

Valuing ecosystem services in the Columbia River Treaty

by

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Project Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Public Policy

in the
School of Public Policy
Faculty of Arts and Social Sciences

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Simon Fraser University
Summer 2016

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Abstract

Canada's participation in the Columbia River Treaty is potentially an inefficient use of Canadian water resources because the parties do not account for the value of ecosystem services in the payments made under the Treaty. The purpose of this study is to recommend a mechanism through which the parties could price ecosystem services in a modern Treaty. To inform my analysis of the options, I use economic valuation methods to estimate the major costs to Canada and the major benefits to the US of the Treaty in terms of changes in ecosystem services between two scenarios: Treaty Terminates and Treaty Continues. I also use a jurisdictional scan to identify mechanisms from other payment for ecosystem services schemes around the world. Results of the economic valuation suggest that the US benefits from ecosystem services are worth at least US\$225 – 667 million per year. The valuation results also suggest that Canada incurs costs from foregoing benefits from Canadian ecosystem services worth US\$24 to \$41 million annually. The jurisdictional scan provides additional insights into pricing mechanisms. I assess three options based on their effectiveness in achieving the objective of maximizing the net internal benefit. I also evaluate the options' sustainability, stakeholder acceptance, and administrative ease. I recommend that Canada and the US maintain the status quo practice of calculating annual payments on the basis of potential incremental hydropower, and consider the difference between potential and actual hydropower as a proxy for the value of ecosystem services.

Keywords: Columbia River Treaty, payments for ecosystem services, transboundary water resource management

For the Columbia River. May it roll on.

Acknowledgements

I thank Nancy Olewiler and Doug McArthur at Simon Fraser University for their support and guidance during this project and others.

I also thank Deb Harford and Jon O’Riordan at ACT (Adaptation to Climate Change Team) for the opportunity to work on the “unimaginably complex calculus” of the Columbia River Treaty. Comments and ideas from Benoit Laplante and Cedar Morton were highly valued in framing the issue. I also appreciate the opportunity to stand on the shoulders of previous ACT researcher Sukhraj Sihota.

I owe the remnants of my sanity to the Class of 2016, and in particular to Coral Candlish-Rutherford, Max Nichols, Molly Henry, Angela Pati, Anjum Mutakabbir, and Dan Ramroop. Thank you for pushing me to be a better thinker.

Finally, I thank my family for instilling in me the values of serving the public and respecting nature; and my partner Shannon for her love and happiness.

This study was made possible in part by grants from the Social Sciences and Humanities Research Council, Sustainable Prosperity, and the SFU School of Public Policy.

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Executive summary

Problem and purpose

- Under the Columbia River Treaty, hydropower generation and flood prevention are the sole determinants of the value of the payments Canada receives from the United States.
- Canadian actions under the Treaty create many other downstream benefits for the US. These include enhanced survival of fish populations, incremental agricultural production, more recreation opportunities, more navigation opportunities, improved air quality, improved water quality, and other services. Furthermore, Canada incurs costs to provide these benefits to the US, in the form of foregone upstream benefits from similar services.
- Because the parties do not account for the value of these ecosystem services in the payments made under the Treaty, Canada's participation in the Treaty potentially does not maximize the net internal benefits to Canada from the use of Canadian water resources.
- Canada should seek to maximize the financial value of the payments it receives from the US under a modernized Treaty. To participate in a Treaty that does not maximize the payments, and so the net social benefit to Canada, would be an inefficient use of Canadian resources.
- The payments made under the Treaty should at minimum be equal to the opportunity costs that Canada incurs going forward by deviating from an operating plan in which Canada operates its dams and reservoirs to maximize its own net social benefit (i.e. a "Canada Max" plan). At maximum, the payments could be equal to the US' maximum willingness to pay for the incremental benefits the US receives under a continued

Treaty (i.e. a “US Max” plan). Historical costs and benefits of the Treaty cannot be considered in determining these payments.

- To account for the full suite of benefits and costs of the Treaty, the parties should compare the difference between the physical state of the ecosystems under the two plans. Different states of ecosystems will provide different levels of ecosystem services. The value that Americans place on the change in level of ecosystem services in the US is the value of the US benefits; the value that Canadians place on the change in level of ecosystem services in Canada is the value of the Canadian costs.
- The purpose of this study is to recommend a mechanism through which the parties could price ecosystem services in a modern Treaty that would result in the maximum benefit to Canada.

Options

- In the context of the Columbia River Treaty, there are three viable options for pricing ecosystem services.
- The first is the status quo approach, in which the difference between actual and potential hydropower generation serves as a proxy price for the value of other ecosystem services.
- The second is an annual ex-post payment indexed to changes in ecosystem services.
- The third is a 10-year ex-ante payment based on estimated changes in ecosystem services.

Research: Economic analysis and jurisdictional scan

- To inform my analysis of the options, I use economic valuation methods to estimate the major costs to Canada and the major benefits to the US of the Treaty in terms of changes in ecosystem services.

- I also use a jurisdictional scan to identify best practices in other payment for ecosystem services schemes around the world.
- I estimate that the value of the US benefits is approximately \$225 to \$667 million (2016US) annually. The major sources of this value are flood control (\$75 million), hydropower (\$26 to \$418 million), fish (\$99.65 million), agriculture (\$14.5 to \$55.09 million), and recreation (\$10 million). This estimate does not include the value of non-fish recreation, navigation, air quality, water quality, or other ecosystem services, which are likely greater than zero.
- I estimate that the value of the Canadian costs is approximately \$24 to \$41 million (2016US) annually. The major sources of this value are hydropower (\$22 million), fish (\$5.6 to \$26 million), agriculture (\$1.2 to \$1.8 million), air quality (\$1 million), and other ecosystem services (\$1.6 million).
- Payments for ecosystem services (PES) are common programs or policies in other jurisdictions where the actions of one party creates ecosystem service benefits for another party that are not captured in by existing markets.
- PES programs adopt different pricing mechanisms depending on the unique circumstances of the buyers and sellers.
- Most PES programs do not attempt to monitor changes in ecosystem services because of the resources and scientific understanding required.

Analysis and recommendation

- The options differ in terms of their effectiveness in maximizing Canadian net benefits, their sustainability, their administrative ease, and their acceptance among the primary stakeholders.

- The analysis highlights that a trade-off exists between efficiency and administrative ease, largely because of the costs associated with measurement and attribution. Acceptance of the options among stakeholders varies, depending on the value stakeholders would receive or have to give up.
- The status quo (i.e. price of proxy good) option represents the best available mechanism to price ecosystem services in the Columbia River Treaty. I recommend that the Province seek to maintain the status quo with respect to the payments made under the Treaty in the upcoming negotiations with the US.
- The status quo (i.e. price of proxy good) option offers several advantages over the annual ex-post and 10-year ex-ante options. First, the option represents a reasonably efficient use of Canadian resources in that it results in a payment to Canada that likely far exceeds the Canadian opportunity costs. The Entitlement is currently worth on average \$214 million annually; I estimate the Canadian opportunity costs at \$24 to \$41 million annually. The 10-year ex-ante option, while offering the most sustainable approach, carries too great a risk that the US could negotiate a lower price. The annual ex-post option could result in the greatest payment to Canada, but brings too high transaction costs and too great scientific uncertainty.
- I also recommend that, to strengthen the Canadian negotiation position, the CRTR commission several further studies to better understand the effects of Canadian dam and reservoir operations on ecosystem services in the US

1 Introduction

1.1 Policy problem

Canada and the United States share the Columbia River and manage the river under the Columbia River Treaty. Under the Treaty, Canada empties Canadian reservoirs during the spring freshet to store water to minimize downstream flooding and releases water to maximize downstream hydropower generation. In exchange for 60 years of the flood control benefits, the US paid Canada US\$64 million in 1964. In exchange for power benefits, the US pays Canada half the value of the incremental potential hydropower generation in an annual payment called the Canadian Entitlement, worth an average of US\$214 million.

In addition to flood prevention and hydropower generation, Canadian operations also create many other downstream benefits for the US. These include enhanced survival of fish populations, incremental agricultural production, more recreation opportunities, more navigation opportunities, improved air quality, and improved water quality. Furthermore, Canada incurs costs to provide these benefits to the US, in the form of foregone upstream benefits from similar services.

As of 2014, either side is able to unilaterally terminate the Treaty with 10 years' notice.

In 2024, the original flood control purchase will expire. The Treaty will continue, but after 2024, Canada could have more flexibility to operate Canadian dams for beneficial uses such as hydropower and recreation, rather than for US flood control. The US, in contrast, could be obligated to operate US dams to control floods, which will result in less flexibility and potential costs from foregone uses in the US, such as fish abundance, agricultural productivity, recreation opportunities, navigation opportunities, as well as water quality, air quality, and other ecosystem services.

The potential change to the Treaty is prompting both sides to consider whether and how to include the value of other ecosystem services in addition to hydropower and flood

control in the payments made under the Treaty. Canada takes the position that the payments should reflect the full range of benefits and costs from the management of the river on both sides of the border. The US wants to Canada to contribute to the restoration of the Columbia's ecosystems, but also wants to reduce the value of the annual payment, claiming that the actual hydropower generated from Treaty operations is much less than the potential hydropower generation.

Because the parties do not currently account for the value of these ecosystem services in the payments made under the Treaty, Canada's participation in the Treaty is a potentially inefficient use of Canadian water resources. The purpose of this study is to recommend a mechanism by which the parties could price ecosystem services in a modern Treaty and so ensure that Canadian water resources are allocated to their highest value uses.

To inform my analysis of the options, I use economic valuation methods to estimate the major costs to Canada and the major benefits to the US of the Treaty in terms of changes in ecosystem services. I also use a jurisdictional scan to identify best practices in other payment for ecosystem services schemes around the world.

1.2 Outline of study

This study is organized into eight chapters. Chapter Two provides further context on the Columbia River and the ecosystem services it provides. Chapters Three outlines the methods of the economic valuation and jurisdictional scan. I provide the results of the research in Chapter Four and Five. Chapter Six uses these results to develop a set of options for pricing ecosystem services in the Treaty. Chapter Seven evaluates the options against a set of criteria, including efficiency, sustainability, stakeholder acceptance, and administrative ease. Chapter Eight concludes by recommending a pricing approach, outlining further studies, and discussing implications and limitations.

2 Background

2.1 The Columbia River Treaty

The Columbia River begins 820 metres above sea level in the Canadian Rockies near the town of Canal Flats in British Columbia. The ninth longest and fifth largest river in North America, the Columbia flows 2000 kilometres and carries over 247 billion cubic metres of water before emptying into the Pacific Ocean near Astoria, Oregon, in the United States of America. Together with its tributaries, the Columbia drains an area of 668 000 square kilometres that covers portions of seven American states and one Canadian province (**Figure 1**).

Figure 1. Map of the Columbia River Basin¹.



Precipitation in the basin falls mostly in winter in the Canadian Rockies and west of the American Cascades in the Willamette sub-basin; the arid low-lying regions in the basin's centre receive little precipitation in either winter or summer (Cohen et al. 2000). Sixty-six percent of precipitation in the basin falls as snow and so natural flow in the Columbia is dominated by melting snowpack, which peaks in June and bottoms out in January. Flows in the river are highly variable and major spring floods were common

¹ Adapted from ("Columbia River" 2016)

before development. While only 15 percent of the Basin's area is in Canada, Canadian run-off typically accounts for about 50 per cent of peak flood flows at The Dalles, Oregon (Volkman 1997).

Canada and the United States entered into the Columbia River Treaty in 1964 with the objectives of taming the highly variable, flood-causing flows of the river and tapping the huge capacity of the river and its tributaries to generate hydroelectricity. Under the Treaty, Canada built three dams in Canada – Hugh Keenleyside, Mica, and Duncan – and allowed one American dam – Libby – to create a reservoir that extends into Canada. Hugh Keenleyside Dam created the Arrow Lakes Reservoir, Mica Dam created the Kinbasket Reservoir, and Duncan Dam created the Duncan Lake Reservoir. Libby Dam created the Lake Koocanusa Reservoir.

In exchange for the construction and co-ordinated operation of the Canadian dams, the US agreed to pay Canada for the flood control benefits and return to Canada half the value of the incremental downstream hydropower benefits. The net present value of the flood control benefits was paid as a lump sum of \$64.4 million (1964US).

Canada also agreed to operate its dams so as to maximize the value of hydropower generated downstream. Operating the dams with the objective of optimizing hydropower has had the effect of “flattening” of the river's natural hydrograph, reducing flows in summer and increasing flows in winter, when power is more highly valued to meet demands from heating. The value of Canada's share of the hydropower benefits is called the Canadian Entitlement and is calculated based on the incremental potential hydropower generation enabled by the flow regimes the Treaty makes possible. The first 30 years of the Entitlement was sold to a consortium of utilities in the US for \$254 million 1964USD (United States Army Corps of Engineers, n.d.). From 1998 to 2013, the Entitlement generated on average \$214 million 2013CAD for BC's general revenue (“Columbia River Treaty Review Website FAQs” 2015)².

² Since 1998, the Entitlement has been returned to Canada in the form of electricity, which is then marketed and sold in both Canada and the US.

2.1 Economic value of ecosystem services

The concept of *ecosystem services* can be helpful to think clearly about the full range of benefits and costs of the Treaty. An ecosystem can be defined as the set of living organisms (e.g. salmon, bears, and eagles) and non-living objects (e.g. water, silt, rock) that exist in a particular space and are connected to one another through flows of energy and materials. Humans, as living organisms, are one component of ecosystems. One way to think about the relationship between humans and other components of ecosystems is to conceive of the structures and functions (i.e. the materials and processes) of ecosystems as providing goods and services to humans³. Many of the goods provided by ecosystems are tangible: fish caught from a river, crops grown on a farm, or timber cut from a forest. The services provided by ecosystems can be less tangible: wetlands filter pollutants from drinking water, falling rivers power electricity generators, forests prevent soil erosion. Ecosystems also benefit humans in even less obvious ways. Lakes and mountains attract people to exercise and recreate. Plants and animals serve as inspiration for culture, art, and science. Geological features create senses of belonging or figure in systems of spirituality or religion. Economists and analysts use the term *ecosystem services* refers to the set of goods and services provided by ecosystems to humans.

