Appendix H [DRAFT]

Development of Kootenay Performance Measures

Relative to the Columbia River, the Kootenay River system has not had as extensive a history of public planning processes to develop information about interests that may be affected by reservoir levels and flows. As a result, the project team undertook desktop studies to fill in some of the information gaps on the Kootenay system.

Estimating how interests on the Kootenay River system might directly be affected by water management alternatives was undertaken using the following methods:

- 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 BC for which performance measures had already been developed; and
- The Fish and Wildlife Technical Committee had as a key focus to develop fish and aquatic ecosystem, and vegetation and wildlife performance measures for the Kootenay system.

This appendix reviews the development of the new Kootenay performance measures covering the environmental performance measures reviewed by the Fish and Wildlife Technical Committee and social performance measures on interests that have been raised by basin residents. While detailed information on the Kootenay performance measures is provided in Appendix G, this appendix focuses on the interests that for various reasons did not have a performance measure developed.

First Nations Culture and Archaeological Sites

The linkages between aboriginal people and the Kootenay River system are long and enduring. The mountains provide for spiritual retreats and seasonal gathering areas. The passes, valleys and the lakes and river systems provided routes for travel, transportation and associated trade. Further, these valleys and aquatic systems provided fresh water and abundant food supplies. Typically, where people live, they gather for sustenance, so it should be expected that the areas inundated by reservoirs and surrounding areas are likely to have cultural sites and archaeological artefacts. However, specific information on the elevations associated with sites of the kind available for the Columbia River were not available for Kootenay River system for this process. As a result, performance measures have not been developed.

1.0 Koocanusa Reservoir

Table 1 summarizes the performance measures developed for Koocanusa reservoir.

Table 1: Performance Measures developed for Koocanusa Reservoir

Interest	Description	PM #
Vegetation and Wildlife	Hectares of vegetation flooded for more than 10 weeks, Lower is better. Reducing the period of inundation during the growing season at the Kootenay-Koocanusa confluence (near full pool) could potentially produce a similar community to that observed in the Revelstoke Reach of the upper Arrow Reservoir. Therefore, strategies which do not fill Koocanusa to full pool, and limit flooding to 8-10 weeks at lower elevations during the growing season, have the potential to achieve the desired vegetation objective. Vegetation is also a proxy for associated wildlife species (e.g. birds).	50
Primary Productivity	Biomass of algae measured in metric tons of carbon, an indicator of the amount of carbon available to higher trophic levels at a given point in time. Higher is better. The performance measure is a relative measure of the impacts of changes in reservoir size and residence times on the production and retention of carbon in the reservoir. The change in algal biomass at each time step involves the addition of new production and the loss of biomass in discharge water. New production is proportional to the current reservoir area and the current seasonal production per unit area. The loss of biomass is proportional to amount of water discharged and the biomass per unit volume of discharge.	51
Recreation	Three measures, two of which are presented in the consequence table: 1) Days in general preferred elevation range 2) Days in boat access elevation range and 3) Fishing effort in angler days. CBT (2004) found that a range of recreation stakeholders generally preferred a reservoir level range of 2445’ (745.2m) - 2455’ (748.3m), Victoria Day (May 24) – Labour Day (September 8). This preferred range incorporates several negative factors that emerge at lower elevations, including the emergence of sand bars, the potential for dust mobilization during wind storms, and unpleasant aesthetics. Kokanee account for 98% of the recreational harvest of Koocanusa reservoir. An empirical relationship was developed relating angling days in Canada for kokanee to kokanee length and reservoir elevation.	52

Other interests that were identified but were not developed as performance measures for Koocanusa reservoir are described in **Error! Reference source not found.**.

