Mountain Station Consultants Inc. 1124 Hoover Street, Nelson, B.C. Canada V1L 4Y2
v: 250-505-5376 email: mtnstn@telus.net

September 14, 2013.

Heather Matthews P.Eng
Manager, Columbia River Treaty 2014 Review
Generation Resource Management
BC Hydro and Power Authority

Dear Heather;

RE: High Level Evaluation of Three Post 2024 Scenarios for Duncan Dam and Constant Mid-Elevation Pool Scenario for Arrow Reservoir for the Columbia River Treaty Review

BC Hydro Contract Order 78245

Please find attached a letter report concerning the above. The information contained in the report was presented at the Columbia River Treaty (CRT) Sounding Board meeting held in Cranbrook July 5th 2013 and elaborates on material presented at the Fauquier CRT public meeting on June 15th 2013. As per your instructions the letter report is a brief and high level analysis that outlines the various scenarios described herein. Many of the outcomes suggested due to possible operational changes of the Arrow and Duncan reservoirs are based upon professional opinion, and numerous BC Hydro, Provincial and consultants' reports. Further and more detailed analysis is recommended to develop a complete understanding of the outcomes, costs and benefits associated with a constant mid-pool elevation scenario for Arrow Reservoir which shows potential of satisfying multiple objectives and interests.

If you have any questions or would like to discuss the letter report please contact me.

Kind regards,

Mountain Station Consultants Inc.

Alan Thomson MRM P.Eng.

High Level Description and Evaluation of Three Post 2024 Duncan Dam and Reservoir Operation Scenarios and A Constant Mid-Elevation Pool Scenario for the Arrow Reservoir.

Prepared by:

Alan Thomson MRM P.Eng.,

Mountain Station Consultants Inc., Nelson B.C.

September 14, 2013.

Introduction

Two of three possible outcomes of the current Columbia River Treaty (CRT) Review are that the Treaty is terminated ("Treaty Terminate") or changed ("Treaty Plus") to reflect current values and interests not addressed in the original Treaty. The third possible outcome is that the Treaty Continue with few or minor changes. Under a Treaty Terminate decision, the three Canadian Treaty dams (Mica, Keenleyside and Duncan) would no longer be bound by Treaty directives and could be operated to satisfy primarily Canadian interests. The Canadian Treaty dams are operated primarily for flood risk reduction and power benefits in Canada and the US. In return for the services to the US, British Columbia receives the Canadian Entitlement in the form of power valued at approximately $200M per year on average.

Although considered extreme by some, a possible operating scenario post 2024 for two Treaty dams - Duncan and Keenleyside (HLK) - involves significantly changing their core water-shaping functions or removing one or both of these facilities and returning the respective watersheds to a more natural ecosystems-focused state. With these possibilities in mind, the Columbia River Treaty Review Sounding Board[1] requested a high level analysis of possible post 2024 operating scenarios for the Duncan reservoir (see Section 1.0 below), costs and procedures related to decommissioning Duncan and HLK dams (see Section 2.0 below), and the potential benefits and issues associated with a constant mid-elevation stable pool operating regime for Arrow Reservoir (see Section 3.0 below). At the Sounding Board's request, these subjects and analysis were presented at their July 15th 2013 meeting in

[1] The Sounding Board is a geographically balanced group of Columbia Basin residents with knowledge and/or experience with dam/reservoir planning and operations who provided a Basin-wide perspective on the Treaty Review

Cranbrook, BC. This letter report summaries the presented information and provides a high level overview of selected scenarios for the two Treaty dams and addresses the dominant issues and concerns of each facility. Many of the predicted responses and outcomes are generalized and are based on professional opinion, and information and assessments found in BC Hydro, consultants' and CRT Review reports concerning the Arrow and Duncan watersheds. Modeling, numerical and additional qualitative analysis' and consultation are required to determine the validity and magnitude of the possible outcomes and responses presented below.

Section 1: Duncan Dam - High Level Analysis of Three Scenarios

The Duncan Dam is located in the Regional District of Central Kootenay at the north end of Kootenay Lake. It impounds at full pool 1.4 million acre-feet of water in the Duncan River watershed and is operated by BC Hydro. The dam was the first of the three CRT dams constructed by the province and has a spillway, two low level outlets, and no hydroelectricity generating facilities.

The three scenarios post 2024 for the Duncan Dam facility that this letter report examines include:

1. status quo operations;
2. decommissioning the dam and returning the Duncan River watershed to a more natural ecosystem-focused state; and
3. installing hydro electricity generating capacity at the facility.

