=Lower) in the numbers in each row and the column labelled "PM" indicates the PM Information Sheet in Appendix F.

6.1 Results by Geographic Area

6.1.1 Kinbasket Reservoir

The performance of water management alternatives for Kinbasket reservoir interests closely follows the hydrological differences between the alternatives. Figure 4-6 showed that, although many of the alternatives are similar for Kinbasket, three alternatives are significantly different from the others: Alternatives Alt 3 TC, 4TC and 4TT each result in a drawdown depth of about 20 ft (6.1 m) less than the other alternatives. For the Alternatives 4TC and 4TT this was by design, but for 3TC it was the unintended result of meeting constraints on Arrow Lakes reservoir.

Table 7 shows a summary of the performance of the alternatives for Kinbasket reservoir.

Table 7: Performance of Alternatives in Kinbasket Reservoir

Objective	Performance Measure	Units	Dir	Ref TC	3TC	4 TC	Ref TT	3 TT	4 TT	5 TT	6 TT	PM
Kinbasket												
Veg & Wildlife	Elevation bands flooded > 18 wks	# 2m bands	L	6.1	7.2	6.0	6.8	6.8	8.6	6.8	7.0	(#5)
Aquatic Productivity	Residence time	Days	H	622	529	427	687	709	496	670	727	(#7)
Heritage	Site erosion	Weighted Days	L	203	239	238	203	201	267	204	202	(#3)
Heritage	Site inundation	Weighted Days	H	524	627	568	556	555	770	555	559	(#3)
Rec - Water - Canoe	Pref range: 2404 < days < 2475	Days	H	148	170	170	145	145	185	146	146	(#2)
Rec - Water - Columbia	Pref range: 2375 < days < 2475	Days	H	52	68	69	51	52	52	52	50	(#2)
Rec - Shore - Columbia	Pref range: 2444 < days < 2473	Days	H	175	182	184	175	175	184	176	176	(#2)
Dust	Areal extent	SqKm - Days	L	1,468	1,134	1,133	1,393	1,240	991	1,407	1,229	(#6)
Erosion	Elev>=2470	Days	L	54	85	35	70	65	123	68	79	(#4)
Navigation	Downie Timber access (>=2360)	Ave Days/yr	H	348	362	365	362	364	365	363	361	(#1)

Legend
Better than highlighted alt
Worse than highlighted alt
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The lower drawdown associated with Alt 3TC, 4TC and 4TT translates into higher performance on recreation and dust measures. Heritage impacts may be interpreted differently depending on which measure is used: Site erosion may be worse than Ref TC for Alts 3TC, 4TC and 4TT. However, sites are fully inundated for longer under all the alternatives relative to Ref TC.

The potential impacts of the alternatives on Kinbasket vegetation is based on an elevation-based performance measure. This measure indicates that the Ref TC alternative has the least amount of "excessive flooding" of any of the alternatives, and thus has the best performance for vegetation. The actual potential for vegetation to establish in the various elevation bands depends on a number of factors including substrate, slope, and groundwater table and thus the vegetation performance measure has significant uncertainty.

Erosion is worse than Ref TC across all of the alternatives except 4TC, and navigation is improved slightly across all alternatives relative to Ref TC.

6.1.2 Mid-Columbia River

Mid-Columbia River (Columbia River from Revelstoke Dam downstream to the beginning of Arrow Lakes Reservoir) performance measures are better when Arrow Lakes Reservoir levels are lower, and worse when Arrow Lakes Reservoir levels are higher. When reservoir levels are high, areas of important habitat for vegetation, birds and other wildlife may be inundated. The performance of the alternatives is shown in Table 8.

Table 8: Performance of Alternatives in the Mid-Columbia River

Objective	Performance Measure	Units	Dir	Ref TC	3TC	4 TC	Ref TT	3 TT	4 TT	5 TT	6 TT	PM
Mid Columbia River												
Veg & Wildlife - Veg Flooding	Hectares flooded > 18 wks	Hectares	L	2,352	1,388	1,388	3,234	2,352	3,426	3,234	1,871	(#11)
Veg & Wildlife - Nesting birds	% Useable habitat	Percent	H	20	48	40	-	17	-	0	70	(#13)
Veg & Wildlife - Fall Mig. Birds	% Useable habitat	Percent	H	15	87	71	-	55	-	0	34	(#13)
Aquatic - River Habitat	Functional large river habitat	Km	H	31	35	34	18	23	19	19	26	(#12)
Aquatic - Sturgeon	Larval habitat availability	Km	H	2.84	2.85	2.85	2.77	2.85	2.83	2.79	2.85	(#12)
Rec - Boat Access	Days > 1435	Days	H	64	2	21	153	26	153	145	59	(#10)
Rec - Shore Access	Days < 1435	Days	H	119	181	162	-	157	-	8	94	(#10)