When humans are provided ecosystem services, they gain welfare (also known as well-being, satisfaction, utility, etc.). While changes in welfare are impossible to truly measure, an estimate of the *economic value* of the welfare gained from receiving goods and services provided by ecosystems can be obtained by determining the recipient's maximum willingness to pay (WTP) for those goods and services. Similarly, the economic value of the welfare lost from ceasing to receive goods and services provided by ecosystems is equal to the former recipient's minimum willingness to accept compensation (WTA). If a policy or project (such as the implementation of a treaty governing the management of a river) changes the structure or function of an ecosystem, the ability of that ecosystem to provide goods and services also changes. Changes in the

³ For an interesting discussion of the origins and the history behind the concept of ecosystem services, see (Gómez-Baggethun et al. 2010).

level of goods and services provided by ecosystems result in changes of welfare of the recipients of those goods and services, and so society's willingness to pay to receive those goods and services or society's willingness to accept compensation for not receiving those goods and services – i.e. the value of those goods and services – also changes.

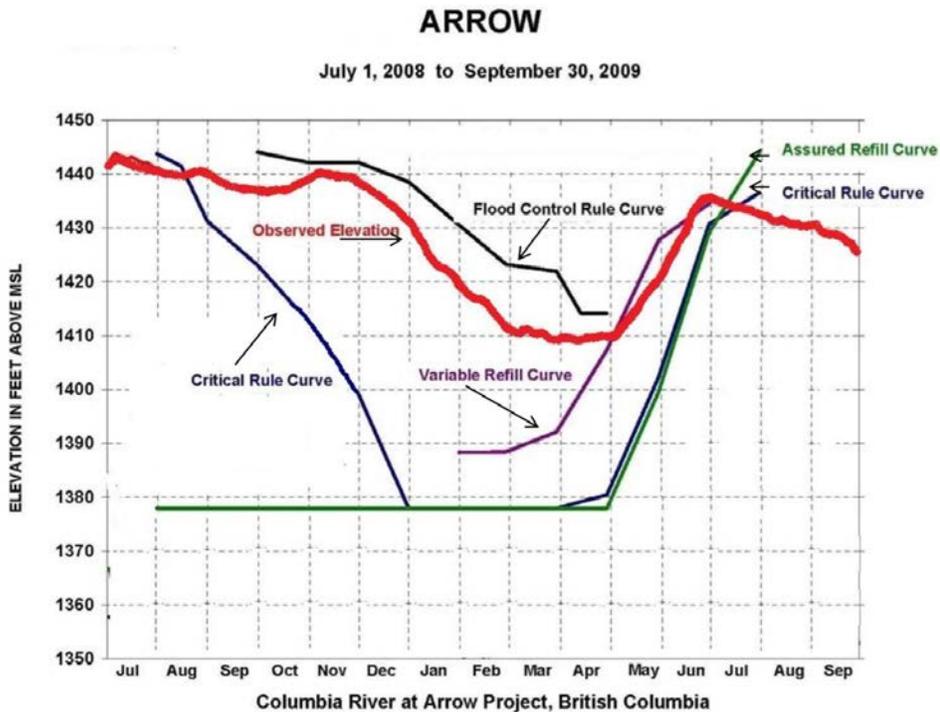
2.2 US benefits of the Treaty

While hydropower and flood control are the only services considered in the determination of the value of the payments made under the Treaty, Canada's participation in the Treaty benefits the US in many other ways. These benefits are not historical benefits that the original construction of the dams created. Rather, they are ongoing benefits that could be reduced or eliminated if the Treaty were to terminate.

The full range of US benefits from the Treaty include:

- **Avoided or reduced damages from flooding.** A number of major American cities and towns have been built on the floodplain of the mainstem Columbia. These include Vancouver and St. Helens in Washington State as well as Portland, Longview, and Astoria in Oregon State. Canada provides this flood control benefit by drafting the Arrow Lakes Reservoir low in the late winter so that the reservoir will have the capacity to store the spring freshets and so allow downstream flows to stay below the flooding threshold (Figure 2).

Figure 2. Arrow Lakes Reservoir operations⁴.



This figure shows the various constraints that the Treaty puts on Arrow Lake Reservoir elevation. The observed elevation (red) must be below the Flood Control Rule Curve so that the Reservoir can store spring freshets and so avoid flooding in the US.

- **Increased hydropower generation.** The US Federal Government operates 31 hydroelectric facilities on the US Columbia River mainstem and tributaries with a combined generation capacity of 20 347 MW, about 60% of the generation capacity in the Pacific Northwest (Federal Columbia River Power System 2003). The system also supplies power to California. Under the Treaty, Canada times releases from its reservoirs in order to increase the quantity and/or value of hydropower generated downstream.
- **Enhanced survival of fish populations.** The Basin’s rivers and streams support a variety of anadromous and non-anadromous fish species (Pacific Northwest

⁴ Adapted from (Canadian and United States Entities 2009).

National Laboratory Ecology Group 2010). Canadian water releases support the survival of several US species by increasing flow speeds at critical periods during the species' life cycles. Faster flows result in quicker downstream migration and so less exposure to predators and disease-causing warm waters, resulting in increased fish survival.

- **Incremental agricultural production.** Irrigation for agriculture is the dominate consumptive use of water in the US basin, accounting for about 93% of all withdrawals (Volkman 1997). Canadian actions under the Treaty may support agricultural production by releasing water for hydropower in low-flow or drought conditions, resulting in an increased supply of water for irrigated agriculture and so increased production of crops and associated revenues.
- **More recreation opportunities.** Recreation and tourism are significant industries in the US basin. The Treaty supports recreation and tourism insofar as the Treaty results in the US being able to maintain reservoirs at more consistent elevations. Without the flood control provided by Canada under the Treaty, the US may be required to empty and refill reservoirs more often to provide its own flood control. Such a fluctuation of reservoirs would result in reduced access to water for recreational purposes like boating and windsurfing. The reduced aesthetic appeal of muddy banks may also negatively affect recreation opportunities or tourism revenues.
- **More navigation opportunities.** The Columbia River has over 790 kilometers of navigable river and serves 36 ports and carries approximately 40% of all U.S. wheat. Over 35 million tons of cargo each year worth approximately \$12 billion annually are exported and imported along the River (Government of British Columbia 2013b). Canada's participation in the Treaty may support the activity of these ports by maintaining water levels in drought conditions high enough to avoid groundings of commercial ships or closing of ports.
- **Improved air quality.** Reservoir fluctuations can result in reduced air quality from increased dust due to conversion of stable riparian land into muddy banks.

- **Improved water quality.** Many municipalities in the American basin withdraw water from the Columbia for domestic water supplies. In low flow or drought years, Canadian releases may result in increased quality of water by reducing temperatures or diluting particulate concentrations.
- **Other benefits.** The US may benefit from Canadian actions under the Treaty in other ways, including increased carbon sequestration and increased wildlife populations from stable riparian habitats.

2.3 Canadian costs of the Treaty

Canada incurs costs to provide these benefits to the US, in the form of foregone upstream benefits from similar services. Comprehensive assessments of water use interests in the region have been undertaken through the development of various Water Use Plans (WUPs) for the Columbia and Duncan Rivers⁵, which involve provincial and federal government agencies, First Nations, local citizens, and other interest groups. These processes have identified that the costs to Canada of the Treaty include:

- **Foregone hydropower generation.** Facilities in the Canadian CRB generate nearly half of the total electricity generated by BC Hydro (21,860 gigawatt-hours, or 45.5 per cent of BC Hydro's total of 48,000 GWh).
- **Reduced fish abundance.** Significant anadromous and resident fish species in the Canadian CRB whose populations can be affected by dam and reservoir operations include rainbow trout, mountain whitefish, white sturgeon, walleye, and kokanee. Fish survival can be harmed because of impaired access to spawning streams.
- **Less recreation opportunities.** The recreation and tourism industries are significant in the Canadian CRB and can be affected by reservoir and dam

⁵ A WUP does not exist for the Kootenay River system because FortisBC, not BC Hydro, is the owner of the storage water license.

operations because of impaired recreational access (i.e. boats cannot get to water) and lowered aesthetics from mud banks.

- **Less navigation opportunities.** Some forestry sites are only accessible when reservoirs are at a certain level.
- **Loss of air quality.** Increased dust from loss of vegetation in stable riparian areas causes a reduction in air quality.
- **Other costs.** Damage to indigenous burial grounds from continual submersion/exposure cycles.

There are no significant consumptive withdrawals for agriculture along the Canadian Columbia River (Columbia River Treaty Local Governments’ Committee, n.d.), nor are there significant impacts to water quality from Canada’s participation in the Treaty. Canada receives flood control benefits from the Treaty, as several communities in the Canadian CRB rely on the storage created by the Treaty dams for flood control including Revelstoke, Castlegar, Trail, and Nelson.

Table 1 summarizes the major classes of ecosystem services that the dams and reservoirs of the Columbia provide and whether the Treaty results in a positive, negative, or insignificant change in the value of that service to Canada and the US.

Table 1. Changes in value of ecosystem services from the Treaty.

	US	Canada
Flood prevention	Positive	Positive
Hydropower generation	Positive	Negative
Fish abundance	Positive	Negative
Agricultural productivity	Positive	Insignificant
Recreation opportunities and tourism revenues	Positive	Negative
Navigation revenues	Positive	Negative
Air quality	Positive	Negative
Water quality	Positive	Insignificant
Others	Mixed	Mixed

2.4 Changing waters: a policy window opens

As of 2014, either side is able to unilaterally terminate the Treaty with 10 years' notice. Both Canada and the US have indicated their intention to continue, rather than terminate, the Treaty (United States Entity 2013b; Government of British Columbia 2013a). However, the two sides remain divided on a number of issues, including the specifics of the imminent switch to Called Upon Flood Control, the inclusion of ecosystem-based function as a primary objective of the Treaty, and the value of the Canadian Entitlement.

2.4.1 Imminent switch to Called Upon Flood Control

In September 2024, the flood control portion of the original agreement will expire. After 2024, flood control operations will change to a "Called Upon" basis, under which the US will be required to make "effective use" of American storage to mitigate floods before calling on Canada. Called Upon Flood Control will allow Canada more flexibility to operate Canadian dams for Canadian interests. One proposed alternative operation is the so-called "Mid-Arrow" alternative, in which the fluctuations of the reservoir would be minimized to reduce the negative impacts on the various water use interests. Post-2024, the US will lose the right to assured Canadian storage. Only when flows at The Dalles exceed a certain threshold will the US be able to "call upon" Canada to provide storage. Canadian storage accounts for fifty percent of the total storage available on the mainstem Columbia. As a consequence of the switch to Called Upon, American reservoirs will be required to draft lower to make storage available for flood control. The burden of the problems associated with fluctuating reservoirs, as described above in the context of Arrow Lakes, could therefore shift to the US. In addition, because forecasts of precipitation and run-off volumes are uncertain, the reservoirs could run the risk of not re-filling to desired levels. The effects of lower than desired reservoirs could include, for example, reduced water supply for irrigation, reduced flows for summer fish life cycle needs, and reduced recreation opportunities (United States Entity 2012).

The imminent switch to Called Upon Flood Control operations in 2024 is prompting both Canada and the US to review the Treaty and to consider how it may need to be modified to account for impacts on ecosystem services going forward.

A number of aspects of the switch to Called Upon are points of contention in negotiations. First, the Treaty text calls for the US to use “all related storage” to provide flood control. Canada interprets this broadly as meaning all dams on both the mainstem Columbia and tributaries, while the US prefers the narrower interpretation that the clause refers to only the federal dams on the mainstem. The difference is important because a broader inclusion of dams would mean that Called Upon would be invoked less frequently and so the impacts on Canadian reservoirs would be less significant (i.e. vegetation likely could be re-established in a mid-Arrow alternative even if significant drawdowns occurred occasionally). Correspondingly, a broader interpretation means that the impact on American water use interests would be more widespread and significant. Second, the parties contest at which threshold of flows the US would be able to make requests for Called Upon. The US is calling for a 450 000 cubic feet per second threshold; Canada for a threshold of 600 000 cfs. A higher threshold would mean less requests for Called Upon and more effects on American dams than a lower threshold.

2.4.2 Inclusion of ecosystem-based function as a primary objective

The US has also taken the position that “[t]he health of the Columbia River ecosystem should be a shared benefit and cost of the United States and Canada” (United States Entity 2013b). While open to interpretation, this statement can be interpreted as the US suggesting that Canada should operate its dams so as to provide a timing, quantity, and quality of flows that maximizes the survival of fish and wildlife populations in the US as well as in Canada, and should consider the improved “health” of the ecosystem as a whole as compensation. Regarding ecosystems, BC states: “Ecosystem values are currently, and will continue to be, an important consideration in the planning and implementation of the Treaty. The Province will explore ecosystem based improvements recognizing that there are a number of available mechanisms inside and outside the Treaty.” (Government of British Columbia 2013a).

2.4.1 Potentially unbalanced Entitlement

The US is seeking to “re-balance” the Canadian Entitlement to reflect the actual, rather than potential, value of co-ordinated operations to hydropower generation. Multiple plans guide the use of the Canadian storage and the quantity and timing of flows released at Canadian dam and so determine the value of the Entitlement (Figure 3). The Entitlement is calculated six years in advance based on the precipitation and run-off and demand for electricity that the parties predict in the Assured Operating Plan (AOP). Changes in these predictions result in adjustments to the AOP, but do not result in changes to the value of the Canadian Entitlement. Changes in downstream operations also do not affect the value of the Entitlement. In essence, the Entitlement reflects the value of a predicted quantity of water going over the border at a certain time as if that water is used solely for generating hydroelectricity.

Figure 3. Operating plans that determine flows and value of Canadian Entitlement.



The Flood Control Operating Plan (FCOP), mostly recently revised in 1999, specifies an amount of storage at Kinbasket and Arrow lakes that must be evacuated over the winter. The Assured Operating Plan and Detailed Operating Plan, prepared six and one years in advance, respectively, set out operating rules aimed at maximizing hydropower benefits.