The results of a high level analysis of the three scenarios as they pertain to the main environmental and socio-economic issues for the dam, reservoir and lower Duncan River are found below in Tables 1.0 and 2.0. Primary information sources for information and the basis for possible outcomes presented in the tables include multiple consultant's reports, the Duncan Water Use Plan (WUP) Consultative Committee Report and numerous WUP annual reports. The purpose of the WUP was to develop recommendations defining a preferred operating strategy for the dam and reservoir using a multi-stakeholder consultative process. The WUP Consultative Committee's deliberations and reporting increased understanding of known and suspected socio-economic and environmental impacts of the dam's operations and as such are a reliable source of information from which to assess different possible reservoir operational regimes. BC Hydro through additional field studies, operational changes and physical works continues to address impacts and issues identified in the WUP. The review of the Duncan WUP is scheduled for 2019.

1.1 Duncan Dam Status Quo Operations - Scenario A

When the Duncan facility was completed and commissioned in 1967, it flooded approximately 7,300 ha of a complex mix of forests, wetlands and lakes. The inundation resulted in disruptions of aquatic ecosystems in the reservoir and lower Duncan River, loss of riparian and terrestrial vegetation in the reservoir, loss of upstream and downstream fish migration opportunities between Kootenay Lake and spawning habitats in the upper Duncan River and tributaries, socio-economic impacts on local residents who either were relocated or otherwise affected, and other impacts. In return, however, the facility helps control flooding of Kootenay Lake residences and downstream areas, increases revenue from power generation at Canadian Kootenay River plants and contributes to the annual Canadian Entitlement.

The WUP, CRT and associated operating plans determine the drawdown and recharge operational characteristics of the reservoir. Reservoir operations follow the same pattern annually - a spring drawdown of approximately 100 feet followed by a rapid recharge during freshet followed by a controlled discharge over summer to early winter months. In a status quo scenario, reservoir operations as described above and as required by the CRT and as allowed under subsequent agreements and mandated WUP-derived mitigation programs will continue post 2024.

1.2 Decommissioning Duncan Dam - Scenario B

A decommissioned dam scenario involves partially or completely removing the dam and related facilities that impound and control water in the Duncan River watershed. Natural water impoundments (lakes, wetlands, etc.) would re-establish both in physical and ecological function over the long term and discharge from the watershed into Kootenay Lake would likely follow pre-dam patterns - peaking during spring freshet and slowly declining over summer months and stabilizing over late fall to early spring. In the long term (many decades) the watershed ecosystems could potentially revert to near pre-dam conditions. Primary services and benefits that the facility provides - flood control for Kootenay Lake residences, additional power generation revenue from Kootenay River plants, and a portion of the Canadian Entitlement as currently calculated - would be forfeited.

1.3 Power Generation at Duncan Dam - Scenario C

No hydroelectric generation facilities exist at the Duncan Dam. It is strictly an impoundment facility that releases water for enhanced power generation at Canadian Kootenay River and US Columbia River plants. Installing generation capacity however has been examined by BC Hydro and more recently by

Columbia Power Corporation (CPC). Given the current discharge and dam operating regime, CPC has estimated a hydroelectricity generation facility could:

- have 20-30 MW generation capacity or 80-120 GWhr per year;
- operate January - June during the winter drawdown and spring freshet periods;
- be comprised of two generator/turbine units installed in the existing low level outlets;
- require a new transmission line to Kaslo with upgrades south to interconnection points; and,
- cost $100-130 per MWhr and have a capital cost of $125M-$175M.

Neither BC Hydro nor Columbia Power Corporation has plans to proceed with installing generation capacity at Duncan Dam at this time.

Table 1.0: Comparison of Three Scenarios for the Duncan Dam and Reservoir Post Year 2024

	Three Scenarios High Level Scoping Evaluation		
Main Issue Indentified in WUP	**A/ Status Quo Facility and Reservoir Operations**	**B/ Decommissioning Dam and Returning Reservoir and Dam Site to Pre-Dam Conditions**	**C/ Hydroelectricity Generation Installed at Dam**
Cultural and archaeological resources.	Three sites have been identified as potentially impacted by reservoir operations. Due to the sensitivity of the sites, little public information is available. Impact to three sites will remain of concern. Physical works may be required to preserve sites.	Sites will be permanently exposed and may require physical works to preserve the sites while vegetation is re-established.	Likely no change from status quo.
Reservoir riparian establishment	Riparian vegetation cannot or has difficulty establishing in the drawdown zone due to prolonged inundation periods and erosive wave action. Vegetation in some of the reservoir drawdown zones remain absent. This impacts wildlife utilization of the zone and contributes to dust generation.	Large sections of riparian vegetation may over the long term return to near pre-dam condition. A riparian vegetation re-establishment plan that includes active measures (i.e. planting, invasive weed control) and passive measures (i.e. monitoring natural recruitment) would be required.	Likely no change from status quo.
Recreational use of the reservoir	Provision of recreational sites and reservoir access continues. Maintenance of full pool required through high recreational use month of August.	Over time recreational use within the reservoir footprint would change from lake based recreation to land/lake/stream recreation. Recreation site at Glacier Creek would be physically far removed from any future lake (assessment based on historic photos of lower valley areas).	Likely no change from status quo.