Legend
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Worse than highlighted alt
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Alternatives Ref TT, 3TT, 4TT and 5TT are associated with consistently higher Arrow levels throughout the year (compared to Alt Ref TC), and this translates to significantly poorer performance for vegetation and wildlife in this area. Areas of vegetation flooded for longer than 18 weeks increased by between 38% to 46% for Alternatives Ref TT, 4TT and 5TT. Existing areas of shoreline and fall migratory bird nesting sites are completely eliminated under these alternatives. Since Arrow levels are generally higher under the Treaty Terminate (TT) alternatives, areas of functional large river habitat decrease by between 17% and 40% across these TT alternatives.

Sturgeon larval habitat availability changes across the alternatives by less than 3%.

By contrast, alternatives 3TC, 4TC and 6TT result in lower Arrow levels than the reference case (Ref TC), resulting in a 40% gain in vegetated area not flooded for an excessive duration as well as large improvements in effective bird nesting areas.

Shoreline-based recreation areas are increased by 37% to 52% under 3TC and 4TC, but are eliminated under Alternatives Ref TT, 3TT, 4TT and 5TT. Boat access and shoreline based recreation share an inverse relationship.

6.1.3 Arrow Lakes Reservoir

Arrow Lakes Reservoir interests are similarly driven by reservoir levels. Recreation interests, kokanee access to tributaries, dust control, power and navigation interests are all favoured by higher reservoir levels; all Treaty Terminate alternatives with the exception of 6TT result in higher reservoir level regimes (compared to Ref TC) throughout the year. The performance of the alternatives is shown in Table 9.

Table 9: Performance of Alternatives in Arrow Lakes Reservoir

Objective	Performance Measure	Units	Dir	Ref TC	3TC	4 TC	Ref TT	3 TT	4 TT	5 TT	6 TT	PM
Arrow Lakes												
Aquatic - Kok Trib. Access	Days > 1430'	Days	H	60	37	50	82	82	82	82	22	(#20)
Aquatic Productivity	Epilimnetic residence time	Days	H	107	101	98	95	93	84	94	70	(#7)
Heritage	Site erosion	Weighted Days	L	227	135	151	365	332	357	363	233	(#17)
Heritage	Site inundation	Weighted Days	H	190	56	95	763	524	750	735	430	(#17)
Recreation - General	1435 < days < 1440	Days	H	97	75	72	197	197	197	197	41	(#16)
Dust	days < 1410	Days	L	41	61	61	-	-	-	-	-	(#18)
Navigation	Weighted-Days	Days	H	219	226	219	211	248	211	226	248	(#15)

Legend
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Worse than highlighted alt
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As expected, Table 9 suggests that all of the Treaty Terminate alternatives with the exception of 6TT have higher performance measures than Ref TC for kokanee tributary access, dust control and navigation interests. Beyond improving kokanee access, however, the Ref TT, 3TT, 4TT and 5TT alternatives may have reduced epilimnetic[6] residence times (driven by higher reservoir discharge rates during the spring runoff period), possibly indicating reduced productivity in Arrow for a wide range of aquatic life.

As with Kinbasket, Heritage impacts vary depending on the measure being used: site erosion may be worse than Ref TC in Ref TT, 3TT, 4TT and 5TT. However, sites are fully inundated for longer durations under these alternatives (as well as 6TT) relative to Ref TC, thus providing more protection for heritage features.

The Ref TT, 3TT, 4TT and 5TT alternatives result in Arrow levels that are fairly high (at optimum levels for power production) during the entire summer period, and these levels are also within the generally preferred recreation range[7] for Arrow Lakes Reservoir.

6.1.4 Lower Columbia River

The performance of the alternatives in the Lower Columbia River (between Arrow Dam and the border) is shown in Table 10.

