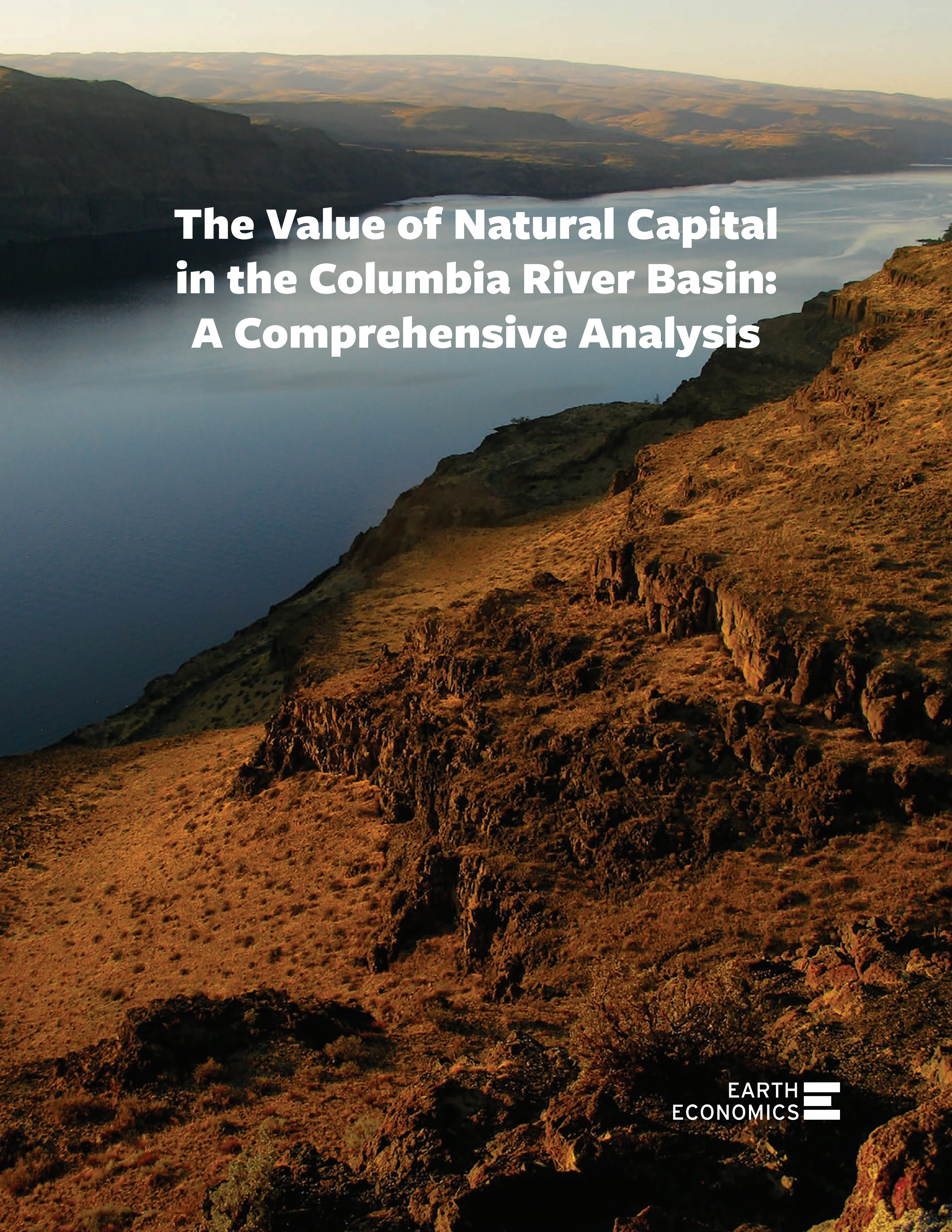
The Value of Natural Capital in the Columbia River Basin: A Comprehensive Analysis



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Errata: This report was corrected to address minor copyediting errors which may confuse the reader. These include:

Page 54: The weighted average at the bottom of Table 10 was incorrectly printed as $4,373,356,570. The correct value is $3,373,356,570, as printed in this edition.

Page 76: The weighted average at the bottom of Table 22 was incorrectly printed as $3,373,356. The correct value is $3,373,356,570, as printed in this edition. Also, the Current Conditions value for Wettest Water Years was incorrectly printed as $3,644,655,116. The correct value is $3,664,655,116, as printed in this edition.

We would like to thank Marc Gauthier and Keith Kutchins for finding the errors.

Cover Photo: Columbia Plateau, Source: Brian Gruber

Table of Contents

List of Tables

List of Figures

Acronyms and Abbreviations

3Ea-80	Modernized Columbia River Treaty scenario, official 80-year modified flow
AA	Action Agencies
AF	Acre-feet
aMW	Average Megawatt
AOP	Assured Operating Plan
BiOp	Biological Opinion
BPA	Bonneville Power Administration
BTM	Benefit Transfer Methodology
CBO	Congressional Budget Office
cfs	Cubic feet per second
CIS	CRITFC Information System
CO_2	Carbon Dioxide
COMPASS	Comprehensive Passive Model
CRB	Columbia River Basin
CREST	Columbia River Estuary Study Taskforce
CRITFC	Columbia River Inter-Tribal Fish Commission
CRT	Columbia River Treaty
CSS	Comparative Survival Study
DFO	Department of Fisheries and Oceans
EbF	Ecosystem-based Functions
EE	Earth Economics
EMS	Energy Management System
ES	Ecosystem Services
ESA	Endangered Species Act
ESV	Ecosystem Services Valuation
EVT	Ecosystem Valuation Toolkit
FCRPS	Federal Columbia River Power System
FCRPS	Federal Columbia River Power System Biological Opinion
FEMA	Federal Emergency Management Agency
FLISR	Fault location, isolation, and service restoration
FWCP	Fish and Wildlife Compensation Program
GIS	Geographical Information System

GWH	Gigawatt hour
HVAC	Heating, Ventilating and Air Conditioning
Kcfs	Thousands of cubic feet per second
kWh	Kilowatt-Hour
LCA	Life Cycle Assessment
LCI	Land Cover Institute
MEA	Millennium Ecosystem Assessment
MW	Megawatt
MWh	Megawatt-hour
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NPV	Net Present Value
O&M	Operation and Maintenance
OMB	Office of Management and Budget
PEB	Permanent Engineering Board
PNCA	Pacific Northwest Coordination Agreement
RCC-80	Reservoir Current Conditions-80 years
SEDAC	Socioeconomic Data and Applications Center
UCUT	Upper Columbia United Tribes
USACE	U.S. Army Corp of Engineers
USBR	U.S. Bureau of Reclamation
USD	U.S. Dollars
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
WRC	U.S. Water Resource Council
WRDA	Water Resources Development Act
WTP	Willingness-to-Pay
WY	Water Year

Executive Summary

The Columbia River Basin (CRB) is globally recognized for its abundant watersheds and rivers that founded unique natural assets and capital including immense forests and other native vegetation, the largest salmon runs in the world and diverse and abundant wildlife. These assets have supported native peoples for millennia. Although these resources still have substantial existence value, they have been seriously degraded by development of built capital such as dams. When assets, whether built or natural, are not managed sustainably, economic loss occurs through resource degradation. In the CRB, past and current economic practices have developed and operated built capital assets while undervaluing, or entirely disregarding, natural capital assets. Yet, natural capital assets provide the region with essential goods and services such as sustainable food, jobs, recreation, clean water, and carbon sequestration, among many others.

THIS REPORT ILLUSTRATES AND DOCUMENTS THE IMMENSE ECONOMIC VALUE OF THE COLUMBIA RIVER BASIN'S NATURAL ASSETS AND PROVIDES CLEAR EVIDENCE OF THE INCREASED VALUE THAT CAN BE GAINED BY ADDRESSING ECOSYSTEM-BASED FUNCTION IN A MODERNIZED CRB RIVER MANAGEMENT REGIME. Thus, this report substantiates that changes in extant river management can enhance sustainable natural capital wealth for present and future generations.

The following economic analysis provides robust present and future assessments of the CRB's economic value by comparing two modeled river management scenarios: current conditions (RCC-80), and conditions under a modernized Columbia River Treaty ecosystem-based function (3Ea). The RCC-80 scenario identifies the value of present CRB river operations. **THE 3EA SCENARIO FOCUSES ON THE POTENTIAL FUTURE VALUE OF THE CRB IF RIVER OPERATIONS WERE TO BE MODIFIED TO ADOPT AN ECOSYSTEM-BASED FUNCTION PARADIGM FOR MANAGEMENT DECISIONS.**

The 3Ea scenario would augment spring and early summer river flows with reservoir storage, thereby also stabilizing reservoirs, providing for restoration of fish populations to historical areas, and increasing the sustainable, regional economic value of the basin. This is evident despite reductions in the present built capital value from hydroelectricity generation. Although hydrogenation would be reduced by $69 million (from its present annual value of almost $3 billion), the **3EA SCENARIO WOULD INCREASE THE TOTAL CRB ECONOMIC VALUE BY APPROXIMATELY $1.5 BILLION ANNUALLY.**[a]

Furthermore, reduced hydrogeneration appears to be the only benefit that declines under the 3Ea scenario, and this loss is mitigated by numerous other enhanced benefits. For example, non-tribal commercial fishery value would increase by $7

a The values presented here are rounded to the nearest million, and could be slightly different than the values presented in the report tables below.

million per year. General recreation is expected to experience a slight increase of $39,000, while angling value would increase by $46 million. The 3Ea scenario, which provides additional valuation of increased spring and early summer water flow, would value at $389 million, and nutrient enhancement could reach an estimated value of $31 million. The flood risk management, agriculture and navigation values for both RCC-80 and 3Ea remained the same.

With the existence value increasing by $1 billion, the 3Ea scenario represents the largest annual asset increase in the analysis. Thus, enhanced regional benefits from the ecosystem scenario could produce positive and sustainable values for the regional economy and environment. This value is very conservative and would likely be substantially increased. For example, numerous other populations of fish and wildlife benefits, not quantified in this analysis, would benefit from a modernized river management scenario. **IF THE COLUMBIA RIVER BASIN WERE TO SEE EVEN A 10 PERCENT INCREASE IN ECOSYSTEM-BASED FUNCTION, IT COULD ADD $19 BILLION TO THE TOTAL NATURAL CAPITAL VALUE.**

The CRB's profound cultural value is expressed qualitatively in this report. The cultural value description focused on the relationships with the landscape and rivers and the socio-economic losses that tribes and others continue to suffer due to regional actions that largely promote non-tribal economic values. Loss of natural, sustainable capital (i.e. salmon and other tribal first foods) has impoverished tribal people, causing higher rates of death, disease, and poverty than among non-native communities. Monetary valuation of these impacts and cultural and spiritual losses are difficult to quantify, but are much underappreciated.

The analyses in this report highlight the extensive value that the CRB currently provides and show the potential to increase sustainable economic values of non-tribal commercial fisheries, recreation, existence, nutrient enhancement, and ecosystem services by modifying management regimes to engage in restoration activities and enhance conservation policies.

As Columbia River Treaty assessments continue and U.S. domestic decision-making processes ensue, it is essential that sustainable natural capital value be given serious consideration in actions that affect river management. Considering the findings in this report, an informed course of action should carefully examine pathways to promote sustainable ecosystem function and increased ecosystem health. The economic values provided in this report support and advocate for the inclusion of ecosystem-based function into the Treaty and other regional processes, and they should help guide restoration and conservation efforts throughout the basin.

Key Points

1. **The Columbia River Basin holds immense natural capital value.**
2. **3Ea would modernize the Columbia River Treaty in a way that recognizes the Basin's natural capital value.**
3. **A 10 percent increase in ecosystem-based function would add $19 billion to the Basin's natural capital value.**

Report Overview

This report evaluates and compares different resources, including ecosystem services, non-tribal commercial fisheries, existence values, hydropower, recreation, navigation, and agriculture under two scenarios (RCC-80 and 3Ea). Furthermore, nutrient enhancement and increased water flow are also valued for 3Ea. In addition to the basin's monetary value, this report also presents a cultural analysis to demonstrate the CRB's integral connections to tribal culture. The report is outlined as follows:

CHAPTER 1: INTRODUCTION. This chapter introduces the goal of this report and the study area, briefly describing the natural characteristics of the Columbia River Basin. The report focuses on defining basin-wide natural capital, particularly as it relates to tribal socio-economics including tribal first foods. The chapter also outlines a brief history of the Columbia River Basin, highlighting some of the major threats to ecological health. Finally, the chapter describes current river management under the Columbia River Treaty.

CHAPTER 2: ECOSYSTEM FUNCTIONS OF THE COLUMBIA RIVER BASIN. Chapter 2 defines three key concepts that appear throughout the report: ecosystem-based function, ecosystem services, and natural capital. This chapter also presents the value of ecosystem services provided by different land and water cover types present throughout the Columbia River Basin, including a description of the methods used to assess this value.

CHAPTER 3: THE CURRENT VALUE OF THE COLUMBIA RIVER BASIN. This chapter presents our analysis of the CRB's resources under the first scenario, current conditions (RCC-80). The analysis values non-tribal commercial fisheries, existence, hydropower, flood risk, recreation, navigation and agriculture currently present in the basin.

CHAPTER 4: THE MODERNIZED VALUE OF THE COLUMBIA RIVER BASIN. Chapter 4 calculates the potential increase in natural capital value under a modernized management regime scenario (3Ea). We assess the benefits provided under a modernized scenario for non-tribal commercial fisheries, existence, hydropower, recreation, nutrient enhancement, and ecosystem services. Total economic values for each of the resources listed above are presented at the end of this chapter.

CHAPTER 5: THE CULTURAL VALUE OF THE COLUMBIA RIVER BASIN. Because tribes and other residents value the Columbia River Basin for far more than monetary value alone, this chapter analyzes the cultural value of the basin. The chapter focuses on qualitatively describing cultural and spiritual components, including links to first foods, tribal fishing, and tribal resources.

CHAPTER 6: DAM OPERATIONS AND MAINTENANCE COSTS. This chapter summarizes some of the costs associated with hydropower generation and flood risk management.

CHAPTER 7: CONCLUSION. Chapter 7 discusses the results of our analyses within the context of the Treaty. This chapter also includes recommended next steps and further research to promote the inclusion of ecosystem-based function into decision making and secure the benefits of modernized river management under an inclusive, updated treaty.

Chapter One
Introduction

"Evidence says we've been here for 10,000 plus years. Our elders say we've been here since time immemorial."

– Quanah Matheson – Coeur d'Alene Tribe, Cultural Director[1]

"The tribal vision for the future of the Columbia River Basin respects and reflects upon the tribal memories of the past. It simultaneously looks ahead, with a vision filled with images of Indian and non-Indian use and enjoyment of clean air and water, healthy lands, fish, wildlife, plants and other resources. The tribal vision calls for recognition and appreciation of the spiritual values of these, not merely to extract and exploit them for monetary or other economic value they may hold, but to restore and sustain them to bless the human spirit."

– The Tribal Vision for The Future of the CRB & How to Achieve it.[2]

The Columbia River is North America's fourth-longest river, a vital component of both the regional economy and the environment. It is also foundational to tribal culture and traditions as a source of vital first foods. However, dams and other developments are degrading the river's ecosystem, causing fish populations to decline. There are ongoing discussions between sovereign nations and other stakeholders regarding how to address these challenges in an updated Columbia River Treaty. In Chapter 1, we introduce the main goal of this report, followed by an introduction to the history of resources throughout the basin and a brief description of the socioeconomic, geographic, and climatic characteristics of the study area. Finally, this chapter describes the major threats that contribute to declining fish populations and introduces the Columbia River Treaty and the modifications currently being discussed by sovereign nations and other stakeholders. Throughout the report, our focus will be on Native American tribal relationships to the Columbia River and the resources, including essential first foods that it provides.

Goal of this Report

The primary goal of this report is to identify, understand, and value ecosystem-based functions (EbF) within the Columbia River Basin (CRB) under the Columbia River Treaty (CRT) and to explain how valuing EbF relates to tribal socio-economics. This report compares two potential post-2024 scenarios- current condition (RCC-80) and a modernized scenario (3Ea) in which ecosystem-based functions are integrated into river operations decision making.[b] This report explores the relationship between natural and built capital, highlighting the benefits produced from natural capital that are currently ignored or undervalued.

Site Overview

The Columbia River, at 1,243 miles long, spans a vast basin of 258,000 square miles. With headwaters in British Columbia, the river and its tributaries flow through seven U.S. states. Although it is much smaller than the U.S. portion, the British Columbia area of the basin has the largest river management potential due to the existence of three large reservoir storage areas and a stable snowpack. Because it covers such a large area, the basin encompasses several unique climates, including arid semi-desert zones, lush temperate areas, and cold continental mountainous climates. Figure 1 maps the watershed's eleven ecological sub-regions and Table 1 describes their features.

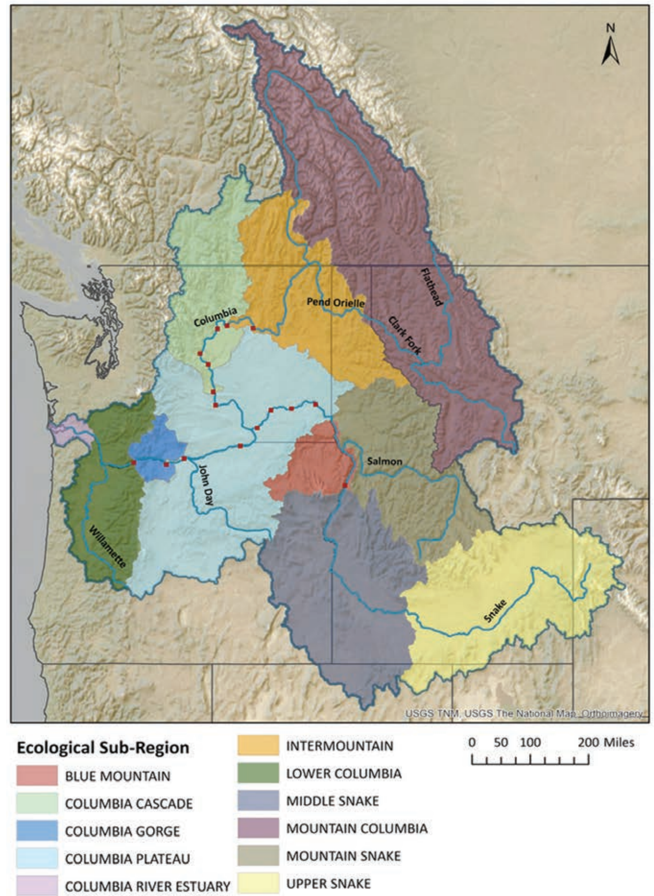


Figure 1. Sub-Regions of the Columbia River

b Both scenarios originated from the CIS model. More detail of this model can be found in the methodology section in Chapter 2.

Table 1. Important Characteristics of the Major Sub-regions of the Columbia River[c]

SUB-REGION	STATE/MAJOR CITIES	MAJOR RESERVOIRS	MAJOR TRIBUTARIES
Blue Mountain	Lewiston, ID; La Grande, OR	Wallowa Lake Reservoir	Grande Ronde River, Snake River, Imnaha River, Kootenai/y River
Columbia Cascade	Kelowna, BC; Vernon, BC; Penticton, BC; Wenatchee, WA	Lake Chelan, Wanapum Reservoir, Lake Entiat	Methow River, Okanogan River, Entiat River
Columbia Gorge	The Dalles, OR	Lake Bonneville, Lake Celilo	Klickitat River
Columbia Plateau	Spokane, WA; Yakima, WA; Bend, OR; Kennewick-Pasco-Richland, WA	Lake Umatilla, Lake Wallula, Banks Lake	Yakima River, John Day River, Deschutes River, Snake River, Palouse River, Umatilla River, John Day River
Columbia River Estuary	Longview, WA	None	Grays River
Intermountain	Spokane, WA; Coeur d'Alene, WA	Franklin D. Roosevelt Lake, Lake Pend Orielle, Coeur D'Alene Lake	Saint Joe River, Sanpoil River, Hangman Creek, Kettle River, Spokane River, Little Spokane River, Clark Fork River and Coeur d'Alene River
Lower Columbia	Portland, OR; Salem, OR; Eugene, OR; Albany, OR; Corvallis, OR; Longview, WA.	Riffe Lake, Swift Reservoir	Willamette River, Clackamas River, Tualatin River, Cowlitz River
Middle Snake	Boise, ID; Nampa, ID	Brownlee Reservoir, Lake Owyhee, Cascade Reservoir	Snake River, Malheur River, Owyhee River, Payette River
Mountain Columbia	Missoula, MT	Lake Koocanusa, Hungry Horse Reservoir, Flathead Lake	Blackfoot River, Clark Fork, Flathead River
Mountain Snake	Lewiston, ID	Dworshak Reservoir	Snake River, Salmon River, Clearwater River
Upper Snake	Idaho Falls, ID; Pocatello, ID; Twin Falls, ID	American Falls Reservoir, Palisades Reservoir, Jackson Lake	Henrys Fork, Snake River

c Cities: USGS, 2014. Small-scale Dataset – Cities and Towns of the United States 201403 Shapefile; Rivers: USGS, 2015. National Hydrology Dataset, High Resolution GDB; Reservoirs: Lehner, B., C. Reidy Liermann, C. Revenga, C. Vorosmarty, B. Fekete, P. Crouzet, P. Doll, M. Endejan, K. Frenken, J. Magome, C. Nilsson, J.C. Robertson, R. Rodel, N. Sindorf, and D. Wisser. 2011. Global Reservoir and Dam Database, Version 1 (GRanDv1): Reservoirs, Revision 01. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC).http://dx.doi.org/10.7927/H4HH6H08.

Brief History of Natural Resources in the Columbia River Basin

Since time immemorial, Native American communities in the basin have centered their lifestyles on the resources provided by their native land and river systems. A variety of fish are highlighted in this report, including burbot, lamprey, and salmon. These fish and other first foods are important, sustainable, natural capital. Within the Columbia River Basin, they nourish native people and hold immense cultural value. Sharing resources such as fish, game, roots, or berries at ceremonies has been central to tribal cultural values for hundreds of years. Although all resources gathered from the Columbia River and its watershed are of great importance, particular attention is given to salmon, as they are an "indicator species".Salmon productivity is tied to the health of multiple ecosystems, including estuaries, coastal areas, the open ocean, and rivers. [3] Improvement through restoration in one of the types of salmon habitat improves habitat for all other species within that habitat. In addition, the consumption of salmon via natural predators fertilizes riparian soils, increasing forest productivity and the system-wide provision of ecosystem function.

Pre-European settlement, the Columbia River and its tributaries produced abundant salmon runs with an average year producing runs of up to 16 million.[4] The Columbia and Snake River systems, formed to their current geologic state by massive ice-agefloods about 14,500 years ago, have long fostered thousands of miles of habitat for fish populations.

Although human settlement in the Columbia River Basin can be documented back about 14,500 years[5], European "discovery" of the river's mouth didn't happen until the mid-18th century. European, Canadian and American governments subsequently spent decades exploring and disputing claims to the region. When white settlers first arrived in the basin, they were in awe of the massive salmon runs. As late as the mid-1850's, salmon runs were likely not greatly affected by the anthropogenic demand for salmon.[6] Though white entrepreneurs salted, packaged, and sold salmon purchased from tribes, the environmental impacts were not yet apparent.

In the latter part of the 19th century, however, the introduction of a salmon canning industry took advantage of these immense salmon runs. By the end of the century, it was clear that commercial fishing was depleting the once abundant chinook salmon runs. To help offset the high demand for canned salmon, canneries began processing other salmon runs, including sockeye, steelhead, coho, and chum. Between 1891

Celilo Falls fishery, Source: CRITFC

and 1895, canneries packaged approximately 23 million pounds of salmon annually. Although salmon canneries are no longer major contributors to salmon run depletion, other mechanisms such as permanent hydrological alterations due to dam development continue to negatively impact fish populations and fisheries.

By the 1930s, the vision for development of the Columbia River and tributaries became clear: establish large public works projects that would provide substantial volumes of controlled reservoir storage and altered flow regimes for the benefit of hydroelectric power, navigation, flood control, and irrigation. Where possible, but as an afterthought, these projects attempted to allow for fish passage. These alterations to the river would substantially change the natural capital and ecosystem-based function of the basin (concepts defined in Chapter 2). The 20th century became an era of dam building, navigation, and agricultural projects by federal and local agencies as well as private entities. These projects relied on incomplete analyses that failed to include ecological and economic tradeoffs, ultimately ignoring the value of natural capital. During the 20th century, attitudes toward the environment shifted as education and research addressed the nature of people's relationship with the environment more holistically.[7] Methodological developments within economics now allow economists to account for the changing perceptions and values embraced in the modern day, which were largely ignored in earlier times.

Over the course of the 20th century, fish runs experienced severe population declines. Fish species native to the Columbia River Basin such as salmon, sturgeon, bull trout, eulachon and steelhead were listed under the Endangered Species Act (ESA), in addition to the dozens of salmon runs extirpated from the basin.[8] The decline in fish populations can be attributed to many different sources, but the construction of dams along the mainstem Columbia River is at the center of this analysis.

First Foods

First foods are the traditional foods provided by a functional ecosystem. Tribes have harvested first foods for thousands of years, and they continue to rely on them today as a primary source of sustenance for their families. These foods define the nourishment, trade, and health of tribal members as well as the land and water.

First foods are culturally, socially, and spiritually significant. Because of their wide-reaching significance, they are recognized and honored through trading and ceremonies that express gratitude and respect for the nourishment they provide. These foods are honored with ceremony and prayer,

CRITFC researchers sampling salmon smolt populations in the Hanford Reach, Source: CRITFC

D.R. Michel with large Chinook Salmon from the FV Dream Catcher, Source: Keith Kutchins

following the first foods order—first water, followed by fish, game, roots, and berries. Water comes first in this order as the sustainer of other first foods. Without water, there would be no fish. Berries and roots need water to grow. Game such as elk and deer also need water to survive.

First foods directly affect the resilience and longevity of the Columbia River tribes, and tribal ancestors have always protected and cared for first foods. In that way, they are also a gift from the past.

The gathering of first foods has declined substantially since pre-contact times. Prior to European contact, tribes would harvest tens of millions of pounds of first foods. Tribal first food harvests are now ten times lower.[9] Access to many fishing, hunting, and gathering areas has been lost. Immense areas of the Basin have been blocked to upstream and downstream migrations and access. More than 33,000 acres of land once used to hunt game and gather roots and berries have been flooded. Where tribes once used to fish, fish have now disappeared.

Within this hunting and gathering culture, the well-being of the land and water determine the well-being and prosperity of tribal people and their culture. As threats to Columbia River ecosystems have emerged, so too have tribal culture and health been impacted.[d]

Threats to Columbia River Ecosystems

This section briefly explains some of the threats to the ecosystems in the Columbia River Basin, specifically noting threats to salmonids, which are directly affected by the management of hydropower dams throughout the river. The Columbia River Basin contains a myriad of ecosystems that house thousands of animal and plant species. The threats to these species are numerous. Several major threats to these species are known as the "four H's": habitat (degradation and total loss of), hydropower (dams as barriers and reservoir flooding), harvest (overharvesting) and hatcheries (fish competition). There are also other factors worth noting, such as climate change, increased floodplain development, and riparian degradation. This section will describe some of the threats listed above to demonstrate the complexity of conserving ecosystems and restoring fish runs throughout the basin.

HYDROPOWER AND LOSS OF HABITAT: Hydropower dams along the Columbia River have degraded habitats that are crucial to anadromous fish and other species. The key dam-related factors that degrade ecosystems are: altered thermal regimes, excessive nutrients, anoxic and hypoxic conditions, altered flows, inundated habitats, slowed water velocity, increased water temperatures, slowed upstream and downstream fish migration, and creation of habitat for predatory fish species. Dam construction and other types of development such as mining, agriculture and forest practices have severely altered stream hydrology and geomorphology, thus greatly impacting habitat for salmon and other riverine species. Each dam blocks sediment from traveling downstream, starving the riverbed of needed gravel and cobble that provide salmon spawning habitat. Additional habitat stressors, such as dam management-induced water velocity alterations, are discussed in the burbot and lamprey case studies in Chapter 5's Tribal Fishing section. Over time, the reductions in the quality and quantity of habitat have decreased salmon populations, and thus their harvest.[10] For example, the Nez Perce Tribe's current salmon harvest is only 160,000 pounds, compared with salmon harvests of 2.8 million pounds in pre-contact times.[11]

d More information on first foods and how it relates to health can be found in Chapter 5- The Cultural Value of the CRB.

WATER QUALITY, TEMPERATURE AND DEPTH: Each CRT dam immediately affects upstream and downstream water quantity and quality.[12] Especially during drought years, water levels are much lower, further limiting salmon's ability to move up and downstream. During drought years, dam operators refill reservoirs from winter power drafts, reducing spring and early summer flows causing temperatures to increase more quickly. Elevated river temperature was cited as the primary cause of low adult sockeye salmon passage and high mortality during the 2015 drought.[13] Water quality is also threatened by land uses such as livestock grazing, timber harvest, agriculture, rural residences, roads, mining, and recreation. These activities have an effect on water quality due to increased water temperature and sediment, excessive nutrients, channel alterations, and increased pollution.[14]

DAMS AS BARRIERS: Dams are barriers to fish in multiple ways. First, they impede the downstream migration of juvenile fish to the ocean where they will spend their adult lives. For example, juvenile survival rates through the system have been as low as 7 to 15 percent in low water years. They also impede or hinder adult salmon, lamprey, and sturgeon from swimming upstream to spawning areas. Adults may fallback over dams one or more times, depriving them of vital energy needed for spawning. Dams can act as temperature solar collectors, causing direct or indirect fish mortality. Some dams and reservoirs block passage to some of the most historically productive spawning areas. This is the case for the Hells Canyon Complex, where this dam system alone inundates 95 miles of historical fall chinook habitat.[15] Efforts have been made to facilitate passage around some dams. Fish ladders and other mechanisms have been constructed at many facilities, such as Bonneville Dam on the Columbia River. The Army Corps of Engineers' original budget for the Bonneville Dam fish ladders was $640,000 in 1937, although the mechanism eventually cost the agency nearly $7 million after additions were made to the original plan, small bill for multiple benefits.[16]

HARVEST: Due to their patterns of ocean distribution and the timing of their spawning run up the Columbia River, salmon are subject to incidental harvest by both ocean and in-river fisheries. Coastal fisheries in California, Oregon, Washington, British Columbia, and Southeast Alaska annually report recoveries of tagged fish from the Columbia River. The timing of returns of many fish coincide, and the harvest of a particular runs of fish isn't easy to distinguish, therefore incidental by-catch, and overfishing are problems.[17]

PREDATION: Ecosystem alterations attributable to hydropower dam created bottle necks and modification of river and estuarine habitat such as creation of bird colonies on dredged habitat have increased the of salmon and steelhead predation. The abundance has of certain predators

Grand Coulee Dam 2013, Source: Brian Gruber

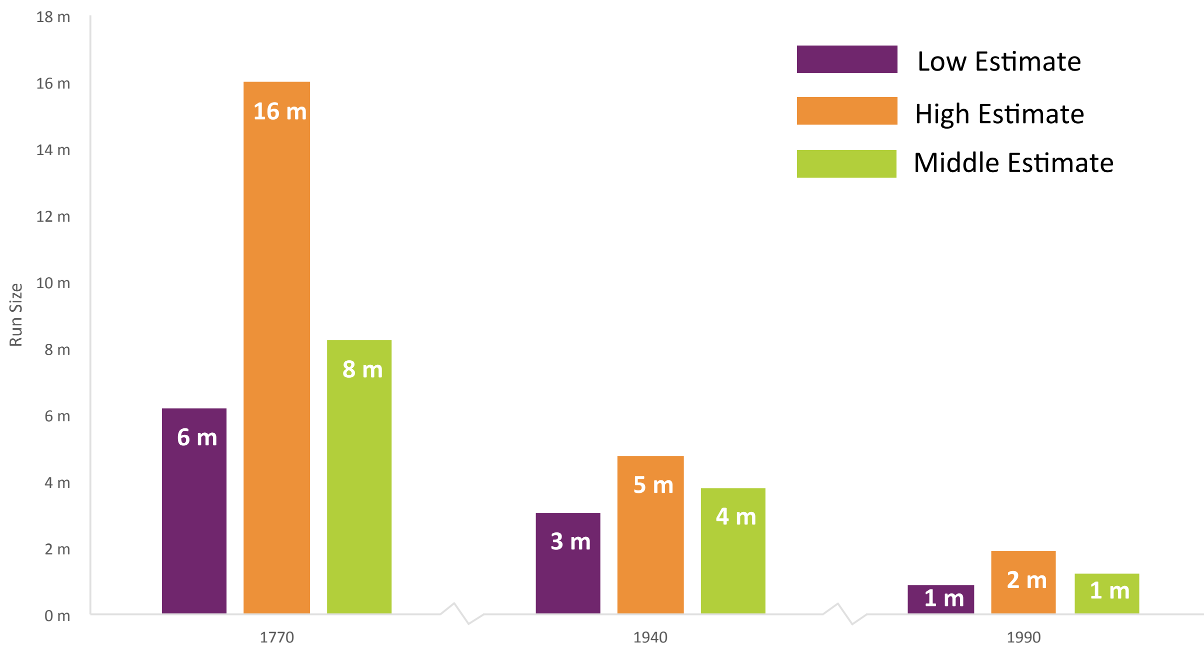


Figure 2. Salmon Entering the Columbia River

has increased exponentially, particularly in localized areas. Some notable predators are birds, marine mammals and native, and non-native fish.[18]

HATCHERIES: Salmon produced in hatcheries can pose a threat to wild salmon by competing for available food and habitat and by reducing the genetic fitness of wild fish. A recent NOAA study suggests that some hatcheries in the CRB must undergo operational changes to reduce the risks mentioned above.[19] These changes include halting the use of hatchery brood stock that originates outside the CRB to reduce genetic risk to native fish; reducing hatchery production in the same place; increasing hatchery production where stray hatchery fish are not a threat to recovery of protected salmon and steelhead; additional research and monitoring to better track and understand the effects of hatchery fish on wild salmon and steelhead populations.[20] However, hatchery fish can be an important restoration tool to restore and promote fish productivity in areas of degraded habitat from built capital such as dams (which is most of the CRB). Hatchery fish also provide important tribal and non-tribal harvest opportunities.

CLIMATE CHANGE: The health of aquatic resources within the Columbia River Basin is dependent on the maintenance of historical temperature and hydrological conditions. Future climate change in the Pacific Northwest is predicted to cause increased water temperatures and major alterations in the seasonality and volume predictability of river flow. As winter air temperatures rise, precipitation patterns shift away from snowfall and towards winter rainfall, reducing the size of spring freshets, reducing summer flows and reducing quality of riverine and riparian habitat.[21] Climate change compounds the environmental and built capital management challenges ensuing from basin population growth such as excessive floodplain development, riparian vegetation degradation, increased hydropower and agriculture and municipal water demand, and water pollution.

FLOODPLAIN DEVELOPMENT: Development along riverine systems has significant economic benefits, which are tied to the development of infrastructure such as cities, ports, industrial uses, navigation, the fertility of riparian lands, access for irrigation, recreation and other opportunities. However, all of these benefits come at a cost to the river and the community of plants and animals linked to riverine and riparian habitats. Levee construction disrupts the hydro period (seasonal pattern of water levels) of riparian vegetation, altering the type and density of vegetation that will grow in riparian areas.[22] Development of riparian areas for grazing also reduces vegetation coverage, further leading to increased erosion rates, less shade (leading to increased water temperatures), limited input of woody debris (reducing the complexity and quality of riverine habitats), and infiltration and proliferation of invasive species into riparian areas.[23] Constructing large areas of impermeable pavement and other development only compounds the challenges of restoring floodplains. Runoff from paved areas cannot infiltrate into groundwater, but carries with it the pollutants (i.e. nutrients, petrochemicals and other synthetic compounds) associated with urban development, negatively impacting habitat and water quality.[24]

RIPARIAN VEGETATION DEGRADATION: Riparian vegetation plays a vital role in supporting riverine habitat. Habitat stressors such as increased air temperatures, urban runoff, and bank erosion can all be mitigated through adequate riparian vegetation levels.[25] Degradation of riparian vegetation via hydrological disruption and floodplain development reduces riparian effectiveness in regulating to regulate the health of aquatic environments. Given the complexity of riverine health, riparian vegetation loss cannot be successfully addressed without considering major stressors, such as floodplain development and climate change.

Columbia River Salmon

The Columbia River Basin is home to four types of salmon: sockeye, chinook, coho, and chum, as well as steelhead, an anadromous rainbow trout. Salmon hatch and rear in freshwater rivers and streams, migrate to the Pacific Ocean as juveniles, and return to the Columbia River to spawn—mostly in the same tributary where they hatched.[26] Since the first dams were constructed in the late 1930s, salmon runs have sharply declined.[27] Although this reduction can be attributed in part to urban development in Columbia River Basin floodplains and historical overharvesting, dam construction has also directly and significantly contributed to much of this population reduction.[28] Figure 2 presents a snapshot of salmon run declines since the 1770s.[29]

Understanding the benefits provided by the Columbia River Basin's built infrastructure (hydropower generation, irrigation, navigation, and flood control) is important, but understanding the economic value of the basin's natural functions is equally as important for making sound management decisions. How the dams are managed under their authorized purposes can have significant economic effects, many of them negative. Currently, dams included within the Columbia River Treaty are managed for hydroelectric production and flood control. Although natural capital value and ecosystem-based function are equally significant, current dam management practices do not maximize these benefits or even give them equal prioritization in management decisions. As the 1964 Treaty is updated, holistic management guidelines should be incorporated into a modernized treaty.