The actual value of incremental downstream hydropower benefits is likely less than the potential value because the US hydropower system operates under a number of self-imposed constraints. These constraints (e.g. flow targets) are aimed at increasing the populations of endangered anadromous fish in the US portion of the Basin. The US claims that actual value of coordination for hydropower is \$26 million 2013USD⁶ – a tenfold reduction from the current average payment. The BC Government, however, takes the position that any rebalancing of the Canadian Entitlement should reflect the

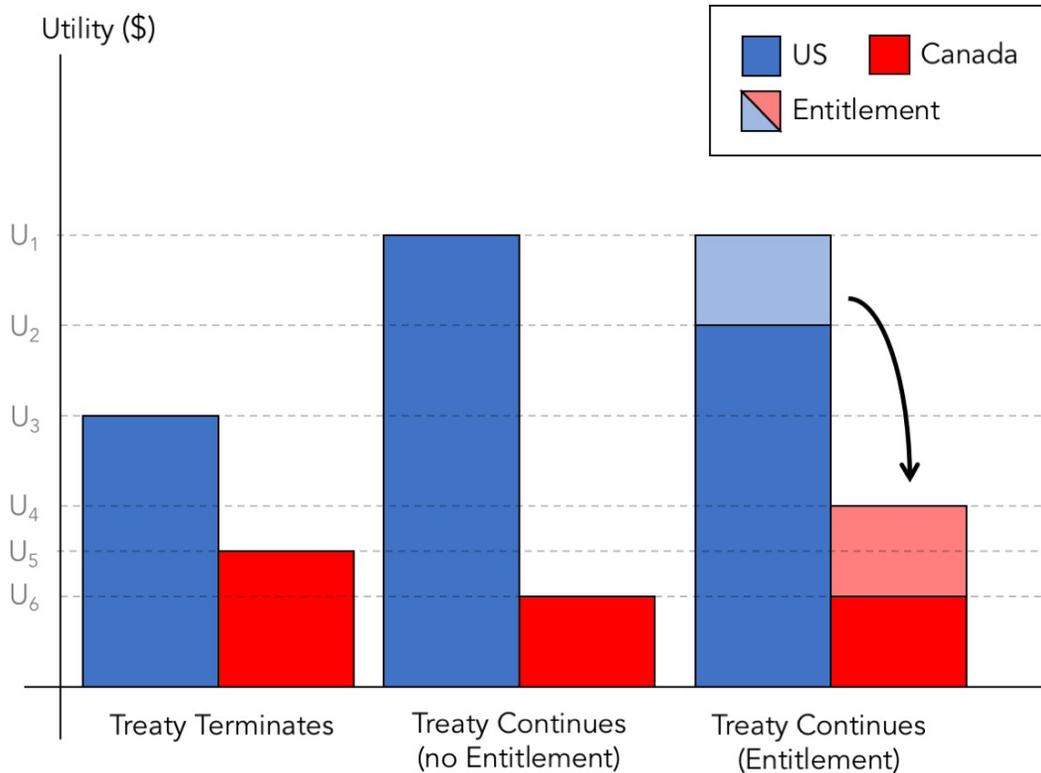
⁶ (United States Entity 2013b)

“full range of benefits in the United States [and] the impacts in British Columbia” (Government of British Columbia 2013a). Specifically, the Province has stated: “All downstream U.S. benefits, such as flood risk management, hydropower, ecosystems, water supply (including municipal, industrial and agricultural uses), recreation, navigation and any other relevant benefits, including associated risk reduction arising from coordinated operations compared to alternatives available to each country, should be accounted for and such value created should be shared equitably between the two countries” (Government of British Columbia 2013a).

2.5 Policy problem

Regardless of the outcome of the negotiations regarding Called Upon or the inclusion of ecosystem-based function as a goal of the Treaty, the upcoming negotiations represent an opportunity for Canada to correct a potential policy problem. Canada’s participation in the Treaty is an efficient use of Canadian water resources if and only if Canada maximizes the value of the payment it receives under the Treaty. Because the parties do not account for the value of ecosystem services in the payments made under the Treaty, Canada’s participation in the current Treaty is potentially an inefficient allocation of Canadian resources. A minimally efficient allocation would be one where the payment is at least equal to Canada’s lost economic value from negative changes in ecosystem services (i.e. Canadian opportunity costs). A maximally efficient allocation would be one where the annual payment was equal to the US’ maximum willingness to pay to receive the benefits of positive changes in ecosystem services. Figure 3 illustrates the nature of the policy problem.

Figure 3. Distribution of utility between the parties under termination and continuation of the Treaty.



This figure illustrates the nature of the policy problem. The blue bar indicates US utility; the red Canadian. If the Treaty were to terminate and Canada were to operate its dams so as to maximize its own benefits, the US and Canada would each receive a certain level of benefits – U_3 and U_5 , respectively. If the Treaty continues as is, the US receives more benefits from enhanced ecosystem services and so enjoys a higher level of utility (U_1). In order to provide these benefits, Canada incurs costs and so its utility falls to U_6 . After the exchange of payments under the Treaty, Canada's utility rises and the US' utility falls. In this figure, the payment is arbitrarily set at half the incremental gain in US benefits and so results in a rise in Canadian utility to U_4 . In order to maximize its net internal benefit and make the most efficient use of its water resources, Canada should seek to maximize the share of the incremental gain in US benefits that is captured by the payment. At minimum, the payment should compensate Canada for its opportunity costs ($U_5 - U_6$). At maximum, the payment could reflect the American's maximum willingness to pay to receive the benefits ($U_1 - U_3$).

2.6 Research questions

The purpose of this study is to recommend a mechanism by which the parties could price ecosystem services in a modern Treaty and so ensure that Canadian water resources are allocated to their highest value uses. To inform my analysis of the options, I use economic valuation methods to estimate the major costs to Canada and the major benefits to the US of the Treaty in terms of changes in ecosystem services. I also use a jurisdictional scan to identify the advantages, drawbacks, and applicability to the context of the Columbia River Treaty of pricing mechanisms in other payment for ecosystem services schemes around the world.

3 Methods

3.1 Economic valuation

The purpose of the economic valuation is to estimate the economic value of the benefits the US receives and the costs Canada incurs from changes in ecosystem services due to the presence or absence of Canadian co-ordination (i.e. the Treaty). The valuation proceeds as follows. First, I identify the alternative operational plans I compare and my understanding of the difference between these plans in terms of the physical state of the river ecosystem (e.g. flow timing and speed and reservoir elevation levels and fluctuations). Second, I discuss how these impacts could affect the provision (i.e. quantity or quality) of ecosystem services. Third, I identify the appropriate economic valuation technique that economists use to estimate the economic value of a given change in an ecosystem service. Where possible given the current publically-available data and the resources at my disposal, I assess the feasibility of quantifying changes in the provision of ecosystem services in terms of the resources that may be required for monitoring these changes and the scientific understanding that may be required for attributing these changes to the presence or absence of the Treaty going forward. Information comes from various academic articles, consultant reports, and government documents, including summaries of consultations with stakeholders in Canada and the US.

3.2 Cross-jurisdictional case studies

The jurisdictional scan or cross-jurisdictional case studies seek to illustrate the advantages and drawbacks of different pricing schemes. Cases were selected for inclusion in the study primarily so as to represent a range of different pricing mechanisms. Preference was given to cases sharing geographic, political, and socioeconomic characteristics with the Columbia River Basin. Certain cases from developing countries were also included to illustrate advantages or disadvantages of specific pricing mechanisms or to illustrate the effect of a specific aspect of policy design on efficiency.

To structure the analysis, the following aspects of each program were considered.

- **Pricing method.** How is the price paid for the change in ecosystem determined?
- **Administrative resources required.** Who administers or enforces the program? What (if anything) is monitored? What are the penalties for non-compliance?
- **Problem.** Why was the program implemented? What is the program's objective?
- **Sellers.** Who is selling? Is their participation voluntary?
- **Actions / products sold.** What are they selling?
- **Buyers / funding source.** Who is buying? Where is the money coming from? Is buyer's participation voluntary?
- **Service received (explicitly recognized).** The provision of what ecosystem service is understood to be affected by the program?

3.3 Expert interviews

Expert interviews were conducted with representatives from various organizations in the Canadian and Columbia River Basin. The primary purpose of these interviews was to inform the background, literature review, case studies, and analysis components of this study.

4 Economic valuation results

4.1 Defining a baseline

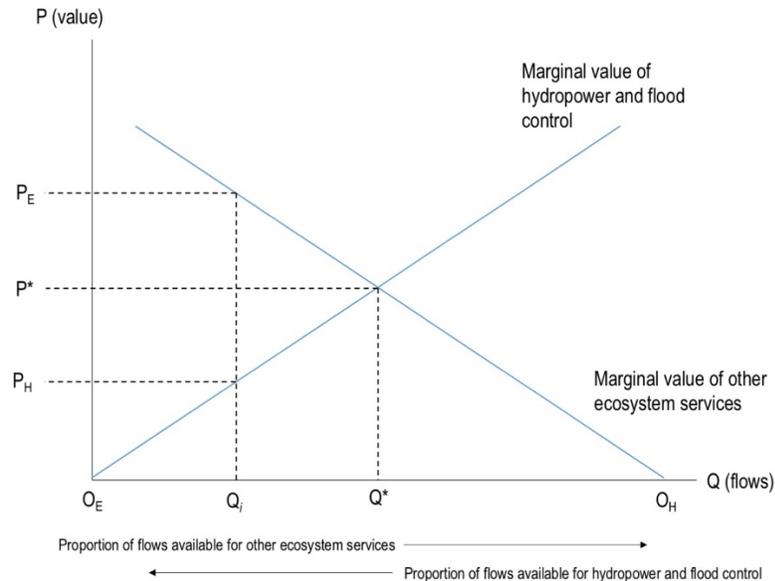
The building of the three Canadian dams and Libby resulted in many social and environment costs to Canada. Communities on the banks of the rivers were relocated, farmland was flooded, and local forestry and mining industries were disrupted (Government of British Columbia 2013b). Approximately 2300 people were displaced and 60 000 hectares of land were flooded (Davidson and Paisley 2009). The community of Golden has estimated that the cumulative impacts of the Treaty have caused \$115 million in damages: \$7.5 million in lost annual revenues due to damage to the local timber supply; \$50 million in lost waterfront recreation development; \$45 million lost due to depletion of wildlife resources, and \$13 million in loss of waterfowl resources (Davidson and Paisley 2009). Stakeholders in the region around the Kinbasket Reservoir have raised similar concerns during BC Hydro's recent consultations regarding the expansion of Mica Dam's power generation capacity (Davidson and Paisley 2009).

While significant, the parties cannot consider these sunk costs to Canada – nor the sunk cost of the already-made payments to the US – in determining the future payments that will be made under the Treaty going forward. Instead, the parties should determine the future payments based on the incremental benefits gained and decremental costs incurred as a result of the Treaty continuing relative to the benefits and costs that would exist if Canada were to terminate the Treaty and operate its dams so as to maximize its own benefits.

The parties should therefore compare two alternative operational plans: one in which the Treaty terminates and Canada maximizes its own benefits – a “Canada Max” plan, and one in which the Treaty continues and Canada maximizes the downstream US benefits – a “US Max”. Each plan will result in a different physical state of the ecosystem in the basin, both in Canada and in the US. Each plan will also therefore result in the ecosystem providing a different quantity or quality of goods and services to Canadians and Americans.

Determining the US and Canada Max operating plans can be understood as an optimization problem where the quantity to be optimized is the total economic value of US or Canadian benefits. The total economic value of benefits is the sum of the total economic value of the benefits received from each of the various ecosystem services (i.e. hydropower, flood control, agriculture, etc.). The value of the benefits received from each service is itself a function of a number of variables, two of which are the change in flow speed and timing across the border and the change in reservoir elevations. Optimizing for the maximum total economic value of US or Canadian benefits in a given year would then give the annual hydrograph that would represent the US or Canada Max operating plan. Economists define optimum allocation as an allocation between uses which equates the marginal value derived from an additional unit of the resource allocated to any given use.

Figure 4. Optimal allocation of water between two consumptive uses⁷.



This figure represents a simplified model of flow as a rivalrous good allocated between two uses: “hydropower and flood control” and “other ecosystem services” (e.g. fish, irrigation, recreation).

At an initial level of flow allocation Q_i , the proportion of flows allocated to use for other ecosystem services is $O_E Q_i$, while the proportion of flows allocated to hydropower and flood control is $O_H Q_i$. The system is out of equilibrium at this point.

Before any transfer of flows between uses occurs, the marginal value of flows for other ecosystem service use at P_E (a measure of the marginal social benefit) is higher than the marginal value of water for hydropower and flood control use at P_H (the marginal product of flows).

Gains would result from transferring flows up until the point where the “other ecosystem service” share increases to $O_E Q^*$. At this equilibrium, P^* is the marginal value of flows for both uses, and the optimal allocation of water resource has been achieved between hydropower and flood control and other ecosystem service uses.

If the reallocation goes beyond Q^* , overall returns to society would begin to diminish. The additional other ecosystem service benefit (while still positive) would be less than the benefits if that water had been used for hydropower and flood control.

In practice, the shape of the marginal “other ecosystem service” value curve is not known with certainty. This increases the risk of reallocating either too few or too many flows to the other ecosystem services (relative to the efficient allocation).

While it is a pressing issue, the purpose of this study is not to recommend policies or institutions that would result in a more socially efficient allocation of the water resources in the Columbia River Basin among the various uses. Previous studies have examined this problem in depth and have recommended varying approaches including setting up a transboundary water use planning institution, adding ecosystem-based function as a third primary purpose of the Treaty, and adopting principles of integrated water resource management (Sihota 2015; Kruger 2014). Each of these policies are aimed at increasing the total level of utility in the basin. The purpose of the present study is to recommend policies aimed at maximizing the value that Canada receives for the use of the resources over which it has a sovereign right. In other words, the purpose of this study is to not to figure out how to increase the size of the pie of incremental economic value in the basin, it is to figure out how to ensure that Canada maximizes its share of whatever pie exists.

The above discussion on efficiency does, however, bear on the problem at hand. Ideally, the incremental economic value would be estimated by exploring the difference between Canada Max and US Max. However, these operating plans do not currently exist. This study therefore uses two proxies for these alternatives that the Entities have already established: *Treaty Terminates* and *Treaty Continues under Pre-2024 Conditions*.

Canadian and US Entities developed these plans as part of the Phase 1 Study, which was a joint study conducted to explore, among other things, the potential effects of terminating the Treaty on hydropower generation. The Entities developed *Treaty Terminates* under the assumption that without the Treaty, Canada would operate its Treaty Dams with the objectives of minimizing flood damage to existing communities in Canada and maximizing the net revenue from hydropower generation in Canada. *Treaty Continues under Pre-2024 Conditions* was developed using the current operating objectives of minimizing flood damage to communities in both Canada and the US and maximizing the net revenue from hydropower generation in the US. Because these plans exclude other ecosystem services as objectives, *Treaty Terminates* does not necessarily

⁷ Adapted from (Productivity Commission 2010)

maximize the net social benefit to Canada and *Treaty Continues under pre-2024 Conditions* does not necessarily maximize the net social benefit to the US.

Understanding these caveats, we can begin to explore the effects that the Treaty will have on ecosystem services going forward in both the US and Canada receives due to Canada's participation in the Treaty by considering the two different states of the ecosystems in which these two plans will result.

Treaty Continues under pre-2024 conditions (Treaty Continues). If the Treaty were to continue under its current provisions, the river system would look much like it does today. On the Canadian side, Arrow Lakes' elevation would continue to fluctuate significantly to provide flood control for the US. Canada would also time cross-border releases to maximize hydropower generation in the US. On the US side, US storage reservoirs would have the ability to maintain more stable elevations because the US would not need to empty them for flood control purposes. The timing and quantity of cross-border releases would enable the US to regulate flow velocities in such a way as to maximize either hydropower generation or fish migration.