The Lower Columbia River would generally experience higher spring flows under the Treaty Terminate alternatives, since it is expected that the Arrow Reservoir would be operated closer to full-pool during the spring, and there would be less empty storage available to manage increased local inflows. This is reflected in an increase in the flooding concerns represented by the mean number of days of flow above 165 kcfs (4672.3 cms) at Genelle in Ref TT, 3TT, and 4TT. (The duration with flows above 177 kcfs (5012.1 cms) is also provided as this flow threshold reflects the onset of flood damage based on observations during 2012). The pulse flow during the summer associated with fisheries alternatives 5TT and 6TT may provide benefits for fisheries and sturgeon,

[6] Epilimnetic residence time is an indicator of productivity. The epilimnion is a surface band of water in a reservoir.
[7] The actual numbers for this performance measure have been adjusted to more accurately represent the beneficial recreation performance of these alternatives that could be achieved with minor adjustments – See Appendix F, PM Sheet#16 for details.

but could also deliberately cause some flood damage unless additional infrastructure for flood protection was built.

Beyond sturgeon, fish impacts may be mixed in this area. Mountain whitefish and rainbow trout welfare may improve in alternatives Ref TT and 4TT, as illustrated by a newly constructed (but uncertain) performance measure that looks across a range of hypotheses for mechanisms that drive biomass growth for these species (See Appendix E).

Table 10: Performance of Alternatives in the Lower Columbia River

Objective	Performance Measure	Units	Dir	Ref TC	3TC	4 TC	Ref TT	3 TT	4 TT	5 TT	6 TT	PM
Lower Columbia River												
Boat Access	40000 < days < 103000	Days	H	95	98	94	79	78	71	75	83	(#26)
Shoreline Access	60000 < days < 99000	Days	H	79	75	86	61	65	54	57	45	(#26)
Flooding at Genelle (1)	days > 165 kcfs	Days	L	2	2	2	6	6	8	6	32	(#27)
Flooding at Genelle (2)	days > 177 kcfs	Days	L	1	1	1	3	3	4	3	11	(#27)
Whitefish / Trout	INDEX	INDEX	H	-	-	- 0.13	0.63	- 0.18	0.97	0.36	- 0.15	APPX E
TGP	days > 115%	Days	L	NA	NA	NA	NA	NA	NA	NA	NA	(#28)
Sturgeon	Pulse provided	Yes / No	H	No	No	No	No	No	No	No	Yes	NA

Legend
Better than highlighted alt
Worse than highlighted alt
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6.1.5 System-Wide Impacts

The financial value is composed of three factors: the annual operational power benefits associated with the individual operations of each alternative, the value of the Canadian Entitlement, and the replacement cost of firm energy for alternatives 4TC and 4TT. The values in Table 11 are changes in financial value (millions of dollars per year) relative to the Ref TC alternative. The value of the annual operational power benefit and the Canadian Entitlement is based on the BC Hydro electrical price forecast in 2024 (average market price of $38 MWh[8]). The firm energy value is based on BC Hydro's reference price of $129/MWh, which is the replacement cost of clean energy built in BC. These prices are detailed in Appendix F, Sheet #30, and are summarized in Figure 5.

Table 11: System Wide Impacts

Objective	Performance Measure	Units	Dir	Ref TC	3TC	4 TC	Ref TT	3 TT	4 TT	5 TT	6 TT	PM
System Wide												
Relative loss in Power Values	Incremental Cost	$M/yr	L	-	22	181	180	186	350	181	201	(#30)

Legend
Better than highlighted alt
Worse than highlighted alt
Highlighted alt

.

[8] $38 MW/hr is within the $30-$50 MW/hr range of prices used by the U.S. Entity in their Iteration #1 studies.