	Three Scenarios High Level Scoping Evaluation		
Main Issue Indentified in WUP	**A/ Status Quo Facility and Reservoir Operations**	**B/ Decommissioning Dam and Returning Reservoir and Dam Site to Pre-Dam Conditions**	**C/ Hydroelectricity Generation Installed at Dam**
Fish (all species)	Duncan reservoir contains multiple species for which there is incomplete stock assessment. Several monitoring and assessment field programs concerning bull trout, rainbow trout, kokanee and burbot are ongoing. It is probable that all species populations are impacted by dam and reservoir operation although comparisons between pre and post abundance is difficult due to lack of abundance data.	Species relative composition and abundance could likely approach pre-dam populations over time as aquatic ecofunctions adapt to the new water regime, although this would be difficult to determine as fish abundance studies were not completed before dam construction commenced. Fish passage between Kootenay Lake, the Lower Duncan River and Upper Duncan River would be unrestricted and allow for in and out-migration of fish.	Likely no change from status quo.
Fish passage into reservoir	The dam prevents upstream passage of all species with the exception of bull trout. Bull trout with the assistance of BC Hydro staff use one of the low level outlets to access the reservoir.	Unimpeded upstream and downstream fish migration would be restored upon dam decommissioning.	Assisted bull trout passage would be prevented. An alternate form of migration assistance such as a fish ladder around the dam could be provided. This would allow for upstream migration of all species as required. Allowing for effective downstream migration past the dam would be more difficult.
Terrestrial wildlife	The drawdown zone largely prevents forage and mature vegetation utilized by wildlife from establishing. A wildlife monitoring plan for the reservoir is in early stages with no published results.	Wildlife abundance and utilization of the reservoir drawdown area may return to near pre-dam conditions over time as terrestrial and riparian ecosystems re-establish and mature.	Likely no change from status quo.

	Three Scenarios High Level Scoping Evaluation		
Main Issue Indentified in WUP	**A/ Status Quo Facility and Reservoir Operations**	**B/ Decommissioning Dam and Returning Reservoir and Dam Site to Pre-Dam Conditions**	**C/ Hydroelectricity Generation Installed at Dam**
Generation Revenue	Duncan Dam releases water in the summer and fall months for power production in the Kootenay River plants and in US hydro electric generation facilities. Neither BC Hydro nor Columbia Power Corp. has plans to install generation capacity at the dam at this time.	Decommissioning the dam would result in lost revenue at Kootenay River and US hydroelectricity generation facilities, plus a portion of the Canadian Entitlement.	Likely no change for Kootenay River plants and no impact on hydroelectricity generation at US facilities.
Flood Control	Facility would continue to provide partial flood control for Kootenay Lake residences, and to a lesser extent lower Columbia River communities.	All flood control services would be forfeited.	Likely no change from status quo.

Table 2.0: Comparison of Three Scenarios for Impacts on the lower Duncan River Post Year 2024

	Three Scenarios High Level Scoping Evaluation		
Main Issue Indentified in WUP	**A/ Status Quo Facility and Reservoir Operations**	**B/ Decommissioning Dam and Returning Reservoir and Dam Site to Pre-Dam Conditions**	**C/ Hydroelectricity Generation Installed at Dam**
Erosion protection in the Lower Duncan R.	The Argenta Slough is being eroded in part due to dam releases. Efforts to protect Argenta Slough from erosion are incomplete yet ongoing.	Erosion protection may not be required upon dam decommissioning. However, all erosion protection works currently planned or anticipated should be constructed and in place well before decommissioning could realistically occur.	Likely no change from status quo.
Total Gas Pressure	Total Gas Pressure (TGP) occurs when excessive spill occurs at the dam. Measures to reduce TGP include discharging additional water through the low level outlets. This issue continues to be of concern.	Elevated TGP levels lethal to fish would not occur since spill would be eliminated.	May reduce or maintain current TGP levels.

	Three Scenarios High Level Scoping Evaluation		
Main Issue Indentified in WUP	**A/ Status Quo Facility and Reservoir Operations**	**B/ Decommissioning Dam and Returning Reservoir and Dam Site to Pre-Dam Conditions**	**C/ Hydroelectricity Generation Installed at Dam**
Water Temperature	Dam operation is known to influence lower Duncan River water temperature although the relationship between dam operation and water temperature is complex. Determinants of downstream water temperature include season, reservoir level and temperature stratification, location of dam discharge (low level gates or the spillway), extent of mixing of water from various input streams, and Lardeau River discharge and water temperature relative to that of Duncan Dam discharge and water temperature. Dam operations can increase or decrease the hourly variability in downstream water temperature or change the average hourly temperature by making it warmer or colder than natural conditions. Generally water released into the lower Duncan River fall to spring period is warmer than would occur naturally, while water released in the spring - fall period is cooler than would occur naturally although exceptions can occur. Water temperature monitoring studies have reported temperature variation between years and monitoring locations. Influence of the dam operation decreases as distance downstream from the dam increases. Scientific studies are inconclusive as to whether the influence of Duncan Dam on downstream temperature affects fish productivity.	It is inconclusive as to whether water temperature impacts on lower Duncan River fish productivity would be better or worse without the dam. Water releases through the low level outlets may be having a cooling benefit downstream during summer months and warming effect during winter months.	Likely no change from status quo.