Table 2: Issues not developed into Koocanusa reservoir performance measures

Interest	Description
Nutrients	Changes in reservoir elevation and release patterns from Libby are likely to affect trophic status in Koocanusa, Kootenai River and Kootenay Lake. Increased reservoir volume and area will lead to higher primary production and greater phosphorous retention in Koocanusa Reservoir. Passing more water in winter through Libby Dam when there is very limited or no primary production in Koocanusa Reservoir likely reduces the annual retention rate of phosphorous and potentially increases phosphorous loading into Kootenay Lake. The primary production model (PM #51) captures the effects due to area, flushing, and timing of flow releases. Also, surface elevation of Koocanusa Reservoir during freshet flows affects the turbidity of the lake; higher turbidity associated with low reservoir elevations will limit primary production reduce kokanee growth.
Bull Trout	Bull trout in Koocanusa reservoir spawn in Canada and use the reservoir for feeding. However, bull trout are only harvested in the US portion of reservoir. When reservoir elevations are low fish are concentrated and the harvest rate likely increases, creating increased conservation concern in BC. However harvest rates are largely controlled by US angling regulations, so bull trout should be quite insensitive to changes in reservoir operations. Nevertheless, bull trout growth will increase with kokanee density, which could be effected by reservoir operations (covered by PM #51)
White sturgeon	It is uncertain if Kootenai River white sturgeon used areas upstream of Libby Dam prior to its construction, and Koocanusa Reservoir does not appear to provide high quality white sturgeon habitat. A performance measure was not developed.
Entrainment	Entrainment of fish and zooplankton is expected to be higher at Libby Dam than at either Corra Linn or Hugh Keenleyside, though Koocanusa has relatively low productivity. This issue is partly covered through the use of PM#51.
Burbot	Little information on burbot is available in general, and there have been no studies specific to Koocanusa reservoir. It is unclear to what degree burbot spawn along the shores of Koocanusa reservoir, in the tributaries, or more deeply in the reservoir. A performance measure was not developed.
Other fish, tributary access	See extended discussion below.
flooding and erosion	Interests affected by flooding and erosion, as well as various commercial operations appear to be generally aligned with those of recreational interests in terms of preferred operating ranges, so a separate measure was not developed as it appeared to be redundant.

Tributary Access – Kokanee, Bull Trout, Cutthroat and Rainbow Trout

Kokanee access to spawning tributaries can be compromised when gravel accumulates at stream mouths and discharge is at seasonal lows. Under these conditions, streams become wider and shallower and much of the stream flow can be sub surface. These types of aggraded channels with extensive gravel deposition are common in situations where the slope of the channel decreases sharply in streams with high bedloads. Gravel accumulations also occur at the mouths of tributaries entering lakes, but these normally develop into relatively stable alluvial fans with much of the finer gravel moving into the lake. In reservoirs, fluctuations in reservoir elevation can result in a wider, less stable deposition zone. In particular, the timing of reservoir elevation changes may result in a stream depositing gravel at high elevations that is then exposed at lower elevations (Drieschner et al 2008, Hawes et al 2012). Under these conditions, access for migrating fish may be compromised at these lower elevations.

Several factors reduce tributary access concerns in the Koocanusa Reservoir. Two of the main fish of interest (kokanee, bull trout) both spawn in the fall, when reservoir levels are normally high and disturbed portions of the stream channel are inundated. In Canadian tributaries to Koocanusa Reservoir, most (85%, Westover 2003) kokanee spawning takes place in tributaries to the upper Kootenay River (Bull, Lussier, Norbury) rather than direct tributaries to the reservoir. The Kootenay River is large enough that fish access is not impeded by low flows. Many bull trout also spawn in tributaries to the Kootenay River, but some also spawn in the Wigwam River. The Wigwam is a tributary to the Elk River, which is also a large river with no access issues.

Cutthroat and rainbow trout spawn in the spring when reservoir levels are low and seasonally inundated portions of the stream channel are likely to be exposed. Although spawning and subsequent inundation of eggs in this zone may be a concern, most of the cutthroat trout in the Upper Kootenay Drainage reproduce and are resident in upstream areas of larger tributaries. Potential losses to rainbow trout reproduction are less of a management concern because this species is not native to this drainage and hybridizes readily with native cutthroat trout.

2.0 Creston Valley Flood Plain

Table 3 summarizes the performance measures developed for the Creston Valley Floodplain.