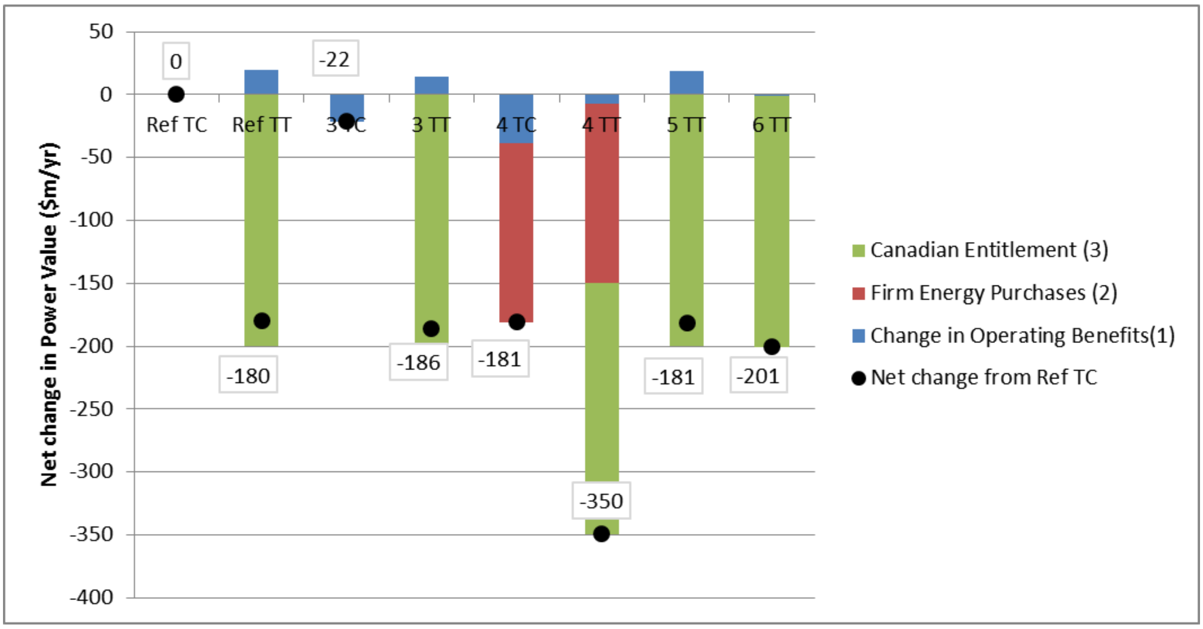

Figure 5: Breakout of major components in value of power generation calculation

6.2 Summary of System Trade-offs

A Treaty Terminate scenario would lead to a wider range of possible water management alternatives. Table 12 simplifies the presentation of some of the system wide trade-offs associated with possible water management alternatives under a Treaty Continue and Treaty Terminate scenarios by grouping together performance measures in the same geographic region that are directionally consistent.

Table 12: Summary of Systemic Trade-offs

	Treaty Continue			Treaty Terminate				
	Ref TC	3TC	4 TC	Ref TT	3 TT	4 TT	5 TT	6 TT
Kinbasket Rec/ Nav / Dust	NA	Rec Days (+15-30%)	Rec Days (+5-30%)			Rec Days (+0-20%)		
Mid-Columbia River Veg / Wildlife/River Habitat		Veg Area (+40%) Bird Hab. (+>100%) River Hab (+12%)	Veg Area (+40%) Bird Hab. (+>100%)	Veg Area (-38%) All Bird Habitat Lost River Hab (-40%)	River Hab (-25%)	Veg Area (-46%) All Bird Habitat Lost River Hab (-40%)	Veg Area (-38%) All Bird Habitat Lost River Hab (-39%)	Veg Area (+70%) Bird Hab. (+>100%) River Hab (-17%)
Arrow Rec / Dust /Kokanee access		Rec Days (-23%) Kok Access (-38%)	Rec Days (-26%) Kok Access (-17%)	Rec range all season Full Kok Trib Access	Rec range all season Full Kok Trib Access	Rec range all season Full Kok Trib Access	Rec range all season Full Kok Trib Access	Res drops 60' in summer
LCR Fish (1) TGP		TGP X%	TGP X%	TGP X%	TGP X%	TGP X%	TGP X%	TGP X%
LCR Fish (2)				Possibly better for MW / RBT		Possibly better for MW / RBT		Major sturgeon pulse
LCR Flooding							Flow >177kcfs (5012 cms) every year	Flow >177kcfs (5012 cms) every year
Annual Power Value Change		-$22m	-$180m	-$180m	-$190m	-$350m	-$180m	-$200m

Legend
Better than Ref-TC
Worse than Ref-TC

Within the Treaty Continue scenario, the trade-offs associated with Alternatives 3TC and 4TC will be familiar to participants in previous Columbia River planning processes: limited gains are possible on Kinbasket reservoir due to its large operational range. Limiting the drawdown of Kinbasket by 20 ft (6.1 m), as modelled in Alternative 4TC, has a large cost impact because of the replacement cost of firm energy. Alternative 3TC has significant benefits to vegetation, bird and wildlife values in the Mid-Columbia River; however these must be weighed against the loss of power values and declines in kokanee tributary access and recreation days in Arrow Lakes Reservoir.