Treaty Terminates. If the Treaty were to terminate, the river system could look very different. Canada would likely choose to operate its dams differently, and reduce the level of fluctuation that Arrow Lakes currently undergoes. Flow releases timing would likely be timed to benefit only Canadian fish and hydropower. The US would likely lose the certainty of Canadian operations and would have to provide its own flood control. Consequently, reservoir elevations in the US would likely undergo a greater range of fluctuation.

Ultimately, the outcome of the Treaty has two broad categories of physical effects: changes in flow timing and velocity, and changes in reservoir elevations and stability. Ideally, an analysis of changes in ecosystem services would begin with two well-defined scenarios and robust data on these two physical effects. For example, it would be ideal to be able to say that Treaty Terminates will result in a 23 per cent reduction in flow velocities during the critical downstream migration period of sockeye relative to Treaty Continues, which causes an 18 per cent decline in sockeye populations

due to increased predation. It would also be ideal to be able to say that Treaty Terminates will result in an annual 45-foot variation in the elevation of a given US storage dam, whereas under Treaty Continues the same dam would only experience a 5-foot variation in elevation. However, such detailed analysis of the hydrological operations under the two scenarios is beyond the resources and/or available data of the present study⁸. Lacking such resources and/or data, the following economic valuation makes a number of assumptions about the physical effects of the two alternatives. Those assumptions differ depending on the ecosystem service in question and so I discuss them in their appropriate context.

4.2 Framework

Table 2 in Chapter 2 (replicated here) lists the nine categories of ecosystem services that I have identified as at stake in the Treaty negotiations. The economic valuation proceeds first with the US services and then with the Canadian services. The aim of the valuation is to replace the initial estimates of positive, negative, insignificant, or mixed with a dollar value where possible. Where monetization is not possible, or only possible with significant assumptions, the analysis identifies the gaps in data or understanding that the parties will need to fill to refine these estimates.

Table 2. Changes in value of ecosystem services from the Treaty.

	US	Canada
Flood prevention	Positive	Insignificant
Hydropower generation	Positive	Negative
Fish abundance	Positive	Negative
Agricultural productivity	Positive	Insignificant
Recreation opportunities and tourism revenues	Positive	Negative
Navigation revenues	Positive	Negative
Air quality	Positive	Negative
Water quality	Positive	Insignificant
Others	Mixed	Mixed

⁸ I discuss recommendations to overcome this limitation in Chapter 10 of this report.

4.3 US benefits

4.3.1 Flood prevention

In its white paper *U.S. Benefits from the Columbia River Treaty*, the Government of BC writes: “[...] recent estimates by USACE estimate that, on average, annual flood damages avoided on the U.S. Columbia system are approximately \$100-200 million. Given that Canadian storage accounts for approximately 50% of total active storage on the system it can be estimated that the operation of Treaty projects provides approximately **\$75 million per year** in avoided flood damages (Government of British Columbia 2013b)”.

4.3.2 Hydropower generation

Assuming that the Canadian Entitlement represents half of the downstream power benefits, the incremental hydropower generation enabled by the Treaty is approximately **\$418 million per year** (double the average annual value of the Entitlement (“Columbia River Treaty Review Website FAQs” 2015)). As a lower bound estimate of incremental hydropower generation benefits, one could use the U.S. Entities’ estimate of **\$26 million per year** (United States Entity 2013a).

4.3.3 Fish abundance

Operations-abundance relationship

The Treaty’s effect on fish abundance in the US is complex. The first layer of complexity is that the basin’s rivers and streams support a variety of anadromous and

resident fish species (Pacific Northwest National Laboratory Ecology Group 2010). Thirteen anadromous stocks – groups of salmon or steelhead that breed at the same time and place – and two resident species have been listed under the US Endangered Species Act (ESA) since the early 1990s (Harrison 2011). These species and their spawning grounds are shown in Figure 4. The Basin also supports several non-endangered species of both resident and anadromous fish whose survival could be affected by changes in river operations.

Figure 4. Map of spawning grounds of endangered fish in the Basin.



If Canada is to claim that co-ordination generates a valuable benefit in terms of increased fish populations for the United States, it must establish a relationship between changes in hydropower operations (i.e. in-stream flow speeds and timing and reservoir levels and stability) and changes in fish population survival. Even considering only

anadromous fish (i.e. excluding resident fish), there are multiple mechanisms through which hydropower operations affect abundance. These include (National Research Council (U.S.) 2004):

- high reservoir levels inundating the shallow, rocky, fast-moving streams where salmon spawn;
- large variation in daily maximum and minimum flows stranding and dewatering eggs and juveniles
- low volume, velocity, and poor timing of flows that carry juvenile fish to the ocean, and;
- raising the temperature of water beyond survivable thresholds.

Despite the complexity, there has been a large scientific effort in the last few decades to attempt to understand the relationship between hydro-system operations and anadromous fish survival (Anderson 2001). Today, the scientific consensus is that there is at least a demonstrable relationship between flow velocity and survival of anadromous fish. Researchers have developed several models to predict the effects of other effects of alternative hydropower operations on salmon survival rates. These models are the COMPASS Comprehensive Passage Model, developed by the NOAA, and the Comparative Survival Study (CSS), developed by the Fish Passage Centre⁹.

While it is beyond the scope of this analysis to evaluate the accuracy of these models' predictions; it is important to point out some limitations of these models. One major limitation of operations-survival models is that there are many factors of the salmon decline which hydropower operations do not control (i.e. variables that could confound a posited relationship). These include (NOAA Fisheries 2014):

- habitat loss from to changes in river accessibility, levels, and flows due to other dams and agricultural infrastructure,
- habitat degradation from soil erosion and pollution due to forestry and industry
- increased predation due to slower passage of juveniles during downstream migration (e.g. from cormorants and sea lions)

⁹ "The Fish Passage Center provides technical assistance and information to fish and wildlife agencies and tribes, in particular, and the public in general, on matters related to juvenile and adult salmon and steelhead passage through the mainstem hydrosystem in the Columbia River Basin." ("Fish Passage Center Homepage" 2016)

- over-fishing (both recreationally and commercially, at ocean and in river)
- loss of genetic diversity due to hatchery operations, and
- warming waters due to natural and human-caused changes in ocean currents and climates.

A second limitation is different fish species respond differently to the same change in operations. The COMPASS model predicts that the same change in operations will cause increased survival in Snake River spring/summer Chinook but decreased survival in Snake River steelhead (Zabel et al. 2008).

Five percent scenario

As a result of these uncertainties, rather than attempting to predict the actual change in fish abundance that might result if the Treaty were terminated, I posit a scenario in which the difference between Treaty Terminates and Treaty Continues results in an arbitrary percentage change in fish abundance. For the purposes of illustration, I arbitrarily posit that terminating the Treaty will result in a 5 percent decline in all anadromous fish stocks in the US portion of the Columbia. The mechanism is that without the Treaty, Canada will operate its dams in such a way that will result in a flow speeds and timing that is some percentage less than optimum for fish survival, and that sub-optimal flow pattern will result in a 5 percent decline of the current population level. The goal of the economic valuation is then to estimate the value of this 5 percent decline in fish population.

Economic value of anadromous fish

Fish provide multiple services to humans, each of which has an economic value. If the incremental number of fish surviving due to co-ordinated Canadian operations relative to a given baseline could be determined, the question becomes: what is the value of an incremental fish? An incremental fish can be said to have the following values¹⁰:

¹⁰ Once numbering over 16 million¹⁰, the anadromous fish of the Basin are in decline (Bottom et al. 2005). Current research suggests that the Basin currently sees the return of 2.8 million salmon annually (Independent Economic Analysis Board 2005b) – the majority of which are hatchery-reared¹⁰ (National Research Council (U.S.) 2004). Described as “electrons in the currents” that

1. Non-use value¹¹

Many people are willing to pay simply for the continued existence of fish in a region (or a particular type of fish in a particular region). This is known as a passive use or passive use value. The passive use value of fish can be measured through contingent valuation surveys, in which people are asked directly what they would be willing to pay to maintain or increase a given number of fish.

A number of studies have estimated the non-use value of salmon in the Pacific Northwest. Based on surveys and other information regarding the potential increase of salmon in the Lower Snake River, Loomis (1999) developed a marginal WTP benefit function that estimates the marginal value of fish based on the size of the underlying population. Loomis (1999) demonstrates that fish have a declining marginal value (i.e. society's WTP for an additional fish when the total population is 1000 is far greater than when the total population is 1 million). Helvoigt and Charlton (2009) used Loomis' WTP function to estimate that Northwest residents (the 46 million people living in California, Oregon, and Washington) are willing to pay an average of 1800 2007USD annually per salmon. Assuming an average annual population of 830 000 salmon, they estimate the total annual use value of the entire Rogue River salmon to be just over 1.5 billion 2007USD.

Using an average value of salmon of 576 2007USD at a population level of 1.5 million, a back-of-the-envelope calculation suggests that the 2.8 million salmon in the Columbia River Basin are associated with a passive use value of 1.6 billion 2007USD. Assuming that, in the absence of the Treaty, fish populations fall by 140 000 fish, and that each fish is associated with a passive use value of \$576 (2007US), the value of the

sustain life in the Pacific Northwest (Sandford, Harford, and O'Riordan 2014), anadromous fish embody the flow of nutrients from the ocean to the continent and are keystone species that support a diversity of plant and animal life in the region. Salmon in particular have been celebrated by the region's indigenous populations as a symbol of wealth and prosperity as well as one of dependability and renewal ("BC Aboriginal Legends and Symbology" 2015).

¹¹ Passive use value is sometimes described as non-use or non-consumptive use.

Treaty in terms of passive use values from anadromous fish is \$81 million (2007US) or \$93 million (2016US).

Helvoigt and Charlton (2009) point out that their estimate likely represents a lower bound because society's marginal WTP for benefits to a specific stock of salmon are likely larger than for the general salmon population as a whole. They also point out that Loomis's estimate was also based on estimates of WTP for increases in salmon species that were not endangered, meaning that the actual WTP for the 13 endangered species in the Columbia River are likely much higher. Another consideration is that the Pacific Northwest is not a homogenous population, and so WTP may range between groups. Indigenous groups in particular are likely to have a high WTP relative to their income. Furthermore, because WTP is bounded by income, estimates of the economic value of salmon that take a WTA changes in populations approach may be even higher.

2. Commercial fisheries

Fish are also valued by commercial fishing industries both in the CRB and in other jurisdictions where fish produced in the CRB are caught (i.e. BC, Alaska, and California). The value of incremental commercially-caught fish can be estimated by the change in productivity method, where changes in revenues from the fishing industry net of operating costs are estimated with and without co-ordination.

Personal income generated by anadromous salmonid production from commercial fisheries in the Pacific Northwest is estimated to be \$109 million (2005US) annually (Independent Economic Analysis Board 2005a). Assuming (1) a constant marginal value of production and (2) that 5% of this production can be attributed to Treaty operations, the value of the Treaty to commercial fisheries is \$5.45 million (2005US), or \$6.65 million (2016US).

Huppert et al. (2004) suggest that "harvests of Pacific salmon from the Columbia River or ocean areas will make smaller contributions to the value of seafood supply and to local incomes in the future". While relatively small compared to the total income of the region – \$400 billion (2005US) (Independent Economic Analysis Board 2005a) – there

would likely be distributional impacts of changes in commercial fish landings as some communities in the region have close ties to the fishing industry.

3. “Reduced risk of liability” value

Another component of the economic value of endangered anadromous fish is the US Federal Government’s willingness to pay to avoid the costs of litigation that could be brought against the US government by indigenous groups if the salmon were to go extinct. In the 1850s, several indigenous tribes in the Pacific Northwest ceded land to the US Federal Government in exchange for provisions to protect their fishing rights. Some estimates of the liability to the US are in the range of 10 billion 1999USD (“Salmon Extinction Could Cost Billions | Taxpayers for Common Sense” 2016), based on the market value of the land received by the US or the economic value of the fish lost to Tribes.

The costs of liability would also include the sunk costs of money already invested in salmon recovery. The BC Government claims that “BPA alone spends approximately \$700 million 2013USD annually on fish and wildlife enhancements in the Basin...\$180 million [of which] was a result of power losses by reregulating of power flows for fish” (Government of British Columbia 2013b). Landry (2003) suggests that federal spending¹² on fish recovery efforts is around \$575.5 million 2003USD per year. A report commissioned by Washington State estimates that spending on salmon recovery efforts aimed at habitat-restoration alone (i.e. excluding spending on hatchery and harvesting improvements) totaled 2.927 billion 2011USD for the period of 2010-2019, an annual average of \$322 million 2011 USD.

¹² Landry’s estimate is for \$2.8785 billion for 1998-2002 and considers spending between BPA, the Army Corps of Engineers, Department of the Interior, Department of Commerce, the Department of Agriculture, and the Environmental Protection Agency.

4.3.4 Agricultural productivity

Irrigation for agriculture is the dominant non-power use of water in the Basin, accounting for approximately 93 per cent of surface water diversion in the Basin in 1997 (0.1 Maf per day) (National Research Council (U.S.) 2004). The economic value of irrigated crop production from the Columbia Basin Project alone is estimated at \$1.44 billion 2008USD annually. Demand for water from irrigation peaks in the late summer months when drought can reduce the available flows.

Incremental water supply in low flow years due to Canadian operations would have a value as an input to agriculture. If Canadian dam operations result in incremental water being available for surface water diversion to irrigated agriculture, and incremental water being available results in increased agricultural productivity, then the economic value of Canadian participation is the change in net revenues from the change in agricultural productivity.

Huppert et al. (2004) reviewed the potential economic effects of increases in agricultural water supply due to Washington State granting additional withdrawal permits to farmers along the Columbia River. They use a multi-step method to determine the change in net revenues from agricultural productivity that could be modified to suit the context of the Columbia River Treaty.as follows:

- Determine exactly how much less water will be available for consumptive withdrawals for irrigated agriculture under Treaty Terminates relative to Treaty Continues (one would also need to know if this change in water availability will occur only in drought years or each year)
- Estimate which farms or counties would maintain their current levels of water withdrawals and which would reduce their use
- Determine how changes in water rights would affect crop distribution and quantities

- Determine the difference in net revenue from a given crop distribution and quantity under Treaty Continues vs Treaty Terminates

As this type of analysis is beyond the scope of this study, I assume for the sake of illustrative example that the Columbia River Treaty results in a 1 MAF increase in water supply for agricultural production. Huppert et al. estimate that such an increase would result in an increase of between \$11.5 and \$43.7 million (2004US), or \$14.5 and \$55.09 (2016US) in net revenues to agriculture production. I adopt this estimate as the potential loss of net revenues that would occur under Treaty Terminates.

