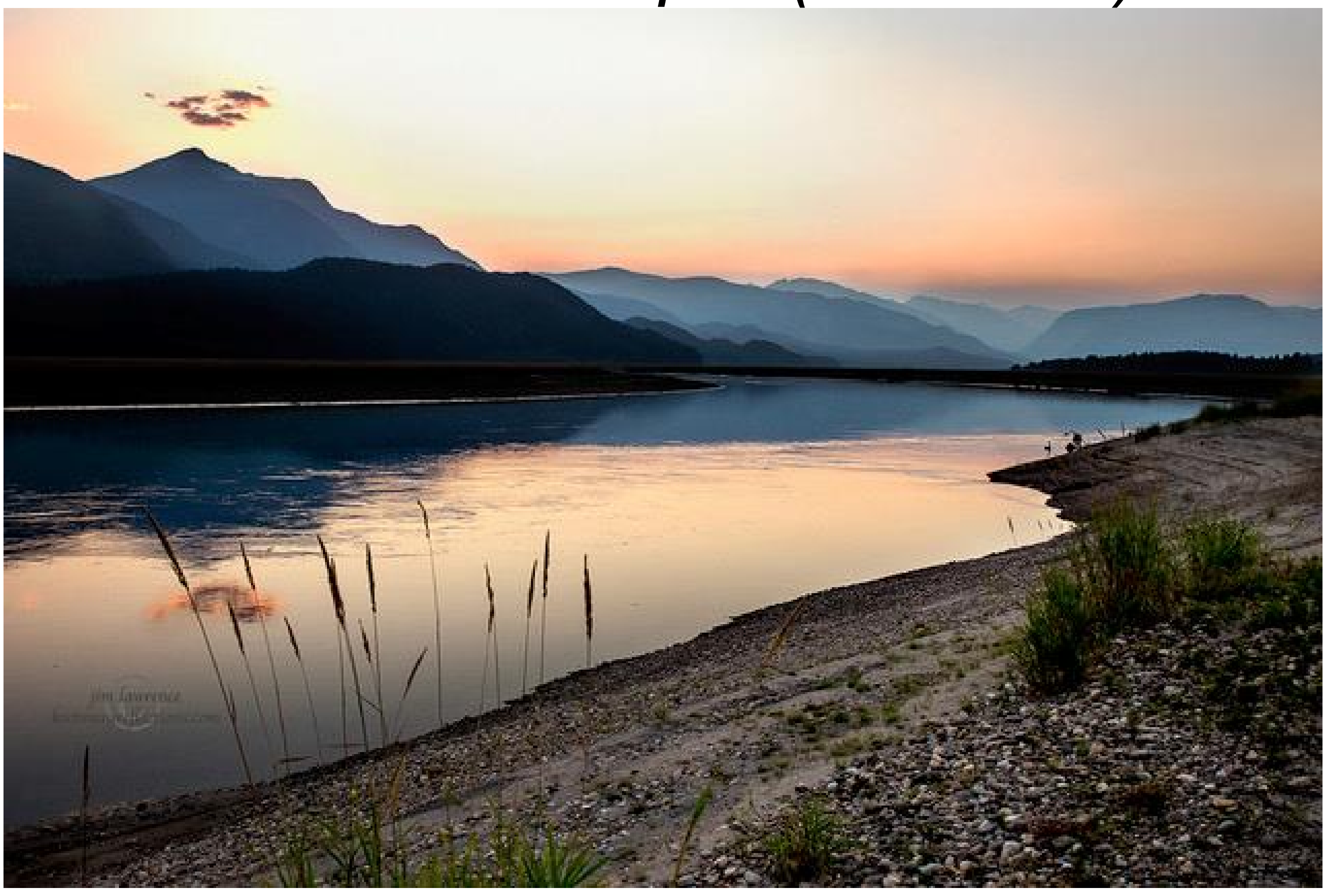
Improving Ecosystem Function in the Upper Columbia Basin

Discussion Paper (version 2)



Prepared by:

Upper Columbia Basin Environmental Collaborative (UCBEC)

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Cover photo: Jim Lawrence

1.0 INTRODUCTION

The Upper Columbia Basin Environmental Collaborative (UCBEC) is a partnership, comprised of a cross-section of Canadian environmental voices from the Upper Columbia Basin. We represent provincial, regional and local environmental organizations, supported by select scientific, technical and policy experts. Current membership includes the Sierra Club of British Columbia, BC Nature, Wildsight, Yellowstone to Yukon Conservation Initiative, Friends of Kootenay Lake Stewardship Society and the North Columbia Environment Society. Martin Carver serves as the UCBEC Lead, coordinating and facilitating Committee activities. Greg Utzig serves as UCBEC's Technical Advisor[1].

UCBEC began meeting in late 2016 to provide a unified environmental voice for consideration by all parties engaged in the modernization of the 1964 Columbia River Treaty (CRT) and other related processes. Our primary focus is to improve the function of Canadian ecosystems impacted by dams and reservoirs in the Columbia Basin, including those in terrestrial, aquatic and riparian/wetland realms. In particular, we identify science-based perspectives and describe technically robust proposals to support full incorporation of ecosystem function within a modernized CRT. Although our emphasis is on Canadian reservoirs and river reaches, we also promote ecosystem restoration in the US to ensure maximum ecosystem function is maintained and improved throughout the Columbia Basin as a whole. We would like to see ecosystem restoration, creation and/or enhancement occur within, or in proximity to, all Canadian reservoirs and downstream river reaches to the extent possible. We also recognize the need to balance restoration and enhancement efforts among reservoirs and affected river reaches to achieve the greatest net ecological benefit.

Our ongoing work includes participation in the *Columbia Basin Regional Advisory Committee (CBRAC),* along with presentations to that group regarding adaptive management and UCBEC's proposals[2]. UCBEC is also actively participating in the process led by First Nations within the Canadian negotiating team to integrate ecosystem function into the CRT. UCBEC's Technical Advisor is on the CRT Ecosystem Function Subcommittee for this work and is contributing to various studies developing performance measures for analyzing potential benefits to ecosystem function that may result from various future CRT scenarios. UCBEC also maintains close contact with the CRT Local Governments Committee (LGC) and shares many CRT renewal objectives with that group[3]. Additionally, UCBEC is contributing to periodic teleconferences and local conferences with First Nations, tribes and US environmental non-governmental organizations (ENGOs) organized by the international Columbia River Roundtable[4]. These activities offer opportunities to maintain communication and coordinate with other organizations with similar objectives to incorporate ecosystem function into a renewed CRT.

UCBEC has been actively researching, refining, discussing and promoting the ideas presented in this Discussion Paper. In both Canada and the US, representatives and members of UCBEC have participated in and/or presented at numerous forums related to the renewal of the CRT. Examples of these include:

- the *International CRT Modelling Working Group* in Vancouver BC and Portland OR (2016-2017)
- a CRT ecosystem function workshop in Nelson BC (Jun 2017)
- the *Lake Roosevelt Forum* in Spokane WA (April 2018)
- the Canadian Water Resources Association's CRT Symposium in Victoria BC (May 2018)
- the *Pacific Northwest Economic Summit* in Spokane WA (Aug 2018)
- the *Adaptive Management in the Columbia Basin Workshop* in Berkeley CA (May 2019)
- the *Regulated Rivers II* conference in Nelson, BC (May 2019)
- the *One River: Ethics Matter* conference in Castlegar, BC (May 2019)
- the *Columbia Basin Transboundary Conference: One River, One Future* in Kimberley BC (September 2019)

Further details on UCBECs work and some of our presentations and publications (including this Discussion Paper and a summary) can be found at: http://www.kootenayresilience.org/columbia-river-treaty.