Under a Treaty Terminate scenario, a considerably wider range of opportunities exist. However, Alternative 4 TT shows that reducing the drawdown of Kinbasket reservoir under Treaty Terminate may not necessarily result in significant benefits for that location.

In the Ref TT, 3TT, 4TT and 5TT alternatives, Arrow Lakes reservoir may be operated higher, and thus more suited to recreation interests. However, there are competing ideal reservoir levels for different recreational uses (e.g. shoreline versus boat access), and these conflicts would need to be resolved under any of these Alternatives. Alternatives Ref TT, 4TT and 5TT benefit Arrow recreation at the expense of vegetation and wildlife interests in the Mid-Columbia River (where all current bird nesting habitat would be lost). However, Alternative 3TT improves the reservoir for recreation while having less of a negative impact on the Mid-Columbia River area.

A Treaty Terminate scenario would enable consideration of some very different approaches to managing water in the system, such as that illustrated in Alternative 6TT. This Alternative provides for a major flow release to benefit sturgeon in the Lower Columbia River (though the potential benefit of this flow is uncertain as it may or may not result in sturgeon recruitment). This alternative also performs well for most Mid-Columbia River vegetation and wildlife interests. However, Alternative 6TT results in a significant (60 ft/18.3 m) drawdown of Arrow Lakes reservoir in the summer season, rendering it unsuitable for recreation interests.

6.3 Key Findings

Preliminary key findings may be summarized as follows:

Operating constraints on Kinbasket reservoir have the highest costs (especially if firm energy is impacted), regardless of Treaty Termination *Improvements to recreation, navigation and potentially vegetation/wildlife and the operating cost and cost of building new sources of firm energy are similar whether the Treaty continues or is terminated.*	
Treaty Continue	Treaty Terminate
Due to the large generation capability at Mica and Revelstoke (5700 MW, ~50% of BC Hydro's capacity), changes at Mica are the most costly and provide limited gains for interests around the reservoir.	In Treaty Terminates, more radical changes to operations could be developed that could provide greater benefits to interests around the reservoir, but at an even higher cost. This domestic trade-off remains the same.

With Treaty Termination, Arrow Lakes operational choices become less linked to choices made at Kinbasket	
Treaty Continue	Treaty Terminate
Under the Treaty Continue scenario, there will always be a need to balance between Kinbasket/Arrow as the *border flow* releases from Canadian storage are set by the Treaty operations. If Arrow is low,	Under a Treaty Terminate scenario, Arrow reservoir levels can change without having the same impact on Kinbasket reservoir, thereby creating more opportunity to operate Arrow for other interests.

Kinbasket will be higher and vice versa.	

Regardless of the Treaty's future, value trade-offs at Arrow will remain	
Treaty Continue	Treaty Terminate
Alternative 3 demonstrates the trade-off at Arrow reservoir under a Treaty Continue scenario where significant benefits to vegetation, bird and wildlife values in the Mid-Columbia River can be gained by a lower reservoir elevation, however these result in the loss of power revenues and declines in kokanee tributary access and recreation days in Arrow Lakes Reservoir	The de-linking of Kinbasket and Arrow reservoirs enables different operations at Arrow reservoir that could provide a different (and potentially better) balance between the high and low Arrow reservoir interests. However, as Figure 6 illustrates, several of the key interests in Arrow Lakes reservoir are mutually exclusive, and so tough trade-off choices will remain.

Treaty Terminate opens up new trade-off opportunities / constraints between Arrow and the Lower Columbia River	
Treaty Continue	Treaty Terminate
Under the Treaty Continue scenario, BC Hydro is able to meet Lower Columbia River spawning flows in the January through June period, although this does result in high Arrow reservoir levels in the spring which impacts the Mid-Columbia interests that prefer lower levels in the spring but benefits reservoir based recreation.	The potential for different operations creates quite different trade-offs between Arrow reservoir and the downstream river section that were not investigated in the WUP.