Table 3: Performance Measures developed for the Creston Valley Flood Plain

Interest	Description	PM #
Dyke Management Operations	The number of days with Kootenay Lake level below 1750' (533.4m) prior to mid-June (Higher number of days is better) In the north end of the Creston Valley Floodplain, keeping Kootenay Lake below 1750' prior to mid-June reduces the quantity and complexity of water pumping operations	53
Farming Equipment Handling	The number of days when the Kootenay Lake level is below 1739.32' (530.1m) in March 1 and April 30 (Higher number of days is better). Some farmers in the Creston Valley Floodplain expressed a preference for relatively dry farmland during March and April in order to move farming equipment to desired locations	53

Other interests that were identified that were not developed as performance measures for the Creston Valley Floodplain are described in Table 4.

Table 4: Issues not developed into Creston Valley Flood Plain performance measures

Interest	Description
Vegetation and Wildlife	See extended discussion below.
Agriculture	Agriculture has been an economic driver in the region since impoundment began. The valley supports mixed crops and livestock, fruit trees, hay, oats, canola, turf, sod farms, and nurseries. However, this interest is not directly linked to water management operations beyond the performance measures noted above.
Dyke erosion	Higher peak flows followed by rapid drawdowns in the Kootenai River erode dyking infrastructure in the Creston valley. This has been the case since the dykes were constructed from the 1930s onwards. In response to stakeholder concerns that the rate of erosion had increased significantly as a result of the VarQ operation of Libby dam, as part of this review BGC Engineering (2012) was contracted to investigate whether VarQ operations are responsible for increased dyke erosion rates. BGC notes that most dykes were constructed well before Libby dam, which has considerably reduced the peak flow in the Kootenai River. While current operations developed under VarQ do have a somewhat higher peak flow than the 'power only' operation Libby originally prior to 1982, the peak is still much reduced relative to pre-Libby levels. BGC concludes: "It is … our opinion that the implementation of VARQ FC has not had a significant negative impact on diking infrastructure adjacent to the Kootenay River between the Canada-US border and Kootenay Lake". Regardless of whether VarQ made erosion worse than before, erosion certainly continues and dykes need continuous maintenance to prevent them from failing. However, the link between this issue and water management alternatives is unclear and a performance measure has not been developed at this time.
Recreation	Creston Valley area includes bird watching, canoeing, kayaking, boating/water skiing, cross country skiing, cycling, fly fishing, trolling, guiding, hiking/walking, horseback riding, hunting, wildlife/nature viewing (CBT ,2004). Given the lack of clear linkage between Kootenay River flow and these activities and the complex hydrological relationships that govern elevations on Duck Lake (See PM sheet # 53 for further discussion), a performance measure for recreation and tourism in the Creston Valley has not been developed.

Vegetation and Wildlife

Prior to the 1930s, the large glaciated valley on the Canadian side of the border was a wetland that experienced wide seasonal variations in river flows. Since then, the area has been extensively impounded by 93 km of dykes, predominately for agriculture but also for transportation corridors as well as residential and commercial developments. As a result of this impoundment and the construction of Libby dam, which significantly reduced peak flows in the Kootenai River, the land in the valley is relatively hydrologically stable.

The dykes are managed by five dyking authorities and the Lower Kootenay Band. There is also one dyke authority on the Goat River (BGC Engineering 2012). At the north-west end of the Valley, incorporating Duck Lake, the Creston Valley Wildlife Management Area (CVWMA) is a 7,000-hectare (17,000-acre) area of provincially protected Crown land that is managed to create a suitable environment for wildlife and waterfowl habitat. Much of the remaining dyked areas to the south are managed for various agricultural uses (Figure 1).

Figure 1: Creston Valley Floodplain

Vegetation and wildlife interests are a major concern in this area. The area within the CVWMA in particular has a wide range of provincially important ecosystems and species. The CVWMA website (https://www.crestonwildlife.ca/) provides specific details, but these include over 300 bird, close to 60 mammal, 17 fish, six reptile and six amphibian species in addition to thousands of invertebrate and plant species. The website notes that the Creston Valley is a migration corridor for Tundra Swans, Greater White-fronted Geese, and other waterfowl and is the largest regional locale for wintering birds of prey in the interior of the Province. There is a strong local interest in maintaining or expanding this degree of biodiversity. An agreement in June 2012 between the BC MFLNRO and Ducks Unlimited to co-manage the CVWMA may lead to further habitat restoration activities in the area.