[1] For further information contact Martin Carver aqua@netidea.com or Greg Utzig ecofred92@gmail.com
[2] See https://engage.gov.bc.ca/columbiarivertreaty/2019/05/08/april-15-16-2019-meeting-9/.
[3] See LGC draft recommendations, available at http://akblg.ca/columbia_river_treaty.html.
[4] See https://celp.org/columbia-river-roundtable/

1.1 Why This Discussion Paper?

Like other river developments from the same era, the CRT values the Columbia River and its tributaries exclusively for the purposes of maximizing hydropower generation and minimizing flood risk in support of downstream human development. However, in both formal documents[5] and public communications, the governments of British Columbia, Canada, and the US have, to varying degrees, endorsed the need to prioritize ecosystems in a modernized CRT. Negotiations over the future of this agreement began in May 2018.

As negotiations proceed, each country�s negotiating team may be privately evaluating what ecosystem function could look like in a modernized CRT to inform its own negotiation agendas. However, there is also a need to advance research and discussion on this topic in the public realm. Alongside its narrow economic focus, another core feature of the original CRT was its neglect for appropriate public consultation. It is important to respond to this unfortunate history by prioritizing robust and ongoing public education, engagement, and consultation in the present modernization process. Furthermore, studying and discussing ecosystem function in the public realm creates an opportunity for ENGOs with relevant expertise (such as those involved in UCBEC) to help inform Treaty negotiations and contribute to our shared future.

Accordingly, the purpose of this Discussion Paper (version 2) is to present proposals for further studies and operational changes to dam operations that lead to improving ecosystem function and environmental values in the Canadian portion of the Upper Columbia Basin (UCB). The scope of the Discussion Paper includes reservoirs and reaches of the Columbia, Kootenay and Pend d�Oreille Rivers affected by hydroelectric and/or water-storage dams. The focus is on improving terrestrial, aquatic and wetland/riparian ecosystems within Canadian reservoir footprints and improving large riverine habitats in and along the river reaches downstream of impoundments. The major ecosystem components considered here are shown in Figure 1 and summarized in Table 1. Figure 2 shows facilities on the Kootenay River between Kootenay Lake and Columbia River.

Table 1: Components of the Columbia-Kootenay River system affected by dams in Canada.

Aquatic Component	Relevant Dam(s) Controls	Treaty?*
Columbia River System		
Kinbasket Reservoir (Treaty/ Non-Treaty Storage)	Mica	Y(N)
Revelstoke Reservoir	Revelstoke	N(Y)
Columbia River between Revelstoke Dam and Arrow Reservoir (*i.e.* Revelstoke Reach)	Revelstoke (Mica)	Y
Arrow Lakes Reservoir (Treaty/ Non-Treaty Storage)	Keenleyside	Y
Columbia River between Keenleyside Dam and the USA border	Keenleyside (Revelstoke/Mica) (Kootenay & Pend d�Oreille)	Y
Pend d�Oreille River System	Waneta, Seven Mile and US dams	N
Kootenay River System		
Koocanusa Reservoir	Libby	Y(N)
Kootenay River between Libby Dam and Kootenay Lake	Libby	Y(N)
Duncan Reservoir	Duncan	Y
Duncan River between Duncan Dam and Kootenay Lake	Duncan	Y
Kootenay Lake	Libby and Duncan Dams and International Joint Commission (IJC)	N(Y)
Kootenay River between Kootenay Lake and Columbia River	Corra Linn, Upper Bonnington, Lower Bonnington, South Slocan, Kootenay Canal, Brilliant	N(Y)

*parenthetical entries indicate partial or indirect Treaty impacts

[5] For example, see B.C. Decision: https://engage.gov.bc.ca/app/uploads/sites/6/2012/03/BC_Decision_on_Columbia_River_Treaty.pdf
Also see US Entity�s Regional Recommendation for the Future of the Columbia River Treaty after 2024: https://www.bpa.gov/Projects/Initiatives/crt/CRT-Regional-Recommendation-eFINAL.pdf

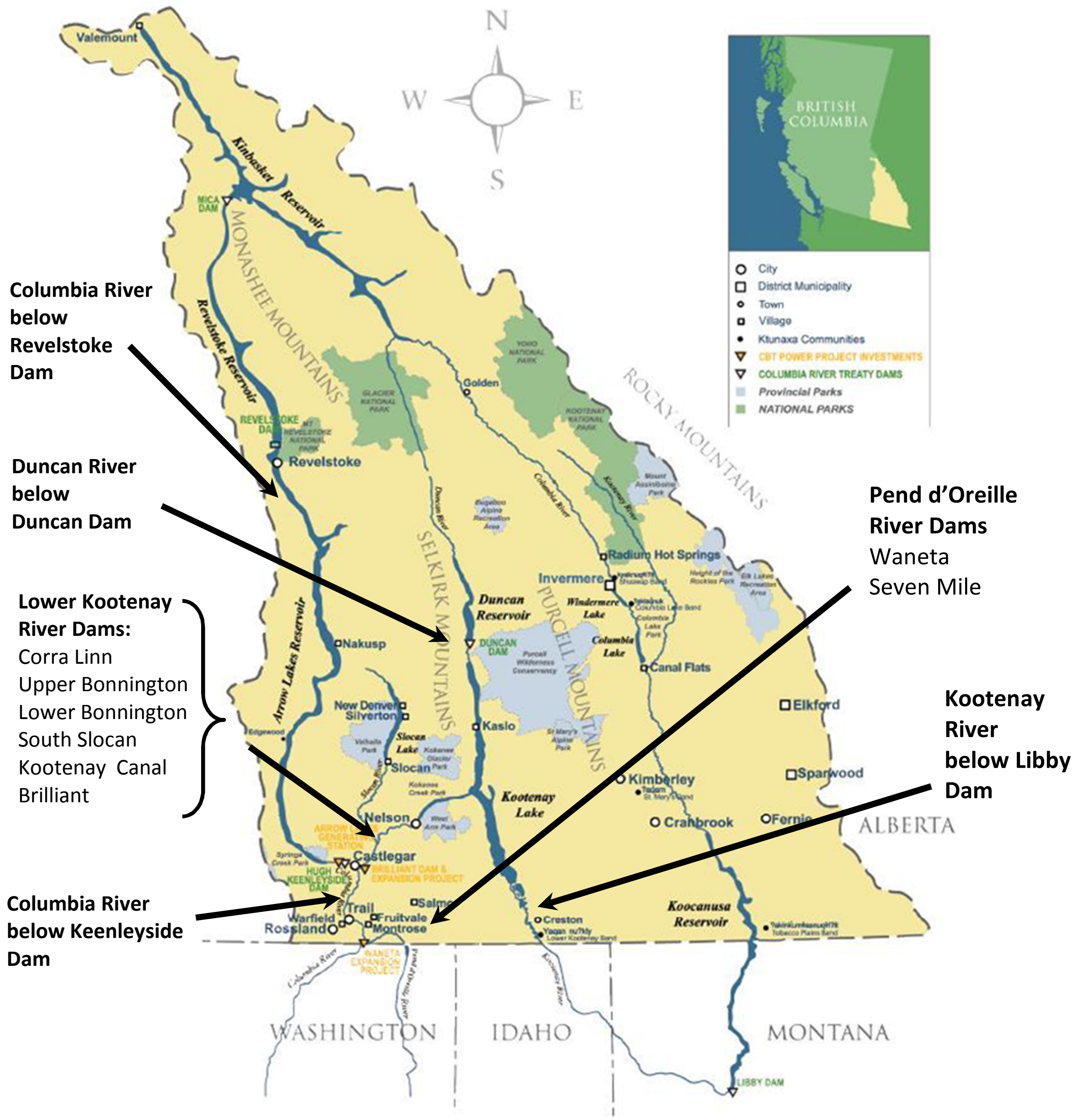

Figure 1. Dams, reservoirs and river reaches on the Canadian Columbia, Kootenay and Pend d'Oreille Rivers (adapted from the Columbia Basin Trust).