For example, salmon populations within the Snake River and Upper Columbia have declined since the installation of four federal dams on the lower Snake River decreased juvenile passage survival and since the privately owned three-dam Hells Canyon Complex eliminated passage to historical spawning grounds and led to irrigation water removals upstream of the Hells Canyon Complex. A variety of methods have been tested to ameliorate the impact of dams upon salmon, but populations continue to experience serious decline, at times to extirpation. Hatchery production was employed but it was not a panacea. For example, the high proportion of salmon runs composed by hatchery salmon is threatening the survival of wild salmon species, leading to a reduction in genetic diversity of salmon stocks.[30] Some smaller dams have been removed with successful results for salmon, such as Condit Dam on the White Salmon River. Removal of dams on the lower Snake River would allow for recovery of 140 miles of chinook spawning habitat and increased access to 5,300 miles of spawning and rearing habitat.[31] In addition, the costs of dam removal have been shown to be approximately 2/3[rds] lower than initial estimates, making removal a more tractable option than initially thought.[32]

CRITFC researchers sampling salmon smolt populations in the Hanford Reach, Source: CRITFC

The 1964 Columbia River Treaty

The Columbia River Treaty is a 60-year[e] agreement between Canada and the United States that governs the development and operation of dams along the river.[33] When it was established in 1964, the Treaty envisioned the construction of three dams in British Columbia (Duncan,

e The Columbia River Treaty is an agreement with some provisions that expire after 60 years [2024] and some provisions that never end unless one of the parties terminates them with 10 years' notice.

Mica and Keenleyside) and allowed the U.S. to construct Libby Dam in Montana to support flood control in both countries. U.S. President Eisenhower appointed the first U.S. Entity to implement the treaty, and Canadian Prime Minister Diefenbaker instituted the Canadian Entity.

The Permanent Engineering Board (PEB) was established to oversees and monitors the Treaty's implementation. A primary component of the Treaty called for Canada to build three dams capable of holding up to 15.5 million acre-feet of water, and for the United States to build Libby dam, which can store up to 5 million acre-feet of water.[34] The U.S. and Canada are further required to prepare an annual Assured Operating Plan (AOP) to guide Canadian water storage. The AOP is usually completed six years in advance of each operating year, and it specifies flood control and power priorities, which were the only recognized purposes for annual project operations when the Treaty was signed.[35] The AOP also defines the level of Canadian entitlement[f] to downstream power benefits for that year.

The Treaty design ensures that both countries benefit from this agreement, either through reduced flood risk or hydropower generation. Accordingly, Canada was to be paid half of the estimated value of U.S. flood damages prevented.[36] In lieu of an annual payment, Canada instead elected to receive lump sum payments totaling $64.4 million in 1964 for flood protection benefits through 2024 (approximately $493 million in 2015 dollars[g]).

In exchange for providing and operating the Treaty storage projects for power, Canada also received an entitlement to half of the estimated downstream power revenues generated in the U.S. In 1973, Canada sold its share of additional power for $254 million to a consortium of U.S. utilities for a period of 30 years. Since then, the Canadian hydropower has been delivered daily to the Province of British Columbia at the U.S.-B.C. border for Canada's use or resale. The Treaty also resulted in the development of the U.S. Pacific Northwest Coordination Agreement (PNCA), which helps optimize the operation of Pacific Northwest projects to take advantage of water flow control from Canada. Under the PNCA, most Pacific Northwest hydropower projects operate as though they were owned by one utility, taking advantage of the regional diversity in stream flows and power loads, as well as the ability to optimize all reservoir storage operations to one power load

John Day Dam, Source: CRITFC

Ecosystem-Based Function and the Existing Columbia River Treaty

In 1993, the Canadian and U.S. Entities opted to develop Detailed Operating Plans that consider aspects of river management beyond hydropower and flood protection. Consideration of more expansive aspects may prove to prove to be more advantageous for both countries than the limited objectives in the AOP. Detailed Operating Plans permit the Entities to include fisheries and other non-power objectives that provide mutual benefits, such as meeting Endangered Species Act (ESA) requirements. These other ecosystem-based considerations suggest actions such as flow augmentation agreements.[37]

In spite of the provisions under Detailed Operating Plans, ecosystem-based function is still not a priority among the Treaty's primary objectives. U.S. regulations for meeting ESA requirements do not address the long-term implications of dam management regimes. Even with decades of U.S. environmental policy, including the ESA and Clean Water Act, dams continue to bar migrating fish and altered hydrologic and geomorphologic conditions continue to degrade habitat for salmon and other species.

The Treaty Update

Multiple sovereigns and user groups within the Columbia River Basin are impacted by the current Treaty conditions. These include the following:

- **TRIBES:** The economic, social, cultural, spiritual, and environmental status of tribes is directly affected by

f The Columbia River dams are operated for the collective benefit of the Columbia River region, Canada does not optimize river flows for maximization of power generation. The United States reimburses Canada for this lost benefit by providing power generated by dams within the U.S.

g Adjusting $64.4 million for inflation between 1964 to 2015 the Columbia River dam operations. The tribes call for ecosystem-based function to be part of treaty decision-making and planning.

- **LOCAL ANGLERS, BIRDERS, WILDLIFE SURVEYORS:** Public stakeholders who use waters for environmental and recreational benefits will be affected by changes in the Columbia River. Changes in ecosystem quality or quantity will affect the quantity of fish available for recreation, and habitat restoration will be important for all residents (ex: the Columbia River Gorge National Scenic Area).
- **COLUMBIA BASIN RESIDENTS RECEIVING HYDROPOWER ELECTRICITY:** Accommodating ESA requirements and a changing climate includes changing water levels on areas of the Columbia River, which will influence how hydropower is delivered. Residents that depend on their electricity from Columbia River hydropower may see variable electricity rates due to changes in water flow, rainfall, and flood conditions.
- **FARMERS:** River water available for irrigated agriculture may fluctuate if ESA requirements or climate change result in less water. Reservoir levels will be dramatically affected during drought years, especially with climate change. Farmers' water use is linked to the water needs of their crops.
- **THE U.S. GOVERNMENT:** The federal government is responsible for managing the Columbia River dams for flood control and economic benefits, in addition to the safety of water containment in the United States. The U.S. President and Senate retain constitutional authority over international treaties, and thus have a significant role in decisions concerning the Treaty. The U.S. Army Corps of Engineers and the Bonneville Power Administration are the primary federal agencies involved in developing the Regional Recommendation for reshaping the treaty. The U.S Negotiating Team, headed by the U.S. Lead Negotiator Brian Doherty, will be guided by the Department of State's negotiating

Mt. Hood sunset behind Columbia River, Source: CRITFC position as developed in the Office of Management and Budget Circular 175. This team will represent the needs and focus of the American government in this treaty, including the interests of various federal agencies such as the Environmental Protection Agency and Fish and Wildlife; regional tribes; the States of Washington, Oregon, Idaho and Montana; multiple stakeholders; and the U.S. voters.

- **BC HYDRO AND THE CANADIAN ENTITY:** These entities are responsible for flood control in British Columbia and receive the United States' flood control payment. BC Hydro controls reservoir levels of two Canadian dams and will seek to benefit the interest of the hydropower consumers in BC.
- **THE COLUMBIA RIVER BASIN FEDERAL CAUCUS:** Comprised of ten land, energy, and environmental federal agencies, the Caucus is responsible for the promotion and recovery of native fish and wildlife in the Columbia River. They will be influenced by the need to protect wildlife and habitat under the Endangered Species Act and to adapt to conditions resulting from a changed climate. They will be motivated to uphold their cultural values against any scarcity of native salmon, with interests to improve salmon return rate and habitat quality.
- **U.S. ARMY CORPS OF ENGINEERS (USACE):** The USACE's main responsibility is for flood control and navigation. The USACE, the Bureau of Reclamation (Reclamation), and the Bonneville Power Administration (BPA), collectively referred to as the Action Agencies (AAs), have consulted with NOAA Fisheries and the U.S. Fish and Wildlife Service (USFWS) on the effects of operating the 14 Federal hydropower projects in the Federal Columbia River Power System (FCRPS) on fish species listed as endangered or threatened under the Endangered Species Act (ESA). These consultations resulted in biological opinions (BiOps) from NOAA Fisheries and USFWS that identify FCRPS operations that are implemented by the AAs to avoid jeopardizing the survival and recovery of ESA listed fish species. These protections are implemented to the letter of the law while maintaining the priorities of the Treaty.
- **BONNEVILLE POWER ADMINISTRATION (BPA)38:** BPA markets and transmits electricity for private use from 31 federal dams and one nuclear power facility. BPA provides one-third of the Northwest's electric power and is also responsible for the country's largest fish and wildlife mitigation program.[39] It will seek to operate at profit-maximizing levels, though these may be affected if restrictions are made to their operations and reservoir water elevations. Currently, these elements are designed for maximum revenue generation through hydropower sales, although there are some restrictions for flood control. There are some flow and operational requirements under NOAA and USFWS's Biological Opinion for ESA species and court orders issued under Oregon. v. U.S. litigation and the NWF v. NMFS 2014 litigation over Federal Columbia River Power System Biological Opinion (FCRPS BiOp) under the Endangered Species Act (ESA) and National Environmental Policy Act (NEPA). NMFS has currently started working on a new BiOp with full NEPA review due out sometime between 2018 and 2021. BPA decisions will be influenced by their hydropower customers.

In 2011, the U.S. Entity and the Tribes developed a Sovereign Review Process for collaboration and consultation between four Northwest States (Washington, Oregon, Idaho, and Montana), 15 tribal governments, and the Northwest federal caucus. As part of this process, the U.S. Entity was committed to consult directly with tribal interests through the federal government's tribal trust responsibility.[h] Additionally, BPA and USACE agreed with each state and federally recognized tribes on the review to ensure that the U.S. Entity hears state and tribal concerns are brought to the U.S. Entity for consideration. Through this process, the Regional Recommendation was developed and submitted to the State Department for review in December of 2013.

h This references the Presidential Executive Order of 2000 called "Consultation and Coordination with Indian Tribal Governments."

Chapter Two

Ecosystem-Based Function of the Columbia River Basin

"At the center of tribal cultures lay a deeply ingrained ethic of reciprocity between people, and between people and the land".

– Salish Pend d'Oreille Culture Committee[40]

In this section, we introduce core concepts for understanding ecosystem-based function and natural and built capital valuation. First, we address ecosystem-based function, then natural capital, ecosystem services, and built capital, including a description of how these elements provide value to human communities and the economic systems that sustain them. We conclude the chapter with our methodology and a valuation of the ecosystem services in the Columbia River Basin.

Ecosystem-based function, natural capital, and ecosystem services are three related, yet distinct, concepts for describing nature's value. Ecosystem-based function, a concept embraced by the Columbia River Basin Tribes, describes nature's value as inherent and independent of any human assessment. Rather, humans are an integral part of the ecosystem as opposed to users or benefactors of the ecosystem. The concept recognizes that nature has a voice and a value simply by virtue of existing, and that this value does not depend on any human estimation of what nature provides. Natural capital and ecosystem services, on the other hand, are economic concepts that specifically apply to natural products and processes that produce a benefit for humans and that can be valued monetarily. In this report, the term ecosystem services applies to all natural benefits that are assigned a monetary value.

Finally, built capital is defined as natural capital transformed by human actions. Construction and operation of dams, cities, agricultural systems, navigation dredging, and locks are all examples of built capital that have diminished the historical natural capital that has sustained the tribes over thousands of years.

The following sections explain these concepts in further detail.

Ecosystem-Based Function

Since time immemorial, the rivers of the Columbia Basin have been the lifeblood of the Columbia Basin tribes. For these tribes, the ecosystem-based function (EbF) of the Columbia River watershed is its ability to provide, protect, and nurture subsistence and cultural resources, traditions, values, and landscapes throughout its length and breadth. Clean, abundant water is a core part of this concept. This resource must be sufficient to sustain life, healthy fish, wildlife, and plant populations that are vital to tribal traditions and way of life. A restored, resilient, and healthy watershed will demonstrate EbF through:

- Increased spring and early summer flows resulting in a more natural hydrograph;
- Higher and more stable headwater reservoir levels;
- Restored and improved fish passage to current and historical habitats;
- Higher river spring flows during dry years;
- Lower late summer water temperature;
- Reconnected floodplains throughout the river, including a reconnected lower river estuary ecosystem
- Enhanced Columbia River plume and near shore ocean through higher spring and early summer flows and lessened duration of hypoxia; and,
- An adaptive and flexible suite of river operations responsive to a great variety of changing environmental conditions, such as climate change and population demand.

Improved EbF in the Columbia Basin Watershed is expected to result in:

- Increased recognition, protection, and preservation of cultural/sacred sites, activities, and tribal First Foods, including water, salmon, other fish, wildlife, berries, roots, and other native medicinal plants;
- Restored and resilient tributary, mainstem and estuarine floodplains and riparian areas
- An estuary and mainstem river with an enhanced food web and increased juvenile and adult fish survival;
- Increased juvenile and adult salmon in-river survival;
- Decreased mainstem travel time for migrating juvenile salmon;
- Increased resident fish productivity that provides stable, resilient populations;
- Increased wildlife productivity that provides stable, resilient populations; and,
- Salmon and other juvenile and adult fish passage to historical habitats in the Upper Columbia and Snake River basins, and into other currently blocked parts of the Columbia River Basin.

Columbia River, Grand Coulee Area, Source: Brian Gruber

EbF encompasses both of the economic terms in this report: natural capital and ecosystem services (ES). Figure 3 illustrates the spatial relationship between these three core concepts using the value of restored fish passage as an example. The black arrows describe the flow: natural capital is the source of EbF, while EbF and functions flow into each other; ecosystem services and benefits flow out because they are a product of EbF. Quantification of ES is the only concept that lies outside of EbF. In Figure 3, the ES food (in the form of salmon) is subject to degradation from external forces, which will thus impact its monetary value. Degraded ecosystems will not be as productive as healthy ones.

Again, the primary distinction between EbF and ES is that ES are monetarily valued. These dollar values provide an economic argument for ecosystems that can be leveraged in decision-making processes. In the following, we outline the core economic concepts of natural capital and ecosystem services.

Natural Capital

In economics, there are five types of capital which determine our quality of life: natural, built[41], financial, human, and social capital. Together, these five building blocks create the conditions for a healthy, sustainable economy. Natural capital, however, is the foundation for all other types of capital. It consists of any "minerals, energy, plants, animals, ecosystems, [climatic processes, nutrient cycles, and other natural structures and systems] found on Earth that provide a flow of natural goods and services".[42] Natural capital thus plays a particularly important economic role, yet its value is frequently overlooked.

Natural capital performs natural functions that provide goods and services that humans need to survive. For example, natural capital assets within a watershed (e.g. forests, wetlands, and rivers) perform critical natural functions such as intercepting rainfall and filtering water. This natural storage and filtration process supports a clean water supply, which is crucial to human survival and a healthy ecosystem. Benefits such as these that people receive from nature are known as ecosystem goods and services. The tribal concept of EbF encompasses all three of these economic concepts (functions, goods and services, and benefits). In economic thought, however, ecosystem services solely refer to natural goods and services that provide benefits to humans and can be monetarily valued. In summary, natural capital provides what we need to survive. Without healthy natural capital, many of the services (benefits) that we freely receive could not exist. Once lost, if possible, these services must be replaced with costly built capital solutions, which are often less resilient and shorter-lived.[43] Thus, not every service can be replaced, like clean air, clean water, fish and wildlife or culturally significant sites. Sometimes when natural capital is lost, its value is also lost to present and future generations.

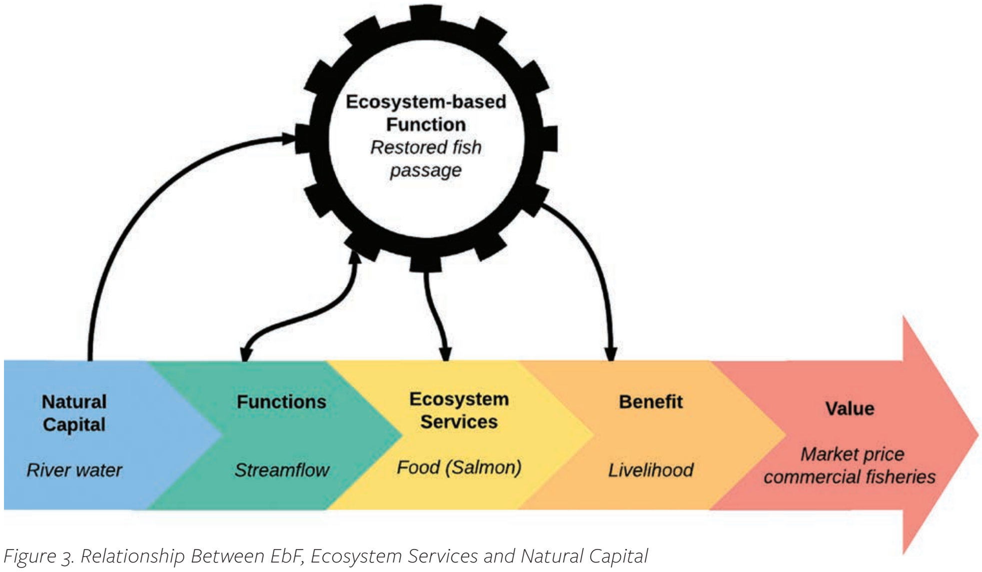


Figure 3. Relationship Between EbF, Ecosystem Services and Natural Capital

Ecosystem Services

Ecosystem services are essential to human survival. Breathable air, drinkable water, nourishing food, and stable atmospheric conditions are prime examples of ecosystem services. Their benefits are similar to other economic benefits typically valued in the economy, such as skilled workers, buildings, and infrastructure. When ecosystem services are lost, economic impacts can be measured in terms of job loss, infrastructure costs, restoration costs, or property loss in the event of storm damage.

Over the last 15 years, considerable progress has been made in systematically linking functioning ecosystems with human well-being. The work of De Groot et al. (2002),[44] the Millennium Ecosystem Assessment (MEA)[45] and The Economics of Ecosystems and Biodiversity (TEEB)[46] marked key advancements in this task. These studies laid the groundwork for a conceptual framework for valuing natural capital and ecosystem goods and services.

Figure 4. Types of Ecosystem Services

Earth Economics' approach to valuation is adapted from the MEA's ecosystem service descriptions. The adapted framework clearly articulates and values the vast array of critical services and benefits that natural capital provides. Under this framework, the four categories of ecosystem goods and services (see Figure 4), which are now commonly used in the field of ecological economics, are as follows:

- **PROVISIONING GOODS AND SERVICES** provide physical materials and energy for sovereign nations and stakeholders that varies according to the ecosystems in which they are found. Forests produce lumber, while agricultural lands supply food and rivers provide drinking water.
- **REGULATING SERVICES** are benefits obtained from the natural control of ecosystem processes. Intact ecosystems keep disease organisms in check, maintain water quality, control soil erosion or accumulation, and regulate climate.
- **SUPPORTING SERVICES** include primary productivity (natural plant growth) and nutrient cycling (nitrogen, phosphorus, and carbon cycles). These services are the basis of the vast majority of food webs and life on the planet.
- **INFORMATION SERVICES** are functions that allow humans to interact meaningfully with nature. These services include providing spiritually significant species and natural areas, natural places for recreation, and opportunities for scientific research and education.

Table 2. 21 Ecosystem Services

GOOD/SERVICE	ECONOMIC BENEFIT TO PEOPLE
PROVISIONING SERVICES	
Food	Producing crops, fish, game, and fruits
Medicinal Resources	Providing traditional medicines, pharmaceuticals, and assay organisms
Ornamental Resources	Providing resources for clothing, jewelry, handicrafts, worship, and decoration
Energy and Raw Materials	Providing fuel, fiber, fertilizer, minerals, and energy
Water Storage	The quantity of water held by a water body (surface or ground water) and its capacity to reliably supply water for multiple purposes
REGULATING SERVICES	
Air Quality	Providing clean, breathable air
Biological Control	Providing pest and disease control
Climate Stability	Supporting a stable climate at global and local levels through carbon sequestration and other processes
Disaster Risk Reduction	Preventing and mitigating natural hazards such as floods, hurricanes, fires, and droughts
Pollination and Seed Dispersal	Pollination of wild and domestic plant species
Soil Formation	Creating soils for agricultural and ecosystems integrity; maintenance of soil fertility, sediment transport for fish spawning areas.
Soil Quality	Improving soil quality by decomposing human and animal waste and removing pollutants
Soil Retention	Retaining arable land, slope stability, and coastal integrity
Water Quality	Improving water quality by decomposing human and animal waste and removing pollutants
Water Capture, Conveyance, and Supply	Providing natural irrigation, drainage, groundwater recharge, river flows, drinking water supply, and water for industrial use
Navigation	Maintaining water depth that meets draft requirements for recreational and commercial vessels
SUPPORTING SERVICES	
Habitat and Nursery	Maintaining genetic and biological diversity, the basis for most other ecosystem functions; promoting growth of commercially harvested species
INFORMATION SERVICES	
Aesthetic Information	Enjoying and appreciating the presence, scenery, sounds, and smells of nature
Cultural Value	Using nature as motifs in art, film, folklore, books, cultural symbols, architecture, media, and for religious and spiritual purposes
Recreation and Tourism	Experiencing the natural world and enjoying outdoor activities
Science and Education	Using natural systems for education and scientific research

Ecosystem Services Valuation

Understanding and accounting for the value of natural capital assets and the ecosystem services they provide can reveal the economic benefits of investing in natural capital. Natural systems have only recently begun to be viewed as economic assets that provide economically valuable goods and services. Yet when these valuable goods and services are lost, people are more susceptible to disasters such as flooding, and they face costly expenditures to replace lost services, like water quality. When the ecosystem services that nature previously provided for free are damaged or lost, they must be replaced by costly, taxpayer-funded built structures. Developing a watershed, for instance, can inhibit or even destroy natural flood risk management, which in turn requires replacing natural protective services with pipes or other infrastructure. In some cases, lost ecosystem goods and services are irreplaceable.

Many ecosystem goods, like food, water, and timber, are already valued and sold in markets. Some ecosystem services, however, are not amenable to markets and have not traditionally been valued. Recreation and climate stability are prime examples of ecosystem services that provide vast value and yet go largely unvalued within traditional accounting. To illustrate, if a stream becomes polluted with toxic chemicals, thus eliminating the public's ability to swim and fish in that stream, this loss can result in significant economic damages to local economies through job losses and reduced spending on fishing equipment, recreation gear, hotels, and restaurants.

Conversely, when investments are made to protect and support ecosystem services, local economies are more stable and less prone to the sudden need for burdensome expenditures on disaster mitigation. For example, during Superstorm Sandy, New York City's Catskills Watershed provided naturally filtered, clean, gravity-fed water with virtually no interruption in service. Previous efforts to protect and restore the watershed helped to minimize disruption. In contrast, New Jersey's damaged pumps, filtration plants, and contaminated intakes left much of New Jersey without potable water for weeks after the storm and with a $2.6 billion tab for water infrastructure repair.[47,48,49] In addition to the economic value associated with these avoided costs, natural capital such as healthy watersheds provides a myriad of other services, including water supply, carbon sequestration, water filtration, and biodiversity. All ecosystem services provide additive economic value locally, regionally, and globally.

Today, there are recognized economic methods to value natural capital and many non-market ecosystem services. When valued in dollars, these services can be incorporated into a number of economic tools, including benefit-cost analysis, accounting, environmental impact statements, asset management plans, conservation prioritization, and return on investment calculations. Inclusion of these values ultimately strengthens decision-making. When natural capital assets and ecosystem services are not considered in economic analysis, they are effectively valued at zero, which can lead to inefficient capital investments, higher incurred costs, poor asset management, and losses related to cultures, such as tribes that rely on these assets.[50,i]

In summary, natural capital provides what we need to survive. Without healthy natural capital, many of the services that we freely receive could not exist. Once lost, these services must be replaced with costly built capital solutions, which are often less resilient and shorter-lived. When we lose natural capital, we also lose the economic and cultural goods and services it provides.

Success Stories: Ecosystem Services Valuation

Ecosystem services valuation (ESV) is a cutting-edge tool that allows analysts to assess the economics value of natural capital. Though ESV has yet to be required for ecosystem conservation, there are nevertheless many success stories that illustrate the value of this type of analysis. For instance, Earth Economics influenced a systemic change in 2013 that affected all 50 U.S. states when FEMA adopted EE's natural capital values for all hurricane and flood disaster mitigation for homeowners, businesses, and government agencies. This policy change improved disaster assistance, helped build community resilience, saved taxpayer money, ensured greater equity, and contributed to conservation efforts.

Earth Economics provided benefit-cost analysis training to 40 applicants for the $1 billion Natural Disaster Resilience Competition offered by the Department of Housing and Urban Development in 2015-16. We valued ecosystems, health, and community cohesion for four of thirteen winners, with awards totaling $475 million of the $1 billion. We provide compelling evidence for investment in natural systems.

Finally, our four-year collaboration with the Eugene Water & Electric Board (EWEB) and the McKenzie Watershed Council has produced measurable conservation results. EE provided

i The same is true when built assets are not considered in economic analysis or asset management. See for example Grubisic, M., Nusinovic, M., Roje, G., 2009. Towards efficient public sector asset management. Financial Theory and Practice 33, 329-362. Available at: http://www.fintp.hr/en/archive/towards-efficient-public-sector-asset-management_283/

the economic justification for greater watershed restoration investment, reducing built capital expenditures: water treatment, levees, and artificial storage. The work increased Eugene's water quality, lowered maintenance costs, and helped stabilize the water supply.

Natural Capital Valuation of the Columbia River Basin

To value the ecosystem services within the CRB, we first determined the extent of natural capital in the study area. Using Geographic Information System (GIS) software, we identified the spatial extent of land and water cover types within the basin. We did not use a historical baseline for natural capital, but rather a snapshot of what is currently present in the basin to best demonstrate the increase in value of the modernized scenario. Next, the benefit transfer method (BTM) was used to determine dollar-per-acre values for ecosystem services. Last, the landcover types and ecosystem service values were combined to estimate the total value of economic benefits provided by the Columbia River Basin. These results were then used to calculate an asset value for the CRB. The following sections provide further detail on these methods and results

Methodology

CRITFC Information System (CIS) Model

Both scenarios, RCC-80 and 3Ea, were created using the CIS model, which is the Columbia River Inter-Tribal Fish Commission (CRITFC) database modeling platform for the Columbia River System. The model foundation is based upon the Bonneville Power Administration (BPA) HYDSIM Columbia River hydro regulation model code, inputs and outputs. The CIS model contains a number of databases, software, queries, and a graphical user interface contained in Microsoft Access. Model outputs are based upon a 14 period time series, generally representing monthly periods, but with April and August split into two periods. Inputs such as volume forecasting, 70- and 80-year historical volumes, flood risk management and power criteria for CIS were obtained from the Corps of Engineers and the BPA. The primary difference between HYDSIM and CIS is that HYDSIM requires manipulation of numerous Excel spreadsheets by hand whereas CIS creates libraries of scenarios in Excel files that are manipulated in the access-based platform. CIS also contains a valuable graphical user interface that quickly constructs table and graphic outputs. In addition, for ecosystem scenarios, CIS has ecosystem rule curves for the largest system reservoirs that drive reservoir operations and

Meacham Creek habitat restoration project. Work done by the Conf. Tribes of the Umatilla Indian Reservation, Source: CRITFC resulting river flows. Various river operational scenarios can be modeled resulting in several metric outputs including, but not limited to, reservoir elevations, flows, power generation, flood risk, dam spill, federal Columbia River Power System Biological Opinion requirements and water particle travel time (a key variable relating to juvenile salmon survival).

The objective function of this model is simulation and comparative analysis of different river operational scenarios with and without climate change. The goal is to create robust output data to assist tribes in decision making regarding future river operations that adapt to climate change.

CIS output data includes historical quintiles and individual water year system and individual project 14 period generation, regulated outflows, ending reservoir elevations, spill per hydro-electric project and other metrics such as meeting BiOp requirements and water particle travel time which is a major component in computing salmon survival. The model is used for comparing current and alterative river operational scenarios including EbF scenarios. Through the CRT processes, CRITFC collaborates with U.S. federal agencies and the Canadian entity in performing modeling studies for the future of the Columbia River Treaty.

Current Condition (RCC-80) Scenario and Modernized Scenario (3Ea)

Two scenarios were selected to compare the economic benefits between the current conditions (RCC-80) and a modernized management scenario (3Ea) that promotes sustainable natural capital through increased ecosystem function and services. For this reason, RCC-80 values benefits provided in a business-as-usual situation, and 3Ea values the increase of benefits under modified river management. Figure 5 illustrates the differences in values in this report between the two scenarios.

Both scenarios represent hypothetical Columbia River Treaty post-2024 situations. However, post-2024 changes to flood risk management required by the Treaty are not reflected in either scenario. The RCC-80 represents a scenario where ecosystem-based function is limited to Biological Opinion operations. For that reason, RCC-80 still has a natural capital value, but it is lower than the value produced under the 3Ea scenario, where increased ecosystem-based functions would be implemented. The same is true for the CRT. Although there is value under the CRT, this value is lower than what the 3Ea scenario would supply.

The modernized 3Ea scenario would increase both EbF and the value of ecosystem services. The 3Ea scenario will also shift built capital, emphasizing the need for green and resilient infrastructure, and creating a Columbia River Basin that can adapt to climate change by restoring spring and early summer flows and reconnecting flood plains. Lastly, 3Ea would increase social and cultural benefits throughout the basin by conserving landscapes, enabling wildlife to thrive and increasing salmon runs and resident fish populations.

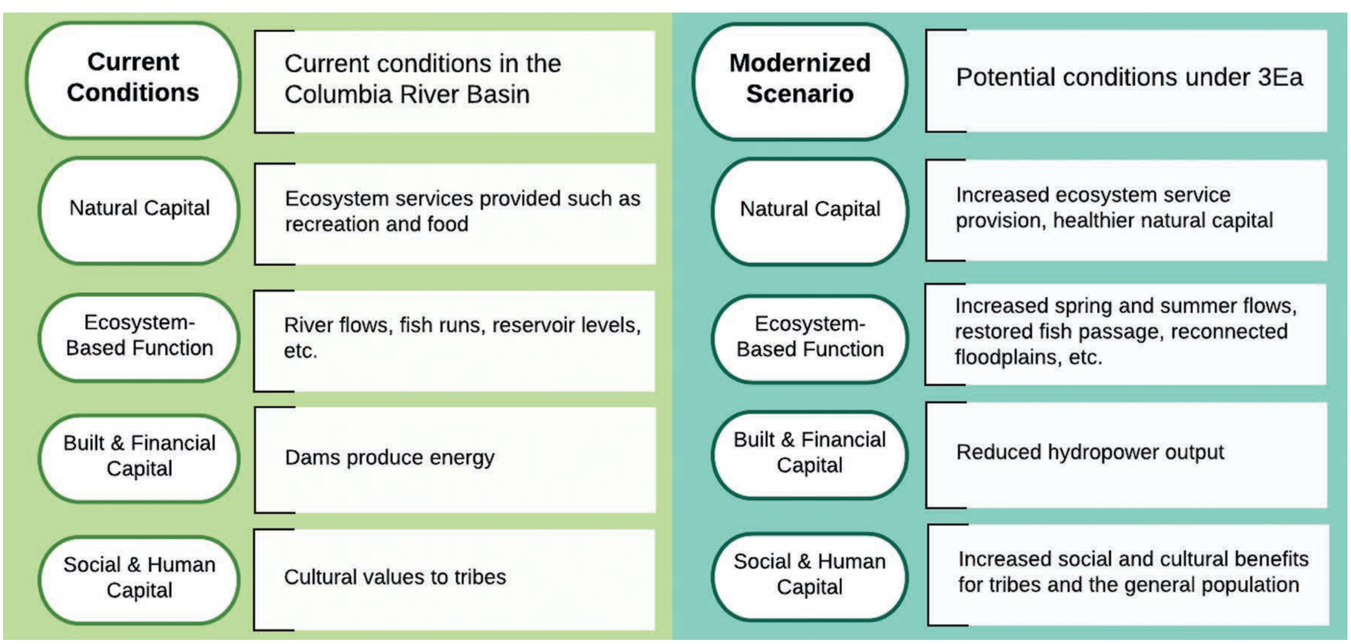


Figure 5. Types of Capital Present in the CRB, Current Conditions and Modernized Scenarios

Major Differences in a Modernized Scenario

The 3Ea scenario describes a Columbia River Treaty in which EbF are included in decision making. Listed below are some of the major changes that would come from this enhanced decision-making, Table 3 also describes some of the differences between the two scenarios:

- A partially restored spring and early summer peaking hydrograph to improve resident and anadromous fish survival and wildlife habitat and help restore tribal First Foods, with a special focus on ensuring flows in low runoff years to allow for hydrologic conditions that promote ecosystem function;
- Increased late summer and early fall flows to improve immigration, habitat, and water quality for resident and anadromous fish;
- Stable reservoir elevations to improve resident fish production and better protect tribal cultural resources;
- Increased spring and early summer spill to increase anadromous fish survival;
- Reestablished floodplain habitat to allow for groundwater recharge and restoration of important habitat for riparian dependent wildlife species;
- Structural modifications to immediately restore fish passage and improve water management and to handle anticipated climate change impacts now and in the future.

Deschutes River mouth, Source: CRITFC

Land Cover Analysis

Land cover acreage for the Columbia River Basin was derived from the USGS Land Cover Institute (LCI) spatial data using GIS software.[52] Acreage was calculated for every land cover category in the LCI data, including cultivated, forest, grassland, shrub-steppe, dammed reservoir, lake, river, and wetland land covers.

The GIS data was modified in several ways to enable a more detailed description of the natural capital of the study area. "Spatial attributes" were constructed to describe unique locations of ecosystems within the landscape. In this analysis, we considered four spatial attributes that affect ecosystem service values: proximity to agricultural areas and the location

Table 3. Expected Differences Between RCC-80 and 3Ea[51]

	RCC-80 (CURRENT CONDITION)	3EA (EBF)
FLOOD RISK	USACE Flood Control Operating Plan	USACE Flood Control Operating Plan
HYDROPOWER	Winter reservoir storage drafted to meet loads	Reduced winter generation- increased spring/ early summer generation
ECOSYSTEM FLOWS	Reduced winter reservoir storage reduces spring-early summer peak flows	Reservoir storage enhances peak spring-early summer freshet down through estuary
RESERVOIR OPERATION	Heavy reservoir drafting destabilizes reservoir environment	Reduced reservoir drafting stabilizes reservoir environment
FISH SPILL	Spring and summer spill	Slightly longer spring spill period
FCRPS BIOP	Misses spring flow targets in most years	Meets spring flow targets in most years
SUPPLEMENTAL AGREEMENTS	Trout and whitefish flows	Can alter trout and whitefish flows in some years

of land covers within riparian, urban, or climate zones. Table 4 describes how each spatial attribute was derived and the datasets involved in calculating the boundaries of each spatial attribute. For example, classifying a certain acre of forest as "riparian" allows us to choose ecosystem service values unique to riparian forests, or categorizing a grassland under dry and arid climates enables the application of different values than temperate grasslands. In addition, a landcover type could have one or more spatial attributes associated with it. For example, riparian wetlands adjacent to agricultural areas provide much higher values in terms of waste treatment from agricultural runoff than wetlands further removed from agricultural areas. Identifying the spatial attributes of landcover data allows the application of more granular study values and increases accuracy as each attribute provides information that narrows the scope of values and mitigates uncertainty. Valuations tend to be more accurate when the spatial distribution of values is taken into account.[53] Appendix B describes some limitations of this spatial attribute analysis.

Water-Based Analysis (Per Acre-Foot)

Increased flows that are beneficial to ecosystem function provide economic value. To estimate the increase in economic value, data from the CIS model is converted from cubic feet per second (cfs) to acre-feet. Assuming a constant rate of release between periods, the cfs is converted to acre-feet per day and then multiplied by the total number of days in the study period. This calculation yields the total acre-feet of water released over given a period. The net change in water volume over the critical period (March 1 through September 31) is calculated by subtracting the volume under the 3Ea scenario from the volume under RCC-80 for the driest, medium, and wettest water years.

Benefit Transfer Method

The benefit transfer method (BTM) is broadly defined as "...the use of existing data or information in settings other than for what it was originally collected."[54] Within the field of ecological economics, this method is a validated, well-established approach for indirectly estimating the value of ecological goods or services. BTM can generate reasonable ecosystem services estimates quickly and at a fraction of the cost of conducting local, primary studies, which may require more than $50,000 per service/land cover combination. Frequently, BTM is the most practical option available for producing reasonable estimates in an ecosystem services valuation.[55]

The BTM process involves taking ecosystem service values from comparable ecosystems as found in peer-reviewed journals and transferring them to a study site, in this case, the Columbia River Basin.[56] The BTM process is similar to a home appraisal, in which the value and features of comparable, neighboring homes (two bedrooms, a garage, one acre, recently remodeled) are used to estimate the value of another home. As with home appraisals, BTM results include a degree of uncertainty, yet the process quickly generates reasonable values appropriate for policy and project analysis.

The first step in the process is to identify primary studies with comparable climate and land cover classifications (wetland, forest, grassland, etc.) as those within the study area. Earth Economics maintains the Ecosystem Valuation Toolkit (EVT), a comprehensive repository of published, peer-reviewed primary valuation studies.[j] Studies under consideration were assessed based on their correspondence to the CRB. Any primary studies deemed to have incompatible assumptions, ecosystem services, or land cover types were excluded. Individual primary study values were adjusted and standardized for units of measure, inflation, and land cover classification to ensure an "apples-to-apples" comparison. Frequently, primary studies offer a range of values that reflect the uncertainty or variability within the research area. As such, high and low dollars per acre values in 2014 USD are included for each value provided in this report. Appendix F lists all primary studies used for value transfer estimates.

Winter in the Columbia River Gorge, Source: CRITFC

j Earth Economics Ecosystem Valuation Toolkit (EVT). More information available at www.esvaluation.org.