	Three Scenarios High Level Scoping Evaluation		
Main Issue Indentified in WUP	**A/ Status Quo Facility and Reservoir Operations**	**B/ Decommissioning Dam and Returning Reservoir and Dam Site to Pre-Dam Conditions**	**C/ Hydroelectricity Generation Installed at Dam**
Fish Stranding in Side Channels; Ramping protocols	Fish can become stranded in side channels when water releases from the dam and/or natural discharge from unregulated rivers decreases. Mitigation programs and ramping protocols are in place and the issue is being monitored through to 2017.	Stranding will still occur in side channels upon dam decommissioning due to natural fluctuations in water levels and changes in discharge. Determining change in stranding frequency and magnitude requires a comprehensive analysis of flow and operational data.	Likely no change from status quo.
Mosquitoes	Mosquitoes are a pervasive problem for local residents and some suggest that dam operations exacerbate the issue in the Lower Duncan River. Mosquitoes are a problem in high inflow years when the floodplain is inundated. Initial studies indicate that mosquito breeding depends on a number of variables such as Lardeau River flows, backwater effects from Kootenay Lake, climate factors and water release timing, duration and magnitude from Duncan Dam. Studies to understand the issue and to develop mitigation strategies are ongoing.	Mosquitoes were apparently problematic before the dam was completed. It is difficult to determine whether the mosquito issue is better in a pre or post dam scenario. Flooding would occur more frequently and a greater wetted area and wetland provides more potential breading grounds. Once completed the Mosquito Monitoring and Management Plan will further define this issue.	Likely no change from status quo.

Section 2.0: Decommissioning Duncan and Hugh Keenleyside Dams

Sounding Board members requested a description and cost estimate of decommissioning the Duncan and Hugh Keenleyside Dams. Dam decommissioning is relatively new in North America. Several dam decommissioning projects have occurred in the western United States and one in B.C. in the last 15 years. All of the decommissioned (or soon to be decommissioned) facilities examined in the US and Canada are unique which makes utilization of existing dam deconstruction and reservoir restoration costing information challenging. For example two concrete dams with small reservoirs on the Elwha River, WA, were removed in 2012 for a total cost of US $351M or on average US $175/dam. Four concrete dams on the Klamath River in California and Oregon will be removed for an estimated cost of US $460M or on average US $115/dam. However, BC Hydro decommissioned the earth fill Coursier Dam in the West Kootenays in 2001 at the cost of $4.6M, a small fraction of one of the US dam decommissioning projects.

The Duncan Dam and reservoir is similar in many respects to the Coursier Dam and reservoir (although significantly larger in size) and as such was used as an rough template to estimate Duncan Dam decommissioning costs. The decommissioned US dams projects are more similar in scope to the potential HLK dam decommissioning which involves removal of concrete structures and generation facilities and as such were used to develop a decommissioning cost for HLK dam. It is important to note that the decommissioning cost figures below are conceptual estimates based on current (2013) unit costs and final costs would likely be higher.

The dam decommissioning process could follow the general steps below. Facility owners would:

- conduct multiple environmental, socio-economic, and engineering assessments that would determine appropriate decommissioning procedures;
- consult with the public, affected parties, agencies and First Nations;
- drain reservoir in a controlled manner that accounts for short term impacts on environmental, social, economic and biophysical resources;
- isolate the construction site from the river and then excavate a notch in dam face large enough to accommodate the Columbia or Duncan River and floodplain, or completely remove the earth fill dam and possibly the spill and generation infrastructure;
- build and stabilize a new river channel though the former dam footprint;

- rehabilitate former reservoir to near pre-dam aquatic and terrestrial conditions using active and passive measures;
- build new or modify existing public municipal, transportation and recreational infrastructure and private residential and business related facilities to accommodate the new water regime in the former reservoir area.

Duncan Dam is a earthen dam approximately 792 m long 38.7 m high and 375 m wide at the base. Cutting a notch with side slopes of 2:1 and a base of 100 m wide would require excavation and disposal of approximately 1.1 Mm^3 of material. At a gross unit cost of \$10/m^3, earthworks alone could cost approximately \$11M. Removal and disposal of the spillway and sealing the low level outlets could cost an additional \$5M. All buildings and other infrastructure could be repurposed. It is estimated that approximately 21.7 km^2 of reservoir area (forested uplands, wetlands and streams) could require long term rehabilitation at a cost of \$60M. Reconstructing a channel through the dam area and relocating public and private infrastructure (wharfs, recreational sites, docks, etc.) could cost an additional \$10M. Thus, a total initial estimate of the cost to decommission the Duncan Dam and rehabilitate the reservoir over time could cost \$70M - \$100M. This is likely a low estimate with the final cost expected to be higher.