Our focus is on ecosystems and habitats, rather than a single-species approach. Dam and reservoir operations have impacted numerous species and guilds, including many species at risk (Utzig and Schmidt 2011). This approach will provide a wider array of benefits than multiple singe-species approaches and will likely be more cost effective.

Additionally, the ecosystem restoration goals described here are complementary to, and potentially prerequisites for, returning salmon to the UCB. The measures proposed would increase the overall resilience of aquatic, wetland, riparian and upland ecosystems to climate change, and therefore may strengthen separate initiatives to return salmon to the UCB.

Some of the measures suggested can be realized without modification of the CRT, while others may require its modification, or at least side agreements between the parties to it. The initiatives suggested can contribute to CRT negotiations (and Non-Treaty Storage Agreements ï NTSAs), but they also provide input into routine reservoir operations planning carried out by BC Hydro, the US Army Corps of Engineers, the US Bureau of Reclamation and other relevant dam managers.

Figure 2. Lower Kootenay River Dams (from International Kootenay Lake Board of Control – International Joint Commission – IJC).

Although the goals and measures identified in this Discussion Paper (v.2) have not been prioritized, UCBEC may prioritize them following further collection of data and discussions with various levels of government, First Nations and stakeholders.

1.2 Context

The aquatic ecosystem of the Columbia River Basin is one of the most regulated systems in the world, with over 80 dams across the watershed in the US and Canada. Thirteen of those dams flood BC portions of the watershed. Three of those thirteen dams (Duncan, Keenleyside, and Mica) were built to satisfy the terms of the CRT and a fourth (Libby) was authorized for construction under the CRT. Although Canada has only about 15% of the watershed, it supplies roughly 35% of the flows at The Dalles, Oregon (the standard measurement location for downstream watershed flow). Previous studies have shown that construction of dams and flooding of the reservoirs in BC have had major negative impacts on ecosystems in the region (*e.g.*, Utzig and Schmidt 2011). The dams have resulted in the loss of the vast majority of low-elevation, low-gradient large riverine habitat in southeastern BC and an additional 1,100 km of smaller rivers and streams. Wetlands and riparian forests experienced severe losses. Upland ecosystems were also impacted, but to a lesser degree. All impacts persist to this day. The dams have also had significant impacts on human communities within the UCB including the flooding of more than a dozen rural communities and valuable agricultural land, the forced displacement of more than 2,300 people (mostly without fair compensation), the flooding of traditional Indigenous cultural sites, and ongoing negative impacts resulting from the fluctuation of reservoir water levels. (Penfold 2012). The impacts to both ecosystems and humans were accepted by the governments of BC, Canada and the US without adequately consulting or informing First Nations, tribes and other UCB residents (Penfold 2012).

Prior to the construction of CRT dams, other dams built further downstream on the mainstem Columbia River (*i.e.* Chief Joseph and Grand Coulee dams) impacted the Canadian portions of the basin by eliminating the return of salmon and other anadromous fish (CBTFN 2015). When asked by US officials in 1934, Canadian officials unilaterally gave the US permission to extirpate anadromous fish in the UCB by choosing not to install fish passage at Grand Coulee Dam, citing Canada's assumed lack of "commercial" interest in UCB salmon runs (NPCC 2020).

The loss of these fish returns has had long-term direct impacts on the aquatic ecosystems including the mainstem Columbia River all the way upstream to Columbia Lake, as well as the Slocan and lower portions of the Kootenay, Pend d'Oreille and Salmo River systems. In addition to the direct impacts, there are significant secondary impacts on species that would utilize the salmon as a food source, and loss of overall riparian and aquatic productivity due to the loss of marine-derived nutrients that were previously obtained from the Pacific Ocean (*e.g.*, Reimchen 2017, Naiman *et al*. 2002). Marine-derived nitrogen has been demonstrated to be present in some plant species up to 200 metres from salmon-spawning stream reaches. The loss of salmon has also resulted in severe cultural and economic losses for UCB First Nations with significant additional impacts to settler communities (CBTFN 2015).

In 2015, Columbia River Basin First Nations (in Canada) and tribes (in the US) released a jointly developed paper on fish passage and reintroduction of salmon to the UCB (CBTFN 2015). Since then, First Nations and tribes have been advancing parallel efforts to restore salmon past dams that currently lack fish passage infrastructure (*e.g.* Syilx Okanagan Nation *et al*. 2019; Harrison 2019). While we recognize these priorities of First Nations and tribes, salmon restoration is not a primary focus for UCBEC, as our emphasis is on ecosystems and habitats. The ecosystem restoration goals described in this paper are complementary to, and potentially prerequisites for, returning salmon to the UCB. Whereas projected climates pose significant risks to the successful return of salmon, opportunities to achieve many of the ecosystem restoration goals described in this Discussion Paper are not jeopardized by climate change to the same extent. The measures proposed here would increase the overall resilience of aquatic, wetland, riparian and upland ecosystems to climate change, and therefore may strengthen separate initiatives to return salmon to the UCB.

1.3 Ecosystem Function and Ecosystem Services

"Ecosystem function" can be defined as "the combination of all processes in an ecosystem and how they work together. Ecosystem functions include not just processes related to individual species, but all the biological and physical interactions that occur in an environment"[6] (see Figure 3). Ecosystem function within the UCB has been severely impacted by dam construction and operations, which have impaired ecosystem processes that underpin ecosystem function. These include the basic process of primary production, as well as others such as reproduction, migration, and production of upland, riparian, wetland and aquatic habitats for ungulates, birds, reptiles, amphibians, fish and invertebrates (Utzig and Schmidt 2011). UCBEC's emphasis on improving ecosystem function signals a desire to restore these basic ecosystem processes wherever possible.

"Ecosystem services" are the subset of ecosystem functions that are recognized and valued as beneficial to humans. Historically, our tendency to emphasize particular ecosystem services has led to attempts at simplifying ecosystems in a way that maximizes the availability of those services. This often leads to a decrease in other functions. For example, in forestry, maximizing the production of particular tree species may be to the detriment of forest diversity and wildlife habitat. In the case of the UCB and the CRT, governments have chosen to maximize two services: water storage (for flood control and other purposes) and power production, with severe consequences to many other ecosystem functions. Management of the UCB under the CRT has simplified managers' perceptions of the complex ecosystem to a series of storage tanks connected by pipes (see Figure 4).