Table 4. Spatial Attributes and Data Sources

ATTRIBUTE	DESCRIPTION	METHODOLOGY	DATA SOURCE
Climate	Different weather patterns like precipitation, humidity, or temperature can result in different conditions under which ecosystem services are produced, e.g. water supply in arid climates may be more valuable than in temperate climates.	The Köppen-Geiger climate classification is based on average temperature and precipitation. In the CRB, three main climates exist: • dry and arid (B climate): 70% or more of annual precipitation falls in the summer half of the year and average annual precipitation less than 20 times the average annual temperature plus 280, or 70% or more of annual precipitation falls in the winter half of the year and average annual precipitation less than 20 times the average annual temperature, or neither half of the year has 70% or more of annual precipitation and average annual precipitation is less than 20 times the average annual temperature plus 140 • temperate (C climate): temperature of warmest month greater than or equal to 100C and temperature of coldest month less than 180C but greater than -30C • continental (D climate): temperature of warmest month greater than or equal to 100C and temperature of coldest month -30C or lower	Rubel, F., and M. Kottek, 2010: Observed and projected climate shifts 1901-2100 depicted by world maps of the Köppen-Geiger climate classification. Meteorologische Zeitschrift 19: 135-141.
Agriculture	Areas within or adjacent to nearby farms which benefit cultivated lands or reduce the impacts of agriculture, e.g. native vegetation near farms can be home to wild pollinators that help increase crop yields.	The USDA tracks cultivated lands nationwide and produces the yearly Cropland Data Layer (CDL). All cropland in the CRB was identified using the 2015 CDL.	USDA National Agricultural Statistics Service Cropland Data Layer. 2015. Published crop-specific data layer [Online]. Accessed 06/15/16. USDA-NASS, Washington, DC. Agriculture and Agri-Food Canada – Land Use 2010 [Online]. Accessed 06/15/16. Agri-Geomatics Service of Agriculture and Agri-Food Canada.

ATTRIBUTE	DESCRIPTION	METHODOLOGY	DATA SOURCE
Riparian	Areas alongside streams and rivers where ecosystem services tend to be produced or demanded in greater quantities due to higher ecological productivity, e.g. some kinds of wildlife viewing or water-based recreational activity.	The National Hydrology Dataset, which provides data on all U.S. rivers, streams, and waterbodies, was combined with Canadian National Hydro Network data. This network is then buffered by 50 feet to approximate the riparian zone.	USGS National Hydrology Dataset. 2015. Accessed 08/10/16.USGS-NHD, Washington, D.C. GeoGratis, National Hydro Network. 2015. Accessed 08/10/16. Natural Resources Canada, Ottawa, CA.
Urban	Areas where the value of some ecosystem survival tends to be higher due to the proximity of dense populations, e.g. urban parks have greater positive impact on nearby property values.	U.S. Census data (Urban Growth Areas for Washington and Oregon and Urban Areas for remaining states) and Canadian Census Metropolitan Areas were used to map urban areas.	U.S. Census Bureau Urban Growth Areas. 2010. Accessed 06/15/16. U.S. Census Bureau, Washington, D.C. U.S. Census Bureau Urban Areas. 2015. Accessed 06/15/16. U.S. Census Bureau, Washington, D.C. Statistics Canada Boundary Files. 2011.Accessed 06/15/16.

Asset Valuation

The asset value of built capital can be calculated as the net present value of its expected future benefits. Provided the natural capital of the CRB is not degraded or depleted, the annual flow of ecosystem services will continue into the future. As such, analogous to built capital, we can calculate the asset value of natural capital in the CRB.

The asset value calculated in this report is based on a snapshot of the current land cover, consumer preferences, population base, and productive capacities. It provides a measure of the expected benefits flowing from the study area's natural capital over time. The net present value formula is used in order to compare benefits that are produced at various points in time. In order for this to be accomplished, a discount rate must be used.

Discounting allows for sums of money occurring in different time periods to be compared by expressing the values in present terms. In other words, discounting shows how much future sums of money are worth today. Discounting is designed to take two major factors into account:

1. Time preference. People tend to prefer consumption now over consumption in the future, meaning a dollar today is worth more than a dollar received in the future.
2. Opportunity cost of investment. Investment in capital today provides a positive return in the future.

However, experts disagree on the appropriate discount rate for natural capital benefits. Public and private agencies vary widely in their standards for discount rates. The Office of Management and Budget (OMB) recommends a seven percent rate for average investments, while the Congressional Budget Office (CBO) recommends a two percent rate for long-term investments. The choice of discount rate is critical, however, as it heavily influences the outcome of the present values of benefits which occur over a long period of time. This report uses two discount rates to analyze the asset value of the CRB: a standard seven percent discount rate, and a lower two percent discount rate. Lower discount rates better demonstrate the value of long-term assets, as benefits hundreds of years into the future are discounted at a smaller rate.

Present values can be calculated over different timeframes depending on the purpose of the analysis and the nature of the project. In the case of natural capital valuations, ecosystems, if kept healthy, show long-term stability and productivity. We chose a 100-year timeframe to reflect this fact; which is longer than many built-capital projects are valued for. Still, if kept healthy, the CRB would provide benefits for much longer than 100 years.

Table 5. Ecosystem Services Valued in this Analysis

	CULTIVATED	FORESTS	GRASSLANDS	SHRUBLANDS	DAMNED RESERVOIRS	LAKES	RIVERS	WETLANDS
Aesthetic Information		X	X					X
Air Quality		X	X	X				
Biological Control	X	X	X	X				
Climate Stability	X	X	X	X				X
Disaster Risk Reduction		X	X	X				X
Food	X	X	X					
Habitat		X					X	X
Pollination and Seed Dispersal		X		X				
Recreation and Tourism		X	X		X		X	X
Soil Formation	X	X	X	X				
Soil Retention	X	X	X	X				X
Water Capture, Conveyance, and Supply		X	X					X
Water Quality		X	X			X		X
Water Storage		X		X		X	X	X

Note: An ‘x’ marks an ecosystem service/land cover combination that was valued in this analysis.
See Appendix G for the dollar-per-acre-per-year results for each combination of land cover and ecosystem service.

Ecosystem Services Identified

For this analysis, 14 ecosystem services were valued over eight land cover types. We were able to value at least one ecosystem service on each land cover type. Table 5 shows the ecosystem services that were valued on each land cover. The greatest limitation to this analysis is a lack of valuation studies representing all of the ecosystem services provided in the CRB. Many ecosystem services that clearly have economic value provided by a land cover type could not be assigned value due to a lack of applicable values available in the literature. In particular, reservoirs, lakes, and rivers could not be assigned many ecosystem service values due to data gaps, yet these ecosystems provide clear benefits. For example, many reservoirs provide people with water supply and flood protection, two key ecosystem services that could not be assigned value for this land cover type.

The Value of Ecosystem Services

In total, the CRB provides annual ecosystem service benefits of $189.9 billion. The highest total benefits accrue from forests at $149 billion, followed by rivers at $11 billion. Given that forests represent over 56 million acres, or 18 percent of the basin’s total area, the high forest value was foreseeable. Rivers, on the other hand, cover only 658 thousand acres (0.2 percent of the basin), and yet had markedly high per-acre ecosystem service values.

However, caution should be taken when comparing ecosystem service values between categories, as the difference in value may be due to data gaps rather than ecosystems' true value. Not every ecosystem service could be valued in this analysis due to a lack of available data in the literature. Furthermore, these values represent underestimates of the watershed's value, as many ecosystem services could not be valued at this time. However, these underestimates still give value to services provided by ecosystems that are currently valued at zero in the market system, therefore these underestimates are vital given they provide needed economic arguments to guide decision-making.

Table 6. Annual Ecosystem Services Valuation Results

LAND COVER TYPE	DRY	TEMPERATURE	CONTINENTAL	AGRICULTURAL	RIPARIAN	URBAN	ACRES	PER-UNIT ESV (USD/ACRE/YEAR)	TOTAL ESV (USD/YEAR)
Cultivated	X						6,496,768	$395	$2,566,223,496
Cultivated		X					6,837,363	$475	$3,247,747,227
Cultivated			X				2,373,152	$225	$533,959,247
Forest	X						406,166	$663	$269,287,966
Forest	X			X			3,448	$663	$2,285,830
Forest	X				X		521	$704	$366,825
Forest	X					X	32	$2,066	$66,460
Forest	X			X	X		4	$704	$2,596
Forest	X			X		X	0	$2,066	$0
Forest	X				X	X	8	$2,107	$16,612
Forest	X			X	X	X	0	$2,107	$0
Forest		X					12,940,699	$2,221	$28,741,291,994
Forest		X		X			5,599	$2,222	$12,440,980
Forest		X			X		41,417	$2,481	$102,754,659
Forest		X				X	41,820	$4,686	$195,968,422
Forest		X		X	X		2	$2,355	$5,448
Forest		X		X		X	5	$4,686	$22,976
Forest		X			X	X	375	$4,819	$1,805,572
Forest		X		X	X	X	0	$4,819	$0
Forest			X				42,574,821	$2,787	$118,661,987,637
Forest			X	X			590,445	$1,475	$870,989,758
Forest			X		X		100,706	$2,787	$280,680,399
Forest			X			X	23,925	$1,346	$32,206,061
Forest			X	X	X		6,459	$2,787	$18,002,904

LAND COVER TYPE	DRY	TEMPERATURE	CONTINENTAL	AGRICULTURAL	RIPARIAN	URBAN	ACRES	PER-UNIT ESV (USD/ACRE/YEAR)	TOTAL ESV (USD/YEAR)
Forest			X	X		X	4,879	$1,346	$6,567,701
Forest			X		X	X	305	$2,658	$809,725
Forest			X	X	X	X	30	$2,658	$79,213
Grassland	X						2,768,587	$117	$323,924,717
Grassland	X			X			373,141	$117	$43,657,532
Grassland	X				X		7,766	$117	$908,661
Grassland	X					X	4,578	$117	$535,655
Grassland	X			X	X		259	$117	$30,310
Grassland	X			X		X	307	$117	$35,902
Grassland	X				X	X	47	$117	$5,454
Grassland	X			X	X	X	0	$117	$38
Grassland		X					2,751,628	$284	$781,462,458
Grassland		X		X			512,737	$282	$144,591,730
Grassland		X			X		8,413	$28,062	$236,085,604
Grassland		X				X	29,830	$3,219	$96,021,617
Grassland		X		X	X		290	$28,062	$8,135,258
Grassland		X		X		X	1,173	$3,219	$3,775,259
Grassland		X			X	X	176	$30,609	$5,394,402
Grassland		X		X	X	X	2	$30,609	$75,360
Grassland			X				4,982,755	$618	$3,079,342,385
Grassland			X	X			326,924	$618	$202,038,935
Grassland			X		X		19,798	$618	$12,235,406
Grassland			X			X	23,491	$584	$13,718,709
Grassland			X	X	X		1,483	$618	$916,650
Grassland			X	X		X	11,291	$584	$6,594,017
Grassland			X		X	X	238	$603	$143,320
Grassland			X	X	X	X	37	$603	$22,493
Shrubland	X						21,463,551	$26	$558,052,321
Shrubland	X			X			826,529	$26	$21,489,743
Shrubland	X				X		45,770	$646	$29,567,184

LAND COVER TYPE	DRY	TEMPERATURE	CONTINENTAL	AGRICULTURAL	RIPARIAN	URBAN	ACRES	PER-UNIT ESV (USD/ACRE/YEAR)	TOTAL ESV (USD/YEAR)
Shrubland	X					X	36,459	$26	$947,923
Shrubland	X			X	X		465	$646	$300,217
Shrubland	X			X		X	647	$26	$16,816
Shrubland	X				X	X	407	$646	$262,865
Shrubland	X			X	X	X	12	$646	$7,856
Shrubland		X					19,548,075	$89	$1,739,778,675
Shrubland		X		X			635,820	$89	$56,587,963
Shrubland		X			X		50,888	$89	$4,529,050
Shrubland		X				X	129,364	$89	$11,513,390
Shrubland		X		X	X		274	$89	$24,364
Shrubland		X		X		X	907	$89	$80,699
Shrubland		X			X	X	1,675	$89	$149,035
Shrubland		X		X	X	X	2	$89	$167
Shrubland			X				30,128,010	$30	$903,840,311
Shrubland			X	X			650,558	$498	$323,977,644
Shrubland			X		X		86,965	$30	$2,608,937
Shrubland			X			X	62,620	$30	$1,878,606
Shrubland			X	X	X		5,165	$498	$2,572,286
Shrubland			X	X		X	6,964	$498	$3,467,984
Shrubland			X		X	X	1,148	$30	$34,425
Shrubland			X	X	X	X	94	$498	$46,724
Reservoir	X						156,078	$785	$122,521,168
Reservoir		X					149,217	$0	$0
Reservoir			X				800,944	$0	$0
Lake	X						222,005	$0	$0
Lake		X					282,507	$1,073	$303,130,201
Lake			X				744,782	$2	$1,489,563
River	X						102,406	$23,277	$2,383,693,226
River		X					343,690	$36,763	$12,635,071,838
River			X				212,458	$23,271	$4,944,110,812

LAND COVER TYPE	DRY	TEMPERATURE	CONTINENTAL	AGRICULTURAL	RIPARIAN	URBAN	ACRES	PER-UNIT ESV (USD/ACRE/YEAR)	TOTAL ESV (USD/YEAR)
Wetland	X						5,528	$21,123	$116,758,266
Wetland	X			X			472	$17,624	$8,321,346
Wetland	X				X		491	$21,123	$10,364,972
Wetland	X					X	0	$21,123	$0
Wetland	X			X	X		11	$17,624	$187,431
Wetland	X			X		X	0	$17,624	$0
Wetland	X				X	X	0	$21,123	$0
Wetland	X			X	X	X	0	$17,624	$0
Wetland		X					103,058	$50,500	$5,204,453,535
Wetland		X		X			2,942	$22,445	$66,022,804
Wetland		X			X		6,995	$56,718	$396,729,112
Wetland		X				X	23,887	$62,054	$1,482,265,913
Wetland		X		X	X		31	$28,663	$896,043
Wetland		X		X		X	71	$33,999	$2,415,884
Wetland		X			X	X	1,404	$68,272	$95,848,837
Wetland		X		X	X	X	0	$40,217	$4,142
Wetland			X				30,283	$43,976	$1,331,735,103
Wetland			X	X			14,544	$114,741	$1,668,740,432
Wetland			X		X		837	$23,851	$19,974,700
Wetland			X			X	2,810	$27,409	$77,026,104
Wetland			X	X	X		225	$102,737	$23,146,603
Wetland			X	X		X	1,271	$114,741	$145,839,563
Wetland			X		X	X	61	$9,393	$576,070
Wetland			X	X	X	X	6	$102,737	$649,164
TOTAL							**161,082,853**		**$189,963,081,928**

In addition to the annual flow of ecosystem service benefits, we calculated a general asset value for the CRB's natural capital. If treated as an asset, the CRB's ecosystem services amount to $2.7 trillion over 100 years using a seven percent discount rate, or as high as eight trillion using a two percent discount rate.

Table 7. Net Present Value of CRB Natural Capital Over 100 Years

DISCOUNT RATE	HIGH (USD)
2%	8,187,095,703,552
7%	2,710,630,841,480

Given that this valuation does not include all ecosystem services across all land cover types; these values should be considered underestimates. Yet, even these conservative estimates demonstrate the sizeable value of the CRB's natural capital. These high values indicate that investments in natural capital can provide vast long-term benefits if these assets are conserved or enhanced. Moreover, investment in natural capital can yield a tremendous return on investment due to both the low cost of investment (relative to building new assets) and because it supports a suite of ecosystem services and benefits, not just a single benefit.

Chapter Three

The Current Value of the Columbia River Basin

"In the way of our elders who came before us, we worship, dance, drum, sing and continue to gather foods, treading along some of the same paths they did to find food for our families and tap into our rich heritage."

– Confederated Tribes of the Umatilla Indian Reservation[57]

This chapter identifies the value of fisheries, existence of species, hydropower, flood risk management, recreation, navigation, and water supply for agricultural uses under current conditions. This scenario, Reservoir Current Conditions-80 years (RCC-80), models post-2024 dam management based on hydrological data from 1929 to 2008, and assumes that the dams will continue to be managed primarily for hydropower generation and flood control.

Chinook Salmon, Source: U.S. Fish and Wildlife Service

Non-Tribal Commercial Fisheries

Commercial fishing has been a source of significant economic value in the Pacific Northwest since the late 1800s.[58] Today, the Columbia River Basin supports multiple commercial fisheries throughout the Pacific, including local tribal and non-tribal commercial fisheries from Oregon to Alaska.[59] Within the basin, there are five species of salmon, but chinook, coho, and sockeye dominate commercial harvests. Steelhead and sturgeon are also caught in great numbers by tribal fisheries, and several thousands of pounds of shad and smelt are harvested each year in non-tribal fisheries.[60] Columbia River coho and chinook travel as far north as southeast Alaska and south along the Oregon Coast, supporting commercial fisheries there, as well as in British Columbia and Washington. Recent declines in salmon runs have cut commercial harvests to a fraction of their historic levels,[61] with related losses to commercial fishing jobs and income.

For Columbia River Tribes, salmon have always been a vital cultural resource for subsistence, ceremonial, and economic purposes. The Treaty tribes (Warm Springs, Nez Perce, Umatilla, and Yakima) have exclusive commercial fishing rights in 147 miles of the Columbia between the Bonneville and McNary dams; treaty fisheries bring in 50 percent of all harvestable adults in the river.[62] Non-tribal commercial fisheries are restricted to the 145 miles of river below Bonneville Dam.

In this section, we evaluate the economic value of non-tribal commercial fisheries. We do not quantify the economic value of tribal commercial, ceremonial, or subsistence fisheries, as these are invaluable to the tribes.

Economic Value of Commercial Fisheries

Methodology

To assess the current state of commercial fisheries within the Columbia River Basin, as well as coastal fisheries that rely on the Columbia River, we valued non-tribal commercial fisheries landings in: the Columbia River Basin and areas off the Washington, Oregon, British Columbia, and southeastern Alaska coasts. We collected data on salmon landings and ex-vessel prices from the National Marine Fisheries Service, Pacific Fishery Management Council, the government of British Columbia, Oregon Department of Fish and Wildlife, and the Alaska Department of Fish and Game. For regions outside the Columbia River Basin, we reduced landings based on estimates of the proportion of fisheries which can be attributed to habitat in the Columbia River. For example, an estimated 28 percent of chinook landings are from the Columbia River, so we only valued 28 percent of chinook landings in Southeast Alaska.[63] Table 8 shows the percent of commercial salmon catch attributed to Columbia River salmon stocks.

Table 8. Percentage of Salmon Catch Attributable to the Columbia River Basin

AREA	CHINOOK	COHO
Southeast Alaska	28%	0%
British Columbia	7%	<1%
Oregon Coast	16%	11%
Washington Coast	32%	1%
Washington Puget Sound	1%	0%

Source: National Marine Fisheries Service[64]

We based current conditions on the average landings over five years (2011 to 2015) for each of the zones identified in Table 8. To value landings, we used the average ex-vessel price per pound for each species over the same years.[65] We used the ex-vessel price per pound[k] because these data are readily

k Ex-vessel price per pound is the price paid to fishermen for their catch. It does not exclude the costs fishermen incur in producing the landed catch.

available and better reflect the net economic value of the resource. Ex-vessel value is the closest product to fish catch.[66] Other prices, such as first wholesale value or retail prices, can include markups for profit and labor. Assessing the impacts of commercial fisheries throughout the value chain is beyond the scope of this report.

Gillnet drying on a rack, Source: CRITFC

The Value of Commercial Fishing Under Current Conditions

Table 9 reports the annual landings and value of non-tribal commercial fisheries in the Columbia River Basin, and coastal fisheries of CRB salmon. Within the basin, non-tribal fisheries catch on average 2.4 million pounds in landings each year, producing $5.4 million in ex-vessel value. Outside of the basin, Columbia River salmon stocks support more than 1.5 million pounds of landed salmon, and an ex-vessel value of about $6.7 million for non-tribal fisheries. The total value of non-tribal commercial fisheries under the RCC-80 scenario is over $12 million.

Existence Value

Many Columbia River fish species, including salmon, are threatened or endangered.[67] There is significant evidence that people are willing to pay to protect rare, threatened, and endangered species[68] In economic terms, this concern is known as "existence value", or the value that people place on knowing that certain ecosystems or species exist, even if they will never see or use those ecosystems or species.[69] Recovering salmon populations in the basin would economically benefit the regional population.

Table 9. Non-Tribal Commercial Fishery Harvests Attributable to the Columbia River Basin, Summary of Salmon Landings

AREA & SPECIES	LANDED POUNDS (WHOLE)	LANDED VALUE
IN-BASIN		
Chinook	1,722,664	$4,343,686
Coho	654,725	$1,046,296
Pink	90	$144
Shad	11,346	$18,131
Sockeye	1,038	$1,659
Total In-Basin	2,389,864	$5,409,916
ALASKA AND BRITISH COLUMBIA		
Chinook	1,177,348	$5,392,618
COASTAL WASHINGTON AND OREGON		
Chinook	406,492	$1,326,975
Coho	2,726	$ 3,635
Total Out-of-Basin (AK, BC, WA, OR)	1,586,566	$6,723,228
GRAND TOTAL	**3,976,430**	**$12,133,144**

In 2009, Richardson and Loomis conducted a meta-analysis on existence value for various species from around the United States, including several cases of Pacific Northwest anadromous salmon populations. We chose this study because the complexity of the Columbia River Basin would be better matched by a meta-analysis of many studies. We used this study and function transfer methodology to estimate the economic benefits of existence value for Columbia River salmon. Function transfer uses economic models estimated in an original study with site-specific data (see Appendix I for the model used here).

The model shows that for current conditions, willingness-to-pay for salmon is about $11 per household per year. Using US Census data,[70] we determined that there are about 2.8 million households within the Columbia River Basin. Thus, the total existence value for households under current conditions is estimated at $37.2 million annually.

Hydropower

In 2014, the US electric power industry generated nearly $400 billion in revenue.[71] On average, hydropower accounts for about half of all electricity produced in the Pacific Northwest, excluding Canada.[72] Electricity produced within the basin powers cities up and down the Western US and Canada, from Vancouver to Los Angeles. Clearly, the benefits provided by the Columbia River Basin extend far beyond its ecological boundaries.

The US Bureau of Reclamation (USBR), the Army Corps of Engineers (USACE), and the Bonneville Power Administration (BPA) collaborate to generate and market hydropower through the Federal Columbia River Power System (FCRPS).[l] Annually, the 31 FCRPS dams provide 75,000 GWh (gigawatt-hour) of power.[73] There are also non-federal dams in the Columbia River Basin that contribute 43 GWh of power to the grid. Four major and seven smaller hydroelectric dams in the Canadian portion of the Columbia River Basin generate 22,000 GWh, about half of BC Hydro's total generation.[74]

Typically, the system can produce high amounts of baseload power and usually meet on demand power needs, meaning that hydropower can cover both the base demand requirements for power and much of the sudden increases in demand up to maximum capacity. In coordination with other generating resources, the system generates surplus power on a monthly basis, especially in high water years.

Chief Joseph Dam, Source: Brian Gruber

Hydropower generation is dependent on several factors, including: water supply within the basin, the regional power demand, irrigation demands, ecological requirements, system and transmission limitations and the climate (i.e. temperature). Year after year these factors can vary greatly, resulting in large fluctuations in the amount of hydroelectric power supplied by dams. For example, drought years can limit hydroelectric power generation, forcing the region to rely on other resources to either meet demand or to reduce environmental, agricultural or other water uses. Of course, in high water years, hydropower can be equal to or greater than regional demand, bumping other generating sources offline or resulting in spill levels (described below) that may cause ecological problems.[m]

Current Power Generation

The current conditions scenario (RCC-80) assumes that the Columbia River hydropower system will continue to be operated with the main objectives of hydropower and flood control. That means that priority is given to meeting power demands and managing reservoir storage levels to minimize flood risk to the best of their ability. Agencies are legally required to comply with fish and wildlife law and regulations, these often are not sufficient and dams are not adequately managed to promote and sustain and dam management does address ecosystem-based function as defined by the tribes. Thus, to a certain extent, more could be accomplished to fully realize this. The current condition scenario mimics the business-as-usual river management.

l Other uses of the FCRPS include flood control, irrigation, navigation and recreation.

m Because of the Public Utility Regulatory Policies Act, utilities are required to market any power produced by non-utility producers, even when there is no demand for said power. On rare occasions, BPA will pay non-utility producers to forego the production of power.

Methodology

Using CRITFC's Information System (CIS) modeling software, scenarios were developed using hydrologic and system operational data from 1929 to 2008. For each water year, data was provided for 14 periods throughout the year. System operational data was measured monthly, with the exception of April and August. These months were split into two periods each because there are often major changes in power operations instream flow during these months. The 80 water years are grouped into five water year quintiles based on hydrologic flow: quintile 1 included the driest 20 percent of water years, and quintile 5 included the wettest 20 percent. With this data, both system-wide and project-specific information was provided by individual water year, water month, and quintile. Furthermore, the data also represented total hydroelectric power generation, system surplus, spot pricing of surplus and deficit power, estimated dollar value of surplus and deficit power, and three types of spill at the dams. Although this approach is robust, one caveat to the RCC-80 scenario is that it does not incorporate climate change.[n]

Spill

Not all water that moves through a hydropower project is used for power generation. Occasionally, water is 'spilled', or released from a reservoir through a dam which bypasses the generating turbines. In addition, water may move through fishways and navigation locks and these sources do not generate electrical power. There are three reasons that water may be spilled from a dam. In the spring and summer, voluntary fish spill is released to assist juvenile salmon migrating to the Pacific Ocean. Second, forced spill can occur when there is more water entering the reservoir than can be run through the turbines (i.e. river flows exceed turbine capacity- which may be due to dysfunctional power generation facilities.) The last type, over-generation spill, occurs when demand for regional power is lagging. Figure 6 shows the volume of various spill types that occured at the Dalles Dam.

The Value of Hydropower Under Current Conditions

The Pacific Northwest relies on power generated by the Columbia River power system, the majority of which comes from hydroelectric dams.

Figure 7, Figure 8, and Figure 9 show the hydroelectric demand and estimated generation based on hydrologic flow in the driest, medium, and wettest water years, respectively. Values are presented in average megawatts, or the electricity produced by continually generating one megawatt for one year. Power generated above the demand line is considered surplus and can be sold on the open market, helping to keep energy costs low for Pacific Northwest ratepayers.

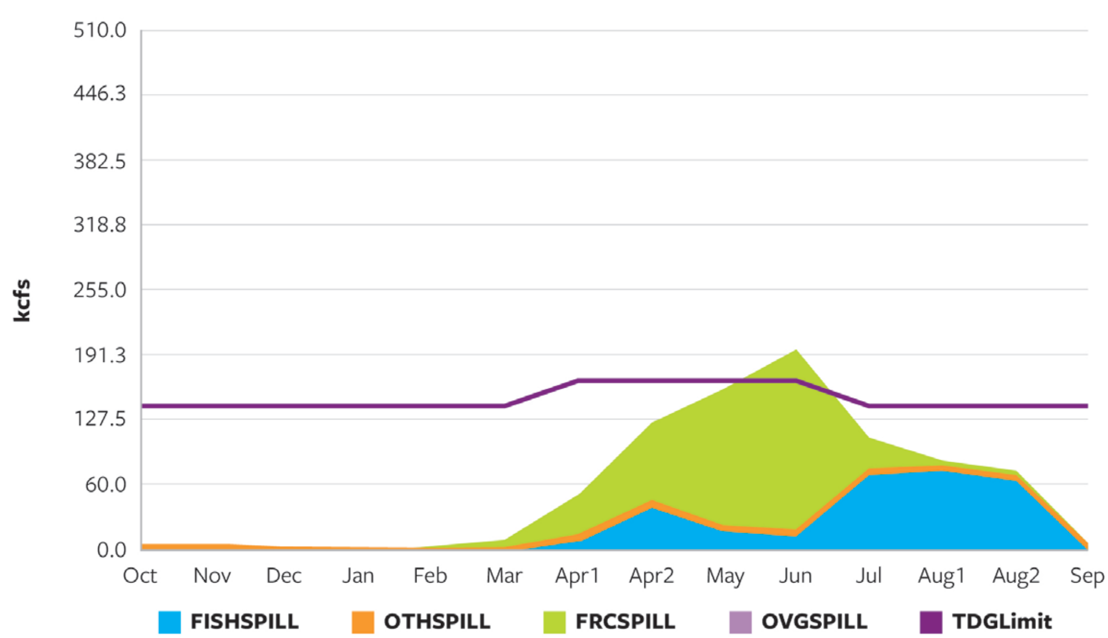


Figure 6. Different RCC-80 Spill Categories at The Dalles Dam for the Highest Flow Years

n The data for basin climate change hydrology is currently being developed and updated through the River Management Joint Operating Committee. Given the need to complete this analysis, climate change hydrology could not be included in any of the modeling efforts.

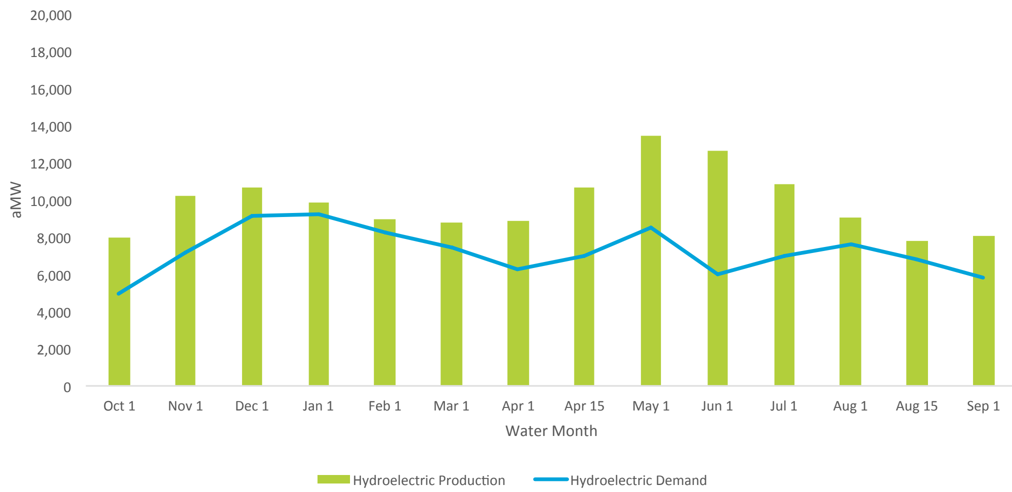


Figure 7. Columbia River Basin Hydroelectric Production—Q1

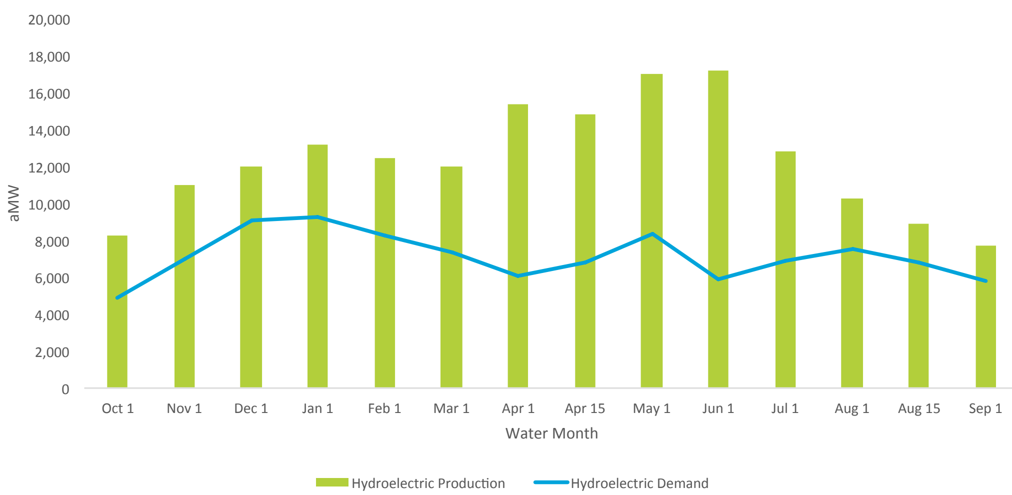


Figure 8. Columbia River Basin Hydroelectric Production—Q3

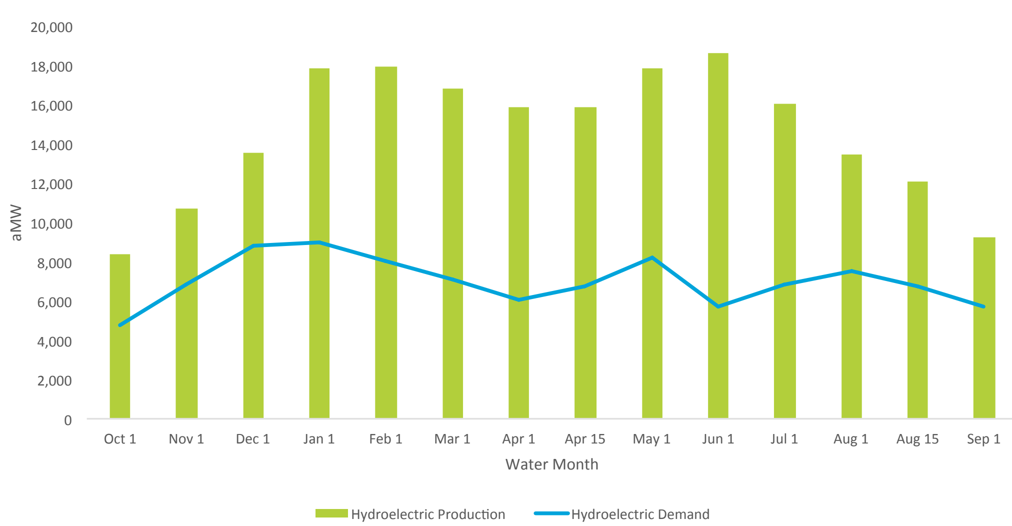


Figure 9. Columbia River Basin Hydroelectric Production—Q5

In all water years, hydroelectric production is greatest in May due to peak natural runoff driven by snowmelt. In most years, the initial controlled flow[o] has occurred by mid-April so that flood control storage requirements can be met. As can be seen by the graphs, hydroelectric demand is being met in all water years, including under the driest conditions. In high water years, the system sees major power surpluses that increase revenue flow, assuming the power generated can be marketed.

Revenues were estimated by using PNW East prices (MID-Columbia Prices) observed for each of the 14 water periods under each water year. Although prices vary by day and even by hour, these prices are assumed to be reflective of the economic value of hydropower. Revenues from hydroelectric power generation are estimated to be $3.1 billion in the driest years, $3.4 billion in medium years, and $3.7 billion in the wettest years. In the current conditions scenario, CIS models estimate demand is met in all months and all water years, leaving surplus power that can be sold on the open market.

Table 10. Value of Hydropower under Current Conditions

HYDROPOWER VALUES	CURRENT CONDITIONS
Driest Water Years	$3,066,514,176
Medium Water Years	$3,388,935,087
Wettest Water Years	$3,664,655,116
WEIGHTED AVERAGE	**$3,373,356,570**

Power-Generating Alternative Resources

The Columbia River Basin is a powerhouse for electricity production. A large portion of this production comes from hydropower, with natural gas, wind, nuclear, and coal making up the majority of the remaining production. The region's power generation and demand is not static, however. While historically shortfalls have occurred, according to the Northwest Power and Conservation Council, there is enough power generated in the CRB to meet expected loads until about 2026 due to reduced southwestern US needs through other sources and energy conservation gains in the CRB. Post 2026 the Council analysis indicates that additional power sources would not be needed unless demand exceeded the median forecast. In addition, the Council reports that shifts in Northwest energy demand from winter to summer as a result of climate change will necessitate changes in power generation timing and distribution.[p] As the population continues to grow and power demands increase, the region faces two choices, which are not mutually exclusive. To meet the needs of an increasing population, the Pacific Northwest must increase power-generating capacity to keep up with demand, or per-capita power must decrease through conservation efforts. BC Hydro is continuing to develop the Peace River Project, which will provide 1,100 megawatts of capacity and about 5,100 gigawatt hours of electricity each year, enough to power about 450,000 homes per year in BC.[75] Additionally, the Northwest Power and Conservation Council's 7th Power Plan identified around 5,100 aMW's of technically achievable conservation potential by the end of the 20-year forecast period (2035).[76]

Meeting Demand through Increased Generating Capacity

All power-generating resources have pros and cons. Coal is inexpensive, but carries high environmental costs. Hydropower does not directly contribute to carbon emissions, but decomposing matter held behind reservoirs produce significant GHG emissions[q], particularly methane. Additionally, hydropower adversely affects the natural hydrograph, and therefore the ecosystem, including impeding salmon production and migration. Wind has low environmental implications, but is inconsistent hour-over-hour, even as it is consistent year-over-year.

Grand Coulee Dam , Source: CRITFC

o According to the USACE Flood Control Operating Plan, the initial controlled flow (ICF) occurs when the runoff forecasts indicate that flood control storage is adequate in system reservoirs to avoid flooding.

p Northwest Power and Conservation Council. 2015. 7th Power Plan. Climate Change Appendix; October 6, 2015 J. Fazio, Senior Systems Analyst- Briefing and Discussion to Council Members of Climate Change 7th Power Plan Climate Change Appendix.

q Washington State University (WSU) researchers say the world's reservoirs are an underappreciated source of greenhouse gases, producing the equivalent of roughly 1 gigaton of carbon dioxide a year. Reservoirs are a particularly important source of methane, a greenhouse gas that is 34 times more potent than carbon dioxide: https://news.wsu.edu/2016/09/28/reservoirs-play-substantial-role-global-warming/

Life cycle assessments (LCA) can help to compare the environmental impact of various power-generating resources by providing a more complete view of environmental impacts over the course of a resource's life. LCA is a comprehensive assessment that includes extraction of resources, production, operations, and decommissioning.

Table 11 lists some of the pros and cons of traditional and alternative energy sources with their associated life cycle emissions, expressed as grams of CO_2 equivalent per kilowatt hour of electricity produced. These values are not specific to the Columbia River Basin resources.