? Other potential key findings? – For discussion.	
Treaty Continue	Treaty Terminate

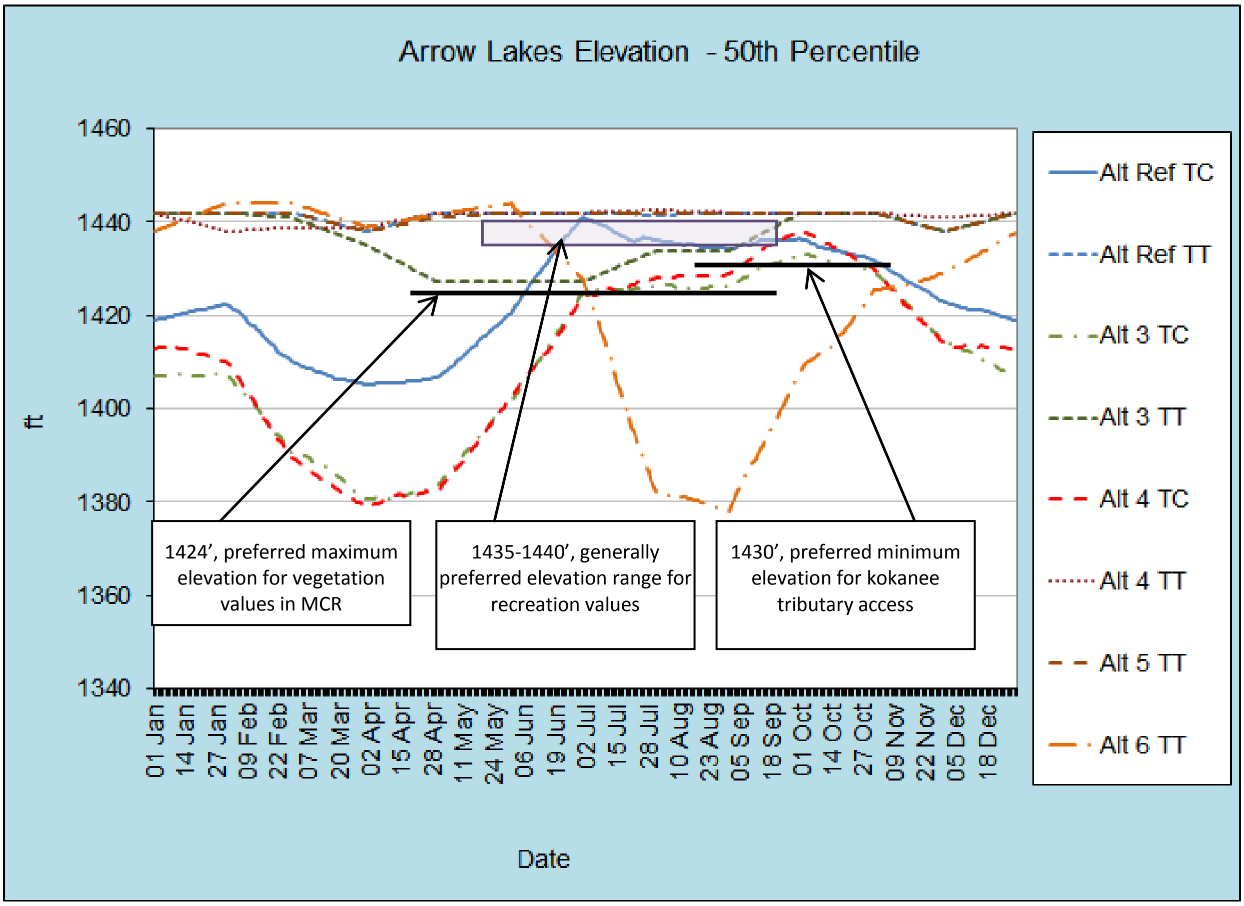

Figure 6: Some competing value interest elevation thresholds / ranges on Arrow lakes Reservoir

In conclusion, the Treaty Terminate scenario widens the operational flexibility of the Columbia River system and creates opportunities to find a new balance of interests through a future Water Use Planning process. This analysis of a small number of possible 'bookend' Treaty Terminate alternatives has demonstrated the range of benefits and impacts that could occur to Canadian interests. However, some of these benefits may be somewhat mutually exclusive, and any specific water management alternative will necessarily still involve trade-offs between different values in the system. Some of the central trade-offs that were contemplated in the Columbia Water Use Plan would remain while new trade-offs would emerge. Moreover, the Treaty Terminate alternatives come at the cost of the loss of the Canadian Entitlement, valued at approximately $200 million per year.

An additional component to remember when considering the potential implications of the Treaty Continue and Treaty Terminate scenarios is that there is still uncertainty on how Called Upon flood control operations may impact Canadian reservoirs.