In working toward restoration of ecosystem function within the UCB, it is important to avoid repeating previous mistakes. We don't want to replace one set of ecosystem service priorities with another. Instead, we need to place emphasis on the full range of ecosystem functions, starting at the basic level of primary production, moving up trophic levels to production of a wide range of habitats, and eventually a full complement of species – regardless of whether or not they have specific human values attached to them. This approach is much more likely to restore biodiversity, build long-term ecosystem resilience and, as a byproduct, achieve the persistence and productivity of the ecosystem services we desire. The primary objective of UCBEC is to widen the focus of Columbia Basin management from Figure 4 back toward Figure 3.

[6] Definition adapted from (Feb 10, 2020): https://serc.si.edu/research/research-topics/ecosystems-ecology/ecosystem-functioning

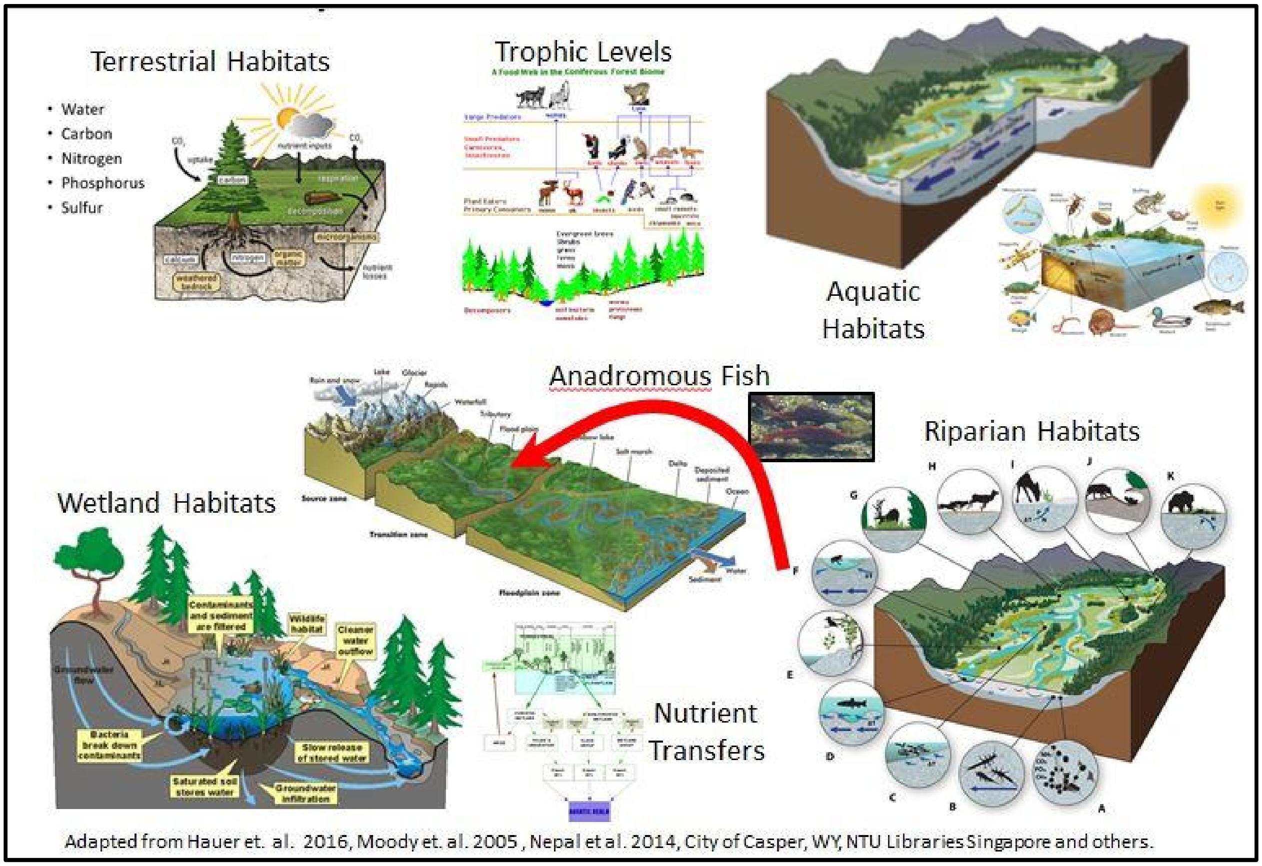

Figure 3. A schematic representation of a watershed demonstrating some of the complexity of ecosystem functions present in a fully functioning Columbia/ Kootenay basin.

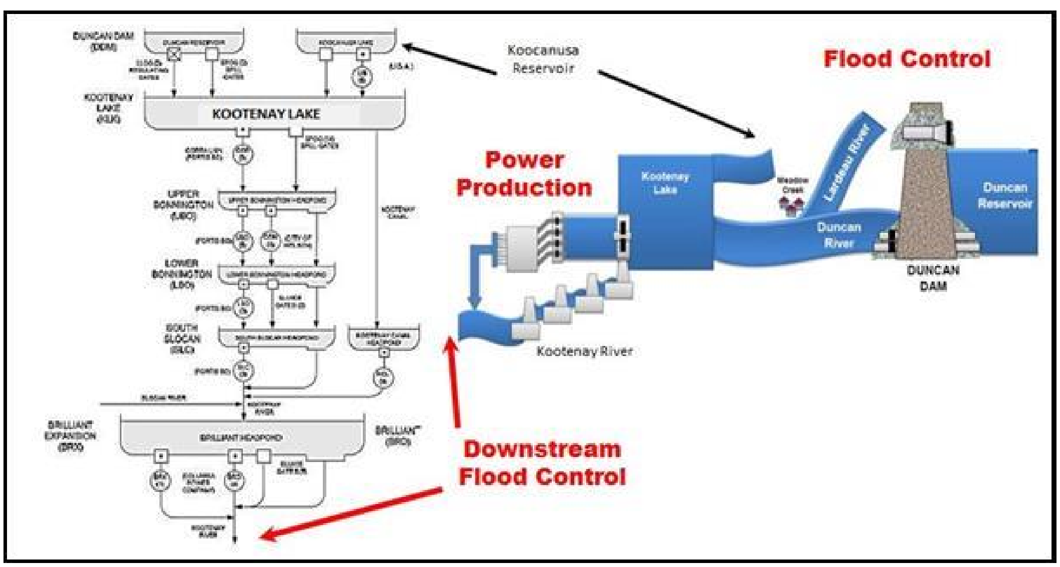

Figure 4. Schematic diagrams of a portion of the Columbia/ Kootenay dammed watershed demonstrating the functions as seen by managers operating to maximize the two ecosystem services specified in the CRT.

1.4 Climate Disruption

Climate disruption has already had profound impacts on some parts of the UCB, and is projected to have further effects if society continues to pollute the atmosphere with greenhouse gases. Glaciers are receding at an ever-increasing rate, low-elevation winter precipitation is shifting from snow to rain, and summers are becoming hotter and often drier, creating conditions for increased frequency and intensity of wildfires. Increased summer temperatures are creating lethal conditions for anadromous fish in the lower Columbia, and creating more favourable habitats for invasive species like the northern pike (ISAB 2019). In the lower Columbia, measures are already being investigated to protect anadromous fish from the increasing water temperatures that have resulted in major losses in some returns (US EPA 2019). Precipitation extremes, major rain-on-snow events, and weather whiplash events, sometimes combined with wildfire impacts, are leading to floods, debris floods, and landslide events like the Johnsons Landing slide in 2012, major Kootenay Lake flooding in 2012, the Kuskanook slide in 2004, and major stream channel destruction in Buhl, Elk, Hamill, Fry and Campbell Creeks in 2013.