Table 11. Pros and Cons of Common Energy Sources[r]

ENERGY SOURCE	PROS AND CONS	ESTIMATED LIFE CYCLE EMISSIONS[77]
Coal	**PROS** • Inexpensive • Infrastructure is already in place • Stable large-scale electricity generation **CONS** • Emits high levels of CO_2 • High environmental impacts from coal mining and transportation • Not a renewable resource • Technologies to reduce CO_2 at coal plants are expensive	950-1250 $_gCO_2eq/kWh_e$
Natural Gas	**PROS** • Carbon dioxide, carbon monoxide, and nitrogen are about half that of coal • Gas plants are less expensive than coal plants **CONS** • Environmental impacts from gas exploration • Not a renewable resource • More expensive than other fossil fuels	440-780 $_gCO_2eq/kWh_e$
Nuclear	**PROS** • Cost-effective alternative to fossil fuels • High energy output • High degree of flexibility **CONS** • Excavation of uranium is extremely harmful to the environment • High clean-up cost • High-risk waste produced	2.8-24 $_gCO_2eq/kWh_e$
Hydroelectric Power	**PROS** • Good for base load • Flexible/demand matching • Abundant resource in the Pacific Northwest **CONS** • Adversely affects fish spawning, rearing and passage • Reservoirs in particular are a source of methane emissions from decomposing matter • Traps sediment and nutrients behind dams • Susceptive to droughts • Changes hydrograph and thermograph • High land and water usage • Expensive to build, repair, and decommission	1-34 $_gCO_2eq/kWh_e$

r Source for LCA emissions: Weisser, D., 2007. A guide to life-cycle greenhouse gas (GHG) emissions from electric supply technologies.

ENERGY SOURCE	PROS AND CONS	ESTIMATED LIFE CYCLE EMISSIONS[77]
Biomass	**PROS** • Fuel tends to be inexpensive **CONS** • Waste collection can be difficult • Generates greenhouse gases	35-99 $_{g}CO_2eq/kWh_e$
Wind	**PROS** • Low impact on the environment • Produces no bi-products • Abundant and sustainable • Economic development opportunity **CONS** • Wind production can be intermittent, requires other types of on demand power to be ready • Some turbines can be a threat to birds and bats • Aesthetic impact • High land usage • Significant investment and maintenance costs	8-30 $_{g}CO_2eq/kWh_e$
Solar (photovoltaic)	**PROS** • Low operating and maintenance costs • Safe, renewable, clean power • Economic development opportunity • Abundant and sustainable **CONS** • High initial cost per kw/h • Intermittent • High land usage per kw/h	43-73 $_{g}CO_2eq/kWh_e$

In recent years, the potential for wind and solar power generation in the Columbia River Basin has been realized. Wind now accounts for about 7.6 percent of the region's power, having grown steadily since its introduction to the region circa 2000.[s] Looking forward, solar photovoltaic generation is expected to increase market share as costs per kilowatt hour continue to decrease.[78] Grid energy storage may eventually help to smooth the delivery of these more intermittent power sources.[79] However, grid energy storage will also carry its own lifecycle costs.

Many of the governments within the Columbia River Basin are adopting their own standards for renewable energy, several of which exclude the use of hydropower to meet these standards. For instance, Washington passed Initiative 937 in 2006, requiring utilities to use eligible renewable resources for at least 15 percent of their loads by 2020. Although these standards are a positive push towards clean renewable energy, they still present a large task for utilities to balance loads from sometimes erratic generating sources. As the shift towards renewables continues, hydropower will be important in this balancing act.

Meeting Demand through Conservation

Meeting regional demand through conservation simply means using less energy to provide the same level of services. One example of conservation would be changing from incandescent to LED light bulbs, which use less energy. Conservation is being promoted throughout the Northwest, not just within the Columbia River Basin. Box 1 below highlights the Northwest Power and Conservation Council's (NPCC) findings on where conservation can be improved by sector.

s The region is defined as those states contributing at least a portion of their electrical generation directly to BPA's grid (Idaho, Montana, Nevada, Oregon, Washington, and Wyoming).

The Grid

The BPA-operated power transmission lines reach Washington, Oregon, Idaho, western Montana, northern California, northern Utah, and western Wyoming.[80] Given the scope of this network, coordination between electrical power users and suppliers is a complex process. Investments within six categories can improve the efficiency and reliability of BPA power delivery (Table 12), leading to reduced environmental impacts from power generation and increased economic stability of businesses on the grid.[81] The expected benefit-cost ratio for implementation of smart grid technology is 1.8, indicating the feasibility of smart grid investments.[82]

RESIDENTIAL SECTOR: 2,300 aMW through improvements in water heating efficiency, lighting efficiency, and heating, ventilating, and air-conditioning (HVAC) efficiency.

COMMERCIAL SECTOR: 1,900 aMW through improvements in lighting systems, ventilation, server rooms, and other 'plug loads'.

INDUSTRIAL SECTOR: 580 aMW through effective management practices could increase savings from eqipment and system optimization measures.

AGRICULTURAL SECTOR: 130 aMW through irrigation system efficiency improvements, improved water management practices and more efficient dairy milk processing.

UTILITIES: 200 aMW through improved efficiency in distribution systems.

Adapted from the NPCC 7th Conservation and Electric Power Plan

Box 1. Potential Conservation Actions as Outlined by the Northwest Power and Conservation Council

Table 12. Grid Improvement Options

INVESTMENT CATEGORY	TECHNOLOGIES	IMPLEMENTATION OUTCOMES
Transmission & Distribution (T&D) Optimization	Smart Voltage Reduction	Increased efficiency of electricity delivery
Grid Reliability	Fault location, isolation, and service restoration (FLISR)	Reduced duration of grid outages
Dynamic & Responsive Demand (DR)	Energy management system (EMS) controlling HVAC load based on price signals	Reduced electricity use during times of peak demand
End Use Energy Efficiency (EE)	Smart thermostats automatically optimizing customer HVAC energy consumption	Reduced electricity demand
Grid Storage Integration & Control	Customer-sited, utility controlled, Li-Ion battery	Charging during low demand allows for reduction in power use during peak demand
Utility Operational Efficiency	Automated Advanced Metering Infrastructure (AMI) meter reading & billing software	Reduced operation and maintenance costs

Climate Change Impacts on Hydropower

Changes in Basin climatology/hydrology combined with PNW population growth will likely force substantial modifications to hydropower demand, production and grid transfer. The NWPCC projects additional regional generation resources would be required post 2026 should loads exceed medium forecasts due to climate change (Figure 10).

In any case, warming winters and warming summers with lower stream flow are expected to change historical regional energy load demands from winter to summer, as less power is needed in winter and air conditioning, which consumes more energy (Figures 11 and 12).

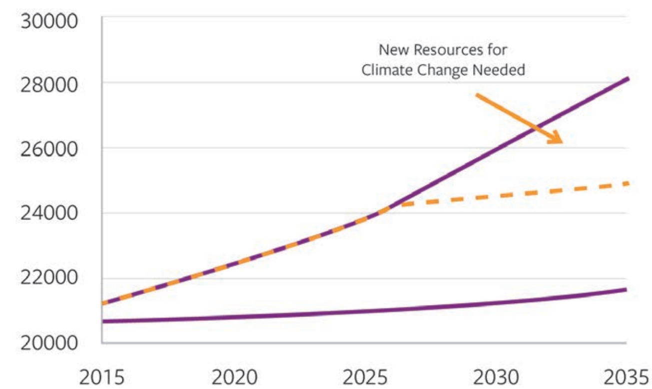


Figure 10. Projection When Additional Energy Resources May be Needed to Meet PNW Loads Under Climate Change Projections (NWPCC 2015)

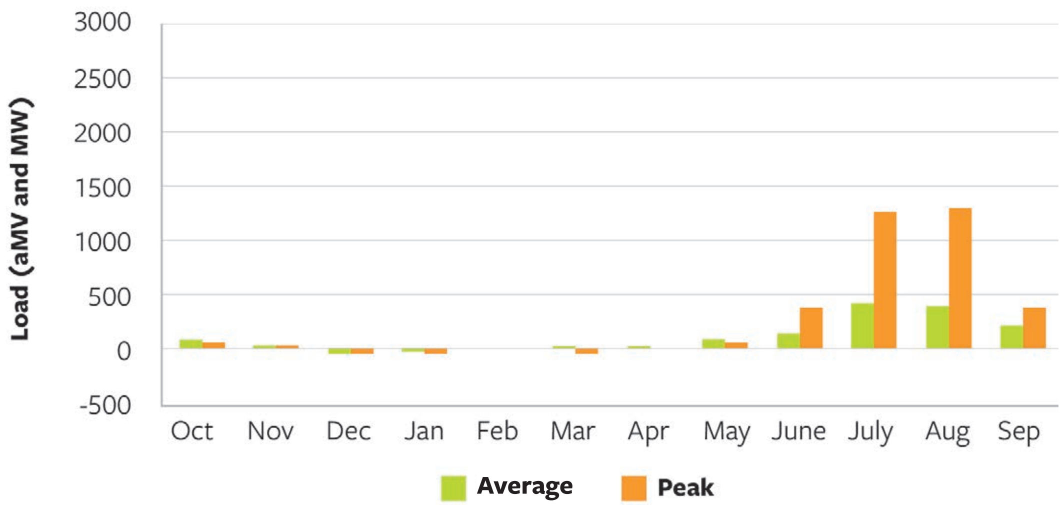


Figure 11. Projected Changes in 2026 Average and Peak Loads (NWPCC 2015)

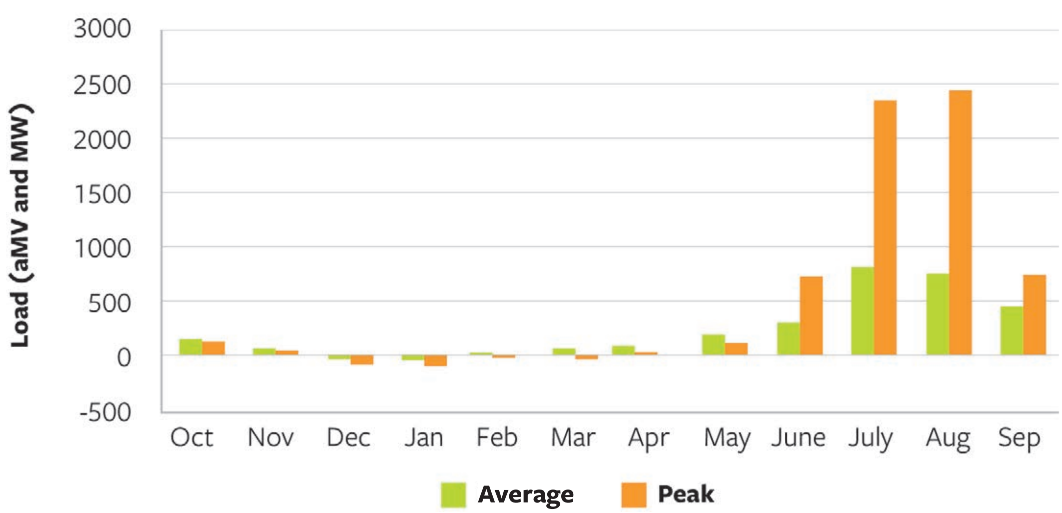


Figure 12. Projected Changes in 2035 Average and Peak Loads (NWPCC 2015)

Table 13. Recommended Actions to Address Energy Loads and Ecosystem Values Affected by Drought and Climate Change

DISTRIBUTED GENERATION—REDUCTION OF TRANSMISSION LOSSES
Strategically placed generation—smaller generation plants such as combustion turbines close to load centers
Peak power true cost-pricing-increase power rates to reflect ecosystem costs
Efficiency improvements—building conservation, lighting and heating efficiencies
Energy consumption timing—incentives to use energy during non-peak periods
Renewable development and integration—solar, wind, conservation
Fuel switching—increase natural gas capacity for selective peak use
Encourage public awareness and utility advances on energy consumption, price mechanisms, and energy efficiency

From Foley, T. and R. Lothrop. 2003. Tribal Energy Vision. Columbia River Inter-Tribal Fish Commission. Portland, OR. Available at CRITFC.org

Table 14. Major Flood Storage Dams in the CRB

	OPERATOR	INSTALLED CAPACITY (MW)	AVAILABLE FLOOD CONTROL STORAGE (ACRE-FEET)
Keenleyside Dam	BC Hydro	185	7,100,00
Mica Dam	BC Hydro	1805	7,000,000
Grand Coulee Dam	USBR	6,809	5,185,000
Libby Dam	USACE	600	4,979,500
Hungry Horse Dam	USBR	428	2,980,000
Dworshak Dam	USACE	400	2,015,800
Duncan Dam	BC Hydro	N/A	1,400,000
Brownlee Dam	Idaho Power	585.4	1,000,000
Revelstoke	BC Hydro	2480	1,000,000
All Other Dams			22,339,700
TOTAL CRB STORAGE			**55,000,000**

Hydropower generation is a valuable asset that has helped fuel the economic development of the Pacific Northwest. Its value will be affected by climate change and dynamic energy market forces that include conservation, renewables, and transmission grid modifications. Hydropower and associated built development would not have been possible without the natural capital that underlies all of the built capital used to produce hydropower. The total annual value of hydropower in the CRB under the current conditions scenario is $3.4 billion.

Flood Risk Management

As previously mentioned, the original Columbia River Treaty sought to maximize flood control and hydropower benefits, through water management via construction and operation of large upper basin storage dams. In doing so U.S. and British Columbia agencies permanently flooded a number of areas in the upper Columbia River Basin and in the impoundments above the dams along the Columbia River and its tributaries.

Today, the basin has approximately 55 million acre-feet of storage, with Kinbasket Reservoir behind Mica Dam as the largest storage with an area of 12 million acre-feet.[83]

Table 14 describes the largest storage projects in the basin and their flood control storage capacity authorized by the CRT. According to the USACE, about 8.95 million acre feet in assured flood storage is available from Canadian reservoirs (USACE Post 2024 White Paper, 2011).

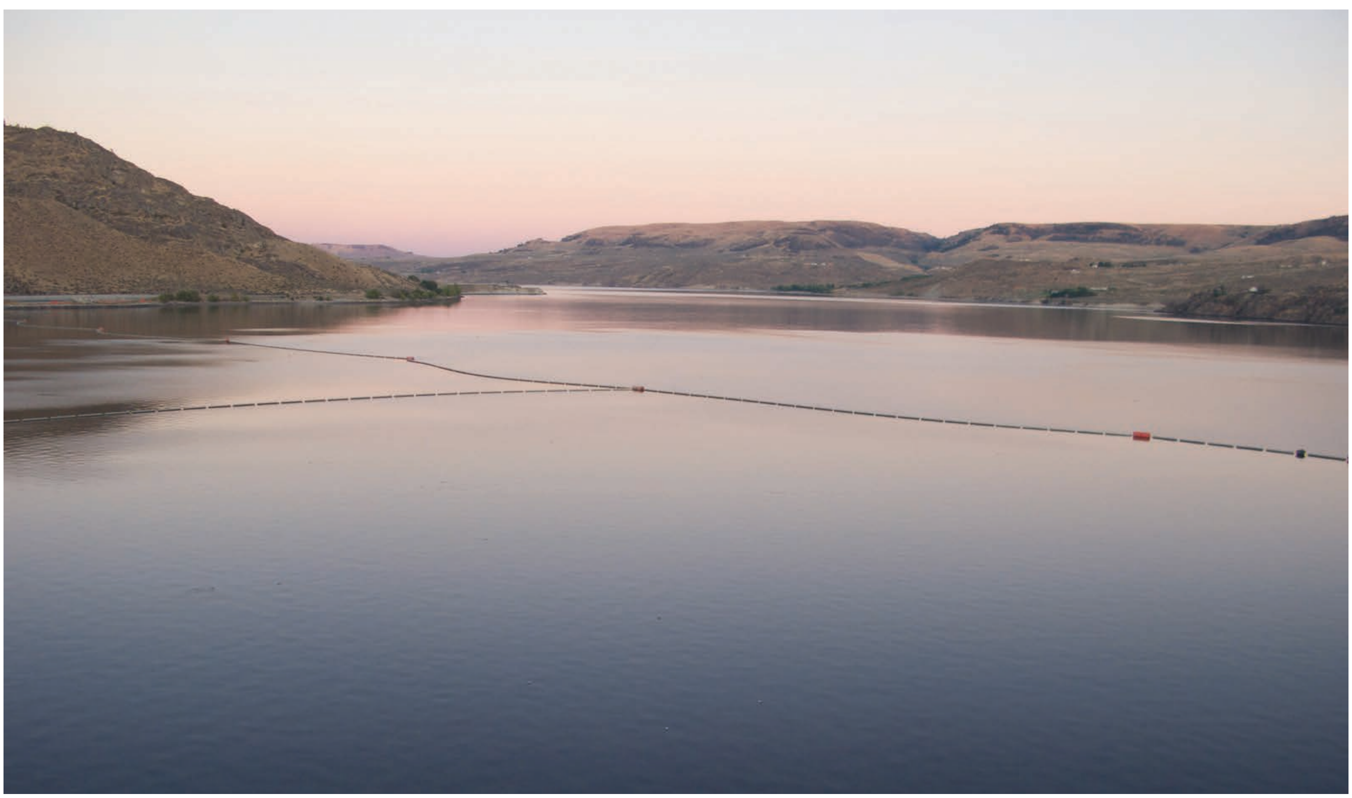
As a result of managing these impoundments for flood risk and hydropower, major flooding events have essentially been eliminated on the Columbia River itself, although it can remain a challenge in some connecting upstream tributaries.[84] In this section, the major flood risk management dams and the uncertainty of future flooding and opportunities within the Columbia River Basin that could mitigate flood risk are described.

Flood Risk Management in the Columbia River Basin

Since the series of dams were built as a result of the 1964 Columbia River Treaty, serious flooding on the mainstem of the Columbia has become rare. However, some outside areas are still permanently flooded by Treaty dams, for example the 4,000 acres of tribal land from the Spokane reservation.[85]

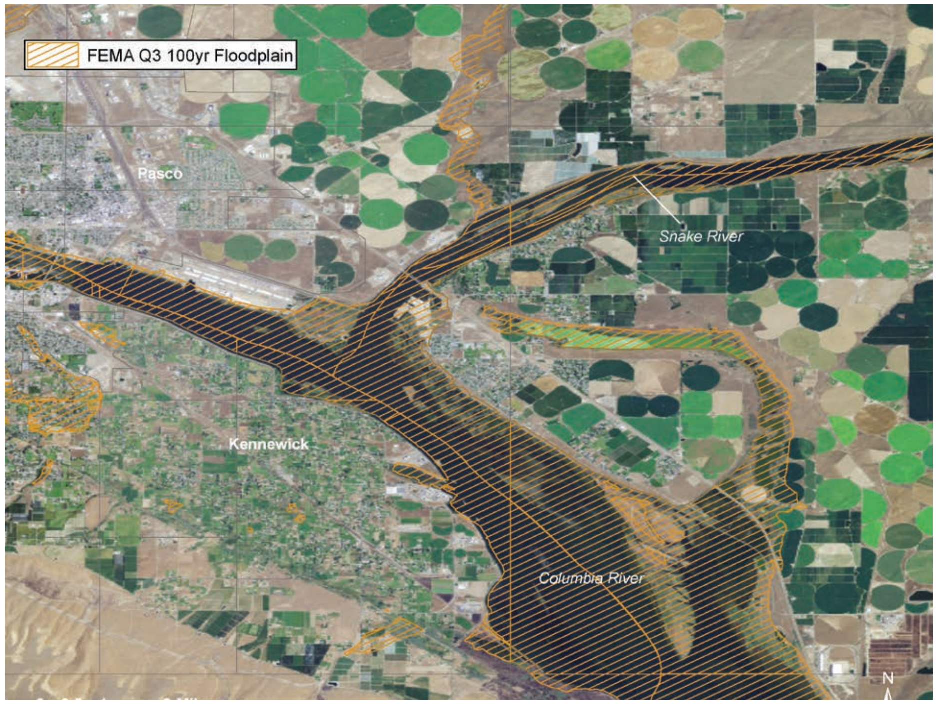
The extensive Columbia River dam system can store nearly a third of all the water that flows through the Columbia in an average year.[86] Current drafting of large storage reservoirs such as Kimbasket and Arrow Lakes for basin winter hydropower provides storage space for flood risk during most years. Despite the river's power and volume, its system of dams and reservoirs moderates major flood events and limits damages. Flood control planning by USACE is based on forecasted flows at The Dalles and overall reservoir storage, where the objective is to keep flows below 600 kcfs whenever possible.[87] In reality, peak flows as the Dalles have seldom exceeded 450 kcfs in recent years. Flood control rule curves are created and implemented so that depending on forecasted runoff, enough reservoir storage is available to impound runoff to avoid major flood events. With regulation, the last time peak stream flows at The Dalles were above 600 kcfs was June of 1972.

Throughout the broader basin, however, extensive flood events have occurred, especially within the last two decades. In 1996, the Willamette Valley experienced extensive flooding resulting in millions of dollars in damage and disaster declarations by 18 counties.[88] Each year since, at least one or two communities along the Columbia River and its tributaries experience extensive rain that causes flooding.



Lake Roosevelt, Source: Brian Gruber

Figure 13. Tri-Cities 100-yr Floodplain



The need for a flood risk management review was identified during the Sovereign Participation Process as a domestic matter to be undertaken in 2014. The Columbia Basin tribes are concerned that the default change to current operations of "on call" to "called upon" and "effective use" after 2024 will adversely affect their efforts to enhance ecosystem-based function because it may: 1) require larger and more frequent drawdowns at Grand Coulee Dam and other U.S. reservoirs in order to provide the minimal flood risk protection presently offered through "Assured Flood Storage" from Canada; 2) adversely impact resident fish, cultural resources, navigation, recreation, riverbank stability and public safety through dramatic changes in reservoir operations; 3) limit system capability to provide necessary spring and summer flows for salmon; and 4) cause serious adverse consequences for the Basin's economy and increased uncertainty and risk related to major flood events in the face of climate change.

The tribes continue to pursue initiation of this review and associated congressional appropriations and if necessary, cost share waivers for a region-wide public process to assess potential changes to the current level of flood risk protection in the Columbia Basin. Such a process should have been initiated in 2016, or as soon as possible thereafter, but must be completed before 2024, when Treaty flood risk provisions are changed. The process should be broadly open to input from the public and stakeholders so that it addresses all options to manage both medium and high flow events.

Current Flood Risk

The greatest flood risks to CRB communities occur in two main areas: where the Columbia River meets major tributaries and at "choke points". In floodplain science, choke points reference narrow stretches of a stream or river, sometimes with sharp bends, where water is funneled.[89] The Snake and Willamette Rivers join the Columbia downstream of the Grand Coulee Dam, the closest substantial flood storage dam. The dams below Grand Coulee are essentially "run of river" projects, incapable of storing flood waters. Although the John Day Dam has some flood control capacity, it does little to reduce flood risk relative to Grand Coulee's capacity.

Several of the most recent flood events, however, occurred when heavy rainfall overwhelmed stormwater infrastructure before the water reached any major river. Rapid stormwater runoff can cause greater damage to CRB communities than flooding directly related to instream flows because current upstream reservoir storage infrastructure is designed to prevent major flood events before they occur. Yet, regions throughout the CRB still experience flood damages, even to the extent that requires a disaster declaration.

Local floodplain managers must rely on floodplain maps to pinpoint risk. However, FEMA's 100-yr and 500-yr maps project flood risks from major rivers, and thus do not accurately reflect urban flood risk from heavy rainfall events. Figure 13 shows that 100-yr maps do not reach far beyond the Columbia River, and thus do not reflect non-riverine flood risk.

CRB communities also face flooding risk from choke points, another event related to heavy rainfall. This feature can often cause a "bottleneck," especially during heavy rainfall or if the river is blocked by debris, resulting in elevated water levels directly upstream and potential flood. Floodplain managers attribute the 1996 Willamette River flood to the combination of heavy rainfall on upland snow combined with the choke point created by excessive Willamette River flows. This combination eventually backed up Columbia River flows. Downtown Portland was nearly flooded after the river crept over the harbor wall along the waterfront. The possibility of other choke points along the middle Columbia River is an increasing threat as the basin experiences larger, more frequent storms.

Climate Change in the Basin

Recent studies forecast warmer, wetter climatic conditions throughout the basin that will result in more intense winter precipitation falling more frequently as rain rather than snow, increasing river flow during winter and early spring months.[90] The same study projected that by 2080, the 100-yr floodplain will increase by 10 to 70 percent in many portions of the Columbia River's tributaries. These conditions call for protection of property and life by securing existing levee system and restoration of floodplains by moving built capital away from flood prone areas and restoring riparian areas. These climate change-induced hydrological changes will make flood management on the Columbia more challenging, particularly near the choke points described above.[91]

The largest cities in the CRB are located where major tributaries meet the Columbia River. Similar to the conditions of the 1996 Willamette River flood, the cities of Hood River, The Dalles, the Tri-Cities, and Portland are all located at confluences that could create choke points under large storm conditions. These cities are also at risk due to limited flood storage along specific stretches of the Columbia River. Although the upper basin has extensive storage, upstream storage is not able to provide flood protection from extensive runoff within the middle Columbia and Snake River. Few dams downstream of Grand Coulee Dam provide any appreciable flood storage. Only one dam in the middle Columbia provides relatively limited flood protection: John Day Dam. Other dams may slow water flow, but are not designed to store floodwater.

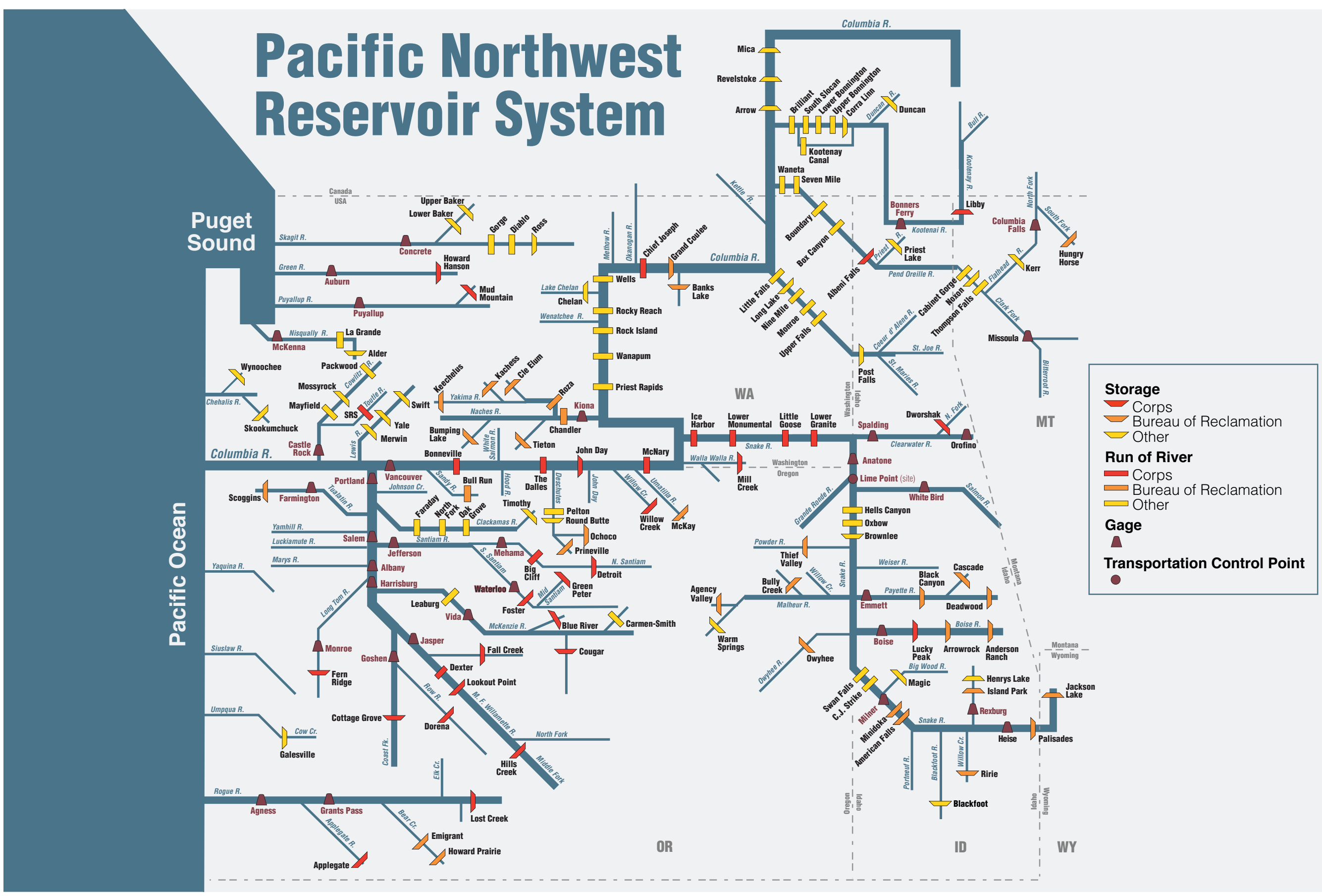


Figure 14. Dams of the Columbia River

Lake Rufus Woods at Bridgeport State Park, Source: Brian Gruber

Recreation

Whether fly fishing on the South Fork of the Snake River or wakeboarding on Lake Roosevelt, Columbia River Basin residents desire high quality outdoor recreation opportunities. Many of these recreation opportunities are greatly impacted by the operation of the Columbia River reservoir system. Degraded salmon habitat affects the quantity and quality of fish available for catch, and boating recreation often becomes inaccessible when reservoir levels drop.

This section evaluates the current economic value of recreation on the CRB's reservoirs and rivers. Additional analysis is presented on Lake Roosevelt and Dworshak Reservoir to estimate the effect on the economic value of recreation with the integration of ecosystem-based functions into the Columbia River Treaty (Chapter 4). Although the economic values presented here do not represent spending effects within the economy, outdoor recreation is still one of the largest job providers and generators of sustainable economic development in both urban and rural areas.[92]

Economic Value of Recreation

The Columbia River and its tributaries offer a wide variety of recreational opportunities, including fishing, kayaking, swimming, boating, wakeboarding, windsurfing/kiteboarding, etc. Some of these activities occur on the free-flowing stretches of river or along lakes, while others are made possible by the reservoirs behind dams.

These recreational activities satisfy consumers. Consumer satisfaction can increase or decrease depending on the quality of the recreational experience. For example, if a family arrives at Lake Roosevelt for a day of swimming and picnicking only to find that the lake level has dropped 20 feet from the level at their previous visit, then their experience (or satisfaction) may be negatively impacted. One way to measure consumer satisfaction is through the willingness-to-pay (WTP) for recreational experiences.

Previous studies have found that WTP increases when reservoir levels increase.[93] On the other hand, when reservoir levels decrease, participants lose access to recreation opportunities and their experiences suffer. For instance, the aesthetic impact of a "bathtub ring" around the reservoir (water marks on reservoir landscape caused by changing reservoir levels) discourages recreational fishing.[94] Additional studies have found there are preferred outflows for angling and other recreation occurring below the dams.[95]

Methodology

For the non-angling recreation analysis, visitation data was collected from federal and state recreation providers. Visitation data was then geocoded[t] and divided into the eleven basin sub-regions (see Chapter 1). Visitation captured by federal and state agencies in the U.S. and British Columbia is by no means a complete representation of recreation in the Columbia River Basin. Recreation also occurs on local and private lands and waters, tribal lands, and federal or state lands where visitation is not actively monitored or cannot be accurately estimated.

This analysis uses the benefit transfer method to measure the net WTP, a measure commonly used by the Army Corps of Engineers, the Bureau of Reclamation, and other federal agencies in economic analysis.[96] Recreational values were derived from a recreation value database developed by Dr. Randall Rosenberger, Professor of Environmental Economics at the Oregon State University.[97] Although dam management may increase or decrease an individual's WTP based on the quality of recreational experience, those potential effects are not modeled here. Values may thus be considered underestimates.

For the angling analysis, data was compiled from the Washington Department of Fish and Wildlife, the Pacific Fisheries Marine Council, the Pacific States Marine Fisheries Commission, and the Pacific Salmon Commission. Estimates are provided for increased fish runs and catch in the Columbia River Basin as well as for out-of-basin catch. Values for the angling analysis were derived from Olsen, et al 1991.[98]

Value of Non-Angler Recreation

The CRB provides numerous opportunities for wide-ranging forms of recreation. Each region offers distinct recreational opportunities, and thus, unique economic values. The following sections outline recreational opportunities, visitation, and economic values for the key recreational areas within the CRB. Values are derived from the Recreational Use Values Database.[99]

The high recreation visitation numbers presented below reflect the quality of recreational experiences within the Columbia River Basin. Without proper management of these lands and waters, economic value will likely diminish and visitation and consumer satisfaction will decline.

As was mentioned in the methodology, this is an incomplete representation of recreation in the Columbia River Basin. Limited participation data means that estimates should be considered extremely conservative. A full list of recreation sites used in this analysis is available in Appendix C.

Blue Mountain

The small Blue Mountain sub-region in Northeast Oregon lies within the Snake River Basin. Visitors come to numerous recreation areas, including the Wallowa Lake State Recreation Area, Hells Gate Recreation Area, and Iwetemlaykin State Heritage Area, the ancestral homeland of the Nez Perce Tribe.

Activities in the Blue Mountain area include boating, fishing, hunting, skiing, hiking, wildlife viewing, and swimming. About 1.1 million recreational participants visit the Blue Mountain sub-region annually, and the economic benefit of this recreation is estimated at $60 million.

National Forest lands in the Blue Mountain sub-region are a large provider of outdoor recreation, inspiring roughly 289,000 recreation trips annually that are estimated to be worth $22 million.

Additional recreation occurs on the Wild and Scenic Snake and Grand Ronde Rivers in the Wallowa-Whitman National Forest. An estimated 56,000 users recreate on the Snake River stretch annually,[100] engaging in commercial powerboat use and commercial or private floating. The Hells Canyon Creek Recreation Site also accommodates 5,000 drive in visitors not captured in the previous records. The economic value of the recreation in this area is estimated to be $5.3 million annually.

Columbia Cascade

Stretching from Central Washington into Canada, the Columbia Cascade is home to many of Washington's state parks, including Lake Chelan, Lake Wenatchee, and Pearrygin Lake. These state parks host over two million recreation participants annually, with a total economic value of $107 million.

The sub-region also receives visitors to Lake Chelan National Recreation Area, although this area is less visited than many of the area's state parks. Lake Chelan National Recreation Area welcomes 32,000 visitors annually, at an economic value of $2.4 million.

The Mt. Baker-Snoqualmie and Okanagan national forests both lie partially within the Columbia Cascade sub-region. Using acreage allocations, an estimated one million recreation participants visit these lands annually, providing an economic value of $83 million.

North of the border in Canada, BC Parks receive 1.7 million visitors annually. Most of their facilities see a high level of

t A set of geographical coordinates corresponding to a location.

day use activities, and about 225,000 overnight campers. The economic value of this recreation is $91 million.

Columbia Gorge

The Columbia Gorge sub-region is another small area on the Washington-Oregon border, home to some of the best windsurfing/kiteboarding in the world. Nearly 4.5 million recreation participants visit the sub-region annually to participate in windsurfing, kiteboarding, hiking, mountain biking, skiing/snowboarding, swimming, boating, and camping. The annual economic value of this recreation is estimated at $148 million.

Four national forests also provide recreational opportunities in the Columbia Gorge: The Columbia River Gorge, Gifford Pinchot, Mt. Hood, and Okanogan-Wenatchee National Forests. Together, the estimated recreation provided is over two million forest visits, at an economic value of $161 million.

Columbia Plateau

The large Columbia Plateau sub-region is located in the heart of the Columbia River Basin. At the very center lies the confluence of the Snake, Yakima, and Columbia Rivers. This gem hosts over 9.3 million recreation participants every year on BLM lands that receive 136,000 visitors, Oregon Parks with over 5 million visitors, Washington State Parks with 2.6 million visitors, and 1.5 million visitors to USACE lakes. These lands provide a recreational value of $500 million annually.

National forest lands are abundant in the Columbia Plateau sub-region, with over five million acres of National Forest Service lands. These lands host three million forest service visits annually and provide an economic value of $233 million.

The total recreation use value of this sub-region is estimated to be $733 million annually.

Columbia River Estuary

Many of the recreation sites in the Columbia River Estuary sub-region, from the mouth of the Columbia River to Portland, are U.S. historical sites. Recreation sites such as Fort Stevens State Park and Fort Columbia State Park receive about 1.5 million visitors annually. The economic value associated with this visitation is $52 million.

Intermountain

The Intermountain region holds large federal project areas and recreational lands including Lake Rufus Woods and Lake Roosevelt, as well as BLM recreational management areas. Lake Roosevelt National Park receives over 1.17 million visitors annually, Lake Rufus Woods receives 267,000, and Albeni Falls receives 277,000 per year. The economic value of recreation on federal lands in this basin is estimated to be $129 million.

In the Canadian portion of the Intermountain region, about 500,000 recreational participants frequent BC Parks. Syringa, Kettle River, Gladstone, and Christina Lake parks are among the most visited in this area. The economic value of this recreation is approximately $27 million.

The Intermountain region also receives about one million national forest visits each year. The estimated value of this recreation is $78 million.

Additionally, there are nine Idaho State Parks and eight Washington state parks in this region. These parks, including Coeur d'Alene Parkway, Priest Lake, Riverside and the Spokane Centennial Trail account for nearly six million visitors and $313 million in recreation-related economic value.

Lower Columbia

The Lower Columbia is one of the largest providers of recreation in the entire Columbia River Basin. Oregon Parks and Recreation

Meacham Creek habitat restoration project. Work done by the Conf. Tribes of the Umatilla Indian Reservation, Source: CRITFC lands, Washington State Parks, and the U.S. Army Corps of Engineers all provide recreational opportunities. Windsurfing on the Columbia River is a popular activity in this sub-region.

Oregon Parks and Recreation operates 38 parks in the sub-region with nine million annual visitors; Washington State Parks operates ten parks with over one million annual visitors; and the Army Corps operates 12 recreation areas with four million reported annual visitors. Altogether, over 14 million recreational participants visit these recreational lands, providing $540 million in annual economic benefits.