4.3.5 Recreation opportunities and tourism revenues

The ecosystems of the Columbia River support several types recreation including recreational angling for resident and anadromous fish, boating activities such as windsurfing, canoeing, kayaking, and power boating, camping and hiking trips. These recreational opportunities can also create significant local economic impacts for nearby communities.

To determine the economic value of recreation, economists typically employ either the travel cost method, which measures actual out-of-pocket expenditures of recreators, or the contingent valuation method, which measures the theoretical maximum willingness to pay of recreators to engage in recreation (i.e. the travel cost + the “consumer surplus”).

The travel cost method recognizes that individuals produce recreational experiences using a number of input factors, including the area itself, travel to and from the area, lodging in the area, and other factors. Because travel and recreation in a given area are complementary goods (i.e. demand for recreation decreases as the price of travel increases), the value of the recreational area can be measured with reference to values expressed in the market for trips to the recreational area (Pearce, Atkinson, and Mourato 2006).

For example, a 2013 study of spending and economic activity in the Columbia River Gorge Management Unit, a division of the Oregon State Park system, found that “the average trip spending of visitors ranges from about \$40 per party per trip for local residents on day trips to nearly \$226 per party per trip for non-local residents on overnight trips away from home...[in total,] the reported 3.5 million visits annually to Oregon State Parks properties in the Columbia River Gorge Management Unit yield about \$50 million in visitor spending in local communities” (White and Goodding 2013).

TCW Economics have estimated the economic value of recreational angling opportunities alone (excluding camping, boating, etc.) related to salmon and steelhead in Washington State at \$181 million 2006US (TCW Economics 2008).

To determine the economic value of recreation that is at stake in the Treaty negotiations using the travel cost method, one would need to relate the physical changes in the reservoir and river to changes in “days spent recreating” or a similar metric.

Regarding recreational angling alone, the Treaty may affect days spent recreating for angling purposes in two different ways. First, sub-optimal flow patterns under Treaty Terminates could result in lower populations. Sub-optimal reservoir level fluctuations could also result in lower populations, via reduced access to spawning streams, increased temperatures, and other factors. Lower populations of fish are likely to decrease the availability of recreational opportunities and so decrease the number of trips taken. Recreational angling in some regions is also dependent on access to boat ramps and launches. Increased fluctuations of reservoir elevations could therefore impair access to reservoirs and so reduce the availability of recreational angling opportunities and decrease the number of trips taken.

A detailed analysis of the economic value of recreational angling is beyond the scope of this analysis. However, in a scenario in which Treaty Terminates results in a 5 per cent decline in recreational activity, a lower bound estimate of the lost economic value is 5 per cent of the \$50 million 2006US in spending in the Columbia River Gorge Management Unit alone, or \$2.5 million 2006US. This number would likely increase if more recreation areas were included and if the contingent valuation method were used to

estimate the maximum willingness to pay of recreators. For example, in a scenario in which Treaty Terminates results in 5 per cent decline in recreational angling, and assuming that Washington State (which includes coastal and other rivers in addition to the Columbia) is a proxy for the total Columbia River basin, and that salmon and steelhead recreational angling is the only activity affected, another estimate of the lost economic value is 5 per cent of \$181 million 2006US in economic value of recreational angling, or \$9 million 2006US, or \$10 million 2016US.

Both these estimates are likely lower than the actual value, as other recreation activities may be adversely affected by decreases in stable riparian area and associated decreases in air quality, aesthetics, and wildlife populations. In addition, these estimates do not take in account local economic impacts in terms of employment and multiplier effects.

4.3.6 Navigation, air quality, water quality, and others

The Treaty may also have effects on the benefits the US receives from navigation, air quality, water quality, and other ecosystem services (such as wildlife populations that are dependent on stable riparian areas, and protection of cultural or religious sites). Due to resource limitations and their likely insignificant relative to the values discussed above, I do not explore these values in this study. However, it is likely that their value is greater than zero, and I indicate so in the summary table.

4.4 Canadian costs

What are the Canadian costs of participating in the Columbia River Treaty? I explore this question first by reviewing BC Hydro's estimates of the effects that various alternative operating plans will have on various ecosystem services. I then explore the potential economic values of the differences in this "performance measures" and identify gaps in the available data or scientific understanding.

4.4.1 Flood prevention

Under either Treaty Terminates or Treaty Continues, Canada will continue to control flooding in Canadian communities. There will therefore be no change in the economic value of flood control.

4.4.2 Hydropower generation

If the Treaty were to terminate, BC Hydro estimates that Canada could produce an additional \$22 million (2013CA) in hydropower benefits (BC Hydro 2013).

4.4.3 Fish

BC Hydro estimates that, relative to the Treaty Continues operating plan, a Treaty Terminates operating plan would have the following results on fish-related performance measurements:

- 65 more days of residence time¹³ in the Kinbasket Reservoir.
- 0.07 more kilometres of white sturgeon larval habitat availability (i.e. length of river not inundated by backwater of Arrow reservoir) in the Mid-Columbia.
- 13 more kilometres of functional large river habitat in the Mid-Columbia
- 22 more days of elevations greater than 1430 feet (i.e. days that water levels enable kokanee to access spawning tributaries) in the Arrow Lakes Reservoir
- 12 less days of epilimnetic residence time in the Arrow Lakes Reservoir

¹³ Higher residence times are more supportive of fish populations. The mechanism is that the longer water remains in a reservoir, the more nutrients (e.g. phosphorous) it retains, the more microscopic life the reservoir supports, the more fish life the reservoir supports.

- 0.63 higher score on a whitefish / trout index in the Lower Columbia

These data indicate that terminating the Treaty will have a generally positive impact on fish populations in the Canadian basin. BC Hydro does not indicate how these impacts may map to changes in fish populations. As the section on US benefits illustrates, the passive use value that Canadians assign to whitefish, sturgeon, and other fish species is likely significant. Further studies that estimate the impact on fish populations in terms of change in number of fish are therefore necessary to accurately estimate the economic value of the Treaty in terms of gained fish abundance.

To illustrate the likely order of magnitude of potential values, I provide two estimates based on current spending by Canadian agencies on fish and wildlife restoration efforts in the Canadian basin. These estimates are likely upper bound estimates, as they may reflect the annual righting of historic wrongs rather than the actual incremental values at stake between Treaty Terminates and Treaty Continues.

First, spending by the Columbia Basin Trust, a Crown corporation governed by residents with a mandate to “support efforts to create social, economic, and environmental well-being” in the Basin, can be used as an upper bound estimate of the value of fish at stake in the Canadian CRB. In recent years, spending by the CBT, which includes a variety of environmental projects, totalled around \$22 million 2014CAD (“CBT Annual Report” 2015). Second, the Columbia Region branch of BC Hydro’s Fish and Wildlife Compensation Program (FWCP), a partnership between the Province, Fisheries and Oceans Canada, First Nations, and public stakeholders, also provides grants for fish and wildlife projects in the Basin. The FWCP approved \$5.6 million 2015CAD for 53 fish and wildlife projects in 2015 and 2016. I include these values as illustrative examples of the potential order of magnitude of the economic value of fish.

4.4.4 Agriculture

Some experts estimate that terminating the Treaty could result in an additional 5000 to 7000 hectares of land available for agriculture (Jon O’Riordan 2016). This additional agricultural land would have two types of economic value.

First, there would a value associated with the increase in net revenues of the agricultural industry from the incremental production. A report by the Vancouver Island Coast Regional Agriculture Framework for Action indicates that average per hectare gross revenues for land in BC’s Agricultural Land Reserve vary from \$1106 (2012CA) per hectare in the Vancouver Island Coast region to \$12 550 (2012CA) in the Fraser Valley. The study also estimates that the average gross margin for agriculture on Vancouver Island is approximately 6.2 percent¹⁴. Assuming that the average per hectare gross revenues for the new agricultural land will be \$1106 and that the average gross margins will be 6.2 per cent, 7000 hectares of agricultural land would generate \$69 per hectare or \$480 000 in total incremental net revenues.

Second, there would be a value associated with the various non-market ecosystem services that farmland provides. These include cultural values associated with viewing and living near agricultural lands and the pollination and dispersal functions of agricultural land. Some studies estimate the economic value of these non-market ecosystem services of agricultural land at approximately \$183 (2009CA) per hectare (Austin and Bagstad 2009). An estimate of the non-market economic value of agricultural land is therefore \$1.3 million (2009CA).

Together, these estimates suggest that Canada could gain between \$1.2 and \$1.8 million in economic value from agriculture by terminating the Treaty.

¹⁴ Gross margins range from 8.5 per cent to negative 17.3 per cent.

4.4.5 Recreation

One source of gains in ecosystem services to Canada without the Treaty are those associated with minimized fluctuations of Arrow Dam (Thomson 2013). These include recreation and tourism benefits from increased boat and shore access. Community members have also noted that sudden changes in river flow can adversely affect recreation on the Lower Columbia.

According to the BC Hydro Technical Studies, terminating the Treaty would have the following impacts on recreation relative to Treaty Continues (BC Hydro 2013):

- 3 fewer days that the Kinbasket Reservoir would be in the preferred elevation range for canoeing
- 1 fewer day that the Kinbasket Reservoir would be in the preferred elevation range for water-based activity
- 90 more days that the Mid-Columbia River would be in the preferred range for boat access
- 119 fewer days that the Mid-Columbia River would be in the preferred range for shore access
- 100 more days that the Arrow Lakes Reservoir would be in the preferred range for general recreation
- 16 fewer days that the Lower Columbia River would be in the preferred range for boat access
- 18 more days that the Lower Columbia River would be in the preferred range for shoreline access

These data indicate that there would generally be a positive impact on recreation in the Canadian Columbia River Basin, but also that there is a trade-off between shore and boat access with recreation.

As indicated in the section on US benefits, the primary methods to estimate the economic value of recreation are the travel cost method and the contingent valuation method. Using the travel cost method, one would need to know how many fewer trips take place as a result of the reservoir being out of the “preferred range” for recreation. One could then use an estimate of a per-day expenditures to calculate the total value of recreation.

However, results from a BC Hydro-commissioned study on the effect of fluctuating reservoir levels on Arrow Lakes indicates that:

“frequency, volume and different types of public use of Arrow Lakes Reservoir are not substantively influenced by fluctuating water levels, suggesting factors other than water levels (i.e., total precipitation, maximum daily temperature, type of day and season) dominate people's decision to visit the Arrow Lakes for recreation activities. Where water levels do account for a variation in use, a minority of visitors are affected. (LEES+Associates 2015)”

This finding suggests that it is unlikely that there is substantial economic value at stake in terms of recreation between Treaty Terminates and Treaty Continues.

4.4.6 Navigation

The Technical Studies indicate that terminating the Treaty could result in the following impacts on navigation in the Canadian Columbia River Basin (BC Hydro 2013):

- 14 more days of access to the Downie Timber site on Kinbasket Reservoir
- 8 fewer days that Celgar is able to transport logs through the narrows of Arrow reservoir

The economic value of these impacts could be estimated using change of productivity methods (i.e. by determining how much more net revenue would accrue to

the forestry industry). However, the difference is likely insignificant and does not warrant further study.

4.4.7 Air quality

Reduced air quality due to dust generated by mudbanks created by fluctuating reservoir levels is another adverse impact of the Treaty in Canada that would be reduced under Treaty Terminates. The Technical Studies indicate that there would be 41 fewer days that Arrow elevation would be below 1410 feet, where dust generation potential is greatest.

Economists typically estimate the economic value of an increase in air quality via either the hedonic pricing method, in which preferences for air quality are revealed through examining how the price of a market good changes with changes in air quality (holding other factors constant), or a contingent valuation method, in which a population is asked to state their preference (i.e. their willingness to pay) for a given change in air quality.

Assuming that dust generation could be eliminated under Treaty Terminates, the economic value of this change can be determined by estimating resident's willingness to pay for such an improvement to air quality. Such a study requires two pieces of information: (1) the exact difference in air quality between two scenarios (i.e. how dust generation potential changes with marginal changes in elevation) and (2) how much residents would be willing to pay to receive that change in air quality. For example, a study of residents of Sofia, Bulgaria found that residents are willing to pay 4.2 percent of their income for a program to improve air quality.

Without a primary data collection study, it is impossible to determine these values. However, in a scenario in which residents are willing to pay just 0.05 percent of their annual income for improvements to air quality, one could use the number of residents in the Arrow Lakes region and their annual income to approximate an order-of-magnitude estimate of the economic value of increases in air quality. The population of

the Central Kootenay Regional District (an area including the Arrow Lakes) over 18 is 45 190. The average annual income of people over 15 in the area is \$48 490 (2011CA). If each resident was willing to pay a \$24 annual fee for air quality, the total willingness to pay for air quality improvements would be approximately \$1 million. This estimate is likely a reasonable lower bound.

4.4.8 Water quality and other ecosystem services

There are few withdrawals for consumptive municipal or industrial use in the Canadian Columbia River Basin (Columbia River Treaty Local Governments' Committee, n.d.).

However, another potential significant source of economic value are the ecosystem service values associated with the stable riparian habitat that might be re-established under Treaty Terminates. Riparian areas provide several ecosystem services including habitat for wildlife including birds and small mammals and for unique plant species. As illustrated by the section on US benefits above, passive use values for wildlife abundance can be significant. This fact warrants further studies that quantify the difference between Treaty Terminates and Treaty Continues in terms of impacts on wildlife populations.

Riparian zones also have value in terms of carbon sequestration: a study of the carbon sequestration potential of riparian forests in the L'Ormiere River watershed in Quebec estimates that one hectare of riparian forest can sequester an average of 23 tonnes of carbon dioxide equivalent over a 25-year period. BC Hydro states that the difference between full and low pool at the Arrow Lakes Reservoir is 2000 hectares. Assuming that all of this zone becomes riparian forest, and at a social cost of carbon of \$36 per tonne of CO_{2e} (US EPA 2016), the value of sequestered carbon by a re-established riparian zone is approximately \$1.6 million (2015US).