Over the coming decades, changes in temperatures, precipitation patterns, and extreme events are projected to affect the seasonal flow patterns of all the tributaries within the UCB, and to a lesser extent the mainstem Columbia and Kootenay Rivers themselves. In general, winter flows will increase and late summer/ fall flows will decrease; however, the changes to low-elevation drainages will be greater than high-elevation drainages. The main outcome will be increased uncertainty regarding timing and magnitude of flows, the control of which is the main focus of the CRT.

Environmental changes from climate disruption are not the only factor leading to increased uncertainty. Markets for the electricity produced by the dams on the Columbia and Kootenay systems will also become less certain. Winter heating requirements may decrease, but summer air conditioning needs may increase. How rapidly will society move to a low carbon future? Will there be a wholesale conversion to electric transportation and/or electric heating? What increase in solar and wind power will occur? How will the grid adapt to a different distribution of electricity production and storage? There are many unknowns and uncertainties. However, it is clear that local efforts to improve ecosystem function in the Columbia Basin must be accompanied by meaningful global action to reduce carbon emissions and expand carbon sinks as quickly as possible.

2.0 GENERAL PROPOSALS FOR RESTORING ECOSYSTEM FUNCTION UNDER THE CRT

2.1 Addition of Ecosystem Function as a Third Purpose of the CRT

Canada and US negotiators should amend the CRT to include ecosystem function as a third primary purpose, equal in priority to the existing Treaty purposes of flood-risk management and coordinated hydropower production. Consideration of ecosystem function should include all aquatic, wetland, riparian and upland ecosystems impacted by dams throughout the Columbia Basin, on both sides of the international border. UCBEC outlines what this would mean for the UCB in section 3 below.

In addition to operational changes at dams and reservoirs, the Treaty should also include the establishment of an ongoing funding source for ecosystem restoration and mitigation programs, including adaptive management research programs. The funding could be derived from the economic benefits of the Treaty dams, including those for both hydroelectric production and flood-risk management. The proportional cost sharing should take into account the magnitude of Treaty benefits, and the magnitude and location of ecological impacts resulting from the dams and flow regulation. Programs such as the Fish and Wildlife Compensation Program (Columbia Region) and the Creston Valley Wildlife Management Area are examples of existing programs that could be expanded to better implement ecosystem function restoration in Canada, with due consideration of the actual impacts incurred (see Utzig and Schmidt 2011).

2.2 Governance

Governance under the CRT is primarily controlled by each country’s designated “Entity”: BC Hydro in Canada and the Army Corps of Engineers and Bonneville Power Administration in the US. Those Entities may have been appropriate when management under the Treaty was focused exclusively on flood-risk management and hydroelectric production. With the addition of ecosystem function as a third objective, there would be the need to expand the Entities in both countries to adequately represent the third purpose. Research suggests that implementation of ecosystem function will be ineffective without a change in the governance structure (Cosens and Williams 2012). The new Entity members must have a clear mandate and expertise to advocate for the balanced incorporation of ecosystem function restoration in a shared decision-making process. While the existing Entity members have acquired ecosystem-related responsibilities as new environmental requirements have been applied to their facilities, they have generally not been successful in meaningfully prioritizing ecosystem function alongside their primary mandates. As a result, the Permanent Engineering Board and its committee memberships, which implement Treaty operations, should be revised to reflect the new mandate – *i.e.* include appropriately qualified biologists and/or ecologists. Rather than an “Engineering” Board, it should potentially be re-designated an “Ecosystem and Engineering” Board to reflect its expanded mandate.

The governance mandate must also include development of an active adaptive management program, complete with a clear process for updating management regimes based on the program’s research and results. In addition to its existing mandate, the proposed Ecosystem and Engineering Board should provide regular reporting on the attainment of ecosystem function objectives, ongoing adaptive management activities and implementation of research results.

A revised CRT should respect the rights of First Nations and support the commitments made to the United Nations Declaration on the Rights of Indigenous Peoples and the goals of truth and reconciliation (United Nations 2017; TRC 2015). This implies an Indigenous role in Treaty governance. A revised CRT should also require that the Entities hold periodic consultations throughout the Columbia Basin with local governments, ENGOs, and other affected stakeholders. The consultations should focus on whether current management is meeting CRT objectives and on identifying emerging issues. Results of these consultations and resulting actions should be made publicly available in a timely manner.

Even today, Columbia River Basin residents do not understand the purpose and structure of the CRT nor its historic and ongoing impact on ecosystems and human communities. To support meaningful consultation with the public, a revised CRT should require that the Entities support education programs, financially and by other means, to educate members of the public – especially youth – about CRT-related topics and engage them through available consultation processes.

In July 2019, an informal Columbia River Transboundary Water Working Group convened by the Columbia Basin Trust met in Vancouver, BC. The Working Group drafted a proposal for the creation of a new governance structure for the Columbia Basin designed to facilitate collaborative adaptive management of transboundary issues. Known as International River Basin Organizations (IRBOs), similar structures are used in many other transboundary watersheds around the world. The Working Group’s *DRAFT Proposal for Transforming Transboundary Water Governance in the Columbia River Basin* further explains how an IRBO could benefit the Columbia Basin, how it might be structured, and what steps might be necessary to create it (Anonymous 2019). The IRBO proposal includes many recommendations similar to those presented in this Discussion Paper, but goes further in recommending the creation of the new formal governance structure described above. In September 2019, the proposal was discussed by attendees of the *Columbia Basin Transboundary Conference* in Kimberley, BC. UCBEC supports continued discussion of this proposal involving First Nations and tribes and stakeholders such as local governments and ENGOs.

2.3 Active Adaptive Management

Given uncertainty resulting from climate disruption, and the lack of information regarding the most effective approaches for restoring ecosystem function, there will be need for ongoing research to explore options to alter management to meet multiple objectives in the future. Adaptive management is a structured methodology that includes iterative learning, monitoring and adapting management in the face of uncertainty[7]. Active adaptive management is proactive, where new alternatives are formulated and tested, and the focus is on new learning. This contrasts with passive adaptive management, where the focus is on monitoring current management.

The implementation of active adaptive management will be complex and not be without difficulties (Williams 2016). Implementation will require the incorporation of flexibility into a revised CRT, allowing for the testing of new management regimes that are intended to increase ecosystem function within the system, while coping with climate disruption. The present process of maximizing power production, flood-risk management and revenue generation will have to be balanced with allowing for testing alternative management regimes designed to improve ecosystem function.

To increase potential for restoration of ecosystem function, the watershed system as a whole should be examined for trade-offs. For example, discouraging and/or relocating floodplain development and re-connecting floodplains offer alternative means of managing flooding impacts yet also offer benefits to ecosystem function. The present dependence on reservoir storage of floodwaters should be sharply reduced.

One approach would minimize reservoir storage in years of lower flood risk to allow for revegetation and rehabilitation of low-gradient stream and river reaches in upper portions of reservoir footprints. For example, Thomson *et al.* (2017) propose an operational alternative for the Arrow Reservoir that would allow filling the reservoir in only one-in-seven years (on average), when downstream flood risk was anticipated to be extreme. Based on evidence from pre-dam flooding of Upper Arrow Lake, it has been shown that functioning riparian ecosystems can tolerate this frequency of flooding, as long as it does not exceed 35 days in duration. Thomson *et al.*'s Scenario 3 further recommends lesser seasonal fluctuations in the non-flood 6-of-7 years, with reservoir levels fluctuating between approximately 1417 and 1423 ft. This proposed operating regime would be more consistent with the natural functioning of Arrow Lakes prior to dam construction, and would allow development of a permanent and a diverse vegetated zone, including wetlands, trees and shrubs, in areas above 1423 ft. that are inundated annually under current operations. Exploration and further refinement of the proposal could be achieved with implementation of active adaptive management, approached with the vision of Figure 3, not the narrow focus of Figure 4.