Decommissioning the Hugh Keenleyside Dam / Arrow Lakes Generating Station (ALGS) and rehabilitating the reservoir would be an immense undertaking and unprecedented in scope in BC. The facility is a large industrial complex consisting of an earth fill dam, a navigation lock, four concrete spillways and eight low level outlets, a 185MW hydroelectricity generating station and intake canal. Decommissioning would involve removal and disposal or repurposing of the entire complex in isolation from the Columbia River. In addition, an estimated 13,200 ha of terrestrial and aquatic areas in the reservoir footprint could require both active and passive rehabilitation. Given the large scope of the project, it is estimated that decommissioning the dam and generating station and rehabilitating the reservoir area could cost well in excess of \$250M, not accounting for revenue reduction due to lost ALGS generation (net income of approximately \$14M-\$16M per year), lost taxation and various fees paid to the Province, lost employment, the portion of the Canadian Entitlement associated with Arrow Reservoir operation, and other direct and indirect costs. Dam decommissioning or removal may not be necessary in order to address some of the local environmental and socio-economic concerns associated the facility and reservoir operation.

Section 3.0: Arrow Reservoir Constant Mid-Pool Elevation Scenario

The Columbia River Treaty and the various operating plans and other agreements largely dictate how the Arrow Lakes Reservoir operates throughout the calendar year. Although BC Hydro has some flexibility to adjust Arrow inflows from Mica and discharge from ALGS/HLK dam to account for local non-power related interests such as fish and navigation, the Treaty and related agreements largely define reservoir operations. In a Treaty Terminate scenario (or perhaps a Treaty Plus scenario) the operation of Arrow could be largely redefined as the Treaty-influenced operating plans and agreements would no longer apply.

As part of the Treaty Review process, BC Hydro modeled various bookend scenarios for Arrow Reservoir operations under the Treaty Terminate or Treaty Continue scenarios to examine how various provincial interests could be affected. A possible Arrow Lakes reservoir operating scenario that was not modeled by BC Hydro, and is described below and contrasted with the current operating regime in Table 3.0, involves maintaining the reservoir pool elevation at a constant mid-elevation (i.e. 1,425+/- feet) while allowing for temporary storage during freshet to mitigate downstream flooding and to mimic natural pre-dam function. This scenario was first presented at the public meeting in Fauquier B.C. on June 15th 2013 and further discussed at the Sounding Board meeting in Cranbrook on July 5th 2013.

A constant mid pool scenario for the Arrow Lakes reservoir would have the following operational characteristics:

- the reservoir pool elevation is maintained at a constant elevation that fluctuates a few feet outside of the freshet and subsequent drawdown period of June - August. Within the freshet period, water elevations could fluctuate on average up to 20 ft as indicated by historic Water Survey of Canada hydrometric data for the pre-dam Arrow Lakes. Pool elevation would primarily be managed by passing inflows through ALGS/HLK dam. Using Mica to manage the Arrow Lakes pool elevation, while possible, may have additional upstream impacts that are not considered in this analysis.
- A mid pool water elevation would be in the 1415 ft -1430 ft range. Determination of the most appropriate constant pool elevation within this preferred range requires substantial analysis, modeling and public, agency and First Nations consultation.

- As with an unregulated lake, during freshet the reservoir water surface elevation would rise for a brief period and then return to the pre-freshet level once freshet has passed. Pool elevation would not be kept high for several months as with the present reservoir operation under the CRT except in high snowpack years. In the case of severe flooding potential due to abnormally high snowpack and/or prolonged precipitation events, the reservoir could be used to store floodwaters across the summer to an agreed elevation up to 1,444 feet (the normal maximum storage height of HLK dam) and agreed period. Stored water would be released in a controlled manner after the flood threat had receded.
- ALGS operation could change to a run-of-river operation essentially passing inflows. The turbine discharge would equal the sum of all inflow to the reservoir minus spill required to maintain reservoir water elevations.

Table 3.0 below contrasts the current operating regime with possible responses or outcomes of a constant mid-pool elevation scenario for most of the major socio-economic and environmental issues associated with Arrow Lakes Reservoir operations that were identified in the Columbia River WUP. Downstream impacts have not been described with the exception of flood control. If Mica dam were used to help manage the Arrow Lakes pool elevation there may be additional upstream impacts that have not been examined. The outcomes and responses are high level in nature and largely based on professional opinion and analysis of and information in CRT Review, consultants' and Columbia River WUP Consultative Committee and annual WUP reports. Modeling, numerical and additional qualitative analysis' and consultation are required to validate and determine the magnitude of the possible outcomes and responses presented below.