4.5 Climate change: driving increases in value of ecosystem services

The projected effects of climate change will likely result in significant increases in the values of ecosystem services as discussed here. The delicate balance of water use in the Columbia River Basin has developed based on a predictable, historic range of variation in precipitation, temperature, and run-off. The loss of this hydrological stationarity, one of the expected impacts of climate change, will manifest in an increase in unexpected extreme flood and drought events¹⁵. Current trends of increasing precipitation in winter and decreasing precipitation in summer are expected to continue¹⁶, as. Temperature rises, projected at 2.4 to 3.2°C, are predicted to reduce the amount of precipitation that falls and is stored as snow¹⁷. While cold winter temperatures and the presence of glaciers are expected to buffer the loss of Canadian snowpack for a time, US snowpack is expected to decline more rapidly¹⁸ such that Canada will have an increasingly dominant portion of the natural water storage in the near future. Accordingly, peak flows in many parts of the US basin are expected to shift from spring and summer to late winter¹⁹. Ultimately, glaciers in the BC are expected to all but disappear by 2050²⁰, eliminating the source of about 25 to 35 percent of Canadian discharge in August and September²¹. Hotter, drier summers – and consequent longer growing seasons and increased demand for cooling – will exacerbate tensions between irrigation for agriculture, environmental flows for fish and ecosystems, and flows for hydropower production in the region.

¹⁵ (Murdock, Fraser, and Pearce 2007); (Osborn 2012)

¹⁶ (Murdock, Fraser, and Pearce 2007)

¹⁷ (Murdock, Fraser, and Pearce 2007); (Hamlet et al. 2013).

¹⁸ (Hamlet et al. 2013),

¹⁹ (Hamlet et al. 2013)

²⁰ (Clarke et al. 2015),

²¹ (Jost et al. 2012).

4.6 Summary

Table 3. Summary of costs and benefits of the Treaty.

Ecosystem service	Economic value (millions of \$)	
	US (USD)	Canada (CAD)
Hydropower	26 - 428	(22)
Flood control	75	-
Fish	99.65	(5.6 - 26)
Agriculture	14.5 – 55.09	(> 1.2 – 1.8)
Recreation	10	-
Navigation	> 0	-
Air quality	> 0	(1)
Water quality	> 0	-
Other ecosystem services	> 0	(1.6)
Annual net benefit from ES	225 – 667 USD	(31 – 52) CAD
		(24 – 41) USD

- The major benefits to the US of the Treaty in terms of ecosystem services are flood control, hydropower generation, fish populations, agricultural productivity, and recreation.
- The US benefits from the continuation of the Treaty relative to the termination of the Treaty have an economic value of approximately \$225 to \$667 million (2016US) annually. This estimate likely reflects a lower bound of the total benefits.
- The major Canadian costs of the Treaty are foregone hydropower generation and lost fish populations. Agricultural productivity, air quality, and wildlife populations are relatively smaller values.
- The costs to Canada of participating in the Treaty have an economic value of approximately \$24 to \$41 million (2016US).

- Passive use values of anadromous fish and wildlife are an often over-looked source of economic value and should factor into negotiations.
- Climate change is likely to decrease the supply of water in the American basin and so increase the value of Canadian flows.
- Refining these estimates will require further studies of the hydrological and ecological impacts on US dams and reservoirs. Conducting these studies with the aim of generating data in terms of specific indicators will help economists to assign economic value to these impacts.

5 Jurisdictional scan results

The previous chapter estimated the economic value of some of the costs and benefits of the Treaty in terms of ecosystem services. The study now turns to the question of what lessons the US and Canada can learn from other jurisdictions with programs that attempt to value ecosystem services. The purpose of this chapter is to identify the advantages and disadvantages of different methods of pricing ecosystem services in the context of Columbia River Treaty.

5.1 Payments for ecosystem services

Payments for ecosystem services (PES) refers, broadly, to any program or policy in which a buyer pays a seller to act in such a way that results in a change in the value (i.e. quantity and/or quality) of ecosystem services. PES programs have existed in various forms for several decades. The US Conservation Reserve Program of the mid-1980s, in which the US Government paid farmers to conserve “environmentally sensitive” farmland, is an example of an early PES program. In recent years, PES has received significant attention as a tool available to development banks and governments of developing countries to achieve both human development and conservation goals (Schomers and Matzdorf 2013; Muradian et al. 2013). The theory behind PES programs is that ecosystem services are undersupplied because their value is external to market transactions. By paying for these services, their value is internalized and the market failure will be corrected (Wunder 2005; I. T. Porras, Grieg-Gran, and Neves 2008; Engel, Pagiola, and Wunder 2008). PES are distinct from other approaches to dealing with externalities such as regulation or taxes²².

PES is particularly suited to the Columbia River Treaty because of both Canada and the US have sovereign rights over their own portion of the river and are not able to regulate or tax one another. Indeed, the current Treaty is an example of a functioning PES

²² Some go as far as to say that PES is a reversal of the common principle of “polluter pays” – in PES, the polluter is paid to not pollute.

scheme – the US pays Canada to act in such a way as to increase the overall quantity or quality of ecosystem services in the Basin. As discussed in Chapter 2, the problem in the basin is that the full range of ecosystem services are not considered in the calculation of the payments under the Treaty and so Canada may be engaging in an inefficient use of its resources by not maximizing its net internal benefit.

The solution is to value these additional ecosystem services in the payments made under the Treaty. However, the question then becomes: how? These values, as discussed in Chapter 4, are imprecise and sensitive to many assumptions. Beyond agreeing to *value* ecosystem services, the parties need to agree on how to *price* ecosystem services – that is, the parties need to agree on the methods and assumptions that will be used to arrive at a payment that will cross the border. The financial value of which will likely differ from economists’ estimates of the economic value of the actual difference in ecosystem service levels.

To this end, this study looks at four different methods that different jurisdictions have used to determine the price of payments that are exchanged for ecosystem services. These methods, and the corresponding programs that use them, are listed in Table

Table 4. Pricing methods and programs.

Pricing method	Program
Opportunity cost of sellers	Columbia Basin Water Transaction Program (CBWTP)
Market price in newly-created regulated market	Murray-Darling Restoring the Balance Program (RTB)
Market price of proxy good or service	Costa Rica's Payments for Environmental Services Program (PSA)
Price tied to index of ecosystem service received by buyer	Regional Integrated Silvopastoral Ecosystem Management Project (RISEMP)

5.2 Columbia Basin Water Transactions Program

The CBWTP was established in 2002 with the objective of enhancing stream flows in the tributaries of the Columbia River for the benefit of anadromous and resident fish species through voluntary, market-based transactions. The CBWTP represents a pricing mechanism based on the opportunity costs of sellers.

The CBWTP operates through “qualified local entities” (QLEs), which are local conservation organizations distributed across the basin. QLEs negotiate transactions with local water rights holders, who are typically farmers. Types of transactions include (McCoy and Holmes 2015):

- water rights transfers including acquisitions, leases, diversion reductions, or source switches;
- water efficiency measures on agricultural lands (e.g., switching to lower water use crops or reducing losses from irrigation channels);
- conversion of agricultural lands to alternative land uses; and
- acquisition of land or interests in land for riparian restoration.

The program is administered by the National Fish and Wildlife Foundation and primarily funded by Bonneville Power Administration. Private companies also contribute funds as donors. Since 2002, the program has made more than 400 water rights transactions that have restored 1.13 MAF to date (through 2014), with an additional 6.24 MAF of flow protected for use over the next 100 years, watering over 1500 tributary stream miles within the Columbia Basin (McCoy and Holmes 2015).

Prices in the CBWTP are negotiated between QLEs and local water rights holders. Price levels are determined largely by the water rights holder’s opportunity cost of alternative land use – usually the net revenue from using the water to produce agricultural crops. For example, prices are higher in a permanent acquisition where a farmer is required to develop new infrastructure to meet irrigation needs relative to a short-term lease.

Program officials cite costs of measuring and monitoring changes in indicators of ecosystem services as a barrier to increased efficiency (i.e. to allocating funds to stream reaches that will have the greatest effect on salmon restoration). However, the program has recently adopted a monitoring framework aimed at measuring the contribution of the program to fish survival (McCoy and Holmes 2015). Under the framework, transactions fall into one of four tiers, with each successive tier requiring more extensive monitoring. In the lowest tiers, data is collected on contract terms and flow amounts, while in the higher tiers, data collected is aimed at measuring whether flow increases have affected markers of habitat quality or ecological function.

One option for the parties is to base the payments made under the Treaty on the opportunity costs that Canada incurs by participating in the Treaty (i.e. on the foregone benefits of the best alternative use of flows). This is the approach that nearly all existing payments for ecosystem services schemes adopt. However, most PES schemes to date have been implemented in geographies where farming is the best alternative use of land. In the context of the Columbia River Treaty, the economic value of the best alternative use of water is dominated by hydropower generation, revenue from which could be about \$22 million 2013CAD annually (BC Hydro 2013).

Ultimately, this option does not warrant further consideration in the analysis. Opportunity cost pricing is efficient for the seller only when a buyer is able to purchase ecosystem services from many different sources and the seller is unable to obtain a higher return for their resources. In the context of the Columbia River, Canada is the only seller. While opportunity cost pricing might be efficient from the standpoint of the river system as a whole, it is not efficient from Canada's perspective if there is an option to participate in a different Treaty that will result in a higher return to Canada.

5.3 Australia's Restoring the Balance in the Murrumbidgee-Darling Basin Program

The Murrumbidgee-Darling basin covers approximately one-seventh of Australia and contains portions of five states. In 2010, too much water was being withdrawn from the

River to maintain the proper functioning of the basin' ecosystems. Irrigated agriculture was the primary consumptive use of water; other uses included municipalities and industries. To solve this problem, the Australian Government developed a plan to set a basin-wide cap on the amount of water that farmers and other users could withdraw from the river, and to administratively allocate water between consumptive and “environmental” uses. In the period before the regulation was to take effect, the Government sought to purchase water rights from their current holders – via the *Restoring the Balance* program.

The Government opted to use a reverse auction mechanism to buy back the water rights. In a reverse auction mechanism, the buyer states the quantity of the good they wish to buy, and sellers bid the minimum price they will be willing to accept to sell their goods. Australia's Productivity Commission has argued that the reverse auction mechanism is less efficient than an open market mechanism when a market already exists, as was the case in many areas of the Murray-Darling basin (Productivity Commission 2010). In an open market mechanism, the Government would be one buyer out of many.

One potential option for the Columbia River is to set up a market in which BC Hydro acts as a monopolist producer of actions that provide ecosystem services (i.e. release of flows at a certain time). Representatives of the various water use interests in the US would participate in the market as buyers (i.e. commercial fishing, recreation associations, agricultural associations, Bonneville Power, etc.). Transactions would be achieved through a bidding process. Each buyer would state a maximum bid for a given flow release at a given time. BC Hydro would likewise have a minimum bid that it would accept for given releases at given times.

I exclude this option because it is likely unacceptable to both Canada and the US because of the lack of certainty that such an arrangement would create. Both BC Hydro and BPA are required by their respective regulators to prove their ability to meet a given level of firm energy demand. The Treaty makes it possible to “firm up” what would otherwise be non-firm energy (Federal Columbia River Power System 2001). Secondly,

the various parties in the US are unlikely to act competitively; instead, parties would likely collude to coordinate low bids. In terms of efficiency, the payments Canada receives would therefore not likely reflect the incremental total economic value of the Treaty.

5.4 Costa Rica's Payments for Environmental Services Program

Costa Rica's *Pagos por los servicios ambientales* (PSA) (Payments for environmental services) was established in 1997 as a mechanism to protect forests and the environmental services they provide. The Costa Rican program represents a pricing mechanism based on opportunity cost and the concept of "bundled" ecosystem services, in which a given quantity of land (or water) is assumed to produce a given level of ecosystem services. "Bundling" ecosystem service payments represents an alternative to monitoring changes in level of ecosystem services.

Costa Rica's PSA program was implemented in 1997 largely as a reaction to the significant increase in deforestation rates in that country. Under PSA program landowners are paid for five types of actions: conservation (i.e. not logging), reforestation (i.e. planting trees on previously-logged land), sustainable forestry management (i.e. logging only sustainable yields), and regeneration (define). These actions are assumed to enhance the provision of four ecosystem services: (1) mitigation of greenhouse gases through increased carbon sequestration from growing and healthy forests, (2) "scenic value" (i.e. tourism activity dependent on the beauty of forests, (3) biodiversity, and (4) "hydrological services" (i.e. water quality and quantity for domestic and industrial uses (including hydroelectricity generation). The program is administered by the National Forestry Fund (FONAFIFO). FONAFIFO monitors compliance of landowners and facilitates the sale of ecosystem service credits to buyers.

Demand (i.e. financing) for the PSA program comes from multiple sources, including the Costa Rican government, domestic private utilities, foreign governments, foreign banks, and international non-governmental organizations (NGOs). Government funds, from earmarked portions of fuel and water taxes are the primary source. PES

revenues from fuel tax are about 11.3 million 2013USD annually; between 2007 and mid-2010 water tax revenues were 3.6 million 2013USD. The Costa Rican private sector also contributes. In some cases, private sector contributions are from downstream hydropower or water bottling industries looking to secure specific water quality or quantity services. Other private sector contributions are promoted as a corporate social responsibility activity. In 1997, Norway purchased 200 million tons of carbon dioxide equivalent offset credits for 2 million USD. World Bank and the UN Global Environment Facility have also contributed, in effect “buying” the existence value/carbon sequestration of the conserved forest. Finally, the German Co-operation Bank (Kfw) and the Government of Japan have contributed funds that have been used to finance affordable credit (as an alternative to direct payments).

The payment level is influenced by budget availability and the opportunity cost to the landowner associated with participating (I. Porras et al. 2013). The price of renting land as pasture – the dominant alternative land use in the region – was used as an approximation of the opportunity cost of forested land (about 50 USD/hectare/year in 1995). While some effort appears to have been made to assess the value of forest ecosystem services prior to the launch of the program, the payment level in the PSA program has been described as “a somewhat arbitrary decision” (I. Porras et al. 2013), largely based on average opportunity costs.

A second criticism is that, with the potential exception of carbon sequestration, there is little evidence that increased forest cover (whatever part is actually due to the PSA program) is resulting in an increased provision of ecosystem services relative to the level of services that would have existed with less forest cover. The program is therefore said to lack conditionality. The major barrier to proving conditionality are the transaction costs associated with monitoring changes in level of ecosystem services; as Porras et al. 2013 indicate, “obtaining evidence of actual impact on these services is potentially very expensive”. Monitoring efforts thus focus on compliance (i.e. whether or not landowners take actions expected to provide ecosystem services). However, “Simple can be best, especially in PES. The programme uses land as a unit to account for ‘bundled’ ecosystem services (an input-based approach) rather than accounting for its components, such as

particular species or units of carbon captured (an output-based approach). This emphasizes that a healthy ecosystem is more likely to deliver ecosystem services.” (I. Porras et al. 2013).

A third criticism is that, because sellers’ enrolment in the program is voluntary but FONAFIFO’s purchase is mandatory, the program is unable to target purchases that would create the most environmental benefit per dollar spent on the program (either because the land in question is at higher risk of being deforested or because the land in question provides a higher level of services).