3.0 SPECIFIC PROPOSALS BY RESERVOIR AND RIVER REACH

Section 2 proposes that the Treaty be refocused to include consideration for a wider range of objectives beyond flood-risk management and hydropower production. By broadening membership of the Entities to include representatives focused more on ecosystem function than ecosystem services, and by creating local flexibility in how the regulated flow regimes are determined, the Treaty can be used to create opportunities to restore ecosystem function within the individual components of Canada's Columbia-Kootenay system. Although these components are interconnected, with changes in one potentially resulting in changes in another, each affected reach, be it a reservoir or a regulated reach of a river, has unique opportunities for restoration. This section provides proposals specific to each reservoir and river reach for restoring greater ecosystem function. Addressing potential interactions between restoration activities at different sites is not addressed in the Discussion Paper at this time.

3.1 Columbia and Pend d'Oreille Rivers

The Canadian Columbia River is affected by dams and reservoirs from near the City of Golden downstream to the international border with the US, about 20 km south of the City of Trail. The Pend d'Oreille River (known in the US as the Pend Oreille River) passes through Canada briefly before it empties into the Columbia River just upstream of the international border. Impacts to the Canadian reaches of the Columbia River increased sharply with the 1964 CRT, which approved the construction of four new storage dams to manage flows for downstream US interests. Two of these Treaty dams are located on the Columbia River mainstem: Hugh Keenleyside Dam (completed in 1968), which created the 230-km-long Arrow Reservoir and Mica Dam (completed in 1973), which

[7] A workshop held in Berkeley CA in early 2019 explored opportunities and issues associated with implementing adaptive management in the Columbia Basin (http://riverlab.berkeley.edu/index.php/2019/05/workshop-on-adaptive-management-for-an-international-river-basin-the-future-of-the-columbia-river-treaty/)

created the 430-km^2 Kinbasket Reservoir. The Columbia River was further impacted when BC built the Revelstoke Dam near the City of Revelstoke in 1984.

Under the CRT, dam operations at Keenleyside and Mica typically involve deep reservoir drawdowns before spring to capture seasonal snowmelt, filling reservoirs during early summer, and subsequently releasing water through late fall and winter. The resulting flow pattern below these dams contrasts sharply with the natural hydrograph, which peaks with spring runoff before receding during the rest of the year. The diversity of habitats lost to flooding varies markedly from reservoir to reservoir. For example, Arrow Reservoir is associated heavily with lost lake habitat whereas Duncan Reservoir (on the Kootenay system ï see section 3.2) destroyed extensive riparian floodplains and wetlands. Primary productivity (*i.e.* the production of biomass by plants, which is the foundation of an ecosystemôs food web) has been lost in all reservoirs with the losses associated with Kinbasket Reservoir exceeding that of all the other reservoirs combined. Lost primary productivity results in lost potential for carbon sequestration (as plants pull carbon from the atmosphere during photosynthesis) and contributes further to climate change (Utzig and Schmidt 2011). Drawdown examples are shown in Figure 5.

Figure 5. Drawdown zone in Kinbasket Reservoir (left photo; credit: Brian Gustafson) and Koocanusa Reservoir (right photo; credit: Lars Sander-Green).

Additional incremental activities have added significantly to the Treatyôs direct impacts. For example, Mica dam was built higher than the Treaty requires which has subsequently enabled a supplemental NTSA with the US to further control Canadian river flows for downstream purposes[8]. Additional non-Treaty dams have been built to take advantage of the regulated flow regimes created by Treaty dams. These dams have created incremental ecosystem impacts. For example, on the Columbia River between Arrow Reservoir and Mica Dam, the Revelstoke Dam flooded an additional 115-km^2 to create the Revelstoke Reservoir. The Revelstoke Dam is used in tandem with the Mica Dam to produce electricity at times of peak demand. Known simply as ñpeaking,ò this is defined as the production of electricity to meet short-term consumer demands at intervals as short as minutes and hours. These operations result in extreme fluctuations in discharge below Revelstoke Dam, and rapid changes of flow and water levels in the Columbia River downstream. These rapid changes in flow destroy riverine aquatic and riparian habitats, and result in significant bank erosion that extends kilometres below the dam.

Waneta Dam went into service on the Pend dôOreille River in 1954. The Seven Mile Dam became operational in 1979. These Canadian dams take advantage of the flow regime modified previously by dams further upstream on the US Pend Oreille River. As a result, environmental concern with these Canadian dams is focused on reservoir inundation impacts. In comparison with the footprint impacts of CRT reservoirs, the ecosystem consequences of these Pend dôOreille dams are relatively modest. These two dams are not governed by the CRT.

Although not included in the impact assessments carried out by the BC Fish and Wildlife Compensation Program (Utzig and Schmidt 2011), river reaches downstream of Treaty dams have also degraded ecologically due to the altered flow regimes. Along the lower Canadian Columbia River valley, three remaining river sections are

[8] It is also acknowledged that BC obtained some inter-reservoir storage flexibility under the NTSA.

affected: the reach between the Revelstoke Dam and the Arrow Reservoir, the reach below the Keenleyside Dam on the Columbia and the reach from below dams on the Pend d'Oreille River to that river's confluence with the Columbia River. These losses include direct flow-regime impacts to channel substrate (*i.e.*, riverbed composition), channel stability, and life-cycle requirements of fish species (which often include needs for specific riverbed conditions). Water quality changes (especially temperature, nutrients and dissolved oxygen) have further impacted plant and animal communities and associated functions of aquatic ecosystems. Riparian function in these reaches has also been affected.

Dams differ in their size, structure, and operations and, therefore, differ in their restrictions on upstream and downstream fish passage. Impacts due to lost passage for anadromous fish migration were not considered when the Treaty was signed because pre-Treaty US dams previously blocked passage. There remains no salmonid migration to the UCB despite ongoing efforts to establish passage beyond US dams. If salmon restoration to the UCB were successful, Canadian dams present migrating fish with variable restrictions to their upstream and downstream travel.

The following sections outline recommendations related to individual components in the Columbia and Pend d'Oreille River systems. These will be reviewed and updated as more specific information becomes available through further research including outputs from the modelling exercises being led by First Nations, initiated in 2019 to inform the ongoing CRT modernization process.

3.1.1 Kinbasket Reservoir – Mica Dam

UCBEC's preliminary ecosystem function measures associated with Kinbasket Reservoir are:

- Develop and implement a scoping study similar to the Mid-Arrow study (Thomson *et al.* 2017, see section 2.3 above) to identify various options for Mica Dam operations that could benefit terrestrial, riparian, wetland and stream-reach ecosystems within the upper elevations of the reservoir footprint. These studies should build on existing Water Use Planning studies, and include assessment of various physical works, such as debris management structures and earth works. They should also consider changes to frequency and duration of flooding, such as those considered in the Mid-Arrow study.
- Through CRT and NTSA negotiations, ensure that the implementation of changes to Mica Dam operations identified through ecosystem studies for improving ecosystem function would be feasible and actively promoted under future CRT and NTSA terms.