The Lower Columbia also has 3.5 million acres of national forests that receive an estimated five million visitors annually. Forest Service recreation values estimate that this recreation is worth approximately $385 million.

Middle Snake

The Middle Snake, with the Malheur River, Owyhee River, and the Payette River, receives 4.3 million recreation visitors annually. The most popular recreation site in the Middle Snake Sub-region is Lucky Peak Lake, the reservoir formed by Lucky Peak Dam. The Army Corps and Idaho State Parks both operate recreation facilities on the lake. The Middle Snake is also home to popular Idaho state parks such as Ponderosa and Eagle Island. Visitors to these parks provide an annual economic value of $230 million.

Additionally, 1.6 million visits to Forest Service lands occur annually in the Middle Snake. National forests with the greatest visitation are the Boise National Forest, the Humboldt-Toiyabe National Forest, and the Shoshone National Forest. National forest recreation contributes to $126 million in recreational benefits in the Middle Snake.

Mountain Columbia

The Mountain Columbia sub-region contains 37 British Columbia Provincial and Canada Federal parks with an annual visitation of 1.4 million. Montana State Parks also have a heavy presence in this sub-region with 26 parks and 1.3 million visitors. Libby Dam also sees a large influx of recreational participants, with 191,000 visiting annually. This visitation provides an economic value of $156 million.

The Mountain Columbia also receives a large amount of visitation to national forest lands, largely to Lolo National Forest and Flathead National Forest. A total of four million national forest visits occur in the basin annually, providing a recreational benefit of $303 million.

Most notably, Glacier National Park, which lies partially in the Columbia River Basin, is among one of the most visited national parks in the nation. Because Glacier National Park is only partially within the basin, total visitation has been split in half. Assuming 1.4 million participants are assigned to the Columbia River Basin, the economic value from Glacier NP is $102 million.

Mountain Snake

The Mountain Snake sub-region's most notable recreation opportunity is at Dworshak Lake where the Army Corps and Idaho Parks operate recreation facilities. Together, they provide 300,000 recreational visits per year. Recreation also occurs at Idaho State Parks Winchester Lake and Land of the Yankee Fork. The economic value associated with this level of visitation is estimated to be $30 million.

Additionally, the Mountain Snake receives 1.3 million national forest visits, mainly to the Payette and Sawtooth National Forests. The economic value of these recreational forest visits is estimated to be $102 million.

Upper Snake

From the headwaters of the Snake down to just East of Glens Ferry, Idaho, the Upper Snake sub-region is home to nine Idaho state parks. Most notably, Grand Teton is at the headwaters of the Snake and Yellowstone National Park is partially within the sub-region, with the remaining portion outside the Columbia River Basin. Over 3.1 million recreational visitors are recorded at Grand Teton National Park every year. Visitation to Yellowstone is approximately 3.5 million visitors annually, half of which are assigned to the Columbia River Basin as some of this recreation occurs outside of the CRB on the other side of the continental divide. Cumulatively, the economic value of this visitation is $367 million assuming visitation of 4.9 million.

State parks such as Mesa Falls, Henrys Lake, and City of Rocks are popular Idaho state parks that receive a decent number of recreational visitors. Idaho state parks account for nearly one million recreational visitors. The economic value of this visitation is estimated to be $52 million.

Finally, national forest lands in the basin provide an additional 3.6 million visits. Many of these visits occur in the Caribou-Targhee and Bridger-Teton National Forests. National forest visits account for $275 million in recreational benefits.

The Value of Recreation Under Current Conditions

Summing across the Columbia River sub-regions, the area provides at least 8.2 million recreation days within public parks

Table 15. Annual Non-Angling Recreation Days and Recreational Use Value by Sub-region

BLUE MOUNTAIN	
Recreational Days	1,492,189
Economic Value	$88,532,330
COLUMBIA CASCADE	
Recreational Days	4,816,392
Economic Value	$283,227,183
COLUMBIA GORGE	
Recreational Days	6,511,623
Economic Value	$309,637,236
COLUMBIA PLATEAU	
Recreational Days	12,400,034
Economic Value	$733,227,811
COLUMBIA RIVER ESTUARY	
Recreational Days	1,541,838
Economic Value	$51,728,648
INTERMOUNTAIN	
Recreational Days	9,113,210
Economic Value	$547,170,385
LOWER COLUMBIA	
Recreational Days	19,176,644
Economic Value	$923,991,174
MIDDLE SNAKE	
Recreational Days	5,966,505
Economic Value	$357,115,358
MOUNTAIN COLUMBIA	
Recreational Days	8,234,955
Economic Value	$562,174,659
MOUNTAIN SNAKE	
Recreational Days	1,880,220
Economic Value	$131,749,473
UPPER SNAKE	
Recreational Days	9,464,498
Economic Value	$694,904,337
COLUMBIA RIVER BASIN	
Recreational Days	80,598,106
Economic Value	$4,683,458,594

and recreation areas, as listed in Appendix C. These recreation days equate to a total economic value of $4.7 billion annually. This value is the net economic value, or consumer surplus, and does not take expenditures into account.

Table 15 provides the values associated with recreation in each sub-region.

Salmon and Steelhead Angling

The Columbia River and its tributaries provide opportunities for world-class salmon, steelhead, trout, sturgeon, bass, and other fishing. Though equally important, this section only captures recreational use benefits from salmon and steelhead fishing. Other fishing is captured in the general recreation analysis.

Although salmon and steelhead runs are severely depleted from their once abundant state, hundreds of thousands of fishing days still occur on these rivers. Columbia Basin Salmon and Steelhead stocks also contribute significantly to Pacific coast, Puget Sound, British Columbia, and Southeast Alaska ocean recreational fisheries. These fishing days attract tourists from around the world and have a large economic value.

Total fishing days were estimated using harvest counts from the Washington Department of Fish and Wildlife, Pacific Fishery Management Council, Pacific States Marine Fisheries Commission, and the Pacific Salmon Commission. Per-day economic values are shown in Table 16.

Using values from Table 16, the economic value of salmon and steelhead angling in the Columbia River Basin is $134.5 million annually. For ocean stocks originating from the Columbia River, the economic value is estimated to be $6.4 million. In total, the economic value of Columbia River salmon and steelhead angling is estimated to be $140.9 million, as illustrated in Table 17.

Table 16. Salmon and Steelhead Values per Angler Day and Trips per Catch

SPECIES	LOCATION	PER-DAY VALUE (2016 USD)	DAYS/ CATCH
Chinook	In-river	$91.28	4.81
Coho	In-river	$91.28	4.17
Steelhead	In-river	$85.84	5.26
Chinook	Ocean	$95.01	1.14*
Coho	Ocean	$95.01	1.05*

Source: Olsen, Richards & Scott; 1990
*Weighted average *Sockeye data not available

Table 17. Economic Value of Salmon and Steelhead Angling

ECONOMIC IMPACT REGION/AREA/SPECIES	RECREATION CATCH	ECONOMIC VALUE
COLUMBIA RIVER SYSTEM		
Chinook	116,590	$51,948,853
Coho	57,541	$21,979,192
Steelhead	133,497	$60,572,823
TOTAL COLUMBIA RIVER	**307,628**	**$134,500,868**
OCEAN FISHING—COLUMBIA RIVER BASIN STOCKS		
Chinook Salmon	28,253	$2,355,192
Coho Salmon	44,793	$4,079,371
TOTAL OCEAN	**73,046**	**$6,434,565**
TOTAL	**380,674**	**$140,935,433**

Total Current Value of Recreation

Degradation of the lands that support outdoor recreation risks significantly diminishing the economic value of these areas. Additionally, tourism is a major industry throughout the Basin, with significant land area and parks that bring tens of billions of dollars in consumer expenditures and support hundreds of thousands of jobs.[101] Preserving these lands is an economic priority as much as anything else. The total value of recreation in the CRB under current condition scenario is $4.7 billion for general recreation, plus $140.9 million for salmon and steelhead angling.

Navigation

Navigation is another important capital built resource of the Columbia River. Since time immemorial, indigenous peoples have used the river for navigation and transportation. The introduction of passenger steamboats in the 1800s made river navigation one of the few methods of transportation in the development of the Pacific Northwest (railroad and horse drawn transport were common as well). Today, the Columbia's waters are primarily used for commercial barge transportation and recreation. There are also a few ferryboat crossings along the river that transport commuters more efficiently and over shorter distances than by road. Yet, river management and declining water levels may pose difficulties to navigation. In some cases, navigation has completely halted due to extremely low water levels, lock maintenance, and sediment accumulation. When navigation halts, economic and social losses occur.[102]

This section demonstrates the value of navigation for commercial transportation of goods and some of the costs associated with infrastructure maintenance and operations.

Dredging and Lock Operation and Maintenance

The USACE is responsible for maintaining adequate depth levels for commercial ship navigation. This is accomplished primarily by dredging material from the river navigation channel and port facilities. Over the past 15 years, USACE has dredged almost 63 million cubic yards of material and spent nearly $178 million on dredging vessel operations in the Columbia River.[103] After adjusting for inflation, the dredging costs in the Columbia have increased by nearly $0.15 per cubic yard every year since 2001 (when costs were at $1.90 per cubic yard). Tributaries such as the Snake River also undergo dredging; recent USACE reports indicate that approximately 480,000 cubic yards must be dredged annually to meet navigation obligations.[104] Assuming similar dredging costs for the Snake River and the Columbia, the annual financial cost of dredging this volume is $2.2 million dollars. These high financial costs are accompanied by significant environmental costs as well. Recent research indicates that dredging removes coarse gravel habitat, reduces fish diversity, increases salmon smolt predation by Caspian Terns, increases river bank erosion rates, and reduces the productivity of sub-aquatic vegetation.[105,106] Dredging deeper navigation channels and port facilities has the secondary impact of allowing larger vessels to enter and navigate the river causing other environmental damage such as wave erosion and introduction of pollutants and invasive species through ballast and other vessel discharges.

Locks along the Columbia River need to allow the passage of commercial barges, which requires diverting upwards of 500,000 cubic feet of water from the power generating stations within dams along the Columbia.[107] Annually, lock usage diverts nearly 38 billion cubic feet from the Columbia from flowing through dam turbines and spillways.[108] Prior studies have established relationships between water flow through dams and electricity generation.[109] Approximately 51,000 megawatt hours were lost due to the diverted water. Applying wholesale electricity market rates to the volume of lost electricity elicited annual losses of approximately $1.3 million.[110] Currently, use of the locks is paid for by the USACE thus, ultimately is a subsidy by U.S. taxpayers.[111] In addition to the lost revenue from energy, there are also significant operation and maintenance costs. In 2016, the total operation and maintenance budget for these lock systems was approximately $47.9 million).[112,113]

Methodology

In order to calculate the value for navigation, total financial return to the water must be measured. The most practical means for valuing waterborne commerce is through the alternate cost of railroad transportation, or the next best option.[114] The total freight volume, as determined from USACE data[115], was multiplied by an average trip length of 42 miles on the Columbia River system to find the total amount of "ton-miles" of freight effort required to move goods along the Columbia.[116] We then multiplied the total freight effort by revenue per ton-mile for three shipping options (barge, truck, and rail) in order to compare the total cost of shipping freight.[117]

The Value of Navigation Under Current Conditions

The Columbia River provides a convenient path for transporting goods. Historical records indicate that total annual shipments ranged between 45 and 62 million tons from 1995 to 2015.[118] In 2015, approximately 62 million tons of goods worth over $16 billion were shipped down the river.[119,u] This shipping method saves money relative to other methods. Assuming an average trip length of 42 miles, approximately 2.6 billion ton-miles (one ton of goods traveling one mile) of freight work is required.[120] Barge transport along a river is the cheapest form of freight, with annual savings relative to truck transport at approximately $316 million.[121] These savings are smaller compared with rail transport, which reaches only $13.2 million annually. Given that infrastructure is already set up to handle shipments along the Columbia, these savings may be an underestimate of the true cost of switching transportation methods. The savings implicit in

Keller Ferry, Lake Roosevelt, 2011, Source: Brian Gruber

u Valuation of commodities is based upon price data gathered from IndexMundi, USGS, Energy Information administration, and several other agencies that collect data on less frequently traded commodities.

river transport rely upon the use of locks for traversing dams. Given the costs associated with their use, and the substantial savings of using barge freight, fees for use of locks are a clear revenue generating opportunity. The total value of navigation in the CRB under current condition scenario is $13.2 million, the estimated savings from barge use (relative to rail).

Agriculture—Irrigation

With a high level of regional agricultural production, irrigation is the largest non-hydropower water use in the Columbia River Basin.[122] Between 1981 and 2011, an average of 10.1 million acre-feet per year was devoted to agricultural purposes.[123]

There are approximately 19 million acres of agricultural lands in the Columbia River Basin, both irrigated and non-irrigated. The majority of agricultural lands are non-irrigated (14 million acres), but the Columbia River and tributaries supply water to five million acres of irrigated land. Large and small scale irrigation projects increase the economic value of these typically arid lands. The figure to the right depicts irrigated and non-irrigated agricultural lands within the basin and the boundaries of two massive irrigation projects, the Columbia Basin Project and the Minidoka Project.

Most of the agricultural lands in the Columbia River Basin receive abundant sunshine, but a limited amount of annual rainfall, most of which does not fall during the growing season.[124] Irrigation projects like the Columbia Basin Project, which irrigates 671,000 acres of farmland, help farmers grow crops in arid Eastern Washington.[125] More substantially, the Minidoka Project irrigates more than one million acres of land in the Snake River sub-region.

The 2016 Columbia River Basin Long-Term Water Supply and Demand Forecast reported that between 1981 and 2011, an average of 10.1 million acre-feet of surface water was used for crop production in the Columbia River Basin. Some of this water, about 30 percent, is returned to the river through field runoff

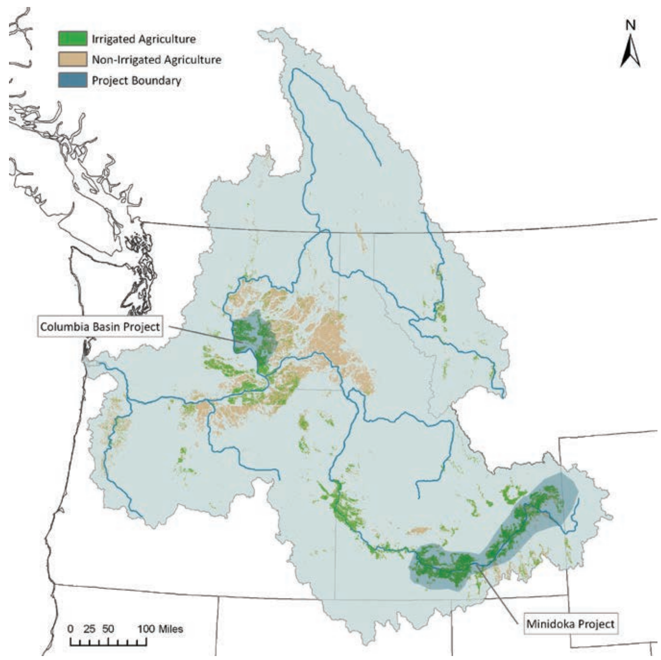


Figure 15. Irrigated and Non-Irrigated Agriculture in the CRB

Table 18. Total Value of Irrigated and Non-Irrigated Croplands

	CROPLAND ACRES		USDA CROPLAND VALUE PER ACRE			
STATE	Irrigated	Non-Irrigated	Irrigated	Non-Irrigated	Difference	Economic Value of Water Supply
Idaho	2,715,004	2,284,997	$5,000	$1,420	$3,580	$9,719,714,320
Montana	150,991	168,872	$2,980	$820	$2,160	$326,140,560
Nevada	875	914	$2,670	$770	$1,900	$1,662,500
Oregon	689,823	2,051,594	$4,650	$2,020	$2,630	$1,814,234,490
Utah	1,390	3,678	$5,350	$1,170	$4,180	$5,810,200
Washington	1,334,598	4,708,974	$8,250	$1,330	$6,920	$9,235,418,160
Wyoming	21,283	20,681	$5,000	$1,420	$3,580	$76,193,140
COLUMBIA RIVER BASIN	4,913,964	9,239,710				$21,179,173,370

and ground seepage, though it can be laden with agricultural chemicals and is much warmer than in free flowing streams.[126] Additional water is returned to the hydrologic cycle through evaporation and transpiration from plants.

Looking forward, higher concentrations of carbon dioxide in the atmosphere will allow crops to grow more efficiently. Therefore, agricultural water demand is estimated to decrease by .5 million acre-feet by 2035 assuming a historical crop mix.[123]

Economic Value of Agricultural Water Supply in the Columbia River Basin

Methodology

This analysis uses the U.S. Water Resource Council's land value method to determine the value of irrigation water.[127] The WRC's method employs a simple comparison of selling prices of irrigated lands with prices of non-irrigated, but otherwise similar lands.[128]

The following steps were taken to determine the economic value of irrigation in the Columbia River Basin:

1. Using GIS data from the United States Department of Agriculture (USDA), we calculated the total irrigated acres within the Columbia River Basin. These acreages were then separated by state. We determined the difference in prices between irrigated and non-irrigated land on a per-acre basis. Due to data and scope limitations, USDA National Agriculture Statistics Service Land Values were used for each state.[v]
2. We multiplied the difference in land values by the total irrigated acreages within the basin for each state to get a total value of irrigation water within the basin for each state.
3. The statewide total irrigation values were summed to yield the total value of irrigation water.

Values were converted to an annual equivalent value using a discount rate and planning period assumption. Results assume a 100-year planning period and are presented at the WRDA 2017 discount rate of 2.875 percent.[129]

Economic Value of Agricultural Lands and Water Supply

The Columbia River Basin's 14 million acres of farmland value is estimated to be over $42 billion. Table 18 presents the per-acre difference of land values associated with irrigated and non-irrigated farmland. The difference in land value of irrigated and non-irrigated land is calculated to be $21 billion

Annualized over 100 years at a 2.875 percent discount rate, the annual economic value of water supply in the Columbia River Basin is estimated to be $647 million. Because these estimates are based on state average cropland values, values should be considered rough estimates.

Table 19. Annual Value of Agricultural Water Supply in the Columbia River Basin

Net Present Value	$21,179,173,370
Discount Rate	2.875%
Periods (years)	100
ANNUAL VALUE	**$649,907,701**

Total Economic Value of Current Conditions Scenario

Table 20 summarizes the total economic value of the CRB under the current conditions scenario. This table is organized in alphabetical order for clarity, and all values are presented in thousands. The total assessed value of the Columbia River Basin under RCC-80 equals to $199 billion.

Table 20. Total Economic Value of the CRB under Current Conditions (number in thousands)

RESOURCE	CURRENT CONDITIONS
Agriculture - Irrigation	$646,908
Ecosystem Services	$189,963,082
Existence Value	$37,289
Hydropower	$3,373,357
Navigation	$13,248
Non-Tribal Commercial Fishery	$12,133
Recreation - General Recreation	$4,683,459
Recreation - Angling	$140,935
TOTAL ASSESSED VALUE	**$198,870,410**

v Land values in Wyoming were not available due to data limitations; therefore, Idaho land values were used to generate an approximate estimate for the value of non-irrigated land in Wyoming.

Chapter Four

The Modernized Value of the Columbia River Basin

"As we make decisions that affect this land, we must consider the consequences those decisions have, at least for the next seven generations."

– Francis Auld – Confederated Salish and Kootenai Tribe Cultural Preservation Officer[130]

As Chapter 3 clearly demonstrated, the Columbia River Basin holds immense value. Yet under a modernized management regime, this value may increase even further. Chapter 4 assesses the potential value of natural capital under a modernized Columbia River Treaty. The modernized scenario, also known as 3Ea, prescribes higher retention of river water in the late fall and winter via storage at upstream reservoirs. The stored water will be released in the spring and early summer, augmenting the natural freshet from basin snow melt. These operations will help reestablish the historical shape of the river hydrograph, particularly in low and medium runoff years. By restoring the historical hydrograph shape, ecosystem functions will also be enhanced and restored. Fish habitat will increase, migration conditions throughout the mainstem and estuaries will improve, and the Columbia River plume into the near ocean environment will also improve. In addition, the modernized scenario will reduce drafting of basin reservoirs, allowing more stable and improved ecosystem function in the reservoir environment and increasing ecosystem service value.

Scenario 3Ea evaluates how changes in river managment from the current conditions (RCC-80) would impact non-tribal commercial fisheries, existence value, hydropower generation, and recreation. The primary difference between RCC-80 and the 3Ea scenario is the rebalancing of value between built capital and natural capital. In effect, the river wealth in historical tribal first foods that was lost to management and operation of built capital for flood risk and hydropower would be at least partially restored, enhancing tribal wealth and sustainable natural capital. The methodologies for evaluating these resources are the same as those outlined in each respective section in Chapter 3. The economic values for flood risk, agriculture, and navigation remain consistent under both scenarios, therefore the value does not change. However, this chapter does provide qualitative descriptions of ecosystem improvements due to 3Ea. In addition, this chapter includes additional valuation for nutrient enhancement and increased flow, given that a modernized management regime would enhance these benefits. Increased salmon and steelhead productivity would also enhance the economic value under scenario 3Ea. Lastly, we conclude with an analysis valuing a 10 percent increase in EbF.

Sturgeon and carp caught in a gillnet, Source: CRITFC

Modernized Non-Tribal Commercial Fisheries

In the Upper Columbia Basin, much of the habitat historically used by anadromous fish has been blocked, inundated, or degraded by dams. However, sites still exist that could support anadromous fish production, and the reservoirs behind the dams may provide juvenile rearing habitat. In the Modernized Columbia River Treaty scenario, we consider fish runs that could be restored to historical Columbia Basin habitats above Chief Joseph Dam in the U.S. and Canada. Earth Economics consulted with fisheries experts to estimate a working hypothesis on potential anadromous fish runs for reintroduction in the Upper Columbia Basin.[131] This paper constructs a range of potential run sizes that could be possible with the reintroduction proposal described in “Fish Passage and Reintroduction into the U.S. & Canadian Upper Columbia Basin, A Joint Paper of the Columbia Basin Tribes and First Nations”, January 9, 2015.

Several assumptions were made to estimate a range in potential run sizes from reintroduction. First, we assume historical habitats in the Upper Columbia Basin would be accessible to anadromous fish and that run sizes could be comparable to historic levels, or even increase because of the additional rearing capacity of reservoirs. For chinook, it was assumed introduction into the Upper Basin would add up to 310,000 chinook annually; for sockeye, up to 600,000 in annual runs; for coho, run sizes could approach 30,000; and for steelhead, run sizes could reach 20,000.[132]

Next, we estimated reductions in fish production due to loss of smelts passing through dam facilities. Finally, runs were multiplied by harvest rate percentages to estimate the potential non-tribal commercial harvest rate attributable to reintroduction of anadromous fish in the Upper Columbia Basin. At the time of writing, coho harvest estimates were not available.

The maximum potential harvests for each species over all these run sizes is about 1.6 million in landed pounds. In effect, the introduction of additional fish above Chief Joseph Dam would increase non-tribal commercial fisheries in the CRB by $7 million.

Table 21. Forecast of Additional Non-Tribal Commercial Fishery Harvests Attributable to the Columbia River Basin, Summary of Salmon Landings

AREA & SPECIES	LANDED POUNDS (WHOLE)	LANDED VALUE
IN-BASIN		
Chinook	15,532	39,164
Sockeye	113,959	187,383
Total In-Basin	129,491	226,547
ALASKA AND BRITISH COLUMBIA		
Chinook	1,322,270	5,928,090
COASTAL WASHINGTON AND OREGON		
Chinook	192,516	854,497
Total Out-Of-Basin (AK, BC, WA, OR)	1,514,786	6,782,587
GRAND TOTAL	**1,644,277**	**7,009,134**

Modernized Existence Value

Our methods for determining existence value under the modernized scenario were the same as those outlined in Chapter 3 for the current conditions scenario. In this case, the model valued increased salmon runs due to reintroduction above Chief Joseph Dam. For more detail, see "Fish Passage and Reintroduction into the U.S. & Canadian Upper Columbia Basin, A Joint Paper of the Columbia Basin Tribes and First Nations", January 9, 2015. Introduction of salmon above Chief Joseph Dam could add up to 960,000 chinook, sockeye, coho, and steelhead to historic annual run sizes. This level is a 26 percent increase compared to historic runs, which were around 3.7 million total for the four species. According to the CSS and COMPASS models, fish abundance below Chief Joseph Dam will increase as well. On average, salmon populations will increase by about 25 percent.

As described in the current conditions chapter on existence value, we utilized the function transfer method to value this ecosystem service. See Appendix I for detailed information on the model and parameters used.

In total, salmon populations could increase by up to 51 percent, based on the information above. Applying the model described in Chapter 3, these salmon runs yield a willingness-to-pay estimate of $404 per household per year for the increase in population size. Given that the total number of households within the Columbia River Basin is about 2.8 million, the annual existence value benefit of increased salmon runs would be $1.1 billion.

Modernized Hydropower

This section addresses the impact to hydroelectric power production under the 3Ea modernized scenario. To assess the difference in benefits provided by the Columbia River Power System hydroelectric generation, data was calculated from the CRITFC Information System (CIS), a model that calculates hydropower generation for 14 water periods throughout the year. This data was used to estimate the value of hydropower generation under both RCC-80 and 3Ea.

Hydropower plays a large part in ensuring the region's power needs are met. In dry water years, hydropower generation drops and the Pacific Northwest must rely on other generating resources or occasionally import power from outside the region. In the wettest water years, generation is high and can be sold to out-of-region customers, such as California. Because hydropower generation varies from year to year based on streamflow conditions, impacts were assessed for dry, wet, and average water years.

Figure 16 through Figure 18 illustrate hydropower production and estimated system demand for hydropower. A comparison of the 14 water periods in the three water years reveals that demand is met in medium and wet water years. In the driest water years, power will likely need to be purchased from outside the region.

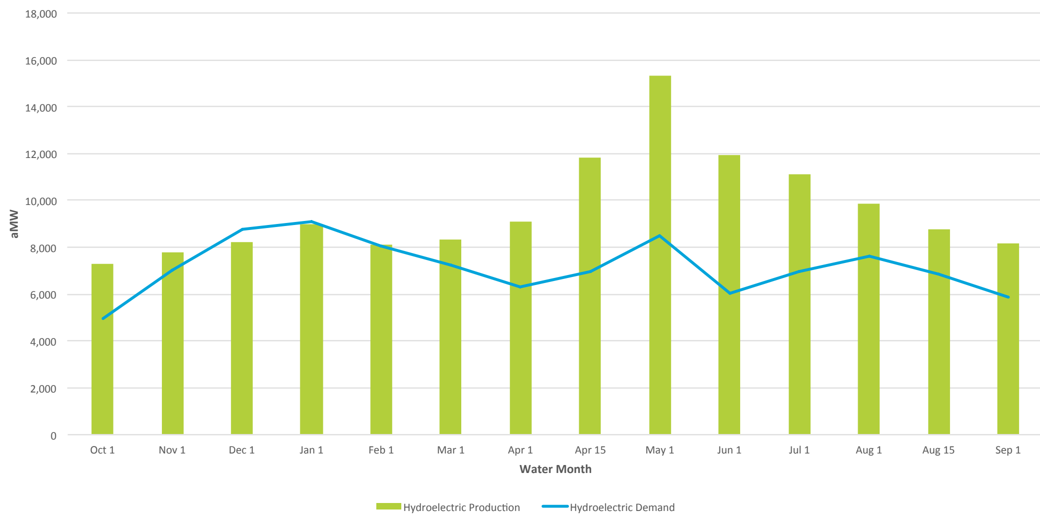


Figure 16. Hydroelectric Production—Driest Water Years under 3Ea

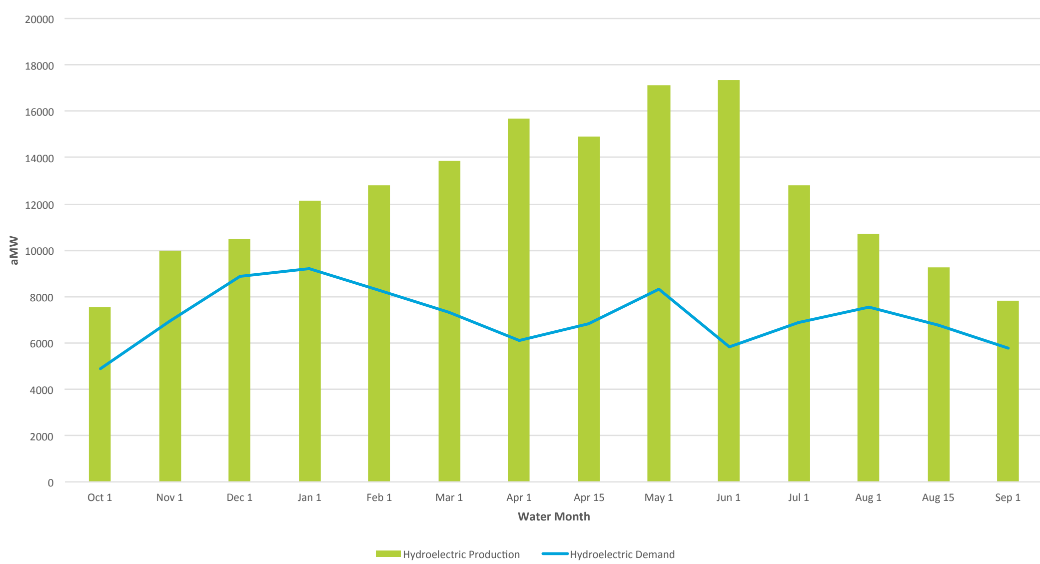


Figure 17. Hydroelectric Production—Median Water Years under 3Ea

Figure 18. Hydroelectric Production—Wettest Water Years under 3Ea

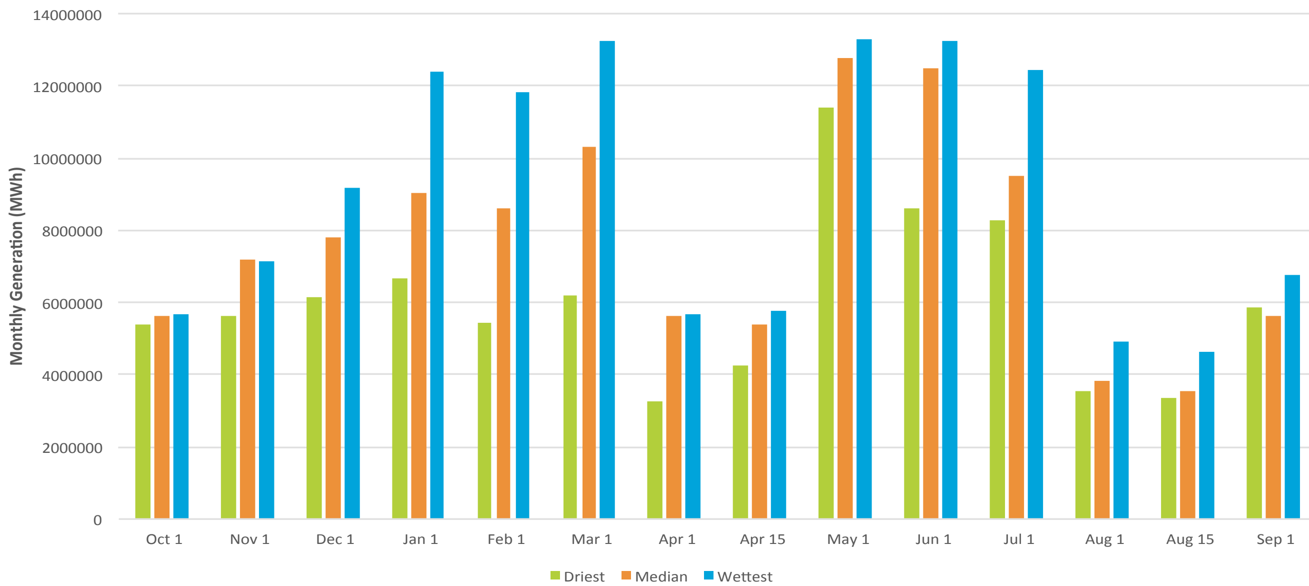


Figure 19. Hydroelectric Power Generation by Water Month and Water Year Quintile

We also estimated the dollar value of hydropower generated within the Columbia River Basin for both RCC-80 (see Chapter 3) and 3Ea. To identify values, wholesale prices were applied to hydropower generated within the given period. Although prices change hour by hour, with peak prices differing from non-peak, monthly average wholesale trading prices at the Mid-Columbia were used to obtain an estimate of total value.

The total value of hydropower in the Columbia River Basin is estimated at $2.95 billion in dry years, $3.33 billion in medium water years, and $3.63 billion in the wettest water years. December and January in the driest water years will likely see a power generation deficit, and the Pacific Northwest may be required to purchase power from out of market. Out-of-market pricing is based off of Southern California trading prices. This deficit may also be filled with other power-generating resources within the basin, but these effects were not analyzed.

Additionally, the net change in hydropower generation was calculated by subtracting the power generation levels under current conditions from the total generation under 3Ea (Table 22).

As can be seen in Table 22, there will be a loss of roughly $69 million in hydropower value under scenario 3Ea. This value loss will be most significant in low water years. Low water years also impact EbF, as resident and anadromous fish species receive large benefits from additional water in crucial migratory months.

Modernized Flood Risk Management

Under a modernized scenario, ecosystem integration supports flood adaptation under projected climate change conditions in that key reservoirs could remain fuller and promote partial restoration of the spring freshet while still providing adequate flood control. Tribes are seeking ecosystem integration in a manner that would not increase high peak flows in the highest water years, thus avoiding increased flood risk. That said, tribes and others in the region seek to reduce conservative drafting of storage reservoirs, especially premature drafting, in order to release storage

Table 22. Net Change of Power Generation in Both Scenarios

HYDROPOWER VALUE	CURRENT CONDITIONS	EbF (3Ea)	DIFFERENCE
Driest Water Years	$3,066,514,176	$2,952,631,383	-$133,882,793
Medium Water Years	$3,388,935,087	$3,327,217,445	-$61, 717,642
Wettest Water Years	$3,664,655,116	$3,633,159,148	-$31,495,968
WEIGHTED AVERAGE	**$3,373,356,570**	**$3,304,324,828**	**-$69,031,742**

and shift river management for ecosystem function values. To accomplish this, tribes and others in the basin seek flood risk management by improved runoff forecasting, structural improvements to floodplain structures that protect important built infrastructure, and reestablishment of floodplain habitat in areas that frequently flood or have less valuable built capital.

Under scenario 3Ea, flood risk management systems will continue to safely accommodate altered water release regimes, as described below. However, to lessen localized flooding and choke points while also gaining further benefits from 3Ea, an increased focus on natural infrastructure is needed. Reconnecting floodplains, restoring riparian zones, and incorporating green stormwater solutions can provide a range of habitat and community benefits in addition to flood risk reduction. As infrastructure ages and local communities work to mitigate the stresses of climate change, natural infrastructure can provide a valuable alternative. These flood risk management solutions are more resilient to shocks and future effects of climate change.

Due to major development in floodplains, extensive built infrastructure has been used to manage flood risk in the Columbia River Basin. Allowing for ecosystem-based function to play a larger role in river management means integrating built and natural capital into flood risk management through natural infrastructure solutions. This section looks first at the proposed flows and the current management capacity of the Lower Columbia Flood Risk Management. Then examples of natural infrastructure are discussed to highlight the importance of natural infrastructure solutions to maximizing benefits of scenario 3Ea.

Overview of Flood Risk

Flood risk is greatest in the wettest water years. USACE flood risk management planning is based on projected flows at The Dalles, where the objective is to keep flows below 600 kcfs whenever possible; such high flows are known to cause serious flood damages[133] As can be seen in Figure 22, unregulated peak flows at The Dalles can exceed 600 kcfs in the wettest water years.

Flood control rule curves are designed so that reservoir storage is available before major flood events and these are dependent upon runoff forecasts. Under scenario 3Ea, water that is held back in the winter would be released in the spring and early summer to partially restore the spring freshet, improving resident and anadromous fish survival. These alterations to streamflow would occur in dry and average water years, but current management procedures would remain constant in the wettest years to accommodate increased flood risk. Although daily flood risk is not analyzed under the 3Ea scenario, monthly streamflow in the driest and medium water years are well below the 450 kcfs threshold for flood damages. For the 14 water periods, neither the current condition or modernized scenarios had monthly flows over 600 kcfs. While there is little difference in the flood control curves and peak flows between 3Ea and RCC-80 for the 14 period outputs for the 80-year water record, there may be differences in flood risk based upon assessment of three- or five-day flood risk. These differences were not analyzed for this report.

Natural Infrastructure in the CRB

The following examples illustrate implemented or planned natural infrastructure projects that provide a suite of ecosystem service benefits while also addressing flood risk. Natural infrastructure is a viable, cost-effective opportunity to improve ecological function and ecosystem services benefits to surrounding populations. Projects such as those discussed below will help maximize the benefits of a modernized treaty.

Columbia River Estuary

In 2014, the Columbia River Estuary Study Taskforce (CREST) completed the Fee-Simon wetland enhancement and levee setback project at the Wildlife Center of the North Coast on a tributary of the Youngs River. Partners for this multi-benefit restoration project included Bonneville Power Administration, the Lower Columbia Estuary Partnership, the Oregon Watershed Enhancement Board, and the U.S. Fish and Wildlife Service.[134] A levee was removed and a setback levee was built to protect adjacent landowners. The reconnected floodplain land consisted of approximately 16 acres of former agricultural land and 33 acres of forested wetland previously disconnected from the hydrology of the river.[135]

This natural infrastructure approach to flood control provides a variety of ecological function improvements. Converting 16 acres of agricultural land to emergent wetland enhances ecosystem service benefits including improved aquatic habitat, increased water filtration potential, and increased storm attenuation. In addition, reconnecting isolated forested wetlands improves their health and function. Although these increases in ecosystem health can be difficult to monetarily value, the results are indeed valuable, including benefits from improved riparian productivity to increased soil nutrients.