In terms of economic efficiency, it is more successful than, for example, a government law banning deforestation without compensation. Such a law would extract benefit for the government (and other receivers of ES) without providing any direct benefit for landowners, who bear the concentrated costs. The program is also resilient to political change despite lack of dedicated funding. A major criticism of the PSA program is that much of the gains in forest conservation observed in the country since the mid-1990s are the result of other policies and laws, rather than the result of the PSA program (Sánchez-Azofeifa et al. 2007). In other words, the gains would have happened without the payments and so the PSA program lacks additionality. “PES-receiving forest owners with holiday cottages who would be unlikely to clear or degrade their forest (Miranda, Porras, and Moreno 2003)”

5.5 Regional Integrated Silvopastoral Ecosystem Management Project (RISEMP)

The RISEMP was a pilot project that ran from 2002 to 2007 in Costa Rica, Colombia, and Nicaragua (Pagiola et al. 2007). The project, like Costa Rica’s PSA program, sought to reduce deforestation from cattle ranching and subsistence farming by compensating land users who adopted silvopastoral practices on their land. Silvopastoral systems are integrated land use systems in which trees or shrubs are combined with livestock and pasture production on the same unit of land. The program was financed by

a \$4.5 million grant from the Global Environment Facility (GEF) and implemented by the World Bank in partnership with local development organizations.

RISEMP adopts a unique approach to pricing by tying payment level to changes in the level ecosystem services as measured by indices of biodiversity and carbon sequestration. Pagiola (2007) describes the index as follows:

The biodiversity index assigned a number from 0.0 to 1.0 from most unfriendly (degraded pasture and annual crops) to most biodiversity friendly (primary forest). Within this range, a panel of experts assigned points to each land use by taking into consideration factors such as the number of species, their spatial arrangement, stratification, plot size, and fruit production. Similarly, the carbon sequestration index assigned points to different land uses according to their capacity to sequester stable carbon in the soil and in hard wood. The two indices were then added to arrive at a single environmental services index, which finally influenced the level of payment.

This approach avoids the cost-ineffectiveness of paying a flat fee based on the size of land for ecosystem services, and allows the sellers of ecosystem to decide how much conservation they were willing to undertake.

5.6 Summary

- Opportunity costs of sellers (i.e. the market value of alternative land or water uses) are the primary determinant of price in nearly all existing payment for ecosystem services schemes.
- Costs and scientific difficulties of monitoring and attributing changes in ecosystem services are a major barrier to payments based on value of ecosystem services.
- A “bundled” ecosystem services approach, in which a given quantity of land (or water) is assumed to produce a given level of ecosystem services, can minimize monitoring costs.

- Efficiency of payment for ecosystem services schemes is enhanced by information regarding benefits and seller's freedom to withdraw if services are not received.
- Baselines and monitoring are critical to proving gains in conservation.
- Either multiple buyers or multiple sellers enhances the efficiency of a market.

6 Policy options

The jurisdictional scan reveals two approaches to pricing payments for ecosystem services that are unlikely to succeed in the context of the Columbia River Treaty. These approaches are a market for ecosystem services and a payment based exclusively on the opportunity costs of the seller. However, the scan also reveals two approaches that could be adapted to the Columbia River: the “proxy benefit” approach, from Costa Rica’s PSA program, and the “measured benefit” approach, from the RISEMP program. I use these programs as the basis for two of the proposed options and develop a third that is not based on a case study: a “negotiated benefit” approach. In this chapter, I propose and evaluate these three mechanisms by which the parties could price ecosystem services in a modern Treaty and so ensure that Canadian water resources are allocated to their highest value uses.

6.1 Option 1: Status quo (i.e. price of proxy good)

The first option for valuing ecosystem services in the Treaty is to use the potential value of hydropower generation as a proxy for the value of all ecosystem services. The annual value of the Entitlement as it is currently calculated is around \$214 million US annually; the US suggests the actual value of the hydropower is around \$26 million US. Rather than adjust the Entitlement to reflect the actual value of hydropower, the two sides could agree that the difference between the potential and actual value of hydropower (around \$188 million US) is a “good enough” approximation of the value of the other ecosystem service benefits that the US receives. This option is viable whether or not a new flood control purchase is made, provided that the flood control purchase price is set only by the value of avoided flood damages and does not include other ecosystem services.

This option requires no measurement and attribution of Canadian contribution to changes in fish populations, agricultural productivity, or recreation opportunities would be required. This option resembles the Costa Rican PES scheme, in which a given set of actions of the upstream party are assumed to create a “bundle” of ecosystem services for

the downstream party. In Costa Rica, the action is the protection of an area of land that generates a given level of ecosystem services (carbon sequestration, air quality, tourism revenue, etc.) per square kilometer. In the Columbia River Basin, the action is the delivery of a certain quantity and timing of cross-border flows that generates a given level of ecosystem services per (for example) million acre-foot. While in Costa Rica the price is largely based on budget availability and the opportunity cost of the landowner (i.e. foregone net revenue from selling crops at the market), in the CRB the price would be determined by a different market commodity with a known price: electricity.

6.2 Option 2: Annual ex-post payment indexed to ecosystem service indicators

The second option is for the sides to calculate an annual payment that varies with changes in several indices that indicate changes in the quantity and quality of services that ecosystems provide in the US. The option is roughly analogous to the RISEMP program, which ties price of payments to landowners to changes in indices of biodiversity and carbon sequestration. As an example, one portion of the payment would be calculated based on changes in the number of anadromous fish. The parties would agree that, for every gain of 10 000 anadromous fish in the US, Canada would receive \$1 million. Another portion would be calculated based on changes in the availability of water supply for agriculture – for every incremental 10 000 acre-feet of water available for agriculture in the US, Canada would receive \$1 million. Another would be based on changes in accessibility of reservoirs and shores for recreation (for every incremental 10 days that a reservoir is accessible in the US, Canada would receive \$1 million). Another would be based on the actual value of the incremental hydropower that the US generates – which, according to US estimates, is approximately \$26 million (2013US). Finally, another portion would be related to avoided flood damages – the index for which would be related to the value of infrastructure and human lives in communities along the US Columbia.

These figures are arbitrary and would be need to be refined to reflect the actual marginal benefit that the US receives from incremental changes in ecosystem services.

For example, as discussed in Chapter 4, an additional 10 000 anadromous fish are worth much more if the underlying population is 100 000 relative to if the underlying population is 10 million. The figures would also need to be refined to take into account the fact that Canadian operations are only one of many input factors that go into the production of ecosystem services. For example, as discussed in Chapter 4, multiple factors influence fish abundance including ocean temperatures, commercial fishing effort, spawning habitat restoration, etc. Accurately *attributing* the portion of incremental gains in US ecosystem services that is *caused* by Canadian operations represents a significant scientific challenge. A trade-off likely exists between the amount of scientific resources devoted to the attribution issue (in terms of personnel and funds) and the accuracy of any attribution estimate.

6.3 Option 3: 10-year purchase based on ex-ante estimates of changes in ecosystem services

The third option is for the parties to enter into a series of long-term contracts where the parties agree to a price based on ex-ante estimates of future changes in ecosystem services under a given operating plan. Each parties would bring to the table their own estimate of the present value of the benefits the US will receive over the length of the contract. Instead of a 60-year term, as in the original Flood Control Purchase, I recommend a shorter term of 10 years, with a new agreement ideally made every five years. Five years will provide both power authorities with the requisite time to plan their load-resource balancing should one party choose to terminate the agreement. If the parties cannot agree to a new contract, the Treaty will switch to Called Upon Flood Control and whatever payment structure that entails.

This option differs from Option 2 in a number of ways. Instead of an annual payment, Option 3 is a payment made every 10 years. Instead of basing the payment on ex-post measurements of actual changes in indices, Option 3 bases the payment on ex-ante predicted changes in indices. This introduces a significant amount of uncertainty, as the question of attribution depends significantly on precipitation patterns – e.g. in drought

years, the portion of gains in ecosystem services relative to a Treaty Terminates that are due to Canadian operations will rise significantly.

The shorter term will allow the parties to adjust the price as new scientific understandings about the relationship between hydropower operations and the various ecosystem services emerge. The parties will also be able to adjust to new hydrological inputs that a changing climate could cause.

This approach is similar to the original non-hydropower benefit purchase that was made in 1964, only instead of flood control being the only benefit considered, the purchase would now take into account other non-hydropower benefits like fish and agriculture. This option requires no ongoing monitoring or attribution; only further initial studies such as this one regarding the potential magnitude of the value of fish, agriculture, recreational, and other benefits.

6.4 Summary

Table 5. Summary of options.

Option	Description
1. Status quo (i.e. price of a proxy good)	Annual payment equal to incremental potential hydropower (i.e. current practice of Canadian Entitlement)
2. Annual ex-post payment indexed to ecosystem services indicators	Annual payment determined by formula based on ex-post measurement and attribution of ES changes and values
3. Six-year purchase based on ex-ante estimates of changes in ecosystem services	Series of short-term payments negotiated based on estimated present values of US benefits

7 Policy analysis

In this chapter, I assess the three options based on their effectiveness in achieving the objective of efficient use of Canadian water resources. I also evaluate the options' sustainability, stakeholder acceptance, and administrative ease.

7.1 Objectives, criteria, and measures

7.1.1 Efficiency

The primary societal objective of the proposed policies is the efficient use of Canadian water resources. Efficient use means that Canada's resources are put their highest value use – i.e. that Canada participates in a Treaty that maximizes its net internal benefit. A minimally efficient outcome would be one where the payment is at least equal to Canada's minimum willingness to accept compensation for the lost economic value from negative changes in ecosystem services (i.e. Canadian opportunity costs). A maximally efficient allocation, from Canada's perspective, would be one where the annual payment was equal to the US' maximum willingness to pay to receive the benefits of positive changes in ecosystem services. I measure options' progress towards a maximally efficient allocation by the estimated financial value of the payments made under the Treaty. The higher the payments Canada receives, the more efficient the outcome (from Canada's perspective).

7.1.2 Sustainability

I also evaluate the proposed options' impacts on another societal objective: sustainability. I define sustainability as the ability of the outcome brought about by the option to endure in the face of changing conditions such as climate change and its impact on the economic value of ecosystem services. I measure options' progress towards sustainability based on an estimation of how the payment will change over time. For

example, an outcome in which the payment declines over time is less sustainable from Canada's perspective than one in which the payment increases over time.

7.1.3 Administrative ease

In addition to the societal objectives of efficiency and sustainability, I also consider two governmental objectives. The first is administrative ease. The Canadian governments involved in the Columbia River Treaty – the federal government and the provincial government – would like to minimize the resources and knowledge required to implement the policy. The primary considerations in this context are the degree of monitoring of ecosystem indices that are required by the various options as well as the complexity and uncertainty involved in the scientific knowledge required. Policies that require no, some, or extensive new practices or institutions (i.e. scientific modelling and monitoring) score high, medium, and low, respectively, on this criterion. I use data from expert interviews as well as professional judgment to measure where the various options fall on this scale.

7.1.4 Stakeholder acceptance

Stakeholder acceptance measures the acceptability of the policy to the governments and stakeholders on both sides of the border. Policies that are acceptable to few, some, or all governments and stakeholders score low, medium, and high, respectively, on this criterion. I use data from published statements about the preferences of the Canadian and US Entities to score the options on this scale.

Table 6. Summary of criteria and measures.

Objective	Criteria	Measure	Index
Effectiveness (efficiency)	Option results in Canada allocating its water resources to their highest value uses	Estimated size of financial payment Canada receives	<p>Very high: Payment is much greater than Canadian opportunity</p> <p>High: Payment is greater than Canadian opportunity costs</p> <p>Medium: Payment is equal to Canadian opportunity costs</p> <p>Low: Payment is less than Canadian opportunity costs</p> <p>Very low: Payment is much less than Canadian opportunity costs</p>
Sustainability	Option results in efficient outcome (i.e. maximum value) over time	Change in payment Canada receives over time	<p>High: Payment increases over time</p> <p>Medium: Payment is constant over time</p> <p>Low: Payment decreases over time</p>
Administrative ease	Administration of the policy is feasible in terms of resources and knowledge required	Amount and complexity of scientific modelling or monitoring of physical ecosystem service indices required	<p>High: Few resources required</p> <p>Moderate: Some resources required</p> <p>Low: Many resources required</p>
Stakeholder feasibility	Policy is acceptable to governments and stakeholders	Number of stakeholders to whom the option is acceptable	<p>High: All governments and stakeholders are likely to accept the policy</p> <p>Medium: Some governments and stakeholders are likely to accept the policy</p> <p>Low: Few to no governments or stakeholders are likely to accept the policy</p>
Stability	Policy results in a predictable, stable outcome		<p>Yes:</p> <p>No:</p>

7.2 Analysis of options

7.2.1 Effectiveness (efficiency)

The status quo option is a highly efficient option in that the financial value of the payment will remain at approximately \$214 million, which is greater than the Canadian opportunity costs (\$24 to \$41 million).

The efficiency of the annual ex-post option is more difficult to assess because of the large range associated with the estimates of the financial value of the payments. If the agreed-upon formula results in a payment that is on the high end of the estimate I provide here, the option would be very highly efficient, as Canada would receive a payment of approximately \$334 million. If, however, the formula results in a payment that is closer to the lower-bound of my estimate (\$113 million), the option would be less efficient than the status quo. Because my estimate was developed with what I consider conservative assumptions, I score the annual ex-post option using the higher estimate of \$334 million, and so it scores as “very highly efficient”.

The efficiency of the 10-year ex-ante option is also difficult to assess because of the above reasons and because it is impossible to predict the outcome of the negotiation process. If the negotiation was exclusively about the assumptions and validity of the science behind attribution, it is likely that Canada would be able to secure a 10-year present value payment that, when annualized, would be approximately equal to the size of the payment in the annual ex-post option (\$113 to \$334 million). However, many factors will influence the outcome of the negotiation. For example, if the US perceives that Canada’s threat to terminate the Treaty or continue under Called Upon Flood Control operations is not credible, the US may be able to insist upon an annual payment that is not significantly greater than Canadian opportunity costs (i.e. just over \$41 million). Indeed, one of the original negotiating tactics of the Canadians in 1964 was to threaten to divert a large amount of water from the Canadian Columbia into the Fraser River. Such an option does not exist today, and so Canada may enter negotiations at a weaker position

relative to the US. For this reason, I score the 10-year ex-ante option using the low estimate of \$113 million, and so it scores as “moderately efficient”.