Table 3.0 Contrast of Current Operations and Constant Mid-Elevation Pool Scenario for Arrow Reservoir Year Post 2024

Issue	General Response under Current Operating Conditions	Possible Response under a Constant Mid-Elevation Pool Scenario
Fish in Arrow Lakes reservoir	Numerous studies and reports have detailed the various impacts that Arrow Lakes Reservoir operations have had on fish resources. However, it is difficult to determine the magnitude of the impact due to poor pre-dam fish population and habitat data. In general, Arrow reservoir operations have had a negative impact on fish populations that is partially addressed by fish compensation and mitigation projects (i.e.- Hills Creek Hatchery, habitat creation, etc.). One of several contributing factors to the negative impact is the loss of biological productivity, richness and macrophyte vegetation establishment of the littoral zone due to the erosive wave action and duration of shoreline inundation. Fish that require access to spawning tributary habitats, in particular fall kokanee spawners, have difficulty in migrating though poorly defined and degraded channels through the drawdown zone. In addition, much of the highest quality low gradient valley bottom stream habitat that is ideal for kokanee spawning is degraded in the drawdown zone, and high quality rainbow trout juvenile rearing stream habitat is inundated much of the year.	Under a constant mid elevation pool scenario, the impact of drawdown on littoral zone may be greatly reduced. Native riparian terrestrial and macrophyte vegetation could re-establish and contribute to increased littoral zone productivity and thus help sustain fish populations that inhabit the littoral zone or depend on littoral zone productivity. Tributary stream banks and beds would stabilize due to establishment of riparian vegetation resulting in higher quality rearing and spawning habitats. Sections of rearing stream habitats would become stabilized and biologically productive.
Power Production at Arrow Lakes Generating Station (ALGS)	Currently ALGS generates electricity year round (except during a planned maintenance period and when the reservoir drops too low to generate) with the lowest output during freshet and the highest in late summer early fall period. Average daily generation since 2003 on days that the plant is operational is approximately 2,200 MWhrs (63% capacity).	Maintaining a constant pool reservoir elevation and thus constant hydraulic head in the 1415-1430 ft range over most of the year could daily generate approximately 1,425 - 3,500 MWhr over a range of discharges throughout the year based on current plant data. Modeling would be required to determine the magnitude of generation under this scenario.

Issue	General Response under Current Operating Conditions	Possible Response under a Constant Mid-Elevation Pool Scenario
Navigation - Commercial log booming through Narrows	Log booming businesses report that running booms through the Narrows is difficult during lower water elevations of 1410 ft (in winter months) whereas elevation of 1420 ft is adequate to boom logs.	Based on information collected during the WUP process, most pool elevation values in a constant pool reservoir elevation in the 1420-1430 ft range would satisfactorily address log booming operational and transport concerns
Recreation - boating, fishing and day use; boat access and shoreline access.	Recreational boating prefers higher water elevations as access to and use of boat ramps and marina facilities is easier and the water is closer to residential properties. Low water levels that prevail during winter and spring periods are disliked. During high water summer period recreational access to shorelines is poor as many beaches are inundated and unusable. Recreational boating safety is compromised at lower water elevations as shoreline hazards are exposed.	Under a constant mid-elevation pool scenario, water elevations are stabilized except during freshet and the water elevation range boat ramps are required to function becomes significantly smaller than that currently required. Proximity of the shoreline and boat docks from residences will be farther during summer periods and closer during fall and winter periods as compared to current conditions. The changes will affect the various communities differently as the beach slope, exposure and topography differs around the lake, and it is unclear how all recreational interests will perceive and accept the changes. Current beaches that are often inundated in early summer will be exposed, although beaches may be further from the water. Natural beach locations may differ from the locations that existed pre-dam. Access to beaches during the late summer would improve in most years. Recreational boating safety may improve as boaters become permanently aware and knowledgeable of hazards that are always present, and can ignore hazards that are deep enough not to be of concern.
Heritage and Culture	Fluctuating reservoir levels can result in cultural sites being exposed and degraded through wave erosion of soils.	Under a constant mid-elevation pool scenario, the water elevation range where wave induced erosion occurs would be narrower and mitigation efforts possibly reduced than under current operating conditions. Detailed information concerning the location and elevation of cultural resources is not publically available making further evaluation of the mid elevation pool scenario difficult.