3.1.2 Revelstoke Reservoir – Revelstoke Dam

UCBEC's preliminary ecosystem function measures associated with Revelstoke Reservoir are:

- Initiate studies to explore operational changes to the Mica and Revelstoke dams that may allow use of a portion of the storage in Revelstoke Reservoir to provide improvements in environmental function downstream, while minimizing impacts on this and other reservoir environmental values. The focus should be on mitigating impacts of peaking and restoring large riverine habitat in the Revelstoke Reach.

3.1.3 Columbia River between Revelstoke Dam and Arrow Reservoir (*i.e.* Revelstoke Reach)

UCBEC's preliminary ecosystem function measures associated with the Revelstoke Reach of Columbia River are:

- In combination with changes to Arrow Reservoir management, implement changes to the operation of the Revelstoke Dam to ensure the restoration and/or maintenance of productive large riverine ecosystems between the Revelstoke Dam and the upper reaches of the Arrow Reservoir. Focus initial studies on reducing and/or mitigating peaking impacts on aquatic habitats, and the restoration of a more natural hydrograph. These changes could include increased variation in Revelstoke Reservoir levels and/or development of pumped, battery or other storage as alternative means of meeting peak demands.
- Examine alternative approaches to lowering peak electrical demand to reduce the frequency and magnitude of rapid water releases pursued at the Revelstoke Dam to reduce stress on riverine ecosystems from dam operations (*e.g.*, more effective use of smart metering and differential time-of-day pricing).

3.1.4 Arrow Reservoir

The Mid-Arrow report (Thompson *et. al.* 2017) outlines potential scenarios that would limit the frequency and duration of flooding within the reservoir above 1420 ft. (See section 2.3 above.) Mid-Arrow Scenario 3 most closely mimics the natural pre-dam Arrow Lakes flooding patterns, and offers increased flexibility for storage that can provide benefits for downstream anadromous fisheries flows and flood control. In addition to the goals associated with implementing Mid-Arrow Scenario 3, UCBEC's further preliminary ecosystem function measures associated with Arrow Reservoir include:

- Develop and implement studies to assess the potential revegetation and stream rehabilitation benefits from the Mid-Arrow Scenario 3. For example, this could include an incremental implementation of the 1-in-7 flooding scenario in the upper two metres of the reservoir over a 15-year period to test the revegetation projections in the study. It could also include modeling and testing of how other dams and reservoirs could be managed to compensate for lost storage in the Arrow Reservoir, and changes in annual flow regimes.
- Implement further studies to answer the other information needs identified in the Mid-Arrow study.
- Assess the feasibility of combining various physical works (*e.g.*, excavated ponds, dyked ponds or wetlands, floating islands) with changes in reservoir operations to maximize environmental benefits.
- Through CRT negotiations, ensure that implementation of the Mid-Arrow Scenario 3 (or something similar) is a viable option under future Treaty terms.
- If salmon return is found to be viable under projected climates and is supported by potential changes in Treaty operations, explore opportunities for restoring salmon habitat and flow regimes that support salmon in this portion of the UCB. Existing licensing requirements at Keenleyside Dam require the installation of fish passage if salmon are successfully restored to the Columbia River below the dam (Green 2014).

3.1.5 Columbia River downstream from Keenleyside Dam

UCBEC's preliminary ecosystem function measures associated with Columbia River downstream of Keenleyside Dam include:

- In combination with changes to Arrow Reservoir management, implement changes to the operation of the upstream Revelstoke and Mica Dams in coordination with operation of the Kootenay System to ensure the restoration and/or maintenance of productive large riverine ecosystems downstream of the Keenleyside Dam.
- Explore opportunities for restoring salmon habitat and flow regimes that support salmon in this reach, if salmon return is found to be viable under future Treaty operations and projected climate change impacts.

3.1.6 Pend d'Oreille River System

UCBEC's preliminary ecosystem function measures associated with Pend d'Oreille River include:

- Develop a research program to explore how modifications in the operations of Waneta and Seven Mile dams in Canada, and the upstream dams in the United States, can be coordinated such that aquatic and riparian ecosystems associated with the lower Pend d'Oreille River and its reservoirs are fully functioning and productive.
- Develop a research program to explore how modifications in operations of the Pend d'Oreille system could be adjusted to be compatible with restoring large river aquatic and riparian ecosystems on the Columbia River below their confluence.
- Develop a research program to identify opportunities for mitigating the environmental impacts of the reservoirs associated with Waneta and Seven Mile dams.
- If salmon return is found to be viable under projected climates and supported by potential changes in Treaty operations, explore opportunities for restoring salmon habitat and restoring flow regimes that support salmon in this portion of the UCB. Existing licensing requirements at Waneta dam require that dam operations not preclude the potential for fish passage at this facility (Green 2014).

3.2 Kootenay River

The Kootenay River begins in Canada, flows south into the US, returns north into Canada, forms Kootenay Lake, and then continues flowing downstream to join the Columbia River below Keenleyside Dam. In Canada, the Kootenay River system is affected by dams and reservoirs in many locations.

Libby Dam was completed in 1972 on Montana's section of the Kootenai River, creating the 188-km^2 Koocanusa Reservoir, which extends 68 km into British Columbia. Although authorized by the CRT, it is operated outside of the CRT by the Army Corps of Engineers for multiple purposes including flood-risk management and hydropower production. Although those two priorities are similar to the CRT focus, operation of Libby Dam is also influenced by court orders issued under the US Endangered Species Act (ESA). For example, since 2008 there are special releases from Libby Dam in late spring in support of white sturgeon in the Kootenai River. Losses associated with Koocanusa reservoir include riparian and wetland ecosystems associated with long sections of a previously free-flowing river. Additional ecological losses accompanied the inundation of various dry habitat types, which are now rare in British Columbia (Utzig and Schmidt 2011).

Whereas the river downstream of Libby Dam is largely within the US (where it is called the Kootenai River), a portion of the Kootenay River is situated in Canada upstream of Kootenay Lake. This reach passes through the Creston Valley Wildlife Management Area. Although the conversion of this region to farming land predates the CRT, this region is of leading importance to valley-bottom ecosystems and presents an opportunity to compensate for some of the longstanding impacts of flow regulation and reservoir flooding.

The Duncan reservoir impacts a significant source area of the Kootenay River with flow-regulation consequences occurring in the downstream river reach. Duncan Dam was completed in 1967 and is operated under the terms of the CRT. Nearly two thousand hectares of wetlands and over a thousand hectares of cottonwood and riparian forests were inundated by Duncan Reservoir, particularly at the upper end, ecosystems that were previously of provincial significance (Utzig and Schmidt 2011). The Duncan Dam has blocked access to over 100 km of low gradient river and stream habitat that was previously accessible by fish from Kootenay Lake (Arndt 2009). Downstream of Duncan Dam, the flow regime of Duncan River is drastically altered. Discharge stays high all winter when it was previously very low. The spring freshet is sharply reduced in support of CRT requirements. The river has important habitat for whitefish, kokanee and bull trout. Limited fish passage is enabled through a chamber in the dam.

Although Duncan and Libby dams affect inflows to Kootenay Lake, its water level is ultimately controlled at the lake outlet by a 1938 Order of Approval for the Corra Linn Dam that was put in place by the International Joint Commission (IJC) under the terms of the Boundary Waters Treaty of 1909. This management system, known as the "IJC Rule Curve", identifies specific water levels to be met by selected dates to manage flood risk. Meeting these water levels requires anticipating spring runoff and is complicated by the natural outflow constriction at Grohman Narrows, near the City of Nelson. Libby Dam assists in reducing Kootenay Lake flood levels, however ESA releases at Libby also add difficulty to achieving the water levels prescribed in the 1938 IJC Order.