Both farming and wetland protection interests have developed over time with the present complex infrastructure on which they are now dependent. Both interests require predictable flows and elevations from the hydroelectric system that do not veer considerably from recent managed historical patterns. For this reason, both interests are represented by the operational performance measures presented in Table 3.

Nevertheless, some people reject the notion that the status quo is acceptable for wildlife interests. They maintain that restoring the valley to a more natural state by removing the dyking infrastructure would be beneficial to wildlife. Removing the dykes would lead to a larger wetland area, but would need to be accompanied by different Libby dam operations to reshape the hydrograph to historical patterns. Either would have considerable social and economic consequences for Kootenay Lake properties and public infrastructure from a flooding perspective. Consideration of such matters is outside the scope of this analysis.

3.0 Kootenay Lake

The natural elevation of Kootenay Lake was raised by the construction of the Corra Lin Dam at the western end of the West Arm in 1938. The lake is a popular tourist destination with an area of 400 square kilometres.

Table 5 summarizes the performance measures developed for Kootenay Lake.

Table 5: Performance Measures developed for Kootenay Lake

Interest	Description	PM #
Fish and Aquatic Ecosystem Health	West Arm Kokanee Spawner Length, an indicator of general productivity Productivity is one aspect of Kootenay Lake fish and aquatic ecosystem health. Productivity is influenced by operations in several ways. For the CRTR process, investigations focused on the relationships between 1) operations and mysis biomass in the West Arm and 2) mysis biomass in the West Arm and kokanee spawner length. As a result of these relationships, a performance measure was developed that linked operations to kokanee spawner length in the West Arm.	55
Recreation, Tourism and Industry	Days in a generally preferred range of between 1744' (531.6m) and 1750' (533.4m) during the recreation season. A broad range of preferred lake levels, 1740' (530.4m) to 1752' (534m), was identified across a broad range of stakeholder interests. BC Hydro notes that a narrower range of preferred lake levels is more consistent with recent stakeholder feedback; hence the selection of the range, 1744' (531.6m) to 1750' (533.4m), for this analysis.	56
Flooding	Percent of years with at least one day at or above 1752' (533.7m) or 1760' (536.4m), Lower is better. This measure indicates the expected frequency of years in which the elevation of Kootenay Lake is expected to exceed 1752' and 1760'. 1760' was selected as it is the Flood Construction Level used by the RDCK. A second measure, to	57

	reflect the onset of incidental flooding expected below the Flood Construction Level is 1,752'. This level has been exceeded on a few occasions since 1984 and is one foot higher than the high lake alert elevation of 1751' (533.7m).	

Other interests that were identified but not developed as performance measures for Kootenay Lake are described in Table 6.

Table 6: Issues not developed into Kootenay Lake performance measures

Interest	Description
Vegetation and Wildlife	See extended discussion below.
Nutrients and Productivity	Alternative Libby operations could result in different quantities of nutrients flowing from Koocanusa to Kootenay Lake, see discussion in Table 2. Since 1992 applications of nitrogen and phosphorus fertilizer have been made by the US to compensate for nutrient losses in the south arm of Kootenay Lake. There is concern that this compensation is not a requirement.
White sturgeon	There are no substantial flow or lake level effects on white sturgeon rearing habitat in the Kootenay River estuary on the south end of Kootenay Lake. The rearing area is very large and juveniles do not make extensive use of the lake margins. As a result, no performance measure was developed. Spawning habitat is located on the Kootenai River within U.S. jurisdiction. Sturgeon currently spawn over substrate that is embedded but it is unclear whether this is their historic spawning location which has degraded due to flow management, or whether they no longer spawn in their historical location due to flow/elevation changes. There is equal support for both of these alternate hypotheses. When comparing alternatives, it is noted whether the alternatives met the current U.S. regulatory requirements in the Kootenai River, which includes flows for sturgeon in the spring.
Burbot	Burbot spawn on shoals in the north end of Kootenay lake (Lardeau River Delta) in late February to early March. Substantial water level decreases following the spawning period could be of concern, depending on the depth of spawning (which is uncertain). This was not considered a major concern by the as lake levels typically rise after the spawning period.
Tributary Access	Tributary access by rainbow trout and bull trout are not considered to be an issue on Kootenay Lake as the drawdown is much less than at other reservoirs.
Kokanee Shoal Spawning	See extended discussion below.
Kokanee Angling	The calculation of kokanee anger days developed for Koocanusa above was not repeated for Kootenay Lake because it was noted that there was insufficient differences in the Kootenay Lake hydrographs to result in significant differences between the alternatives.