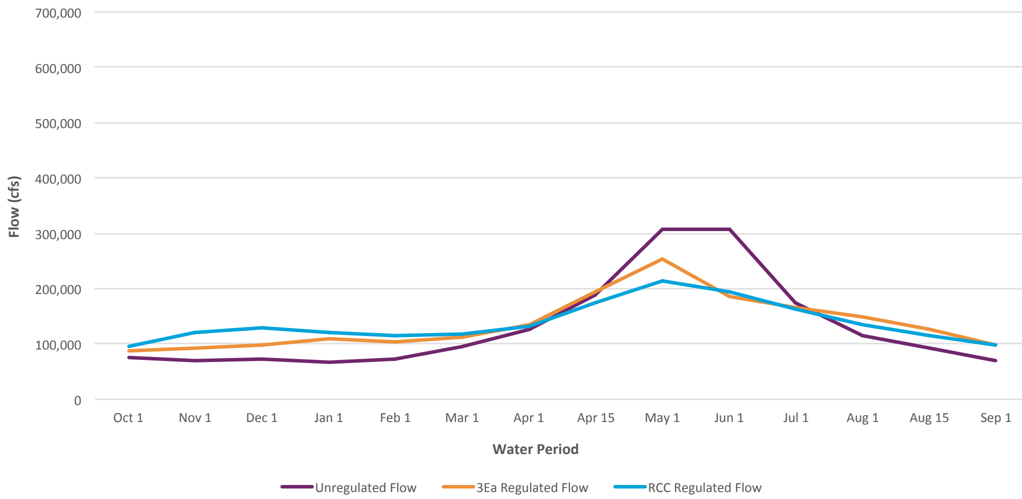


Figure 20. Flow at The Dalles—Driest Water Years

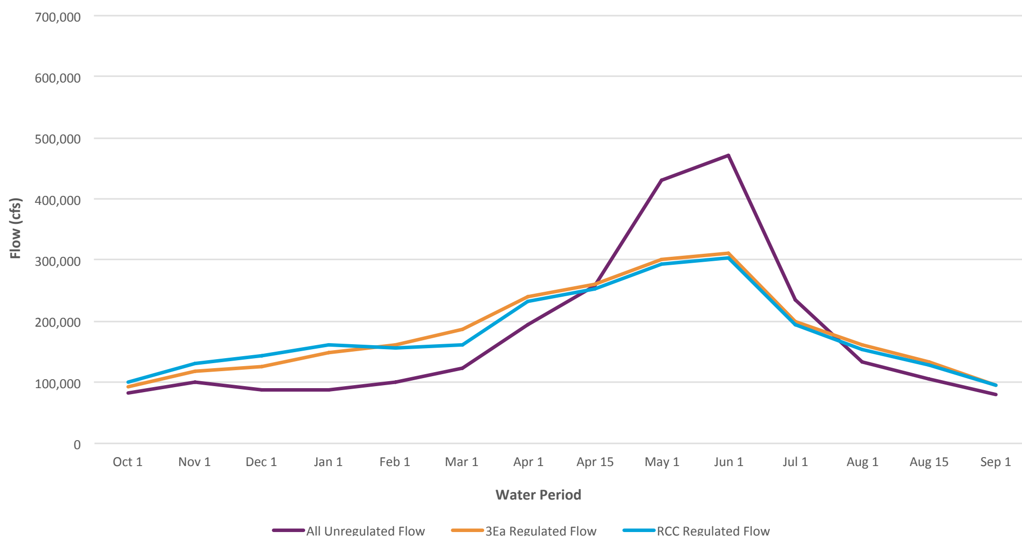


Figure 21. Flow at The Dalles—Median Water Years

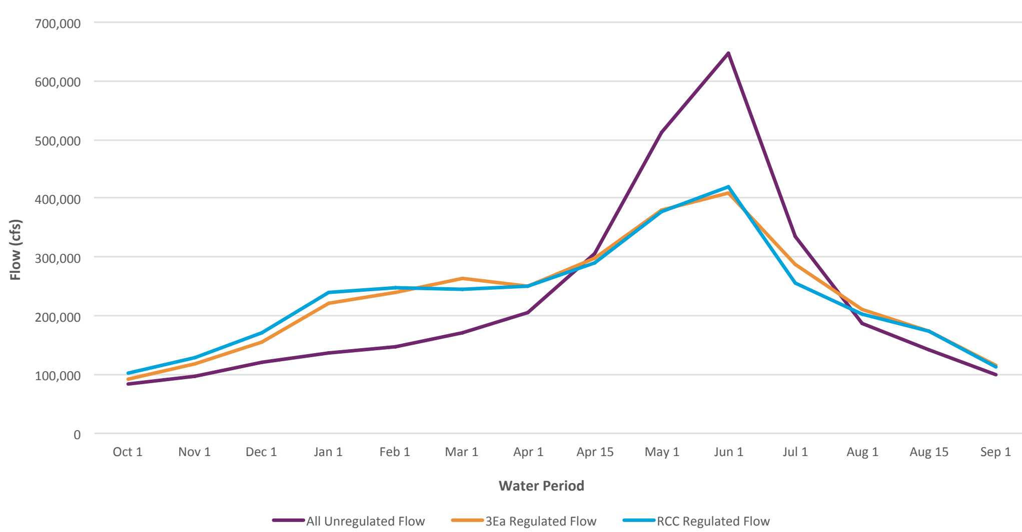


Figure 22. Flow at The Dalles—Wettest Water Years

This project is one example of opportunities in the Columbia River Estuary to improve habitat function and increase floodplain connectivity while maintaining flood protection for land owners. A continued focus on green infrastructure solutions for flood protection and restoration in the lower estuary can safely protect low-lying agricultural land while restoring vital wetland and instream habitat areas. Projects to improve floodplain habitat will catalyze further enhancement of the estuary and build off of other modernized treaty adjustments for ecological function.

Portland, Oregon Metro Region

The proposed setback of the Steigerwald Lake National Wildlife Refuge levee system represents an important opportunity to improve ecological function while also increasing flood protection. Located outside of Washougal, WA, the wildlife refuge is a tract of prime floodplain land that has been isolated from the Columbia River, causing altered vegetation communities, reduced nutrient exchanges, and limited aquatic habitat availability.[136] A flood control and habitat project is currently in the design phase for the site. This project would breach the levee that isolates the refuge from the Columbia River, regrade historic channels to promote floodplain reconnection, build a setback levee, restore natural stream migration across the floodplain, and plant native vegetation.[136]

Potential benefits of the Steigerwald Lake National Wildlife Refuge project will span a range of ecological and economic improvements. Reconnecting over 1,000 acres of the refuge with the Columbia River is a valuable habitat improvement opportunity that would increase the acreage of unrestricted floodplain habitat between the Columbia/Willamette confluence and Bonneville Dam by 16 percent.[137] This increase will provide habitat for a variety of wildlife, particularly waterfowl. Additionally, the increased in-stream tributary habitat will benefit migrating salmon and support lamprey. Other ecosystem service benefits of the project include increased recreation and education opportunities and improved wetland filtration functions. The levee setback project also provides direct economic benefits, lessening operating costs for the Port of Washougal, eliminating the need for dredging Gibson's Creek, and decreasing flood risk. The new setback levee would rezone the port and portions of the surrounding community out of the 100-year floodplain, thereby reducing flood insurance costs.[138]

Steigerwald Lake National Wildlife Refuge is situated along the eastern edge of the Portland Metro Area. Expanding floodplain accessibility here will lessen the pressure on choke points further downstream, where built infrastructure continues to constrain the river. Lower Columbia floodplain expansion projects such as this provide an important habitat link and compound upstream improvements expected under the 3Ea modernized scenario. Importantly, this natural infrastructure approach not only improves habitat, but also provides valuable flood risk reduction and maintenance cost benefits.

Middle Columbia

South of Yakima, WA, a multi-stage effort to decrease flooding on the Yakima River involved removing several levees. These legacy flood risk reduction levees were built to protect property in the floodplain, but have contributed to flooding issues in the nearby towns of Wapato and Toppenish. Additionally, due to its large size and location, the floodplain behind these levees held a high potential for habitat benefits for Yakima River migrating salmon.[139] In planning for future flood risk reduction, multiple partners, including the WA Department of Transportation and Department of Ecology, collaborated to develop an integrated approach to risk reduction that utilizes both natural and built infrastructure to better accommodate river flows.

The Donald Wapato Levee Removal project was conducted in multiple phases. Before the project began, re-engineering a stretch of highway near the site eliminated the need for protection from roadway flooding.[140] The first stage of the project involved acquiring floodplain land currently isolated behind the levees. Once the properties were cleared, levee removal and restoration of natural habitat allowed for a natural river flow, significantly spreading floodwaters across the reconnected floodplain.[140] As opposed to leaving relic flood infrastructure in place, project partners saw the potential benefits of floodplain reconnection and habitat improvement. The removal of levees along this stretch of the river provides in-stream and floodplain habitat benefits in an area previously disconnected from river hydrology and now no longer requiring protection. While removal of floodplain assets may not be feasible for all communities, current infrastructure throughout the CRB can be reassessed as surrounding conditions change, evaluating the necessity and cost-effectiveness of infrastructure upkeep.

Boise, ID

Cities and towns throughout the basin are currently wrestling with localized flooding and outdated stormwater management systems. These systems were often not designed to effectively cope with additional stresses such as unexpected population growth and climate change. An integrated plan for the Boise River lays out several natural infrastructure solutions that will help mitigate localized flooding. In addition to floodplain restoration and riparian improvements along the river, urban solutions such as permeable pavement, bio-swales, and increased tree canopy cover are also highlighted as flood risk reduction measures.[141] While not traditionally thought of for habitat restoration purposes, these types of natural infrastructure projects do provide valuable ecosystem service benefits and fit into the larger picture of improved ecosystem function.

The City of Boise has collaborated with the Ada County Highway District through The Partners for Clean Water to enhance natural infrastructure in Boise's urban streets. Green alleys and parking lots help the city manage localized flooding by intercepting runoff before it enters and backs up the city's stormwater system.[142] Increased tree canopy cover and bioswales also help filter polluted stormwater before it reaches the Boise River. These projects provide ecosystem service benefits in addition to flood reduction and water quality including, but not limited to, improvements in air quality, aesthetics, carbon sequestration, and habitat.

While improving floodplains and riparian areas in the CRB will remain key to increased ecological function, additional urban natural infrastructure solutions are also important to maintaining healthy ecosystems. The shift towards natural urban infrastructure can help support watershed and basin-wide improvement efforts, as seen in the enhancement plan for the Boise River.

Modernized Recreation

One of the largest and most unique public benefits of the Columbia River Basin is its recreation opportunities. Currently, recreation in the Columbia River Basin is worth at least $5 billion. Modifications to reservoir operations will impact the quality of recreation in the basin and change the recreation days demanded.

Modernized General Recreation

A 3Ea scenario may impact recreation through shifting reservoir levels. One of the biggest recreation reservoirs in the Columbia River Basin is Lake Roosevelt, which provides over $100 million in recreational benefits annually. This section examines the potential impacts of 3Ea for the economic value of recreation at Lake Roosevelt.

Lake Roosevelt National Recreation Area

Lake Roosevelt NRA is one of the most popular recreation sites in the Columbia River Basin. The recreation area receives well over one million visitors annually. Visitation to the reservoir created by Grand Coulee Dam can be sensitive to management operations.

As one might assume, visitation is lowest in the winter months and highest in the summer months.[143] As spring approaches, visitation increases at a fairly constant rate from February through April. In May, there is typically no increase in visitation, sometimes even a decrease, when compared with April's visitation. This coincides with the periods when water levels are lowest as pools are drafted for flood control. Refill typically begins in May, and by the end of June, the reservoir reaches near full pool. Peak water levels coincide with a sharp increase in visitation. In the summer months, the lake offers world class opportunities for boating, fishing, swimming, camping, and picnicking.

Reservoir Elevation Impacts on Visitation

The National Parks Service Visitor Use Statistics program has been collecting park ranger comments on the number of visits to Lake Roosevelt NRA since November 2004. In these comments, boat launches out of water were seen to be an issue in 39 out of the 118 months of reporting. Comments by park rangers indicate that boat launches out of water heavily influence park visitation. These comments occurred most frequently in May (11 times) and June (10 times), but also occurred in June for several years. Data collected by park rangers in Lake Roosevelt during low water levels indicate fewer visitations and therefore less recreation dollars during those events.
Under scenario 3Ea, drafting will continue to occur from October to April, then begin to refill May through June. To emphasize EbF, however, the February through April drafting will be about 10 feet less in the driest water years, when there is less flood risk. Drafting schedules for medium and wettest water years will nearly follow current form.

Though many factors can influence recreational participation (water quality, weather, economic climate), changing reservoir levels are known to significantly influence recreational participation.[94] With 3Ea, Grand Coulee operations will continue to be similar in median and high water years and therefore it is assumed that there will be no significant change in recreational visitor days. In the lowest water years, however, reservoir

Chief Joseph Dam, Source: Unknown

management will be slightly different. Regression analysis was used to estimate the effects of reservoir management under RCC-80 and 3Ea.

Economic Value of Lake Roosevelt Recreation under 3Ea

To estimate the effects that 3Ea might have on recreational participation at Lake Roosevelt, monthly visitation data was collected from 1979 to 2015. This visitation data was then regressed against average monthly reservoir levels. As was discussed earlier, many factors influence visitation, but were not found significant in these models. This insignificance is likely a factor of the crudeness of using monthly averages as opposed to daily data.

Using only summer season monthly visitation (May through September) and water elevation data, the regression did have significant predictive power with an R^2 of 0.96. The regression analysis was then used to estimate visitation under both RCC-80 and 3Ea for the driest water years.

Recreational benefits provided by Lake Roosevelt greatly depend on reservoir levels at near full pool for optimum recreation. Even though reservoir levels are at optimal recreation levels in both scenarios, the regression analysis does suggest a small increase in visitation is associated with these higher levels.

As seen in Table 22, total monthly visitation in summer increases in scenario 3Ea. The regression also showed a decrease in monthly visitation in September, when reservoir levels under 3Ea are actually lower than observed in RCC-80. This overall increase in visitation of 518 recreation participants has an economic value of $39,000.[144]

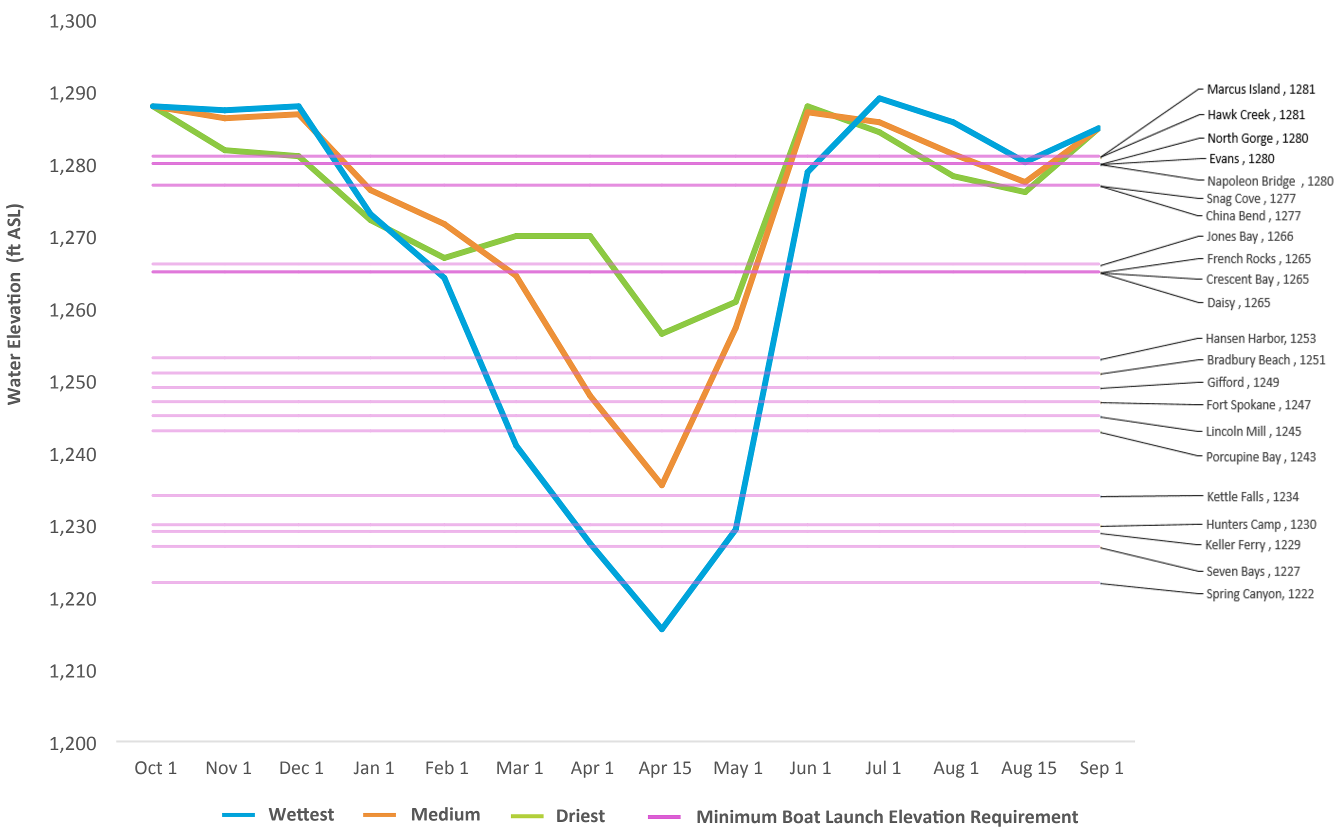


Figure 23. Water Elevation and Minimum Boat Launch Requirements at Lake Roosevelt

The regression analysis does have high predictive power, but these results are still within the margin of error. Nonetheless, it is clear that water levels associated with the 3Ea scenario will not significantly impact recreational opportunities over the RCC-80 scenario. This model does not, however, capture how improvements in EbF may increase the quality of recreational experiences. With improved ecological factors, such as water quality, recreational experiences will be heightened and in turn increase demand for recreation at sites like Lake Roosevelt.

Modernized Angling

Because much of the basin's ecosystem value has been impaired by built capital projects and management, anadromous and resident fish populations are a fraction of their historical numbers. Dams have isolated vast areas of habitat—currently, sturgeon, bull trout, and eulachon, as well as 13 species of salmon, are listed under the Endangered Species Act. The once-abundant Pacific lamprey and burbot populations have also collapsed. The 3Ea scenario addresses these losses through actions to restore habitat quality, function, and diversity and improve migration conditions for anadromous fish and reservoir and river conditions for resident fish.

Comparative Differences in Salmon Survival: Two Scenarios

Estimates for salmon and steelhead survival under the RCC-80 and 3Ea scenarios were acquired from the 2013 Columbia River Treaty Sovereign Review Process. In that process, a scenario similar to 3Ea was developed and compared to a scenario similar to the RCC-80 scenario with respect to salmon and steelhead in-river survival and smolt-to-adult estimates. Two regional fish survival models, NOAA's COMPASS and the Columbia River Estuary Study Taskforce

Table 23. Average Monthly Visitation under RCC-80 and 3Ea—Lowest Water Years

MONTH	1–MAY	1–JUNE	1–JUL	1–AUG	15–AUG	1–SEP
Low Water Year—RCC80	90,916	189,873	309,078	155,915	155,804	135,869
Low Water Year—3Ea	91,142	189,980	309,150	156,088	155,953	135,660

(CREST) were focused on the two most heavily impacted endangered salmon groups in the basin – Upper Columbia Spring chinook and Upper Columbia steelhead. In-river survival and smolt-to-adult survival estimates showed a 3Ea scenario would generate in-river improvement of 8.9 to 10 percent for steelhead, a 2.8 to 6.7 percent gain for Upper Columbia spring chinook over RCC-80 (see Table 24).

Because the river segments for survival estimates differ across models, a direct comparison of smolt-to-adult improvements cannot be made. However, across the full reach from Wells to Bonneville, steelhead in-river survival estimates from both models are similar. Thus, while there is no steelhead COMPASS smolt-to-adult estimate for the Wells-Bonneville reach, it can be assumed to be similar to CSS estimates at a 126 percent improvement for 3Ea (Table 24). For spring chinook, a range of smolt-to-adult estimates from both models yielded a conservative estimate of increased adult returns from the 3Ea scenario of 6.7 to 12.5 percent over RCC-80 (Table 24).

Table 24. Estimated Percent Increases in In-River and Smolt-to-Adult Survival from the Modernized Scenario Over the Current Condition

3EA % IMPROVEMENT FROM RCC-80	COMPASS	CSS
Upper Col Steelhead In-River Survival	8.9 %	10%
Upper Col Spring Chinook In-River Survival	2.8%	16.2
Upper Col Steelhead Smolt-Adult Return (Wells-Priest Rapids)	14.6%	NA
Upper Col Spring Chinook Smolt-Adult Return (Wells-Priest Rapids)	6.7%	NA
Upper Col Steelhead Smolt-Adult Return (Rock Island-Bonneville)	NA	126%
Upper Col Spring Chinook Smolt- Adult Return (Rock Island-Bonneville)	NA	12.5%

The estimates reported in Table 24 were used to estimate growth in recreational catch and economic value within the Columbia River Basin, although growth rates were not calculated for recreational fishing on the ocean. Given the greater salmon and steelhead abundance, in-river recreational catch is estimated to increase by 102,000 fish under the 3Ea scenario. This estimate is conservative, as we did not model effects on the abundance of other salmon and steelhead stocks throughout the basin. However, these stocks are also likely to increase under a 3Ea scenario.

We also estimated the value of reintroducing salmon runs above Chief Joseph and Grand Coulee dam, along with the installation of passage infrastructure that would allow the fish to complete their lifecycle. These actions can be expected to increase recreational catch by 19,000 salmon and steelhead. reports the recreational catch and resulting economic value in the Columbia River Basin and open ocean commercial fishing areas that are expected to result from a 3Ea scenario and reintroducing salmon above Chief Joseph and Grand Coulee. A full breakdown of this table can be found in appendix D.

Table 25 reports the recreational catch and resulting economic value in the Columbia River Basin and open ocean commercial fishing areas that are expected to result from a 3Ea scenario and reintroducing salmon above Chief Joseph and Grand Coulee. A full breakdown of this table can be found in appendix D.

Under RCC-80, the recreational catch is estimated at 381,000 salmon and steelhead, resulting in $141 million in recreational value. Emphasizing the importance of ecosystem function in the Columbia River Treaty and restoring anadromous fish populations will increase the recreational catch from 381,000 to 498,000, and improve annual recreational value from $141 million to $187.4 million. The total annual value of general recreation in the Columbia River Basin under the 3Ea scenario is approximately $4.7 billion, with recreational fishing contributing $187 million to that total. The 3Ea scenario increases recreational value by $46.5 million over RCC-80.

Modernized Navigation

This report does not value navigation changes under the 3Ea scenario, though increasing seasonal flows in late summer under 3Ea and throughout the river during low runoff years would improve opportunities for commercial transport and support much-needed ferry services. 3Ea increases in late August-September flows for adult salmon and steelhead migrations would also benefit lower river navigation needs. The following section describes issues with the Gifford-Inchelium Ferry, and how these could be solved under the 3Ea scenario.

Table 25. Modernized Columbia River Treaty Recreational Values

ECONOMIC IMPACT REGION/AREA/SPECIES	RECREATIONAL CATCH 3Ea	ECONOMIC VALUE 3Ea
COLUMBIA RIVER SYSTEM		
Chinook	137,023	$61,928,073
Coho	57,541	$21,979,192
Steelhead	214,373	$97,269,511
TOTAL COLUMBIA RIVER	**408,938**	**$180,981,728**
OCEAN FISHING—COLUMBIA RIVER BASIN STOCKS		
Chinook Salmon	36,148	$2,355,194
Coho Salmon	53,029	$4,079,371
TOTAL OCEAN	**89,178**	**$6,434,565**
	498,116	**$187,416,293**

Gifford-Inchelium Ferry

The Gifford-Inchelium Ferry provides a vital transportation route between the communities of Gifford and Inchelium,[145] but the ferry has closed in 10 of the past 25 years when water levels in Roosevelt Lake sank below 1,232 feet above sea level.[146] In those years, ferry services was disrupted an average of 30 days,[146] increasing 13,600 commutes between Gifford and Inchelium by 65 miles each way.[w,147] A river management plan that is more sensitive to the needs of local communities could reduce such hardships. The 3Ea scenario would support hydropower generation, flood protection, and navigation, while also increasing critical habitat throughout the basin.

Modernized Agriculture—Irrigation

Agricultural activities were not valued under 3Ea. Estimates under the current conditions scenario are assumed (see Table 20).

Modernized Increased Flow Value

Increased flows are associated with the 3Ea scenario are added to the ecosystem service value in a hypothetical 10 percent increase in EbF.

Before significant human impacts on the Columbia, spring thaws between late April and July would produce streamflows at The Dalles well above 450 kcfs. Known as the *spring freshet*, it was critical to helping juvenile salmon migrate safely downstream. Development within the Columbia River Basin has altered these flows. In an average water year, regulated flows during the spring freshet now only reach about 300 kcfs at The Dalles. A modernized Columbia River Treaty would increase instream flows during the spring freshet.

Based on CIS modeling, we assumed river flow to be constant at 292 kcfs from May 1st to May 31st, although hourly or daily streamflow would clearly vary. To calculate the total flow increase, model data was converted from cubic feet per second (cfs) to acre feet per day,[x] and then multiplied by the number of days in the study period to estimate the total acre feet of water released in a period. The net change in water volume over the critical period (March 1 through September 30) was calculated by subtracting 3Ea volumes from RCC-80 volumes for the driest, average, and wettest water years (Table 26).

The Columbia River Basin has an active water market for water leases and permanent water acquisitions for irrigation, hydropower, municipal use and ecological purposes. These data can be obtained from the Columbia Basin Water Transaction Program.[148] The benefits of increased in-stream flows are calculated by multiplying the per acre-foot water

w Per Analysis in Google Maps

x Footnote: One cubic foot of water per second released at a constant rate for 24 hours is equivalent to approximately 1.98 acre feet.

Table 26. Total Increase in Acre Feet at The Dalles for Period March 1–September 30

WATER YEAR	TOTAL AF RCC-80	TOTAL AF 3Ea80	AF INCREASE	ECONOMIC BENEFIT ($115.32/AF)
Driest Water Year	64,595,391	67,745,126	3,149,735	$363,227,414
Med Water Year	86,608,212	90,305,784	3,697,572	$426,404,015
Wettest Water Year	113,322,637	116,585,825	3,263,188	$376,310,790
ALL WATER YEARS	**88,175,157**	**91,545,311**	**3,370,153**	**$388,646,056**

value (adjusted to 2016 USD) by the increases in water volume under 3Ea. Growth of in-stream flow is calculated at The Dalles for historical purposes. These calculations are seen in Table 26.

Modernized Nutrient Enhancement Value

Prior to river modifications, salmon delivered large quantities of marine-derived nutrients to the upper reaches of the Columbia River Basin, contributing to in-stream, riparian, and other terrestrial ecosystems.[y] Under a modernized Columbia River Treaty, migrating salmon could again move nutrients to the Upper Columbia, by allowing fish passage above the Chief Joseph and Grand Coulee Dams. Annually, 1.5 to 5.2 million pounds of salmon are expected to journey above these two dams.[149]

The Shoshone Bannock Tribe's nutrient enhancement program improves ecosystem health by adding nutrients along tributaries of the upper Salmon River. The nutrient enhancement program demonstrates a willingness-to-pay for improved ecosystem health through salmon-derived nutrient inputs. Nutrients were valued based on both the quantity of nutrients and fieldwork costs. Because the average total annual weight of salmon expected to return above Chief Joseph and Grand Coulee Dams is 3.4 million pounds, the annual value of salmon-derived nutrients would be $30.8 million.

Lake Roosevelt, Source: Brian Gruber

y Salmon River Basin Nutrient Enhancement: Contract Year 2015-2016 RM&E Annual Progress Report, Project Number: 2008-904-00

Total Economic Value of Modernized Scenario

The benefits under current conditions and 3Ea scenarios are shown in Table 27, along with the net change under 3Ea. The total value of benefits under 3Ea increase by $1.5 billion dollars per year. If we assume the 3Ea scenario to increase EbF throughout the basin, the benefits derived from EbF would increase accordingly. Thus, including EbF in decision-making could be expected to increase benefits as well. Table 27 demonstrates the total increased value of benefits under 3Ea, with and without a hypothetical 10 percent increase in EbF.

Table 27. Total Economic Value of the CRB under Modernized Scenario (numbers in thousands)

RESOURCE	CURRENT CONDITIONS	EBF (3EA)	NET CHANGE UNDER EBF (3EA)
Agriculture (Irrigation)	$646,908	$646,908	$0
Ecosystem Services	$189,963,082	$190,351,728	$388,646
Existence Value	$37,289	$1,131,200	$1,093,911
Hydropower	$3,373,357	$3,304,325	-$69,032
Navigation	$13,248	$13,248	$0
Non-Tribal Commercial Fishery	$12,133	$19,142	$7,009
Nutrient Enhancement	$0	$30,847	$30,847
Recreation - General Recreation	$4,683,459	$4,683,498	$39
Recreation - Angling	$140,935	$187,416	$46,481
TOTAL ASSESSED VALUE	**$198,870,410**	**$200,368,311**	**$1,497,902**
10% EBF INCREASE	**$0**	**$19,035,173**	**$19,035,173**
TOTAL ASSESSED VALUE WITH EBF INCREASE	**$198,870,410**	**$219,403,484**	**$20,533,074**

Chapter Five

The Cultural Value of the Columbia River Basin

"Every time I go out in the woods I feel that something is and so I learn something every time I go out, I come back and my life is enriched, you know I took it to heart."

– Salish-Pend d'Oreille Culture Committee[40]

Up to this point, this focus of this report has been on assessing the monetary value of ecosystem services in the CRB. However, the data and information presented above does not convey the intangible benefits people receive from the basin's resources. These intangible benefits are especially valuable to the CRB tribes and cannot be measured in monetary terms. The negotiation of the original 1964 Columbia River Treaty did not involve or even consider the tribal nations or the potential and actual cultural losses associated with implementation of the CRT.

This section aims to identify and document the basin's cultural value in non-monetary terms, in order to contribute to inclusion of ecosystem-based function in the Treaty. In this chapter, we demonstrate the breadth of the CRB's immense cultural value. Due to limited available data, this cultural review accounts for a very small percentage of the cultural richness of this land. Nonetheless this chapter identifies aspects of nature's gifts and contributes to this important conversation, which is oftentimes overlooked.

Recognizing Cultural Value

Ecosystem service frameworks, such as the Millennium Ecosystem Assessment or EPA's Final Goods and Service classification,[150] interpret cultural values in a variety of ways. Some consider spiritual and religious experiences, while others espouse a broader definition that includes recreation, aesthetic beauty, education, and scientific research. In this report, cultural values encompass the perspectives and value systems of PNW tribal communities. Within this context, the natural environment is closely tied to individual, community, and societal identities.

Nature provides ancestral experiences shared across generations and offers settings for communal interactions that shape cultural relationships. Cultural heritage is usually defined as the legacy of biophysical features, physical artifacts, and intangible attributes of a group or society that are inherited from past generations, maintained in the present, and bestowed for the benefit of future generations.[151] Over millennia, the environment has been shaped by constant interactions between humans and nature. The globe is inscribed with not only natural features, but also the legacies of past and current societies, technologies, and cultures.

For many communities and people, certain landscapes and species are strongly associated with cultural identities and place attachments. In some cases, the relationships between ecosystems and religion center on material concerns, such as staking claim to land contested by immigrants, invading states, or development agencies. Nonmarket economic valuation techniques have, in few cases, been successfully applied to cultural heritage objects. However, cultural values such as regional identity or sense of place remain elusive, and even impossible, to value monetarily. Therefore, for the remainder of this report, cultural values will encompass non-monetary goods and services reserved primarily to tribal communities under the themes discussed here.

Cultural Assessment

Decision makers and land managers need a way to assess ecosystem service tradeoffs, both in the biophysical and cultural context. The ecosystem service frameworks mentioned above do little to address the diversity of cultural ecosystem values. Few attempts have been made to develop a framework to assess cultural values in tandem with biophysical ecosystem services, especially as they inform land and water-use decisions.

Likewise, efforts to measure cultural values face methodological difficulties and problems of scale. Nancy Turner, a top ethnobotanist and Indigenous Peoples researcher known for her extensive work on the problems of measuring cultural values, describes how cultural values are embedded into other ecosystem services and, in most cases, cannot be separated.[152] For example, salmon ceremonies require a healthy riparian habitat to provide food, access to riversides, and the historical value of nature of the activity itself. Turner argues that these elements are both inseparable and also extremely difficult to value. Measuring cultural services at large scales and across wide regions is also problematic.[153] Culturally valuable natural areas often exist in small-scale landscapes, home to few communities. Measuring cultural value across broad landscapes risks grouping diverse cultural entities and communities when each site should, in fact, carry unique cultural importance.

To address the aforementioned limitations, the Puget Sound Institute (PSI) and Stanford University created a method to qualitatively measure cultural value for Hood Canal tribes. The goal was to understand how community culture is influenced by land-use decisions and how well-being is improved with access to nearby aquatic resources off the Hood Canal. PSI developed a process for selecting cultural value indicators relevant to natural resource management in Hood Canal.[154] The purpose of this work was to monitor the state of Hood Canal communities and to inform integrated watershed strategies.

The method created by PSI and Stanford (referred to as the "PSI approach" in the remainder of this report) was adopted for this report to demonstrate the importance of cultural values to Columbia River tribes. This method is well-suited to reveal the array of cultural benefits received by tribes in ways that are otherwise ignored in decision making. The PSI approach establishes a comprehensive list of benefits summarized across multiple individuals to illustrate the full suite of cultural values not represented by monetary valuation. In reviewing existing methods, we found this technique to be the most appropriate for the context of this analysis. Other approaches, including in-person interviews and workshops, were not feasible for this analysis. In the following, we describe the PSI approach and its adoption into this report.

The PSI Approach

The original PSI approach was developed in close correspondence with cultural resource specialists, a well-respected member of the Hood Canal tribal community and curator of tribal documentation. The goal of the project was to understand how culture and well-being were influenced by access to river resources like salmon. The PSI approach involved two steps. The first was to interview individual tribal members concerning their day-to-day interactions with a variety of natural resources, and the second step used a data analytics approach to transcribing and coding the interviews. The coded responses fell into six primary categories: psychological, physical, cultural, social, economic, and governance.

Columbia River Basin Cultural Value Approach

For this report, we aimed to demonstrate the array of cultural value that the Columbia River Basin provides to the region's tribes. We applied an adapted version of the PSI approach for this analysis because the method effectively communicates the full array of cultural value that often goes unrecognized and unrepresented in decision-making. Any changes to the methodological approach were made to accommodate differences between the cultural analysis, and the PSI approach for the Quinault tribe. The following paragraphs detail our approach and any changes to the PSI approach.

Due to the timing and scope of this report, we were not able to conduct individual interviews as in the PSI approach. Instead, our analysis relied on media, narrative, and literary documentation to assess well-being indicators, including online video transcriptions, published stories, and documented poetry. Tribal stories, lessons, and poetry are sometimes the only documented sources that show how indigenous peoples throughout the world value natural resources[155], and text analytic techniques are well-recognized in multiple fields of study as an effective data collection tool.[155;156] Tribal member interviews are recommended for future analysis of the CRB cultural values.

The data collected for the CRB cultural analysis consisted of 45 videos, poems, and stories, most of which provided multiple pages of content. Appendix H provides a list of these sources for each tribe. All data was collected from public online sources or directly from the tribes themselves, and the documentation represents 13 of the 15 CRB tribes as well as multiple perspectives and generations within each tribal group. Given the lack of data from the Canadian First Nations they are not included in this cultural analysis. However, many tribes lie across the international border of U.S and Canada, such as the Okanagan and Kootenai Tribes, therefore we could assume that the cultural analysis for first nations would be similar.

Narrative Coding

The narrative coding for the CRB cultural analysis was consistent with the PSI approach. Each of the sources listed in Appendix H were converted or transcribed to narrative. The narrative was coded into the four categories described in Table 28. For example, the following sentence is narrative transcribed from a video about sustainable fishing from the Colville tribes (#16 in Appendix H): "*For us, it's about sustainability- the selective harvest program presents a piece of our traditional thinking and knowledge to better manage our natural resources that being the salmon.*" This sentence was labeled, or coded, as the well-being indicator "traditional practices," which fit under the "Cultural" category.

Classification of Human Well-Being Indicators

The PSI approach created a classification of well-being indicators broken down into six categories. A modified classification was adopted for CRB cultural analysis. The scope of the CRB cultural analysis was over a large area and defines cultural value broadly, and therefore adoption of the PSI classification required aggregation of unique cultural attributes (traditional fish catching methods) into broader categories (traditional practices). Table 28 shows the modified classification used for this analysis, which includes four categories of discussion topics: cultural, governance, economic, and social.

Table 28. CRB Cultural Analysis Classification of Well-being Indicators

CULTURAL	GOVERNANCE	ECONOMIC	SOCIAL
Spiritual Beliefs	Stewardship	Income	Communal Events
Identity	Fairness and Equity	Sustenance	Future Generations
Preferred Lifestyle	Trust	Trade and Giving	Nostalgia
Traditional Practices			Pride
Traditional Values			

Results of the Columbia River Basin Cultural Value Text Analysis

The results in Figure 24 shows the frequency with which each well-being indicator was referenced in the collected documentation. The most frequently referenced indicators were "traditional practices," "stewardship activities," "sustenance," and "nostalgic" memories. The frequency of these references does not suggest that some indicators are valued more than others, but should rather be recognized as a clear indicator of the immense cultural value that tribes and their ancestors place in CRB natural resources.

Furthermore, these results do not reflect the value system across all 15 CRB tribes, but rather provide insight on cultural values from perspectives captured in media. Further research is needed to assess the socioeconomic and cultural values of a broader cross-section of all 15 CRB tribes. Nevertheless, these results are indicative of how tribal members use and value the Columbia River in multiple ways.