Although not managed under the CRT, Kootenay Lake experiences ecosystem and water-level impacts that are consequences of the CRT. Dam construction has reduced nutrient inputs to the lake necessitating a long-term program of nutrient enhancement to support the lake food chain. Kokanee populations in the main lake have shown great variation and have recently collapsed causing great concern for their future viability. Present operations have also been found to negatively impact shore-spawning kokanee in the West Arm and are currently under review. Although aggressive management to maximize the production of Gerard Rainbow trout, a key kokanee predator, is generally cited as a leading cause of the collapse, various other effects including the dams (Duncan and Libby) may also be involved.

Downstream of Kootenay Lake, the river is heavily impacted by a series of six dams and reservoirs, most of which pre-date the CRT. Strung from upstream to downstream below the Corra Linn Dam lies the 1976 Kootenay Canal Project, the 1907 Upper Bonnington Falls Dam, the 1925 Lower Bonnington Falls Dam, the 1928 South Slocan Dam, and the 1944 Brilliant Dam. Some of these dams were built and blocked fish passage locally before the Grand Coulee Dam blocked passage to the UCB entirely. Except for the Kootenay Canal Project and the Corra Linn Dam, these facilities are operated largely as run-of-the-river operations with limited reservoir impacts. The low-gradient riffle-pool section between Kootenay Lake and Corra Linn Dam is an exception and is now free-flowing to Taghum only during the springtime when Kootenay lake water levels are drawn down significantly. The head pond for the Brilliant Dam, located near the confluence of the Kootenay and Columbia Rivers, fluctuates daily to meet peak demand requirements. In general, the complexity of managing

Kootenay Lake and its outlet to Columbia River under current operating arrangements presents challenges to meeting ecosystem needs both in the lake and downstream.

The following sections outline recommendations related to individual components in the Kootenay River system. These will be reviewed and updated as more specific information becomes available through further research and the modelling process led by First Nations (see section 1), which was initiated in 2019 to inform the ongoing CRT modernization process.

3.2.1 Koocanusa Reservoir – Libby Dam

UCBEC's preliminary ecosystem function measures associated with Koocanusa Reservoir include:

- Develop and implement a scoping study similar to the Mid-Arrow study (Thomson *et al.* 2017) to identify various options for Libby Dam operations that could benefit terrestrial, riparian, wetland and stream reach ecosystems within the upper elevations of the reservoir footprint. These studies could include assessment of various options, including adjusting the frequency and duration of flooding, as well as constructing physical works to enhance wetland and riparian habitats (*e.g.*, excavated ponds, dyked ponds, wetlands, and floating islands).
- Through CRT negotiations, ensure that implementation of changes to Libby Dam operations identified though ecosystem studies for improving ecosystem function would be feasible and encouraged under future Treaty terms.

3.2.2 Kootenay River between US border and Kootenay Lake

UCBEC's preliminary ecosystem function measures associated with Kootenay River between the US border and Kootenay Lake include:

- Given the importance of the Creston Valley riparian wetlands, as one of the few remaining valley-bottom wetland riparian complexes in the West Kootenay, develop and implement a scoping study to explore the restoration of natural riparian habitat adjacent to the Kootenay River. This measure would require a review of the existing dyking system and identification of opportunities to enhance floodplain function. This work should include opportunities for improving the operation and effectiveness of the Creston Valley Wildlife Management Area.
- Ensure that an appropriate portion of any environmental mitigation funds resulting from CRT negotiations are made available for effective long-term operation of the Creston Valley Wildlife Management Area and further increasing ecosystem function of the Kootenay River and its floodplain.

3.2.3 Duncan Reservoir – Duncan Dam

UCBEC's preliminary ecosystem function measures associated with Duncan Reservoir include:

- Develop and implement a scoping study similar to the Mid-Arrow study (Thomson *et al.* 2017) to identify various options for Duncan Dam operations that could benefit terrestrial, riparian, wetland and stream reach ecosystems within the upper elevations of the reservoir footprint. These studies could include assessment of various options, including adjusting the frequency and duration of flooding, as well as constructing physical works to enhance wetland and riparian habitats (*e.g.*, excavated ponds, dyked ponds or wetlands, floating islands).
- Through CRT negotiations, ensure that the implementation of changes to Duncan Dam operations that may be identified though ecosystem studies for improving ecosystem function would be feasible and actively promoted under future Treaty terms.
- Explore the options for enhancing the effectiveness of upstream fish passage at the Duncan Dam.

3.2.4 Duncan River between Duncan Dam and Kootenay Lake

UCBEC's preliminary ecosystem function measures associated with Duncan River between Duncan Dam and Kootenay Lake include:

- Modify operations of Duncan Dam to minimize negative impacts on the aquatic and riparian ecosystems in Duncan River downstream of the dam.
- Through CRT negotiations, ensure that there is sufficient flexibility in any Duncan Reservoir storage agreements to accommodate flows that are necessary to maintain fully functioning and productive aquatic and riparian ecosystems associated with the lower Duncan River.

3.2.5 Kootenay Lake

UCBEC's preliminary ecosystem function measures associated with Kootenay Lake include:

- Ensure that operations of the Duncan, Libby and Corra Linn Dams are coordinated in such a way that the aquatic ecosystems of Kootenay Lake are fully functioning and productive. This should include not only fish, but other species such as crayfish and mussels. Operations should ensure that lake levels are compatible for both stream- and shore-spawning kokanee populations.
- Through CRT negotiations, ensure that there is sufficient flexibility in any Duncan and Libby storage agreements to accommodate the timing and magnitude of flows that are necessary to maintain fully functioning and productive aquatic and riparian ecosystems associated with Kootenay Lake.

The need for these measures reflects the complex mix of influences on Canada's Kootenay system including multiple international agreements.

3.2.6 Kootenay River between Kootenay Lake and Columbia River

UCBEC's preliminary ecosystem function measures associated with Kootenay River between Kootenay Lake and Columbia River include:

- Ensure that operations of the Duncan, Libby, Corra Linn, Upper Bonnington, Lower Bonnington, South Slocan, Kootenay Canal, and Brilliant Dams are coordinated in such a way that the aquatic and riparian ecosystems associated with the lower Kootenay River and its associated reservoirs are fully functioning and productive.
- Explore opportunities to minimize the environmental impacts of peaking on the Brilliant Dam head pond (*e.g.*, shoreline erosion; see also discussions of peaking in section 3.1).
- Through CRT negotiations, ensure that there is sufficient flexibility in any Duncan and Libby storage agreements to accommodate the timing and magnitude of flows that are necessary to maintain fully functioning and productive aquatic and riparian ecosystems associated with the lower Kootenay River and its associated reservoirs.
- If salmon return is found to be viable under projected climates and supported by potential changes in Treaty operations, explore opportunities for restoring salmon habitat and restoring flow regimes that support salmon in this reach. Existing licensing requirements at Brilliant Dam (the furthest downstream in this reach) require the installation of fish passage if salmon are successfully restored to the Columbia River below the dam (Green 2014).

The need for these measures reflects the complex mix of influences on Canada's Kootenay system including multiple international agreements.

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