Navigation	Ferries on Kootenay Lake are sensitive to operations when elevations drop to the 1738' to 1739' range. The International Joint Commission order stipulates that the elevation should not be above 1739.32 ft on or about April 1. On rare occasions low inflow due to a late freshet in April results in Kootenay Lake dropping to levels where the ferries are affected. There is not difference between the alternatives in this respect so a performance measure was not developed.

Vegetation & Wildlife

Beyond the Creston valley area at the southern end of Kootenay Lake discussed above, there are several other wetland areas including the Crawford Bay wetlands on the east shore, and the Duncan-Lardeau wetland area to the north. Prior to impoundments, the Duncan Lardeau confluence area consisted of early seral habitats which included a community made up of sedge, grasses, and low density wood shrubs at lower elevations, and a cottonwood community at higher elevations (see Ketcheson 2005).

Impoundment resulted in reduced peak Kootenay Lake levels and reduced peak discharges from the Duncan system. This stabilized water levels in the Duncan-Lardeau Valley, which allowed the vegetation community to evolve into one dominated by very dense stands of wood shrubs and reduced cottonwood recruitment. This latter community is considered to have much reduced values for wildlife. Dense stands of woody shrubs have limited values for waterfowl and shorebirds during their migrations (stopover and feeding use). Cottonwoods form important habitats for many bird, bat, and insect species, and current community is dominated by very old, senescent stands and there are no younger cottonwoods lower in the floodplain (as existed historically). Benefits to the wetland areas could be achieved if Kootenay Lake flooded above 1755 ft more regularly and would reduce the dense woody stands and encourage cottonwood recruitment. Flooding above 1755 ft would however cause significant property damage around Kootenay Lake. As a result, a water management alternative to increase flooding above 1755 ft would not be acceptable so no performance measure was developed.

Kokanee Shoal Spawning

In 2006, large numbers of shoal spawning kokanee were noted in the West Arm of Kootenay Lake. Monitoring of spawning and egg incubation/emergence identified kokanee redds dewatered prior to fry emergence which resulted in fry unable to access Kootenay Lake. In 2007, this issue was raised with Columbia Operations Fish Advisory Committee (COFAC). Kokanee shoal spawners present different characteristics than the stream spawners, however it is not known if they are genetically distinct. It is not known what the population of shoal spawners is and if the dewatering of the redds is affecting the population or not. COFAC is now funding monitoring studies to i)verify the abundance of spawners in peak spawning years, ii) determine if operational changes in the Kootenay Lake reservoir results in fewer dewatered redds, and iii) determine whether kokanee shoal spawners are genetically distinct from creek spawners.

To conduct the studies, hydroelectric system operators drew down the Kootenay Lake water levels to a target level of 1742 ft (at Queen's Bay) during the peak spawning years of 2009 and 2012 for a one-month trial period between Sept 15 and Oct 15. The lower water level during the mid-September to mid-October peak spawning period should force the fish to deposit their eggs at a lower lake elevation. The reservoir is then allowed to fill again for the winter. In spring, when the fish are emerging from their eggs and when the reservoir is drawn down to make room for spring melt,

the expectation is that fewer redds will be stranded, suggesting a higher survival rate for the shoal spawning kokanee.