Issue	General Response under Current Operating Conditions	Possible Response under a Constant Mid-Elevation Pool Scenario
Dust generation/erosion	Reservoir drawdown inhibits permanent establishment of vegetation that binds silts and soils. During low reservoir water elevation periods in the winter, wind can scour the drawdown zone that support minimal vegetation resulting in local dust storms. BC Hydro's fall rye seeding program for dust abatement in the Revelstoke Reach was suspended in 2009 as much of the area now regenerates naturally and the focus has switched to monitoring. The Arrow Lakes Reservoir Re-vegetation Program focuses on higher elevations in the reservoir with the goal of enhancing littoral productivity, wildlife habitat, protection of cultural heritage sites and aesthetic benefits. Evaluation of the re-vegetation program's treatment effectiveness and successes is ongoing and results are preliminary.	Under a constant mid elevation pool scenario mature terrestrial vegetation could establish over the long term and provide enhanced littoral and wildlife habitat benefits. This may reduce shoreline erosion and there would be little potential for dust. Re-vegetation treatments and natural recruitment would be more successful than under current conditions.
Highway damage due to slumping	During unusually high reservoir water events soils in the reservoir banks can become saturated leading to slumping and subsequent damage to highways that closely parallel the reservoir (i.e. Highway 6 between Fauquier and Burton).	High reservoir water events may still occur during freshet but may be of shorter duration as water is discharged from reservoir and water elevations fall sooner. Effects on the risk of road slumping are inconclusive.
Wildlife	Wildlife impacts associated with the current operating regime mostly pertain to the mid Columbia reach which is inhabited by migratory shorebirds and breeding birds, amphibians, reptiles and ungulates. As an example, rising water levels can negatively affect bird nesting success by flooding nests or resulting in the loss of suitable nesting habitats. Physical works are proposed to partially mitigate losses of wildlife habitats in the mid Columbia reach as well as mid and lower Arrow Lakes areas.	Maintaining a constant mid-elevation pool could reduce the low elevation areas that nesting birds choose to inhabit and encourage them to build their nests at higher elevations. High water levels may recede after freshet in time for nesting shore birds and migratory birds to utilize these habitats. In addition, riparian vegetation conducive to shore nesting birds may develop since prolonged inundation would occur less frequently. Increased ungulate habitat resulting in greater ungulate utilization of the current drawdown zone could occur since riparian vegetation preferred by ungulates would establish and mature. The response of this scenario for reptiles and amphibians is unknown as limited data or studies are available for review.

Issue	General Response under Current Operating Conditions	Possible Response under a Constant Mid-Elevation Pool Scenario
Social and Community Health and Well Being	The flooding of the Arrow Lakes valley resulted in significant social upheaval, negative economic impacts on individuals, businesses and communities, and degradation in some cases of individual health and well being. Over 2,000 people in 615 households were displaced, and much productive valley bottom agricultural and forestry land was flooded. Various mitigation and compensation programs have attempted to address some of these issues but for many residents that remain in the valley today deep rooted mistrust and anger towards the Province and BC Hydro persists.	Although some of the anger and mistrust will persist regardless of Arrow reservoir operations post 2024 and regardless of the benefits being provided to the region through the Columbia Basin Trust, stabilizing water elevations at Arrow reservoir may address some of the social and economic impacts that have resulted from 50 years of reservoir operations. For example, limited agriculture that is marginally impacted due to freshet-related high water levels could take place on some sections of reclaimed and rehabilitated land. Celgar forestry transport operations may improve, depending on the elevation chosen. Water based tourism and recreational day use may increase in some locations since the lake aquatic ecosystem and access to shoreline during summer months could revert to pre-dam conditions (but not pre-dam water elevation). In other locations around Arrow reservoir the summer cabins may be further from the lakeshore. A detailed study and analysis is required to determine the extent to which and to what degree social and economic factors at Arrow could be addressed by a mid elevation constant pool scenario, and what impacts it may have on upstream and downstream regions in the basin. Local residents that attended the Fauquier CRT public meeting responded positively to proposals that stabilized water levels at mid elevation. It will be important to hear perspectives of residents in other locations in the Arrow Lakes area.

Issue	General Response under Current Operating Conditions	Possible Response under a Constant Mid-Elevation Pool Scenario
Canadian Entitlement	BC receives between $150M and $350M annually from the US - the Canadian Entitlement - for storing and shaping water discharge favorable for downstream power generation. The value of the Canadian Entitlement is projected to decrease over time. The US Entity is of the opinion that the value of the Canadian Entitlement post 2024 is worth approximately US $26M per year. BC believes the value of the Canadian Entitlement is much higher than the current return when power benefits along with other values and interests that result from coordinated operations are factored in.	If the Treaty is terminated as is possible under this scenario there will be no Canadian Entitlement. It is unknown whether a Treaty scenario that removes all or part of the 7 Million acre-feet of storage at Arrow from the current 15 Million acre-feet of coordinated storage under the Treaty would be of interest to the U.S., or if valuation of other US interests such as navigation, recreation, irrigation and ecosystem function that Canadian Treaty Dam operations facilitate could partially (or fully) replace the Canadian Entitlement potentially lost due to reduced power generation in US plants.