In summary, this method effectively communicates the full array of cultural value that often goes unrecognized and unrepresented in decision-making. The data and information presented in Chapters 2, 3, and 4 do not describe or

Figure 24. Results of Cultural Assessment

account for the intangible benefits people receive from the basin's resources. Figure 24 summarizes the cultural values represented in existing tribal literature, allowing cultural value to be considered with monetary analysis when negotiating the modernized Columbia River Treaty.

As discussed above, cultural value is unique and exists in small-scale landscapes, home to few communities. Measuring cultural value across broad landscapes is difficult as it may miss the diversity of culture specific to tribes, regions, or even species. We therefore focus on examples of unique cultural value in the following sections, highlighting first foods, fishing, and tribal resources.

First Foods

"The prairies were full of bitterroots, which we welcome each spring with prayer as the first of our important plant foods."

– Salish-Pend d'Oreille Culture Committee[40]

First foods are the traditional foods provided by a functional ecosystem that the Tribes have harvested for thousands of years, and that they continue to rely on today as a primary source of sustenance for their families. These foods define nourishment, trade, health of tribal members as well as the land and water and, by extension, the resilience and longevity of the Tribe. First foods have always been protected and cared for by tribal ancestors and, in that way, they are also a gift from the past. They are recognized under tribal law, a management structure that calls attention to ecological processes that are ignored or greatly devalued outside of tribal culture.

Focusing on first foods *order* as a management structure was introduced by Eric Quaempts, Director of the Fisheries Department for the Confederated Tribes of the Umatilla Indian Reservation, a biologist and enrolled Yakama tribal member. Quaempts translated this elegant, centuries-old system into a management tool that guides and prioritizes DNR projects.[158] First foods are ordered by the way they are served in a tribal meal—water, fish (salmon, lamprey), game (elk, deer, moose), roots (celery, camas, bitterroot) and berries (huckleberry, chokecherry). This order follows the belief and recognition that these foods promised to take care of Indian people.

The Umatilla Tribe's Natural Resources Department also embeds first foods into their programs, including water in the Water Resources program, fish in the Fisheries Program,

Lake Pateros, Columbia River, FV Dream Catcher and crew, Source: Keith Kutchins

Ceremonial salmon cooking, Source: Keith Kutchins

big game in the Wildlife Program, and roots and berries in the Range and Forestry programs. Small tribal communities across Oregon are following suit, including first foods into a decision-making framework to ensure the existing of this sustaining good.[158]

The loss of first foods is directly linked to the health of Native peoples. Research has shown that loss of traditional food sources has put Native American people at risk of diet-related illnesses such as heart disease, hypertension, strokes, and more.[159] In particular, harvested fish are accumulating higher amounts of methylmercury as a result of fossil fuel emission (coal and oil fired power plants in particular) deposition into water.[160] Given the effects of bioaccumulation, salmon and other marketable fish have much higher levels of methylmercury than their surrounding environment. As Native Americans consume much more fish than the general population, they are exposed to heightened levels of methylmercury. These heightened methylmercury levels place Native Americans at a high risk of neurodevelopmental disorders, cardiovascular disease, autoimmune disorders, and infertility.[160] If methylmercury levels continue to increase, the value from salmon provision will be eroded as the health costs of methylmercury consumption increase.

American Indians are 2.2 times more likely to have type II diabetes than Caucasians.[161] Native tribes had to give up these healthy, nutrient-rich foods which are typically high in protein, iron, zinc, Omega 3 fatty acids and other minerals, and lower in saturated fats and sugar.[162] In addition, the exercise associated with gathering these first foods had physical benefits. As many traditional gathering grounds have been lost, the loss of this benefit has surely been another factor impacting the health of tribes as well.

First foods are significant in several ways—culturally, socially, and spiritually. As a result, they are recognized and honored through trading and ceremonies that express gratitude and respect for the nourishment they provide. These foods are honored with ceremony and prayer, following the first foods order—first water, followed by fish, game, roots, and berries. Within this hunting and gathering culture, the well-being of the land and water determine the well-being and prosperity of tribal people and culture.

Tribal Resources

"We to hunt for a purpose, you know for survival, you know my grandparents and that's how they survived."

– Salish-Pend d'Oreille Culture Committee[40]

Tribal members find a spiritual connection with other types of outdoor activities such as camping, hiking, and swimming. Whether defined as recreation or subsistence, these practices all rely on quality recreation lands and waters.

Tribal members have access to reservation and trust lands, as well as public lands for hunting, fishing, and gathering practices. Additionally, some tribes allow for permit-use hunting and fishing from non-tribal members, while others do not allow for non-tribal members to access reservation lands for hunting and fishing purposes. Wildlife properties acquired through BPA mitigation funding are required to provide reasonable access to non-tribal members if the tribes are actively using the land for recreation purposes.[163]

Through interviews with several tribes' department of natural resources, providing quality lands and waters for recreation and cultural purposes is a top priority.[164] In one case, the Cowlitz Indian Tribe has partnered with the USFS to have a special forest products program. This partnership allows tribal members to gather traditionally significant plants and maintain spiritual practices.

Tribal Fishing

"As guardians of our ancestral lands it is our duty to conserve the balance of nature."

– Unknown Kalispel Tribal Member[165]

The harvest of traditional resources is integral to tribal culture in the CRB. In particular, fish are a staple of many tribes' diets, one of the traditional first foods that are honored at tribal ceremonies. They appear in many tribal legends and play a significant role in tribal economies.[166]

Salmon is just as important as their nutritional value and cultural uses. Fishing trips shape many people's appreciation for nature. The Yakama, Umatilla, Warm Springs, and Nez Perce exercise commercial fishing in the Columbia River and are authorized to catch half of the harvestable fish in Zone 6. Tribal fisheries mainly occur in Zone 6 of the Columbia River, a 147-mile stretch of river between Bonneville and McNary dams. These rights were secured through lengthy legal battles between tribes and states regarding interpretation of historical treaties agreements regarding fish catch distribution.[167] Tribes often prioritize ceremonial and subsistence fisheries, only opening up commercial fisheries once the needs of these first two are met.[168]

Tribal commercial fisheries have caught 3 million pounds of salmon on average for the past 5 years, translating to $7 million in ex-vessel value annually. Yet, the value of this fishing activity and the fish itself is far beyond this value. Two species serve as excellent examples of the cultural value that transcends monetary values: burbot and Pacific lamprey. Both these species have been adversely affected by the Columbia River dams, and changes in dam management would be required to ensure their future abundance and survival. In addition to the two-species described in detail below, the Columbia River provides habitat for sturgeon, trout, minnows, suckers, cod, stickleback, and sculpin.[169]

Burbot and Pacific Lamprey

The burbot and Pacific lamprey are of great cultural importance to tribes within the Columbia River Basin. Previously abundant, both of these species have experienced significant population declines in their native habitats due to watershed development and dam operations.[171] However, both species are found in different regions of the Columbia River Basin and have unique challenges to overcome to ensure their continued survival and place within tribal culture.

Burbot

Historically, the abundant burbot runs provided a seasonal staple food source for Native Americans and early European settlers.[170] This great abundance continued throughout the 1960s, and burbot fishing was largely unregulated. However, construction of the Libby Dam in 1972, poses a threat to the burbot via high water discharge rates during spawning and increased water temperature due to summer storage of water above the Libby Dam in the Koocanusa reservoir.[171]

After completion of the dam, the burbot population declined rapidly, leading to a fishing closure in Idaho in 1992. Shortly after this closure, British Columbia closed burbot fisheries on Kootenay Lake and Kootenay River in 1997.[172] By the early 2000s, scientists estimated that the burbot population had declined to about 50 fish, indicating the species was very close to extirpation from the Kootenai River.

This steep decline is linked to summer reservoir storage and power generation practices during the winter. Libby Dam is operated with a focus on power generation and is also a large storage reservoir, leading to high levels of discharge during times of peak demand. However, high discharge events disrupt the burbot's spawning movements (December to February). Altered management practices could alleviate this disruption. Limiting flow from the Libby Dam to under 300 cubic meters per second during spawning season would enable the burbot to move upstream far more easily.[173] However, river flow data indicates that over 36 years, the average flow below the Libby Dam ranged from 254 to 481 cubic meters per second during burbot migration.[174] In addition to the rapid rate of flow, the water flowing through the dam is up to 5°C warmer than historical baselines.[175] Restoration of historical burbot runs would require reduction of winter outflows as well as reduction of river water temperature to under 5°C during spawning season.[176] Management options for reduction of river water temperature include the following: Installation of riparian vegetation for river shading, reduction of summer water storage in the Koocanusa reservoir, and reduction of effluent temperatures from industrial wastewater streams.[177,178]

Pacific Lamprey

The Pacific lamprey is an ancient, culturally important species of fish. Fossil records indicate that Pacific lamprey evolved 450 million years ago, making it the oldest fish species within the Columbia River system.[179] Columbia Basin tribal members describe the lamprey as a spiritually significant, historically abundant, easily caught food source that sustained Columbia Basin tribes for thousands of years.[180] Their historical habitat reached to the headwaters of the Columbia River, providing a widespread, reliable food source for riverine predators. Currently, these fish are only found in the middle and lower Columbia River in drastically reduced numbers relative to their historical abundance within the region. For example, returns of lamprey to the Bonneville Dam reached a low of 23,000 in 2010, as compared with the 400,000 returning in the 1960s.[181]

This decline is due to a variety of complex, challenging threats to lamprey habitat, including low water flow, dam passage, floodplain degradation, low water quality (via elevated temperature, chemicals and sedimentation), predation, and climate change.[182] It appears high—and low—head dams are the largest cause of decline due to inadequate adult passage and evidence that juvenile lampreys suffer serious impingement on turbine screens. Two other causes of lamprey habitat damages are watershed urbanization and agricultural runoff.[183] Given that multiple factors threaten habitat, restoring the Pacific lamprey population requires multiple restoration strategies, which can include channel reconstruction, floodplain reconnection, levee removal, riparian revegetation, dam passage improvements and upstream translocation.[184] Currently, two restoration efforts (Pacific Lamprey Research and Restoration and Pacific Lamprey Passage Design) are receiving about $1.2 million of funding annually.[185]

Chapter Six

Dam Operations and Maintenance Costs

"Before the Coulee Dam went in there were salmon, my elders used to say the salmon were so thick you could walk across the river on their backs."

– Unknown Colville Tribe Member[186]

Lake Rufus Woods, Columbia River, Source: Brian Gruber

The Columbia River reservoir and hydroelectric system generates revenues, but it is also expensive to run and maintain. Some examples of costs include resource intensive turbines (requiring large amounts of copper), navigational lock and spillway maintenance, substantial agriculture water-pumping facilities and non-routine extraordinary maintenance (unplanned and emergency maintenance). With an aging dam fleet,[z] general routine and non-routine extraordinary maintenance costs are rising, leading to an increase in overall capital and operating expenses. Additionally, because of the major adverse impacts to the environment, fish and wildlife mitigation and hydrosystem operational compliance requirements result in additional spending obligations that contribute to both federal and non-federal budgets.

The Columbia River hydro system is composed of many parts, but the largest contributors are part of the Federal Columbia River Power System (FCRPS). The FCRPS is a collaboration between the Bonneville Power Administration, the U.S. Army Corps of Engineers, and the Bureau of Reclamation. Together, these agencies collaboratively manage the dams for purposes such as power, flood control, navigation, water supply, and recreation.

Although there are large financial costs from hydroelectric power production, providing for flood risk management and general dam operations also accrues costs, although much of these are covered by hydropower revenues. Other beneficiaries help cover portions of operations and maintenance costs. For instance, dams that provide flood control are partially paid for by taxpayers as a public service provided by the dam. U.S. taxpayers fund the USACE for annual operations and maintenance costs for dams and dredging for navigation. This section provides a big picture assessment of federal and nonfederal operations and maintenance (O&M) expenditures in the Columbia River hydroelectric power system.

z A fleet refers to the large group of hydropower structures working together to produce power for the system. Bonneville, Grand Coulee and Rock Island dams were constructed nearly 80 years ago. In general, the average life of a dam is estimated to be 100 years.

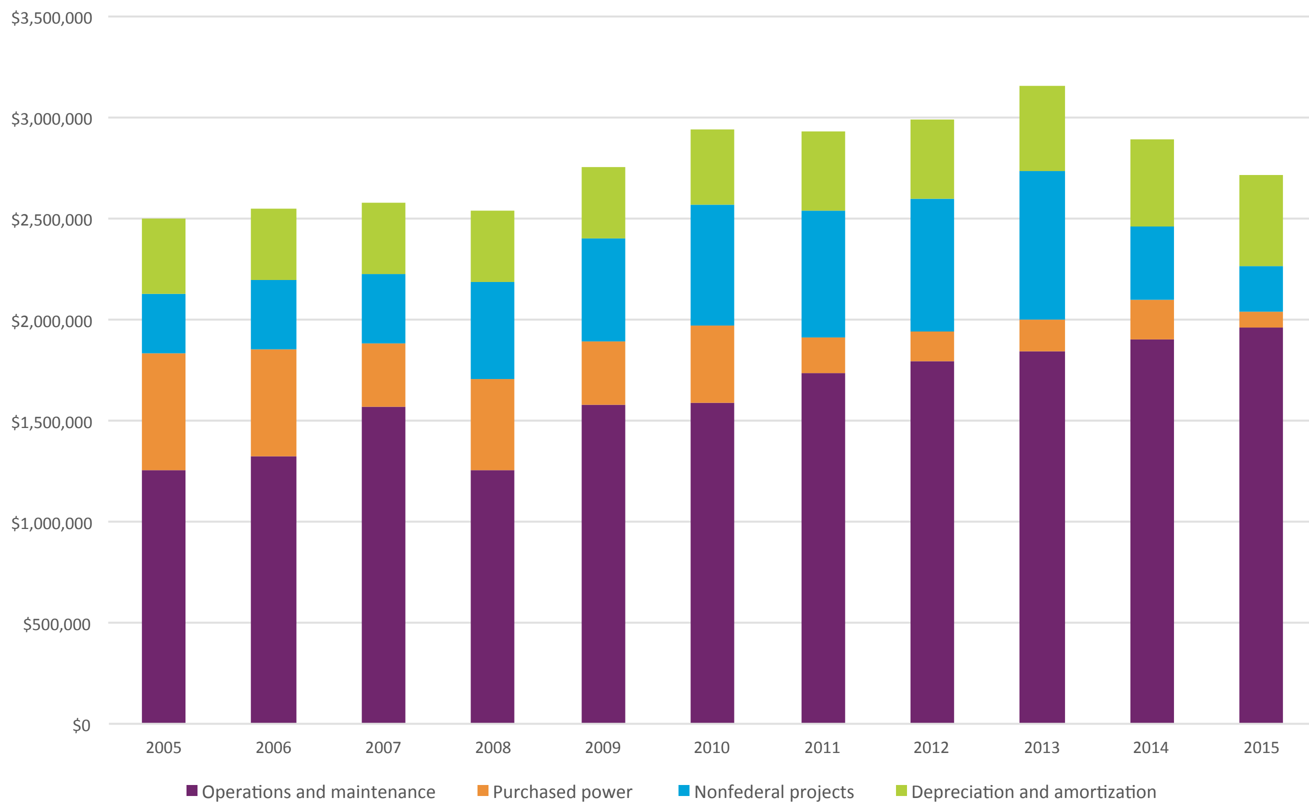


Figure 25. BPA Total Operating Expenses

Bonneville Power Administration

The Bonneville Power Administration (BPA) is responsible for purchasing, transmitting, and marketing power for the Federal Columbia River Power System (FCRPS). With this responsibility, BPA is also responsible for all power related costs of the 31 USBR and USACE owned FCRPS dams which are covered by the revenues collected from power sales.[187] Because the FCRPS dams are multipurpose, fish and wildlife mitigation costs are assigned through a cost allocation process defined in the Northwest Power Act.[188]

In 2015, BPA had total operating revenues of $3.4 billion, and total operating expenses of $2.7 billion.[189] From 2005 to 2015, BPA's total operating expenses remained fairly consistent. During this same period, however, BPA's operations and maintenance expenses have increased 56 percent from $1.26 billion in 2005 to $1.96 billion in 2015. These increases are due to the non-routine extraordinary maintenance and additional spending required to meet regulatory and biological opinion (BiOp) requirements.[aa] With these regulatory and BiOp requirements, a significant portion of BPA's overall operating for budget for power services is from mitigation efforts to offset dam and river management impacts to fish and wildlife.

Bonneville Power Administrations' Fish and Wildlife Program

The FCRPS dams are multipurpose structures, providing hydroelectric power, flood control, navigation, water supply, and recreation benefits. Under the Northwest Power Act, BPA is obligated to protect, mitigate, and enhance the dam impacts on fish and wildlife. BPA is only responsible for the 31 FCRPS dams' hydropower related costs, which account for approximately 78 percent of expenses and are paid for by ratepayers. Non-power purposes (navigation, flood control, etc.) make up for the remainder of the costs and are paid for by federal agencies, which are in turn paid for by taxpayers.

Since 1978, BPA has recorded a total of $15.3 billion in fish and wildlife costs.[190] These costs have increased in the past years as dams have been heavily scrutinized for the impacts they have on the natural environment and federal laws and regulations including the Northwest Power Act, the Endangered Species

aa Bull trout, sturgeon, eulachon, and 13 species of Columbia River Basin salmon and steelhead are listed for protection under the Endangered Species Act. Biological Opinions provide science based guidance to protect and rebuild fish and wildlife populations that are impacted by dam operations within the Basin.

Act and the Clean Water Act. Between 1986 and 1995, BPA's Fish and Wildlife costs averaged $188 million, from 1996 to 2005 costs averaged $561 million, and from 2006 to 2015 BPA's Fish and Wildlife costs averaged $750 million.

In 2015, BPA noted that fish and wildlife costs accounted for approximately 33.3 percent of its' overall operating budget for power services. This estimate includes what are termed foregone power revenue and power purchases. Foregone revenue and power purchases are BPA's way of recording the economic losses incurred from dam operations that reduce hydropower generation but greatly benefit fish passage, such as the dam spill. Though extremely beneficial for fish populations that have been severely degraded, the tribes believe that recording foregone revenue and power purchases as a fish and wildlife expenditures, are a cost of doing business and this cost misrepresents the size of the fish and wildlife mitigation program. Between 1978 and 2015, BPA has attributed a total of $7.7 billion to foregone power costs and power purchases, half of the total recorded expenditures of the fish and wildlife program. Losses to EbF caused by power production and other non-natural uses of the CRB are a cost to EbF. The value, revenue and benefits, of a natural CRB are diminished by these uses.

The Federal Columbia River Power Systems' Aging Fleet

As of 2015, the average age of the 31 FCRPS dams was 55 years. With an aging fleet, non-routine maintenance and large capital improvement costs are increasing. These expenses are required to meet increasing demand and maintain a high level of reliability.

In the past five years, the fleets' hydroAMP ratings (reliability scores for infrastructure; 1 being poor, 10 being good) have declined significantly from 7.8 to 7.3, and about 25 percent of equipment has exceeded its designed life.[191] The decreases in the average hydroAMP rating point toward underinvestment in capital improvement projects, which increases the likelihood of non-routine extraordinary maintenance and unit failure. In 2016, 17 percent of all BPA's operating and maintenance expenditures came from non-routine extraordinary maintenance.

Natural capital works in a similar way and the Columbia River Basin is a degraded system; without investment natural capital, we will continue to see mitigation expenditures increase.

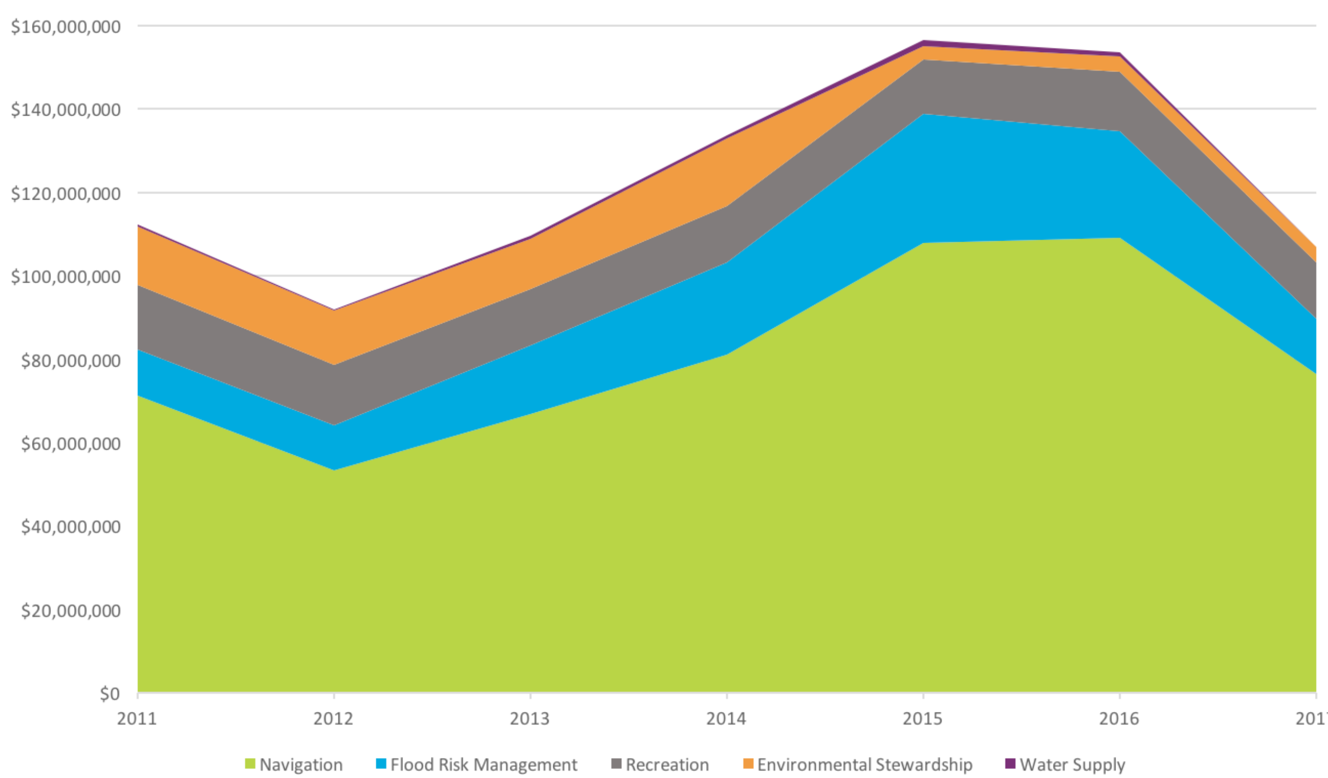


Figure 26. USACE Columbia Basin Operations and Maintenance Costs

Fishing platform across from The Dalles Dam, Source: CRITFC

The Basin needs serious investment to continue providing economic goods and services and as was illustrated in Chapter 4, investment in natural capital makes economic sense.

United States Army Corps of Engineers

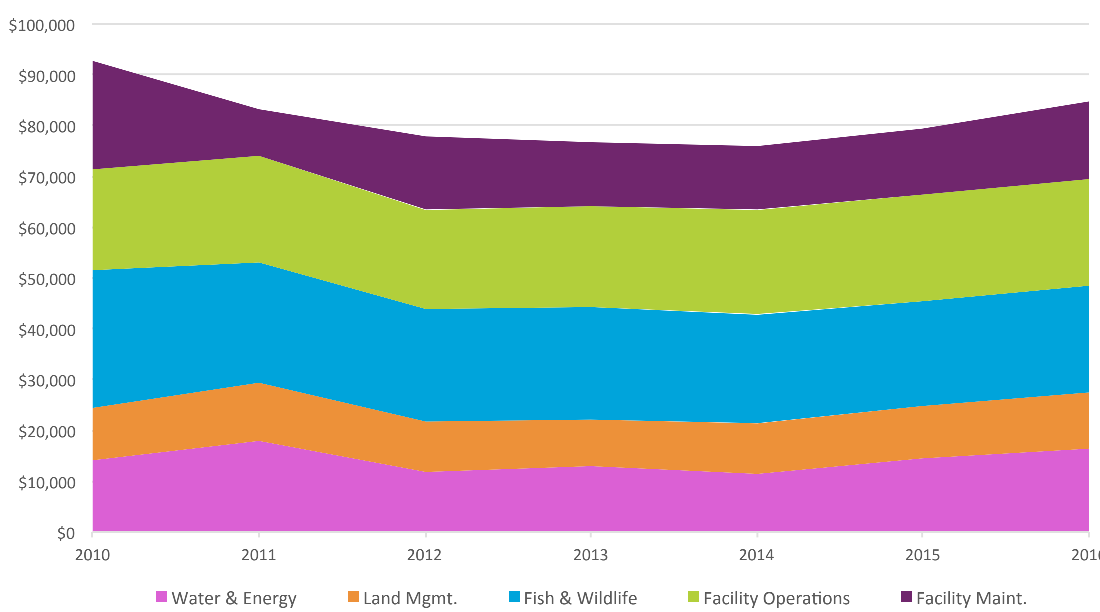
The United States Army Corps of Engineers owns 21 dams in the Columbia River Basin, fourteen of which have the authorized purpose of navigation. Mainstem Columbia and Snake River dams provide navigational channels for the transport of goods as far inland as Lewiston. As multipurpose dams, these projects also provide other benefits such as flood risk management, irrigation, hydroelectric power generation, water supply, and recreation.

A large portion of the costs incurred by USACE are from navigation activities. Between 2011 and 2017, the average budget for operations and maintenance of the locks for navigational purposes was $80 million per year, paid by U.S. taxpayers. U.S. taxpayers, also fund USACE annual operations and maintenance costs, amounting to tens of millions per year and other dam and associated infrastructure projects authorized by the Water Resource Development Act. As was discussed in the Navigation section, barges using the inland waterway do not pay do not pay the full cost of benefits received from using the inland waterway. Unlike hydropower, navigation expenses are directly funded by the federal government and not paid for through power sales. Although the dams do produce hydroelectric power, BPA covers any costs associated with the production of power, but not otherdam expenditures such as spillway maintenance, navigation locks, or fish passage facilities.

United States Bureau of Reclamation

The United States Bureau of Reclamation (USBR) operates and maintains nearly 40 dams in the Columbia River Basin, 10 of which are part of the FCRPS. Most significantly, the USBR operates and maintains Grand Coulee Dam, the largest power producer in the Columbia River Basin and one of the largest in the world. USBR dams provide hydroelectric power, flood control, navigation, irrigation, municipal and industrial water supply, and recreation.

Figure 27. Bureau of Reclamation Columbia Basin Operations and Maintenance Costs



The USBR spends approximately $70 million per year on operations and maintenance. The largest expenditures arise in the Fish and Wildlife department, misrepresented as explained above. Each year, the USBR spends $20 to $30 million to mitigate impacts to fish and wildlife.

Current BiOps will continue to require significant funding and are expected to continue for decades. BiOps require the Bureau to offset, or at a minimum reduce, adverse impacts to fish and wildlife. These actions include facility modifications, operational changes, and habitat rehabilitation. Some of these mitigation actions include hydrosystem improvements, hatchery improvements, avian predation reduction, and habitat improvement. These costs are co-funded by BPA through a cost-allocation process.

The Bureau's aging hydro infrastructure is also of concern, as unexpected maintenance costs will take up a larger part of the ledger in the coming years. Although the power portion of O&M costs are funded by BPA, cost allocations for other authorized purposes will see increases as well.

A breakdown of O&M costs can be seen in Figure 28, which have remained fairly consistent year over year.

Fishing platform across from The Dalles Dam, Source: CRITFC

BC Hydro Fish and Wildlife Compensation Program

BC Hydro's facilities in the Canadian portion of the Columbia River Basin include four major hydroelectric dams, two water storage dams that don't generate power and 7 smaller hydroelectric dams. The Columbia Region of BC Hydro has a total capacity of 5,946.4 MW, which is about half of BC Hydro's total capacity. BC Hydro operates both in and out of the Columbia River Basin. For the fiscal year ending March 31, 2015, total operating expenses both in and out of Basin were $4.5 billion.

To compensate for the impacts that dams have on their surrounding environment, BC Hydro established the Fish and Wildlife Compensation Program (FWCP). The Columbia Region FWCP's goal is to conserve and enhance fish and wildlife in the Columbia region of British Columbia. The Program operates as a partnership between BC Hydro, the Province of B.C., Fisheries and Oceans Canada (DFO), First Nations, and local communities, organizations and groups.

Approximately $5 million is spent annually on Fish and Wildlife compensation that primarily goes towards fish and wildlife enhancement projects. Administration and communications costs make up about 6 percent and 3 percent of the total operating budget, respectively.

Non-Federal Agencies

Of the more than 150 hydroelectric projects in the Columbia River Basin, only 31 are managed under the FCRPS. Whether owned by federal or non-federal agencies, these projects have high operating costs associated with them. Non-federal projects include Idaho Power's Hells Canyon Complex, Grant County PUD's Priest and Wanapum Dams, various irrigation districts, and many others.

Table 29. Annual Fund Category Spending Years 2013 to 2015

FUND CATEGORY	2013	2014	2015
Administration	$331,550	$301,909	$247,256
Wildlife	$1,949,370	$2,260,377	$2,372,244
Communications	$114,645	$140,360	$130,120
Fish	$2,430,090	$2,390,162	$2,513,195
TOTAL	**$4,825,655**	**$5,192,808**	**$5,262,815**

Grand Coulee Dam, Source: Keith Kutchins

Just as with federal agencies, these operators are required to comply with federal, state, regional, and local compliance standards and laws. Individually, these costs seem small in comparison to the large federal projects, but cumulatively they add up to a significant amount. Several examples of non-federal O&M costs are provided below. This list can help give context to the scale of large costs associated with operating projects within the basin.

- From 2013 to 2014, Douglas County saw total operating expenses increase from 1.4 million to $30.3 million. The majority of these expenses were a result of meeting FERC fish and wildlife mitigation measures associated with the Wells dam.
- At Idaho Powers' 17 hydroelectric facilities, Idacorp (Idaho Power) incurred $22 million of environmental expenditures and another $16 million in capital expenditures. These expenditures are associated with license compliance and relicensing efforts at hydroelectric facilities.
- Pend Oreille PUD' largest source of power comes from the Box Canyon Project. Due to debt service associated with a turbine upgrade project, the cost of producing power from this project has increased significantly over the last decade.
- Avista's 2016 capital budget of $392 million includes $22 million in environmental related costs. 40 percent of the power Avista transmits to end users is from hydro.

Continuing to Fund the Columbia River Basin Power System

With aging dams and stricter environmental considerations, hydrosystem costs are expected to rise in the Columbia River Basin in the coming years. The Northwest enjoys some of the least expensive electricity due to the extensive hydro driven generating resources supported by the natural capital within the Columbia River Basin. Investing in this natural capital makes sense from a financial, social, and environmental sense.

Although currently one-third of BPA's power budget is spent on fish and wildlife mitigation (or 22 percent when not including foregone revenue), the Columbia River Basin is still in need of major natural capital investments to restore ecosystem function and sustain natural capital. A consideration to incorporate a natural capital surcharge onto utility bills purchasing power produced within the Columbia River Basin could be consider to realize these investments. Though this analysis does not assess the economic ramifications of increased utility bills from a natural capital surcharge (e.g. the possibility of companies relocating), a case can be made that without the natural capital of the Columbia Basin the region wouldn't have inexpensive power. Investing in our natural capital assets can ensure that we manage these resources sustainably to continue to provide the same level of service well into the future.

The cost and value estimates in this chapter are quite conservative and only provide an incomplete, recent past and present snapshot. Because of the aging dam system, many new and expensive structural and operational improvements are in urgent need of implementation and completion. These include but are not limited to new turbines and generators, dam tailrace improvements and maintenance from erosion, and new spillways (i.e. Grand Coulee Dam). This assessment did not consider these expensive needs nor how they would be financed.

Chapter Seven

Conclusion

"The Earth is part of my body... I belong to the land out of which I came...The earth is my mother..."

– Too-Hool-Hool-Zute, Historical Nez Perce Leader[192]

Columbia Gorge, Source: CRITFC

The Columbia River Basin, with its close ties to tribal culture and its rich environmental resources, is a natural capital asset not only worth preserving, but also enhancing. Sustainable natural capital and ecosystem-based functions and services have been severely degraded in a relatively short period by the non-tribal development and operation of built capital, such as dams and associated infrastructure. Consideration of ecosystem-based functions and services from an economic perspective reveals previously unrecognized aspects of the CRB's value that should be incorporated in decision making and planning for a modernized river management regime under a renewed Columbia River Treaty. In this section, we summarize the report findings and recommend areas for further research. Finally, we identify a number of viable funding mechanisms that could be used to secure the benefits of modernized river management under an updated treaty.

Findings

The CRB is immensely beneficial to communities, and its benefits would only increase under a modernized treaty scenario. However, threats to the basin's ecological balance, including climate change and population growth, endanger these sustainable, nature-based benefits and compromise the livelihoods and quality of life of its residents. Given these severe challenges, enhancing and even maintaining the numerous benefits provided by this natural system demands changes in river management.

This report forecasts the value[ab] that would result from modifications to the current management regime. Resources were identified and valued under two scenarios, RCC-80 and 3Ea. The results clearly indicate that scenario 3Ea, which enhances and integrates ecosystem function into

ab Values are rounded to the nearest million, more exact estimates can be found in Table 27.

river operations, would significantly increase the value of natural capital throughout the basin. The 3Ea scenario would augment non-tribal commercial fisheries, increasing their value by almost $7 million annually due to increased fish populations, particularly in the Upper Basin. Recreation, particularly angling, would also increase by about $46 million per year with higher fish populations. This difference would be especially notable during low-water years.

Because the proposed 3Ea scenario would improve the overall health of the CRB, there are additional areas of benefit. The CRB's ecosystem services value would increase by $389 million annually under the 3Ea scenario. A valuation of higher reservoir water levels accounts for this increase. Extending the reach of fish along the river would also improve the release of nitrogen and phosphorus from salmon carcasses in upstream areas. Increased nutrient levels would then benefit riparian areas throughout the system, adding about $31 million in yearly benefits.

Lastly, the existence value of additional fish in the river would contribute approximately $1 billion. Under 3Ea, improved river operations would increase salmon and steelhead abundance by at least 6.7 percent for spring chinook and 126 percent for steelhead. Reintroduction to areas currently blocked by Chief Joseph and Grand Coulee Dams has the potential to further increase salmon runs by 400 to 800 thousand salmon and steelhead. The modernized scenario will substantially contribute to delisting and recovery of ESA-listed salmon, steelhead, sturgeon, and other imperiled species such as lamprey and bull trout. Thus, the total economic gain assessed under 3Ea would reach about $1.5 billion annually.

Umatilla Board of Trustees Member N. Kathryn "Kat" Brigham, ca. 1970s. Kat was one of the founding Commissioners of CRITFC back in 1977., Source: CRITFC

The valuation of ecosystem services in this report is very conservative. For example, other than two stocks of salmon and steelhead, no additional value was placed on anadromous fish stocks that would benefit from increased spring and early summer flows, nor was any value benefit assessed on resident fish in reservoirs from more stable 3Ea operations. If quantified, these benefits could be substantial. For example, assuming a ten percent increase in EbF[ac] under 3Ea would add roughly an additional$19 billion in annual benefits.

The Columbia River Treaty is one of the most important regional international agreements. The inclusion of EbF and ecosystem services into the Treaty is essential to sustain the CRB's benefits. Substantial effort will need to be applied to create a healthy, sustainable, and functioning CRB. The ecosystem (3Ea) scenario illustrates positive potential changes in river management that can result in positive outcomes for the basin's ecological systems and provide sustainable economic prosperity throughout the region and future generations.

Further Research Needed

Though this report demonstrates clear value in the region, further analysis could greatly complement these results. In this section, we present select areas for further study that would address key areas of interest for tribes and other regional stakeholders. The funding mechanisms section that follows is intended to highlight viable funding opportunities for the CRB.

Enhanced Analyses

ECONOMIC CONTRIBUTION OF PORTS: Transportation of goods along the Columbia River is of vital economic importance for agricultural exporters and any business which

ac 10 percent is an arbitrary percentage and not based on any referenceable citation. This is simply an example of how benefits could increase if widespread ecosystem improvements were to occur under 3Ea.

relies heavily on large-scale container shipments. If ports close down or decrease their activity, the regional economy would suffer, with industries reliant upon agriculture or shipping experiencing the most significant economic consequences. Describing these economic relationships would require a full-fledged economic impact study of the impacts of increased shipping costs on regional economies.

ADDITIONAL SALMON FISHERY ANALYSIS: A more detailed salmon fishery analysis would require input from an ecological modeling team with the ability to model environmental changes and policy options over time. Ecopath with Ecosim is one such model that can facilitate this type of analysis. Additional fish survival and productivity analyses could be conducted using regional state-of-the-art models such as NOAA's COMPASS model and the CRB fishery agencies and tribes' Comparative Survival Study model should also be pursued.

Prior analyses conducted by EE (which were informed by teams of ecological modelers) have coupled biophysical fish modeling with economic models to elicit region-wide economic impact analyses of the economic benefits associated with fisheries. Expanding the scope to include recreational fisheries would require collection of fishing visitation and recreational expenditure data.

Fishers checking their nets on the Columbia River, Source: CRITFC

BUILT CAPITAL REPLACEMENT COSTS: A more detailed analysis of built capital replacement costs would require in-depth, comparative research into engineering-level documentation of capital costs. These kinds of documents are time-consuming to use, but they may offer a more precise estimate of the replacement intervals required to keep dams in operation. In addition, the analysis of future costs should be informed by the projected needs of Columbia River Basin residents. Given market and capacity diversification and changes in regional energy demands, including those driven by climate change (i.e. winter demand shifting to summer demand)[193], electricity generation needs change significantly. The level of investment in hydropower should reflect the direction (up or down) of the change in demand.