Chapter 7: Consequences of Alternatives - Kootenay River System

This section summarizes how environmental and social interests in Canada may be affected by alternative water management objectives at Libby dam in Montana. Unlike the Columbia River, operations on the Kootenay system are not closely linked to the strategic decision to terminate or continue the Treaty because Libby coordination continues whether or not the Treaty is terminated. However, two topics related to the CRT Review that may influence Kootenay River system operations are post 2024 Flood Control operation at Libby and the potential to use discussions with the U.S. on the CRT Review to influence how coordination between Canada and the U.S. on Libby operations occurs. The alternative Libby operations modelled were developed to explore the trade-offs between different Canadian interests in the Kootenay system to help inform future discussions about Libby operations.

Notes: The statistical summaries of each performance measure for the water management alternatives 1, 2, 3b are provided in PM Info sheets in Appendix G. The results presented in this section focus on the mean annual values unless otherwise stated. As discussed in Chapter 4, results for alternative 3a are not carried forward here. The effects of post-2024 flood management (i.e. called upon operations) have not been modelled. A discussion of how these objectives and performance measures were identified and developed for this analysis is presented in Appendix H.

7.1 Comparing Alternatives

In a manner consistent with Gregory et al, (2012), a systematic comparative analysis was undertaken to structure the consideration of alternatives.

In Table 13, Alt-2 and Alt 3b are compared to the current operation of Alt-1. The interests in Alt-2 and Alt 3b are shaded orange (dark text) if the difference is in a preferred direction (i.e. 'better') by more than 10%. A blue shaded (white text) value is more than 10% 'worse' than the reference column. Changes that are within 10% in either direction are not considered significant and are not shaded. Using such a method, comparing alternatives is cognitively simplified (Gregory et al, 2012).

7.1.1 Alt-2 (power & standard flood control)

Relative to current conditions (Alt-1), Alt-2 provides lower Koocanusa reservoir levels during the winter and early spring. This may have positive effects for vegetation and wildlife if vegetation can be established in the drawdown zone; however, it may have negative impacts on aquatic productivity and the preferred recreation range for Koocanusa reservoir.

For Alt-2, the resulting lower discharge from Libby in June/July cause less potential flooding around Kootenay Lake and also reduces the amount of spill at the Kootenay River dams below Nelson (Corra Linn and other river dams). Less spill at these dams provides about $19 million in annual Canadian power benefits and has positive environmental benefits by reducing total dissolved gas in the Kootenay River and reducing how often the Bird Creek wetland area is submerged.

7.1.2 Alt-3b (refill by 30 Jun)

Relative to current conditions, Alt 3b provides benefits to interests in Canada including resident fish and recreation in Koocanusa reservoir, flood reduction at Kootenay Lake, reduced spill in the Kootenay River which produces environmental benefits and $5 million in annual power benefits.

The operation in Alternative 3b essentially lowers Libby outflow in May-June and defers the peak outflow into July, when Kootenay Lake levels, in most years, have already peaked and have begun to recede. With the deferred peak flows from Libby, peak Kootenay Lake levels and outflows are lower and exceed flood levels for a shorter period while Koocanusa reservoir levels are higher. The higher reservoir levels at Koocanusa would benefit resident fish and recreation but could increase the risk of surcharging the Koocanusa Reservoir since less space would be available in late June and early July to regulate inflow spikes from unpredictable large rainfall events. This effect on Koocanusa is not captured.

The dyke management and farming equipment handling performance measures in the Creston area do not show significant variation across the alternatives modelled.

7.1.3 U.S. Fisheries Requirements

Table 13 includes a row to represent the fisheries interest in the Kootenai River that is under U.S. jurisdiction. The fish in this section of the river typically travel back and forth across the international border between Kootenai River and Kootenay Lake. The project team has not tried to evaluate the potential success of U.S. water management alternatives for Libby Dam and the Kootenai River. Instead the value in the table indicates whether or not the alternative meets the current US regulatory requirements for both sturgeon[9] and bull trout.

A similar approach is used to represent whether the water management alternatives meet the current U.S. regulatory requirements for downstream salmon in the U.S. portion of the Columbia River. This information is included to inform those Canadians who do have an interest in these fisheries values.

Alt-2 does not meet the current U.S. regulatory requirements for fish in the Kootenai River or downstream salmon in the U.S. portion of the Columbia River. It is unknown whether the Koocanusa Reservoir draft to 2439 ft (743.4 m) by 30 September, previously part of Libby operations for salmon, had positive benefits for salmon, or if there were changes in other U.S. reservoirs as a result of the change in Libby operations.