Issue	General Response under Current Operating Conditions	Possible Response under a Constant Mid-Elevation Pool Scenario
Flood Control	Of the three Treaty dams and reservoirs, Arrow is considered the most important to the US from a flood control perspective. Close proximity to the US border and its immense storage capacity (7.1 M acre-feet) allow the US to determine and react to flood threats with increased confidence. Freshet water is captured, stored and released according to a complex set of operating curves and rules as dictated by the Treaty, operating plans, regulations and agreements. Arrow water elevations follow a pattern of high summer and fall water levels that slowly decline over the late fall and early winter. From late winter to pre-freshet, water levels fall quickly when needed to adjust for changing runoff forecasts and allow for storage of freshet flows. Water elevations typically fluctuate 40-50 feet annually and can fluctuate up to 66 feet during high snowpack and runoff years. BC received from the US an initial one-time payment of US $64.4M for the benefits due to assured annual flood control operations for the first 60 years. Post 2024 Canadian flood control commitments to the US change to an ad hoc "Called Upon" approach where the US can require Canada to provide flood control space only after effectively using its own storage first. Details of how Called Upon will work remain undefined and subject to disagreement between the Entities.	Some flood containment abilities of Arrow Reservoir will remain *although in a reduced capacity* as compared to current operations. Allowing the space between (say) 1425 ft and 1444 ft to be used for flood risk reduction provides 2.4 MAF of storage. The intent is that this space would be used infrequently, say once every five to ten years. A more detailed study would be needed to understand the flood risk to downstream Canadian communities. Discussions with the US would be required to see if there is any compatibility with this scenario and the US recommendation[2] to negotiate an annual coordinated flood risk management approach.

[2] http://www.crt2014-2024review.gov/DraftRegionalRecommendation.aspx

Summary of Evaluation of Duncan Dam and Reservoir Scenarios

- Many of the pre-dam environmental values and function lost due to dam construction and reservoir operation may return upon dam decommissioning and restoration of the upper and lower Duncan Rivers. However, benefits associated with current flood control and enhanced power generation in Canada would be lost and any Canadian Entitlement associated with the facility would be forfeited.
- Decommissioning the dam, restoring the upper Duncan River watershed, and addressing impacted infrastructure could cost $70M-$100M with the final cost likely being higher.
- Installing power generation at the Duncan Dam has been studied by both BC Hydro and Columbia Power Corporation. The latter estimates that between 20-30 MW of capacity could be installed in the low level outlet areas and produce 80-120 GWhrs per year from January -June. Capital cost would be in the $125M-$175M range. The idea is in the conceptual phase with no commitment from either corporation to proceed to further development phases.
- Installing hydro generation at the Duncan Dam would not significantly change operational environmental impacts on upstream and downstream resources.

Summary of Evaluation of Arrow Lake Reservoir Mid-Pool Elevation Scenario

A constant mid-pool elevation scenario for the Arrow Lakes Reservoir has numerous attributes that make it attractive in this high level scoping evaluation. Detailed analysis may reveal different outcomes.

- Some flood containment abilities of Arrow Reservoir will remain *although in a reduced capacity* as compared to current operations. A more detailed study would be needed to understand the flood risk to downstream Canadian communities.
- A constant mid-pool elevation scenario may resolve and address many environmental concerns that the Columbia River Water Use Plan identified at Arrow reservoir, which various compensation and mitigation programs are targeted to address.
- From a social perspective, operating the reservoir to closely mimic pre-dam water fluctuation conditions (but not the original water elevation in the Arrow Lakes) may address some of the issues that concern local citizens - i.e. return of some inundated land to other uses over time (potentially food production, grazing, etc.), safer navigation, ecological values - and may address some of the residual anger and mistrust that some community members hold.

- The stable mid-pool scenario will have some positive and some negative effects on recreation and will affect the various communities differently. It is unclear how all recreational interests will perceive the changes.
- If the Treaty is terminated as is possible under this scenario there will be no Canadian Entitlement. It is unknown whether a Treaty scenario that removes all or part of the 7 Million acre-feet of storage at Arrow from the current 15 Million acre-feet of coordinated storage under the Treaty would be of interest to the U.S., or if valuation of other US interests such as navigation, recreation, irrigation and ecosystem function that Canadian Treaty Dam operations facilitate could partially (or fully) replace the Canadian Entitlement potentially lost due to reduced power generation in US plants.
- Decommissioning the HLK dam and ALG Station and restoring the Arrow Lakes reservoir to near pre-dam conditions would be unprecedented in scope and cost well in excess of $250M. Dam decommissioning or removal would not be necessary in order to address some of the local environmental or social concerns associated the facility and reservoir operation.

Closure

I trust that the above letter report is to your satisfaction. Please contact me if you would like to discuss any aspect of the above.

Sincerely,

Mountain Station Consultants Inc.

Alan Thomson MRM P.Eng.