This operation presents a trade-off between the Kootenay Lake shoal spawners and the minimum flow targets downstream of Brilliant Dam. With lower Kootenay Lake levels, the minimum flow targets during October may not be met, potentially affecting productivity and rainbow trout and mountain whitefish. A performance measure was not developed as there is a plan in place to study the issue, and the trade-off is primarily a domestic Canadian issue.

4.0 Kootenay River downstream of Corra Linn dam

Table 7 summarizes the performance measures developed for the Kootenay River downstream of Corra Linn dam.

Table 7: Performance Measures developed for the Kootenay River downstream of Corra Linn dam

Interest	Description	PM #
Fish and Aquatic Ecosystem Health	Cumulative Habitat Loss – cumulative area of habitat loss at Bird Creek Wetland as a function of Corra Linn dam spills, Lower is better A high value wetland habitat exists immediately downstream of Corra Linn Dam on the Kootenay River. This wetland is comprised of a variety of habitat types that are used by a broad variety of obligate and facultative aquatic animals. The flood-affected wetland and pond habitats total 7.92 ha with maximum generation at Corra Linn Dam. During periods of spill at Corra Linn, this wetland area is at risk of inundation. As spills approach 63,500 cfs (1800 m^3/s), the wetland habitat becomes fully inundated and no further impact occurs (other than the potential for erosion). Animals at greatest risk when the wetland is inundated are nesting birds, which either lose potential nesting sites or have their nests flooded out (potentially losing their chicks).	55
Fish and Aquatic Ecosystem Health	Total Dissolved Gases - # of days gases exceed 115% pressure threshold (1 Jan to 31 Dec), Lower is better Air supersaturation in water can lead to gas bubble trauma in fish if exposed to gas pressures above 115% saturation. Total gas pressure measurements taken downstream of Slocan Dam have shown that spill discharges at the upper four Kootenay River plants (Corra Linn spill is used as the proxy) can create air supersaturation conditions that exceed the 115% threshold.	56

Other interests that were identified but not developed as performance measures for the Kootenay River downstream of Corra Linn dam are described in Table 8.

Table 8: Issues not developed into performance measures downstream of Corra Linn dam

Interest	Description
Sturgeon	When Brilliant Expansion project first came into service, there were some issues with sturgeon mortality. Sturgeon would enter the tailrace when releases are low, then get injured or killed when flows were suddenly increased. The issue is primarily a domestic operational issue, and is being addressed by specific protocols required when the units are brought back on line. As a result, no performance measure was developed.
Brilliant Dam	The forebay at Brilliant Dam is used for shaping the power generation, matching peak generation with peak load needs such as in the evening. The fluctuations in the forebay can affect interests of those that live near Brilliant Dam such as ferry users. The operation of Brilliant Dam is a domestic issue. No performance measure was developed as changes to Libby operation are not expected to significantly affect the Brilliant forebay fluctuations.

5.0 System-wide

Table 9 summarizes the performance measures developed for system-wide impacts

Table 9: Performance Measures developed for Kootenay System Generation in Canada

Interest	Description	PM #
Power Value	The relative increase in Canadian power value relative to Alternative 1. The alternatives investigated in this analysis focused on potential operational changes at Libby dam, which would affect the ability of BC to generate electricity through Canadian dams in the Kootenay system. This performance measure tracks the financial value associated with this change in Canadian electricity generation.	60

5.0 Interests within U.S. Jurisdiction

Performance measures were not developed for interests within U.S. jurisdiction. This included interests in Montana related to Koocanusa, power generation at Libby dam or other downstream U.S. hydroelectric projects, the Kootenai River between Libby dam and Kootenay Lake which flows for the majority of its length in the United States, and other interests in the U.S. portion of the Columbia River such as salmon.

In the Kootenai River, the US has a variety of programs to monitor and protect fish in the river. The fish in this section 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 the U.S. water management alternatives for Libby Dam and the Kootenai River. Instead, a note is made in the Consequence table presented in Chapter 7 on which alternatives would fully meet the requirements

of US regulations for bull trout and white sturgeon. A similar approach is used to represent whether the Libby water management alternatives meet the current U.S. regulatory requirements for downstream salmon in the U.S. portion of the Columbia River.

4.0 References

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Ketcheson 2005: Reference to follow

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