	Status quo	Annual ex-post	10-year ex-ante
Financial value of payment	\$214 million	\$334 million	\$113 million
Score	<i>High</i>	<i>Very high</i>	<i>Medium</i>

7.2.2 Sustainability

The status quo is the least sustainable option, as there is no mechanism to account for changes in the value of ecosystem services over time. My analysis suggests that the impacts of climate change will likely increase both the value of ecosystem services in the Basin and the portion of that value that is a result of the Treaty. Furthermore, the Entitlement formula takes into account the composition of electricity resources in the US and is predicted to decline as the Americans build more thermal generation capacity in the Pacific Northwest (Canadian and United States Entities 2010). Because the payment declines over time, I score the status quo as a “low” on the sustainability criterion.

The annual ex-post option is moderately sustainable. The option will result in the payment adjusting to the increasing portion of US ecosystem services that can be attributed to Canadian operations. However, because the marginal value functions are fixed, the option is not able to adjust to changing societal values. For example, with respect to fish populations, Canadian operations are predicted to become more valuable to US fish restoration efforts as other factors continue to trend in directions that will have adverse impacts on fish populations (e.g. rising ocean temperatures). The annual ex-post option will be able to capture this change. However, the formula will not be able to capture changes in value of ecosystem services over time, which will likely rise as nature becomes more scarce or developed.

The 10-year ex-ante option will be able to capture this change, and so is likely the most sustainable option. Because the payment is re-negotiated every ten-years, the parties will be able to adjust to any changing circumstance.

	Status quo	Annual ex-post	10-year ex-ante
Change in payment over time	Negative	Positive	Positive
<i>Score</i>	<i>Low</i>	<i>Medium</i>	<i>High</i>

7.2.3 Administrative ease

The status quo would be relatively easy to administer as it would require no new practices or institutions (i.e. scientific modelling and monitoring). The formula and scientific logic the parties currently use to calculate the Entitlement already exist. No additional monitoring infrastructure would need to be developed; and no scientific understanding of the contribution of Canadian operations to American ecosystem services gains would need to be developed.

The major trade-off of the annual ex-post option is that it will be the most demanding to administer in terms of the resources the parties will require. Measuring changes in, for example, fish populations will require a given level of resources to measure ultimate outcomes of interests (i.e. changes in fish population). But attributing these changes to Canadian operations as opposed to other factors will require another level of resources to measure changes in the intermediate factors that affect fish populations which Canada does not influence (e.g. habitat quality, water diversions, land uses, ocean temperatures, etc.). In an interview, a senior representative of the Columbia Basin Water Transaction Program indicated that ecological monitoring efforts in the Basin are currently not well co-ordinated or comprehensive and cited resource limitations and failure to coordinate overlapping effort of different organizations as major barriers to improved monitoring. A new institution (a Joint Scientific Commission) would likely be required to co-ordinate and ensure political independence for these processes.

The ten-year ex-post option scores a medium on administrative ease. This option presents several resource challenges that the status quo does not. First, as my analysis illustrates, there is still significant amount of scientific and engineering studies to be done to determine the portion of the total economic value of ecosystem services that is actually incremental to the “Without Treaty” situation. Second, because a negotiation will have to occur every ten years, it’s likely that both parties would need to maintain ongoing economic valuation studies and keep such studies up-to-date with the current state of the science.

	Status quo	Annual ex-post	10-year ex-ante
Resources required	Few	Many	Some
<i>Score</i>	<i>High</i>	<i>Low</i>	<i>Medium</i>

7.2.4 Stakeholder acceptance

The status quo option is moderately acceptable to stakeholders. It represents a minor loss for both sides. The US negotiators will not have achieved their goal of reducing the financial value of the Canadian Entitlement. Canadian negotiators have indicated their goal is to incorporate the full range of costs and benefits into any financial transaction under the Treaty. The option does not achieve this goal. However, maintaining the Entitlement at the status quo could be viewed as a win for Canada considering the US’s strong intention to reduce the Entitlement.

The annual ex-post option also scores low on stakeholder acceptance. The US is unlikely to be supportive as the option would likely result in an increase in the value of cross-border payments. Canada would be more supportive, as the approach is the logical extension of their interest in valuing the full range of benefits and costs. However, the transaction costs involved in measuring and attributing the benefits and costs, and the uncertainty associated with the future value of the payments, would likely deter either party from accepting such an approach. Another consideration is that the burden of monitoring would fall to the US Entity.

The 10-year ex-ante option scores a medium on the stakeholder acceptance criterion. Because both parties participate in the negotiations and have some control over the direction of the negotiations, both parties are likely to accept the outcome. In addition, Canada has stated its preference to avoid a Called Upon Flood Control scenario, suggest that it represents “a step backwards that does not make efficient use of reservoirs, creating operational uncertainty and unnecessary social, economic and environmental impacts”(Canadian Entity 2013). Canada has also stated its interest in adaptive management, which the relatively short-term structure of the 10-year ex-ante option would allow.

	Status quo	Annual ex-post	10-year ex-ante
American acceptance	Low	Low	Medium
Canadian acceptance	High	Low	Medium
<i>Score</i>	<i>Medium</i>	<i>Low</i>	<i>Medium</i>

7.3 Summary and trade-off analysis

Table 7. Summary of policy analysis.

	Efficiency	Sustainability	Administrative ease	Stakeholder acceptance
Status quo	High	Low	High	Medium
Annual ex-post	Very high	Medium	Low	Low
10-year ex-ante	Medium	High	Medium	Medium

In summary, Table 7 illustrates that among the two options that differ from the status quo, the major trade-off is between efficiency and administrative ease. Accurate measurement of changes in ecosystem service indices, and the high return on Canadian resources it may entail, is costly and complex. The analysis suggests that, as in PES schemes adopted around the world, the transactions costs of a such an approach may be

too large for the involved parties to accept. The simpler, 10-year ex-ante approach represents a balance between efficiency and administrative ease, but would still require significant resources. The status quo scores high on both efficiency and administrative ease, but low on sustainability. Stakeholder acceptance is mixed across the options. The status quo option represents a compromise in which both parties do not achieve their stated goals and the annual ex-post option is likely to be unpopular in the US. The 10-year ex-ante option directly aligns with Canadian preferences and is likely to be acceptable to the US as well.

8 Recommendations and conclusions

This chapter presents the final policy recommendations that follow from the preceding analysis for the consideration of the Columbia River Treaty Review team at the Government of British Columbia.

8.1 Summary of considerations

The preceding analysis has sought to illustrate several points. These are:

- Canada should seek to maximize the financial value of the payments it receives from the US under a modernized Treaty. To participate in a Treaty that does not maximize the payments, and so the net social benefit to Canada, would be an inefficient use of Canadian resources.
- The payments made under the Treaty should at minimum be equal to the opportunity costs that Canada incurs going forward by deviating from an operating plan in which Canada operates its dams and reservoirs to maximize its own net social benefit (i.e. a “Canada Max” plan). At maximum, the payments could be equal to the US’ maximum willingness to pay for the incremental benefits the US receives under a continued Treaty (i.e. a “US Max” plan). Historical costs and benefits of the Treaty cannot be considered in determining these payments.
- To account for the full suite of benefits and costs of the Treaty, the parties should compare the difference between the physical state of the ecosystems under the two plans. Different states of ecosystems will provide different levels of ecosystem services. The value that Americans place on the change in level of ecosystem services in the US is the value of the US benefits; the value that Canadians place on the change in level of ecosystem services in Canada is the value of the Canadian costs.

- Ecosystem services provided by the Columbia River include flood prevention, hydropower generation, fish, agriculture, recreation, navigation, air quality, water quality, and others.
- I estimate that the value of the US benefits is approximately \$225 to \$667 million (2016US) annually. The major sources of this value are flood control (\$75 million), hydropower (\$26 to \$418 million), fish (\$99.65 million), agriculture (\$14.5 to \$55.09 million), and recreation (\$10 million). This estimate does not include the value of non-fish recreation, navigation, air quality, water quality, or other ecosystem services, which are likely greater than zero.
- I estimate that the value of the Canadian costs is approximately \$24 to \$41 million (2016US) annually. The major sources of this value are hydropower (\$22 million), fish (\$5.6 to \$26 million), agriculture (\$1.2 to \$1.8 million), air quality (\$1 million), and other ecosystem services (\$1.6 million).
- Payments for ecosystem services (PES) are common programs or policies in other jurisdictions where the actions of one party creates ecosystem service benefits for another party that are not captured in by existing markets.
- PES programs choose different pricing mechanisms depending on the unique circumstances of the buyers and sellers.
- In the context of the Columbia River Treaty, there are three viable options for pricing ecosystem services. The first is the status quo approach, in which the difference between actual and potential hydropower generation serves as a proxy price for the value of other ecosystem services. The second is an annual ex-post payment indexed to changes in ecosystem services. The third is a 10-year ex-ante payment based on estimated changes in ecosystem services.

- These options differ in terms of their effectiveness in maximizing Canadian net benefits, their sustainability, their administrative ease, and their acceptance among the primary stakeholders.

8.2 Recommendations

The preceding analysis suggests that the status quo (i.e. price of proxy good) option represents the best available mechanism to price ecosystem services in the Columbia River Treaty. I therefore recommend that the Province seek to maintain the status quo with respect to the payments made under the Treaty in the upcoming negotiations with the US.

The status quo (i.e. price of proxy good) option offers several advantages over the annual ex-post and 10-year ex-ante options. First, the option represents a reasonably efficient use of Canadian resources in that it results in a payment to Canada that likely far exceeds the Canadian opportunity costs. The Entitlement is currently worth on average \$214 million annually; I estimate the Canadian opportunity costs at \$24 to \$41 million annually. The 10-year ex-ante option, while offering the most sustainable approach, carries too great a risk that the US could negotiate a lower price. The annual ex-post option could result in the greatest payment to Canada, but brings too high transaction costs and too great scientific uncertainty.

I also recommend that, to strengthen the Canadian negotiation position, the CRTR commission several further studies. Specifically, I recommend the following:

1. **Model impacts of system operations on fish, agriculture, and recreation in the US.** First, the BC Government should commission several detailed studies to model the effects of co-ordinated operations and the switch to Called Upon Flood Control on fish, agriculture, and recreation interests in the American CRB. Specifically, the study should predict the effects of the Treaty on anadromous fish survival, volume of water available for irrigated agriculture, and the fluctuation ranges of American reservoirs that may be used to provide

flood control storage. These data could then serve as inputs to develop more refined estimates of the economic value of the benefits from ecosystem services that the Treaty enables. A meeting between physical scientists (ecologists, fisheries biologists, hydrologists) and social scientists (economists, political scientists) would encourage leaders of each study to ask the right questions (i.e. to develop data in a format that can economists could use as inputs into economic valuation studies).

2. **Develop a “Canada Max” operating plan.** Second, the Government of BC should extend the work that was conducted in BC Hydro’s Technical Studies and develop an operating plan that would maximize the economic value of ecosystem services for Canada as if the Treaty did not exist (i.e. a “Canada Max” operating plan). The performance of various alternatives on the various Performance Measurement indicators has already been modelled; however, an alternative that achieves an optimum balance based on stakeholder values between the various water use interests in the absence of the Treaty has not been developed. This could be done by re-scheduling the planned review of the Columbia River WUP in 2021 for the immediate future and would provide information that could be used to better estimate the actual opportunity costs of the Treaty to Canadians.

9 Limitations

9.1 Complexity and uncertainty

In 1997, senior policy advisor to the National Marine Fisheries Service John M. Volkman wrote:

Whether, where and how we allow the basin once again to weave natural patterns will depend on the way we manage dams in two countries; private water diversions in at least three states; federal, tribal, state and private land in much of the basin; fish harvest in the ocean and in-river; the world's largest hydroelectric system; a major artery of navigation; a regional flood control system; and a sprawling system of fish hatcheries. Each of these factors is connected to all of the others, and so water policy in the Columbia River becomes part of an almost unimaginably complex calculus (Volkman 1997).

This quote captures one of the major limitations of the preceding study: the fact that significant uncertainty pervades many of its conclusions due to the complexity involved. These sources of uncertainty include:

- **Uncertainty regarding the hydrological conditions that would exist under Canada Max and US Max.** Ideally, the economic valuation of changes in ecosystem services would compare two different, clearly defined alternatives that resulted two different, clearly defined states of ecosystem.
- **Uncertainty regarding the nature of the relationship between changes in hydrological conditions and changes in certain ecosystem services such as anadromous fish.** Even if such hydrological data is available, there remains significant uncertainty regarding the responses of ecosystems and their components to changes in hydrological conditions. For example, even if a scientist knew the change in flow speed in a given reach of the US Columbia, the scientist may not be able to estimate to an acceptable level of certainty the response of all the different anadromous fish populations that pass through that reach. Ecosystems are inherently

“unimaginably complex” and so we should be humble in attempting to predict their function based on changes in a limited set of factors.

9.2 Called Upon

This study has not considered the implications of a potential switch to Called Upon on the evaluation of the proposed options. Instead, the study viewed the future of the Treaty as a more or less blank slate, in which the Treaty would either continue as is or terminate. How the parties would determine the value of payments for Called Upon Flood Control remains an open question. One potential option that may warrant further consideration is a “Called Upon For Anything” in which the US paid a per-acre-foot flat fee for requests for additional water above or under a baseline of what would cross the border at a given time if Canada were to operate under Canada Max. The fee structure could shift within a two-by-two matrix (Table 8) depending on hydrological conditions on either side of the basin.

Table 8. Matrix of prices under a Called Upon.

		Canada water availability	
		High	Low
US water availability	High	\$100	\$500
	Low	\$500	\$1000

9.3 Concerns of Canadian First Nations

While First Nations’ rights were considered in the context of the legal liability of the US Federal Government if certain fish species go extinct or fall below harvestable levels, it is important to acknowledge that there are many other impacts of the Columbia River Treaty on First Nations’ groups on both sides of the border. For example, First Nations in BC have expressed interest in using the Treaty renegotiations as an opportunity to explore means to restore anadromous fish to the upper reaches of the Columbia. Grand Coulee and Chief Joseph Dams were built without fish passageways and so have blocked salmon from returning to Canadian spawning grounds since their construction (“First Nations Push to Restore Columbia River Salmon Runs” 2016). The

Province has stated that because these dams were not part of the Treaty, salmon passage past these dams should not be part of the Treaty renegotiations.

9.4 Equity implications

This study did not consider the effects of the options on equity within Canada, which could be defined as the distribution of the Canadian benefits between residents of the Columbia River region, upon whom some the social and environmental costs are concentrated, and non-residents, who receive the benefits from a payment into the general revenue of the Province. Whether the existing programs of the Columbia Basin Trust are succeeding in mitigating the concentrated costs may be important to consider going forward.

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