Alt 3b does not meet the current U.S. regulatory requirements for sturgeon in the Kootenai River in 55 out of the 70 years (although only 62 years were estimated to require a sturgeon operation). It also does not meet the requirements for bull trout in 32 out of the 70 years (mainly in May), and it is unknown whether Alt-3b meets requirements for downstream salmon.

[9] The trial period for the existing U.S. approach to sturgeon pulse flows has not been successful in promoting sturgeon recruitment. The next step for the U.S. is to combine pulse flows with habitat enhancements.

Table 13: Comparison of Alternatives 1, 2 and 3b

Alternative 1: Current Conditions
Alternative 2: Power & Standard Flood Control
Alternative 3b: Refill by 30 Jun

Objective	Performance Measure	Units	Dir	Alt 1	Alt 2	Alt 3b	PM #
Koocanusa Reservoir							
Reservoir Vegetation and Wildlife	Hectares flooded >10 wks	Hectares	L	2,673	1,443	2,720	(#50)
Fish and Aquatic Ecosystem Health	Primary production	Tons	H	14.5	12.6	15.2	(#51)
General Recreation and Tourism	Preferred Elevation Range	Days	H	28.5	16.5	27.0	(#52)
Kokanee Angling	Angling Effort	Angler Days	H	23,629	26,627	29,008	(#52)
Kootenai River and Creston Valley Floodplain							
Dyke Management Operations	Preferred Lake Elevation	Days	H	163	165	165	(#53)
Farming Equipment Handling	Preferred Lake Elevation	Days	H	21	19	21	(#53)
Kootenay Lake							
Fish and Aquatic Ecosystem Health	West Arm Spawner Length	cm	H	31.1	30.2	30.9	(#55)
Recreation, Tourism and Industry	Preferred Lake Elevation	Days	H	67	65	73	(#56)
Flooding	% Yrs above 1752'	Days	L	14%	6%	8%	(#57)
Kootenay River Downstream of Corra Linn Dam							
Vegetation and Wildlife	Cumulative Habitat Loss	Ha	L	4,307	3,242	4,089	(#58)
Fish and Aquatic Ecosystem Health	Total Dissolved Gases	% Sat'n Days	L	45	29	40	(#59)
System-Wide Impacts							
Canadian Financial Value	Increase in Value of Energy	$m/yr	H	-	19.4	4.6	(#60)
US Jurisdiction							
Sturgeon & Bull trout in the Kootenai R	Meets US regulations	Yes / No	H	Yes	No	No	App H
Salmon in the United States	Meets US regulations	Yes / No	H	Yes	No	Maybe	App H

Legend
- Better than highlighted
- Worse than highlighted
- Highlighted

Note: The column "Dir" clarifies the preferred direction of change in the performance measures (e.g. the lower number of vegetation flooding days in Koocanusa, the better) from which the colour coding is derived.

7.2 Summary

Like the Columbia River system there are a number of trade-offs that are inherent in operations on the Kootenay system. Preliminary key findings may be summarized as follows:

Deeper Libby drafts provides benefits in Canada over the current regime for some interests while other interests perform better under the current regime.

The Libby Power and Standard Flood Control operating regime that existed prior to 1993 drafts Libby deeper than the current regime

Called Upon operations are expected to cause Koocanusa to draft deeper more often, possibly resulting in an operation somewhere between the current regime (Alt1) and the Standard Flood Control regime (Alt 2)

Benefits	Impacts
Less flooding on Kootenay Lake, more power benefit, less spill, improvements for aquatic health in Kootenay River below Nelson, potential benefit to vegetation and wildlife on Koocanusa Reservoir.	May have negative impacts on aquatic productivity and recreation on Koocanusa reservoir

There is potential that current operations could be altered to benefit a wider range of interests in Canada through an operation such as that illustrated in Alternative 3b.

Alternatives that do not meet the U.S. fisheries requirements that are court ordered under the Biological Opinion are unlikely to be implemented

Benefits	Impacts
May benefit Koocanusa resident fish and recreation, flood reduction at Kootenay Lake, reduced spill in the Kootenay River which produces environmental benefits and power benefits	May increase the risk of surcharging Koocanusa Reservoir Does not meet the current U.S. fisheries requirements

? Other potential key findings? – For discussion

Benefits	Impacts