IRRIGATION WATER ANALYSIS: Water for irrigation is essential to the CRB's agricultural economy. Climate change and the treaty modernization may affect agricultural practices across the basin as the availability and timing of water supply changes. Water availability for both instream and agricultural use could increase under some climate change and treaty modernization scenarios. Increased instream flows may provide mutual benefits for farmers if more water comes over the border or if modernized operations provide more instream flows at certain times of year, as under 3Ea. Increased water conservation and efficiency could also affect agricultural water use and the water supply available for instream use in the basin.

FUTURE FLOOD RISK ESTIMATION: Future flood risk projections will have to incorporate the hydrological changes (reduced snowpack, increased winter rainfall, and extremely low summer flows) associated with climate change. Hydrographic changes may increase winter flood risk depending on the distribution of snow and rain in the winter season. Extensive research on potential floodplain restoration projects, in concert with information created by the CRITFC and UCUT should be pursued along with the economic valuation assessed. An interdisciplinary team of hydrologists, climate scientists, and ecological economists would be required to rigorously assess future flood risks and mitigation options.

RIPARIAN VEGETATION ANALYSIS: The quality and quantity of riparian vegetation can affect riverine water quality. Excess sediment or nutrient concentrations, for example, can degrade water quality. Increasing the width of riparian buffers reduces the amount of sediment and nutrients that may pass into a river. The social cost of additional pollutant input can be used to find the avoided social costs due to the presence of riparian buffers. Earth Economics has performed this type of analysis for water utilities in the past. It is an intense process both in terms of data and computational requirements.

CLIMATE CHANGE ANALYSIS: The best available scientific information from global circulation models shows a warming climate will substantially alter the Columbia River Basin's hydrology and increase air and stream temperatures. By the end of this century, snow-rain transient areas over most of the U.S. portion of the basin will likely become rain-dominated areas. In Canada, much of the snow-dominated area will remain, although glaciers will likely be seriously compromised.

Climate and hydrological model projections indicate that total precipitation volume will not change, but will be more concentrated in the winter period, which could increase flooding events. The reduction of snowpack and summer precipitation will likely increase the frequency and magnitude of summer low flows and drought conditions. Warming conditions will likely increase both winter and summer air and water temperatures and increase drought frequency throughout the Columbia Basin.

Warmer winters and warmer, drier summers will stress native aquatic species in direct and indirect ways, such as increased fish mortality and competition with invasive species that are expected to thrive in warmer conditions. Climatic conditions will also change power loads with shifts from winter to summer load demands and flood risk management operations for upstream storage reservoirs.

Adaptive measures and planning for EbF should be rigorously pursued. Such measures could include restoring natural or normative hydrograph volumes, timing and shaping via modifications of basin reservoir storage capacity, implementing structural measures at the dams to provide selective release of cool water to downstream rivers, increasing fish passage success at existing dams via dam spill and other measures, restoring fish passage to cooler areas in the basin, and rehabilitating floodplain habitats to provide thermal refuge for migrating fish populations.

Updated climate change assessments that will likely affect temperature and hydrology by the 2040's and certainly by the 2080's are under development through the U.S. River Management Joint Operating Committee. Integrating these model projections with ecosystem, power, and flood risk scenarios will provide information for further economic assessments.

Viable Future Funding Mechanisms

Any flood protection gained from Columbia River dams is predicated upon water being stored behind the dams and flooding previously usable and habitable land. Upstream residents suffer flooding losses and should be compensated.

Rock Creek mouth, Source: CRITFC

Tribal members, in particular the Spokane tribe, have lost portions of their land over time. Considering both the high value of flood prevention and the negative impacts on tribes, it is reasonable to fund riparian and riverine restoration efforts through taxation of downstream beneficiaries of flood risk protection. In particular, taxation of those that gain the most (floodplain residents) would be most appropriate.

Another option for funding riparian restoration would be through navigation fees. Shipping and navigation interests gain financially from continued dredging of the river. Given that dredging and ship passage both cause ecological degradation, it would also be reasonable to apply a riparian restoration fee to ships using locks and navigation features.

Columbia River power generation is financially valuable to the BPA and all of its customers. However, the dams that provide this power also have negative impacts on riverine habitat and fish stock survival. Given the existence of these social costs, it is within reason to apply a river restoration fee on top of energy prices so that funding for restoration can be provided directly by those that gain from dam-based water management. According to the U.S. Department of Energy, all major hydropower-producing dams on the main stem of the Columbia River (dams of interest) create approximately $19 million in revenue per day, or nearly $7 billion each year.[194] A tax could be an important source of additional annual funding for restoration endeavors.

The value of natural capital in the Columbia River Basin is truly extraordinary, and as this report demonstrates, this value can be further elevated with an updated management regime that accounts for EbF. Dated management practices, degraded built infrastructure, climate change, and other threats jeopardize the amount of benefits currently produced. Yet, under a modernized management scenario such as 3Ea, EbF could be included in decision making to sustain and augment this region's value. As seen in chapter 4, 3Ea would increase the value of benefits produced by almost $1 billion in yearly benefits, and that added value merits consideration. Not only does a modernized scenario augment the total value of the CRB, it also supports ecosystems to be more ecologically and economically productive.

Appendix A

Glossary

3Ea80: Modernized Columbia River Treaty scenario, official 80-year modified flow.

Average Megawatt (aMw): the electricity produced by continually generating one megawatt for one year (8,760 megawatt hours).

Base Load Requirement: The minimum level of electricity demand over 24 hours.

Benefit Transfer: Economic valuation approach in which estimates obtained in one context are used to estimate values in a different context. This approach is widely used because of its ease and low cost, but is risky because values are context-specific and must be used carefully.

Biodiversity: The variability among living organisms from all sources including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within and among species and diversity within and among ecosystems. Biodiversity itself is not an ecosystem service, but provides the major foundation for all ecosystem services.

Bonneville Power Administration: The Federal power marketing agency under the Department of Energy responsible for marketing wholesale electric power from 30 Federal dams and one non-Federal nuclear plant throughout Washington, Oregon, Idaho, and western Montana and portions of California, Nevada, Utah, and Wyoming. BPA also sells and exchanges power with utilities in Canada and California.

Built Capital: Refers to the productive infrastructure of technologies, machines, tools, and transport that humans design, build, and use for productive purposes. Coupled with our learned skills and capabilities, our built techno-infrastructure is what directly allows raw materials to be turned into intermediate products and eventually finished products.

Capital Value/Asset Value (of an ecosystem): The present value of the stream of future benefits that an ecosystem will generate under a particular management regime. Present values are typically obtained by discounting future benefits and costs; the appropriate rates of discount are often set arbitrarily.

Cultural Services: Ecosystem services that provide humans with meaningful interaction with nature. These services include the role of natural beauty in attracting humans to live, work and recreate, and the value of nature for science and education.

Discount Rate: The rate at which people value consumption or income now, compared with consumption or income later. This may be due to uncertainty, productivity, or pure time preference for the present. "Intertemporal discounting" is the process of systematically weighing future costs and benefits as less valuable than present ones.

Drafting: Lowering the reservoir elevation for several different purposes such as dam repairs, flood control, increase flows downstream for improving conditions for fish migration, lowering river temperatures, irrigations, as well as industrial and municipal water supplies. Outflow is greater than inflow at the time but the water will eventually be replaced.

Ecosystem-based Function: Concept from Columbia River Basin Tribes, used to explain the innate value of nature, regardless of any human use for these benefits.

Ecosystem Services: Benefits people derive from nature, free of charge.

Elasticity of marginal utility: The change in utility, or consumer satisfaction, gained or lost by people from consumption.

Externalities: A side effect or consequence of an industrial or commercial activity that affects other parties without this being reflected in the cost of the goods or services involved.

Forebay: Artificial pool of water in front of a larger body of water.

Gigawatt Hour (GWh): A unit of energy representing one billion watt hours.

Natural Capital: Refers to the earth's stock of organic and inorganic materials and energies, both renewable and nonrenewable, as well as the planetary inventory of living biological systems (ecosystems) that when taken as one whole system provides the total biophysical context for the human economy. Nature provides the inputs of natural resources, energy, and ecosystem function to human economic processes of production. Nature by itself produces many things that are useful and necessary to human well-being.

Net Present Value: Net Present value is the amount that, at some discount rate, will produce the future benefits less costs after a defined length of time.

Operations and Maintenance Services: Operation and maintenance on gray infrastructure, usually undertaken by utilities or USACE.

Operations and Maintenance, Repair: Same as above, including repair, usually undertaken by utilities or USACE.

Participant Day: A singular visit to a recreational land or a one-time engagement by one individual in a recreational activity.

RCC-80: Reservoir Current Conditions-80 years models dam management using 80 years of historic hydrologic data from 1929 to 2008.

Pre-contact time: Pre-European contact in the Columbia River Basin.

River Basin: The area of land that is drained by a river and its tributaries. This includes all streams and creeks that flow downhill into the river.

Spill: Sending water over a spillway rather than through the turbines to generate power.

Spring Freshet: Increased natural stream flow due to the thawing of snow and ice melt. The spring freshet can help migrating smelt travel downstream.

Stakeholder: An actor having a stake or interest in a physical resource, ecosystem service, institution, or social system, or someone who is or may be affected by a public policy.

Sustainability: A characteristic or state whereby the needs of the present and local population can be met without compromising the ability of future generations or populations in other locations to meet their needs.

Value: The contribution of an action or object to user-specified goals, objectives, or conditions. Value can be measured in a number of ways (see Valuation).

Valuation: The process of expressing a value for a particular good or service in a certain context (e.g., of decision-making), usually in terms of something that can be counted, often money, but also through methods and measures from other disciplines (sociology, ecology, and so on).

Watershed: The area of land where all of the water that is under it or drains off of it goes into the same place. A good example of a watershed is a river valley that drains into the ocean.

Water Resource Council: Establishes guidelines used by USACE for economic and social analysis.

Appendix B

Commercial Fisheries Valuation Data

Washington state data were used for landings in Puget Sound, coastal Washington, and within the Columbia River. Oregon data was used for coastal Oregon landings only. The other data areas were only used in those areas. All prices are inflated to 2015 USD using consumer price indices.

Columbia River

Table 30. Landings and Ex-Vessel Value in the Columbia River Basin

	YEAR	CHINOOK	CHUM	COHO	PINK	SHAD	SOCKEYE
LANDINGS	2015	1,823,756	-	218,974	12	2,440	1,565
	2014	2,185,707	-	1,942,281	8	15,369	991
	2013	1,844,726	-	385,714	67	12,598	590
	2012	1,196,081	465	130,423	-	2,210	1,687
	2011	1,563,052	1,063	596,233	363	24,112	359
EX-VESSEL VALUE	2015	$4,598,588	$-	$349,936	$19	$3,899	$2,501
	2014	$5,511,245	$-	$3,103,899	$13	$24,561	$1,584
	2013	$4,651,464	$-	$616,398	$107	$20,132	$943
	2012	$3,015,910	$393	$208,425	$-	$3,532	$2,696
	2011	$3,941,225	$899	$952,821	$580	$38,533	$574

Source: Oregon Department of Fish and Wildlife[195]

Washington State

Table 31. Dollar Per Pound Ex-vessel Values for Salmon Species in Washington State

YEAR	SALMON, CHINOOK	SALMON, CHUM	SALMON, COHO	SALMON, PINK	SALMON, SOCKEYE
2011	2.60	1.24	1.72	0.51	1.85
2012	2.71	0.74	1.87	0.53	1.91
2013	2.71	0.62	1.90	0.41	1.45
2014	2.29	0.81	1.25	1.23	1.50
2015	2.61	0.58	1.54	0.24	1.62

Source: National Marine Fisheries Service[196]

Table 32. Washington Salmon Landings and Ex-Vessel Value Outside the Columbia River Basin

	YEAR	CHINOOK	COHO
LANDINGS	2015	767,191	22,172
	2014	536,866	118,942
	2013	556,048	46,637
	2012	556,048	25,229
	2011	373,131	23,569
EX-VESSEL VALUE	2015	$2,002,369	$34,145
	2014	$1,230,654	$148,826
	2013	$1,504,668	$88,719
	2012	$1,509,192	$47,125
	2011	$971,162	$40,482

Source: Pacific Fishery Management Council (2017)[197]

Oregon State

Table 33. Dollar Per Pound Ex-vessel Values for Salmon Species in Oregon

YEAR	SALMON, CHINOOK	SALMON, COHO
2011	3.29	1.74
2012	3.87	1.68
2013	3.76	1.86
2014	3.80	1.19
2015	3.94	1.53

Source: National Marine Fisheries Service[198]

Table 34. Coastal Oregon Landings and Ex-Vessel Value

	YEAR	CHINOOK	COHO
LANDINGS	2011	479,803	3,862
	2012	749,345	4,354
	2013	1,499,269	3,014
	2014	2,999,535	78,379
	2015	1,396,351	12,791
EX-VESSEL VALUE	2011	$1,577,435	$6,715
	2012	$2,899,942	$7,324
	2013	$5,643,230	$5,611
	2014	$11,409,643	$93,364
	2015	$5,501,623	$19,570

Source: Oregon Department of Fish and Wildlife[198]

Southeast Alaska

Table 35. Dollar Per Pound Ex-vessel Values for Salmon Species in Southeast Alaska

YEAR	CHINOOK	COHO
2015	3.81	0.78
2014	4.27	1.35
2013	6.82	1.19
2012	4.56	1.52
2011	4.19	1.34

Source: Alaska Department of Fish and Game[200]

Table 36. Total Landings and Ex-Vessel Value of Chinook Catch in Southeast Alaska

YEAR	LANDINGS	EX-VESSEL VALUE
2011	4,612,000	$19,344,573
2012	3,629,000	$16,542,828
2013	2,601,000	$17,724,313
2014	5,092,000	$21,765,766
2015	3,085,000	$11,751,000

Source: Alaska Department of Fish and Game[201]

British Columbia

Table 37. Total Landings and Ex-Vessel Value of Chinook Catch in British Columbia

YEAR	LANDINGS	EX-VESSEL VALUE
2013	2,425,082	$9,113,247
2014	5,291,088	$18,342,418
2015	3,306,930	$17,496,986

Source: B.C. Seafood Industry Year in Review (2015)[202]

Appendix C

Recreational Parks Used in this Study

BC Parks

Akamina- Kishinena Park, Allison Lake Park, Arrow Lakes Park, Blanket Creek Park, Boundary Creek Park, Bromley Rock Park, Bugaboo Park, Cascade Recreation Area, Cathedral Park, Champion Lakes Park, Christie Memorial Park, Christina Lake Park, Cody Caves Park, Conkle Lake Park, Drewry Point Park, Dry Gulch Park, Elk Lakes Park, Ellison Park, Fintry Park, Gladstone Park, Grohman Narrows Park, Height Of The Rockies Park, Inkaneep Park, James Chabot Park, Jewel Lake Park, Jimsmith Lake Park, Johnstone Creek Park, Kalamalka Lake Park, Kekuli Bay Park, Kettle River Recreation Area, Kickininee Park, Kikomun Creek Park, Kokanee Creek Park, Kokanee Glacier Park, Kootenay Lake Park, Lockhart Beach Park, Martha Creek Park, Mcdonald Creek Park, Mount Assiniboine Park, Mount Fernie Park, Moyie Lake Park, Myra-Bellevue Park, Nancy Greene Park, Norbury Lake Park, Okanagan Lake Park, Okanagan Mountain Park, Otter Lake Park, Pilot Bay Park, Premier Lake Park, Purcell Wilderness Conservancy Park (East), Purcell Wilderness Conservancy Park (West), Rosebery Park, Ryan Park, Skaha Bluffs Park, St. Mary'S Alpine Park, Stagleap Park, Stemwinder Park, Summit Lake Park, Sun-Oka Beach Park, Swì“Iwì“S (Formerly Haynes Pt), Sxìœê·É™Xìœ Ê·Nitkê· (Formerly Okanagan Falls), Syringa Park, Top Of The World Park, Valhalla Park, Vaseux Lake Park, Wasa Lake Park, Whiteswan Lake Park, Yahk Park.

Bureau of Land Management

Boundary Dam, Coffeepot Lake, Crab Creek, Fishtrap Lake, Govan, Hog Canyon Lake, Juniper Dunes Recreation Area, Juniper Dunes Wilderness, Odessa Craters, Pacific Lake, Rock Creek, Rocky Ford, Telford, Twin Lakes.

Idaho State Parks & Recreation

Bruneau Dunes, Castle Rocks, City Of Rocks, Coeur D' Alene Parkway, Dworshak, Eagle Island, Farragut, Harriman - Railroad Ranch, Hells Gate, Henrys Lake, Heyburn, Lake Cascade, Land Of The Yankee Fork, Lucky Peak - Discovery Park Unit, Lucky Peak - Sandy Point Unit, Lucky Peak - Spring Shores Unit, Massacre Rocks, Mesa Falls, Old Mission, Ponderosa, Priest Lake - Dickensheet Unit, Priest Lake - Indian Creek Unit, Priest Lake - Lionhead Unit, Round Lake, Thousand Springs - Billingley Creek Unit, Thousand Springs - Box Canyon Unit, Thousand Springs - Malad Gorge Unity, Thousand Springs - Niagara Springs Unit, Thousand Springs - Ritter Island Unit, Three Island Crossing, Trail Of The Coeur D'Alenes, Walcott, Winchester Lake.

Montana State Parks

Anaconda Smoke Stack, Beavertail Hill, Council Grove, Fish Creek, Flathead Lake, Flathead Lake - Big Arm, Flathead Lake - Finley Point, Flathead Lake - North Shore, Flathead Lake - Wayfarers, Flathead Lake - West Shore, Flathead Lake - Wild Horse Island, Flathead Lake - Yellow Bay, Fort Owen, Frenchtown Pond, Lake Mary Ronan, Lewis & Clark Caverns, Lone Pine, Lost Creek, Painted Rocks, Pictograph Cave, Placid Lake, Salmon Lake, Tcl/Logan - Logan, Tcl/Logan- Thompson Chain Of Lakes, Thompson Falls, Travelers' Rest, Whitefish Lake/Les Mason, Whitefish Lake/Les Mason - Les Mason, Whitefish Lake/Les Mason -Whitefish Lake.

National Park Service

Glacier, Grand Teton, Lake Chelan, Lake Roosevelt, Nez Perce National Historic Park, Yellowstone.

Oregon Parks and Recreation Department

Alderwood State Wayside, Bald Peak State Scenic Viewpoint, Banks-Vernonia State Trail, Bates State Park, Battle Mountain Forest St Scenic Corridr, Benson State Recreation Area, Bradley State Scenic Viewpoint, Bridal Veil Falls State Scenic Viewpoint, Cascadia State Park, Catherine Creek State Park, Champoeg State Heritage Area/Visitor Cnt, Cline Falls State Scenic Viewpoint, Clyde Holliday State Recreation Site, Cottonwood Canyon State Park, Crown Point State Scenic Corridor, Dabney State Recreation Area, Dalton Point State Recreation Site, Deschutes River State Recreation Area, Detroit Lake State Recreation Area, Dexter State Recreation Site, Elijah Bristow State Park, Ellmaker State Wayside, Emigrant Springs State Heritage Area, Fall Creek State Rec Area (Winberry), Farewell Bend State Recreation Area, Fort Stevens Historic Area, Fort Stevens State Park, Fort Yamhill State Heritage Area, Guy W Talbot State Park, Hat Rock State Park, Hilgard Junction State Recreation Area, Historic Columbia River Hwy State Trl, Holman State Wayside, Iwetemlaykin State Heritage Area, J. S. Burres, Jasper Point State Park, Jasper State Recreation Site, Koberg Beach State Recreation Site, Lake Owyhee State Park, Lapine State Park, Lewis And Clark State Recreation Site, Ll Stub Stewart State Park, Lowell State Recreation Site, Luckiamute Landing State Natural Area, Mary S Young State Recreation Area, Maud Williamson State Recreation Site, Mayer State Park, Milo Mciver State Park, Minam State Recreation Area, Molalla River State Park, North Santiam State Recreation Area, Ochoco

State Scenic Viewpoint, Ontario State Recreation Site, Peter Skene Ogden State Scenic Viewpoint, Pilot Butte State Scenic Viewpoint, Portland Women`S Forum State Scenic View, Prineville Reservoir State Park, Red Bridge State Wayside, Rooster Rock State Park, Saddle Mountain State Natural Area, Sarah Helmick State Recreation Site, Seneca Fouts Memorial State Natural Area, Silver Falls State Park, Silver Falls-North Falls, Smith Rock State Park, Starvation Creek State Park, Sumpter Valley Dredge State Heritage, The Cove Palisades State Park, Tryon Creek Mu Admin, Tryon Creek State Natural Area, Tumalo State Park, Ukiah-Dale Forest State Scenic Corridor, Unity Lake State Recreation Site , Viento State Park, Wallowa Lake Highway Forest State Scenic, Wallowa Lake State Recreation Area, Warm Springs State Recreation Site, Washburne State Wayside, White River Falls State Park, Willamette Greenway Properties, Willamette Greenway-Yamhill Co-Champoeg, Willamette Mission State Park.

United States Army Corps of Engineers

Albeni Falls Dam, Blue River Lake Or, Chief Joseph Dam, Cottage Grove Lake Or, Cougar Lake Or, Detroit Lake, Dorena Lake Or, Fall Creek Lake Or, Fern Ridge Lake Or, Green Peter Lake, Ice Harbor Lock And Dam, Libby Dam, Little Goose Lock And Dam, Lookout Point Lake Or, Lucky Peak Lake, Mcnary Lock And Dam, Bonneville Lock And Dam-Lake Bonneville, Dexter Lake, Dworshak Dam And Reservoir, Foster Lake, Hills Creek Lake, Lake Umatilla, Lower Granite Lock And Dam, Lower Monumental Lock And Dam, Willow Creek Lake, The Dalles Lock And Dam - Lake Celilo.

United States Forest Service

Beaverhead-Deerlodge National Forest, Bitterroot National Forest, Boise National Forest, Bridger-Teton National Forest, Caribou-Targhee National Forest, Columbia River Gorge National Scenic Area, Colville National Forest, Deschutes National Forest, Flathead National Forest, Fremont-Winema National Forests, Gallatin National Forest, Gifford Pinchot National Forest, Helena National Forest, Humboldt-Toiyabe National Forest, Idaho Panhandle National Forests, Kootenai National Forest, Lewis And Clark National Forest, Lolo National Forest, Malheur National Forest, Mt. Baker-Snoqualmie National Forest, Mt. Hood National Forest, Nez Perce-Clearwater National Forest, Ochoco National Forest, Okanogan-Wenatchee National Forest, Payette National Forest, Salmon-Challis National Forest, Sawtooth National Forest, Shoshone National Forest, Siuslaw National Forest, Umatilla National Forest, Umpqua National Forest, Wallowa-Whitman National Forest, Willamette National Forest.

Washington State Parks and Recreation Commission

Alta Lake, Banks Lake, Battle Ground Lake, Beacon Rock, Bridgeport, Brooks Memorial, Brooks Memorial (Elc), Camp Delany (Elc), Camp William T. Wooten (Elc), Columbia Hills, Columbia Plateau Trail, Columbia Plateau Trail S, Conconully, Crawford, Crown Point, Curlew Lake, Daroga, Doug'S Beach, Dry Falls (Ic), Fields Spring, Fort Columbia, Fort Columbia (Vh), Fort Simcoe, Ginkgo Petrified Forest, Ginkgo Petrified Forest (Ic), Goldendale Observatory, Ike Kinswa, Iron Horse Palouse - Adams, Iron Horse Palouse - Whitman, Jackson House, Lake Chelan, Lake Easton, Lake Wenatchee, Lewis & Clark, Lewis & Clark Trail, Lewis And Clark (Elc), Lewis And Clark (Ic), Lincoln Rock, Maryhill, Matilda N. Jackson, Mount Spokane, Olmstead Place, Palouse Falls, Paradise Point, Pearrygin Lake, Peshastin Pinnacles, Potholes, Puffer Butte (Elc), Reed Island, Riverside, Sacajawea, Sacajawea (Ic), Seaquest, Spokane House, Spokane River Centennial Trail, Spring Creek Hatchery, Squilchuck, St. Helens Visitor Center (Ic), Steamboat Rock (Banks Lake), Steptoe Butte, Steptoe Memorial, Sun Lakes Resort, Sun Lakes-Dry Falls, Twenty-Five Mile Creek, Wanapum Dam, Wanapum Dam - Grant (Kittitas Already Accounted For), Wenatchee Confluence, Wo-He-Lo, Yakima Sportsman.

Appendix D

Angling Analysis Data

Table 38. Current and Enhanced Value of Recreational Catch in the CRB

ECONOMIC IMPACT REGION/AREA/SPECIES	COLUMBIA RIVER RECREATIONAL CATCH			ECONOMIC VALUE		
	RC-CC	3Ea	NET CHANGE	RC-CC	3Ea	NET CHANGE
LOWER COLUMBIA RIVER						
Chinook	78,865	80,238	1,788	$34,806,112	$35,412,179	$606,067
Coho	41,621	41,621	-	$15,898,214	$15,898,214	$0
Steelhead	40,188	90,824	50,636	$18,234,631	$92,520,659	$23,581,703
TOTAL	**160,674**	**212,683**	**52,424**	**$68,938,956**	**$92,520,956**	**$23,581,703**
MID COLUMBIA RIVER						
Chinook	17,889	18,201	406	$7,762,524	$7,897,690	$135,166
Coho	15,920	15,920	0	$6,080,978	$6,080,978	$0
Steelhead	23,243	52,528	29,286	$10,546,144	$24,834,218	$13,288,104
TOTAL	**57,052**	**86,649**	**29,691**	**$24,389,616**	**$37,812,886**	**$12,423,270**
UPPER COLUMBIA RIVER						
Chinook	11,768	11,973	143	$5,487,873	$5,583,432	$95,559
Coho	-	-	-	$0	$0	$0
Steelhead	1,741	1,995	254	$789,944	$905,276	$115,332
TOTAL	**13,509**	**13,968**	**397**	**$6,277,817**	**$6,488,708**	**$210,890**
LOWER SNAKE RIVER						
Chinook	8,067	8,067	-	$3,892,344	$3,892,344	$0
Coho	-	-	-	$0	$0	$0
Steelhead	68,326	68,326	-	$31,002,134	$31,002,134	$0
TOTAL	**76,393**	**76,393**	**-**	**$34,894,478**	**$34,894,478**	$0
UPPER COLUMBIA RIVER—ABOVE CHIEF JOSEPH						
Chinook	-	18,544	18,544	$0	$8,948,380	$8,948,380
Coho	-	-	-	$0	$0	$0
Steelhead	-	700	-	$0	$317,617	$317,617
TOTAL	**-**	**-**	**19,244**	**$0**	**$9,264,997**	**$9,264,997**
COLUMBIA RIVER SYSTEM						
CHINOOK	**116,590**	**137,023**	**20,881**	**$51,948,853**	**$61,733,025**	**$9,784,172**
COHO	**57,541**	**57,541**	**-**	**$21,979,192**	**$21,979,192**	**$0**
STEELHEAD	**133,497**	**214,373**	**80,876**	**$60,572,823**	**$97,2269,511**	**$36,969,688**
TOTAL	**307,628**	**408,938**	**101,757**	**$134,500,868**	**$180,981,728**	**$46,480,860**

Table 39. Economic Impact of Columbia River Origin Recreational Catch

	COLUMBIA RIVER BASIN STOCKS	ECONOMIC VALUE
ECONOMIC IMPACT	RCC-CC	RCC-CC
CALIFORNIA COAST		
Chinook Salmon	-	$0
Coho Salmon	154	$18,150
TOTAL	**385**	$18,150
OREGON COAST		
Chinook Salmon	-	$0
Coho Salmon	14,938	$1,738,251
TOTAL	**14,938**	**$1,738,251**
WASHINGTON COAST		
Chinook Salmon	11,975	$936,521
Coho Salmon	29,538	$2,310,226
TOTAL	**41,512**	**$3,246,747**
PUGET SOUND/STRAIGHT OF SAN JUAN DE FUCA		
Chinook Salmon	1,986	$300,826
Coho Salmon	-	$0
TOTAL	**1,986**	**$300,826**
BRITISH COLUMBIA		
Chinook Salmon	1,060	$82,901
Coho Salmon	162	$12,743
TOTAL	**1,223**	**$95,645**
SOUTHEAST ALASKA		
Chinook Salmon	13,233	$1,034,926
Coho Salmon	-	$0
TOTAL	13,233	**$1,034,926**
CHINOOK SALMON	**28,253**	**$2,355,194**
COHO SALMON	**44,793**	**$4,079,371**
TOTAL	**73,046**	**$6,434,565**

Appendix E

Data Limitations

Climate Change Data

This report does not include climate change in the analyses given that at the time of the completion of this work climate change was data was still being developed. However, most of the analyses can be easily updated once the data is available.

ESV

Valuation exercises have limitations that must be noted, although these limitations should not detract from the core finding that ecosystems produce a significant economic value to society. A benefit transfer analysis estimates the economic value of a given ecosystem (e.g., wetlands) from prior studies of that ecosystem type. Like any economic analysis, this methodology has strengths and weaknesses. Some arguments against benefit transfer include:

1. Every ecosystem is unique; per-acre values derived from another location may be irrelevant to the ecosystems being studied.
2. Even within a single ecosystem, the value per acre depends on the size of the ecosystem; in most cases, as the size decreases, the per-acre value is expected to increase and vice versa. (In technical terms, the marginal cost per acre is generally expected to increase as the quantity supplied decreases; a single average value is not the same as a range of marginal values).
3. To value all, or a large proportion, of the ecosystems in a large geographic area is questionable in terms of the standard definition of exchange value. We cannot conceive of a transaction in which all or most of a large area's ecosystems would be bought and sold. This emphasizes the point that the value estimates for large areas (as opposed to the unit values per acre) are more comparable to national income account aggregates and not exchange values.[203] These aggregates (i.e. GDP) routinely impute values to public goods for which no conceivable market transaction is possible. The value of ecosystem services of large geographic areas is comparable to these kinds of aggregates (see below).

Proponents of the above arguments recommend an alternative valuation methodology that amounts to limiting valuation to a single ecosystem in a single location. This method only uses data developed expressly for the unique ecosystem being studied, with no attempt to extrapolate from other ecosystems in other locations. The size and landscape complexity of most ecosystems makes this approach to valuation extremely difficult and costly. Responses to the above critiques can be summarized as follows (See Costanza et al. (1997)[204] and Howarth and Farber (2002)[205] for a more detailed discussion):

1. While every wetland, forest or other ecosystem is unique in some way, ecosystems of a given type, by their definition, have many things in common. The use of average values in ecosystem valuation is no more or less justified than their use in other macroeconomic contexts; for instance, the development of economic statistics such as Gross Domestic or Gross State Product.
2. As employed here, the prior studies upon which we based our calculations encompass a wide variety of time periods, geographic areas, investigators and analytic methods. Many of them provide a range of estimated values rather than single-point estimates. The present study preserves this variance; no studies were removed from the database because their estimated values were deemed to be "too high" or "too low." Also, only limited sensitivity analyses were performed. This approach is similar to determining an asking price for a piece of land based on the prices of comparable parcels ("comps"): Even though the property being sold is unique, realtors and lenders feel justified in following this procedure to the extent of publicizing a single asking price rather than a price range.
3. The objection to the absence of even an imaginary exchange transaction was made in response to the study by Costanza et al. (1997)[206] of the value of all of the world's ecosystems. Leaving that debate aside, one can conceive of an exchange transaction in which, for example, all of, or a large portion of a watershed was sold for development, so that the basic technical requirement of an economic value reflecting the exchange value could be satisfied. Even this is not necessary if one recognizes the different purpose of valuation at this scale, a purpose that is more analogous to national income accounting than to estimating exchange values.[207]

We have displayed our study results in a way that allows one to appreciate the range of values and their distribution. It is clear from inspection of the tables that the final estimates are not precise. However, they are much better estimates than the alternative of assuming that ecosystem services have zero value, or, alternatively, of assuming they have infinite value. Pragmatically, in estimating the value of ecosystem services, it seems better to be approximately right than precisely wrong.

General Limitations

- **Static Analysis.** This analysis is a static, partial equilibrium framework that ignores interdependencies and dynamics, though new dynamic models are being developed. The effect of this omission on valuations is difficult to assess.
- **Increases in Scarcity.** The valuations probably underestimate shifts in the relevant demand curves as the sources of ecosystem services become more limited. The values of many ecological services rapidly increase as they become increasingly scarce.[208] If ecosystem services are scarcer than assumed, their value has been underestimated in this study. Such reductions in supply appear likely as land conversion and development proceed. Climate change may also adversely affect the ecosystems, although the precise impacts are difficult to predict.

Benefit Transfer/Database Limitations

- **Incomplete coverage.** That not all ecosystems have been valued or studied well is perhaps the most serious issue, because it results in a significant underestimate of the value of ecosystem services. More complete coverage would almost certainly increase the values shown in this report, since no known valuation studies have reported estimated values of zero or less for an ecosystem service. Table 5 illustrates which ecosystem services were identified in the Mat-Su for each land cover type, and which of those were valued.
- **Selection Bias.** Bias can be introduced in choosing the valuation studies, as in any appraisal methodology. The use of ranges partially mitigates this problem.

Primary Study Limitations

- **Price Distortions.** Distortions in the current prices used to estimate ecosystem service values are carried through the analysis. These prices do not reflect environmental externalities and are therefore again likely to be underestimates of true values.
- **Non-linear/Threshold Effects.** The valuations assume smooth and/or linear responses to changes in ecosystem quantity with no thresholds or discontinuities. Assuming (as seems likely) that such gaps or jumps in the demand curve would move demand to higher levels than a smooth curve, the presence of thresholds or discontinuities would likely produce higher values for affected services.[209] Further, if a critical threshold is passed, valuation may leave the normal sphere of marginal change and larger-scale social and ethical considerations dominate, as with an endangered species listing.
- **Sustainable Use Levels.** The value estimates are not necessarily based on sustainable use levels. Limiting use to sustainable levels would imply higher values for ecosystem services as the effective supply of such services is reduced. If the above problems and limitations were addressed, the result would most likely be a narrower range of values and significantly higher values overall. At this point, however, it is impossible to determine more precisely how much the low and high values would change.

GIS Limitations

- **GIS Data.** Since this valuation approach involves using benefit transfer methods to assign values to land cover types based, in some cases, on the context of their surroundings, one of the most important issues with GIS quality assurance is reliability of the land cover maps used in the benefits transfer, both in terms of categorical precision and accuracy.
- **Ecosystem Health.** There is the potential that ecosystems identified in the GIS analysis are fully functioning to the point where they are delivering higher values than those assumed in the original primary studies, which would result in an underestimate of current value. On the other hand, if ecosystems are less healthy than those in primary studies, this valuation will overestimate current value.

- **Spatial Effects.** This Ecosystem Services Valuation assumes spatial homogeneity of services within ecosystems, i.e. that every acre of forest produces the same ecosystem services. This is clearly not the case. Whether this would increase or decrease valuations depends on the spatial patterns and services involved. Solving this difficulty requires spatial dynamic analysis. More elaborate system dynamic studies of ecosystem services have shown that including interdependencies and dynamics leads to significantly higher values,[210] as changes in ecosystem service levels cascade throughout the economy.

Appendix F

Studies Used for Benefit Transfer

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Appendix G

Dollar-Per-Acre ESV Results by Ecosystem Service and Land Cover

Please email info@eartheconomics.org for more information on the dollar-per-acre ESV results (Appendix G).

Appendix H

Documentation
Sources of Cultural
Tribal Narrative

#	TITLE	TYPE	TRIBE	LINK
1	Couer d'Alene Tribe	Website	Couer d'Alene	http://www.cdatribe-nsn.gov/cultural/Overview.aspx
2	Couer d'Alene tribe trying to preserve language	Video	Couer d'Alene	https://www.youtube.com/watch?v=XUuh24EG5HM
3	Why the Traditional Arts Matter	Video	Couer d'Alene	https://www.youtube.com/watch?v=UjdqpPJJJw4
4	Kalispel	Website	Kalispel	http://www.kalispeltribe.com/
5	Kalispel- Water	Video	Kalispel	https://www.youtube.com/watch?v=6n59nDtnpDA
6	Kalispel- Wetlands	Video	Kalispel	https://www.youtube.com/watch?v=Y_Y5sNh_D90
7	Kalispel- Invasive	Video	Kalispel	https://www.youtube.com/watch?v=CoBUmIetRzk
8	Kalispel- People	Video	Kalispel	https://www.youtube.com/watch?v=YmCAi-hk9Yk
9	Spokane Tribe of Indians	Website	Spokane	http://www.spokanetribe.com/
10	Kootenai Tribe of Idaho	Website	Kootenai	http://www.kootenai.org/
11	Interview with Francis Auld, Salish Kootenai	Video	Kootenai	https://www.youtube.com/watch?v=4RIdSs3avdY
12	The Confederated Tribes of the Colville Reservation	Website	Colville Tribes	http://www.colvilletribes.com/
13	Coyote: Stories Along the Columbia	Video	Colville Tribes	http://www.colvilletribes.com/stories_along_the_columbia__1_2_.php
14	Coyote: Stories Along the Columbia Part 2	Video	Colville Tribes	http://www.colvilletribes.com/stories_along_the_columbia__2_2_.php
15	Fish and Wildlife: Friendliest Catch	Video	Colville Tribes	http://www.colvilletribes.com/friendliest_catch.php
16	Fish and Wildlife: Sustainable Fishing for the Future	Video	Colville Tribes	http://www.colvilletribes.com/sustainable_fishing_for_the_future.php
17	Grand Coulee Dam: Price We Paid	Video	Colville Tribes	http://www.colvilletribes.com/the_price_we_paid__1_2_.php
18	Grand Coulee Dam: Price We Paid Part 2	Video	Colville Tribes	http://www.colvilletribes.com/the_price_we_paid__2_2_.php
19	Building Grand Coulee Dam: A Tribal Perspective Part 2	Video	Colville Tribes	http://www.colvilletribes.com/building_gcd___a_tribal_perspective__2_3_.php

#	TITLE	TYPE	TRIBE	LINK
20	Building Grand Coulee Dam: A Tribal Perspective Part 3	Video	Colville Tribes	http://www.colvilletribes.com/building_gcd___a_tribal_perspective__3_3_.php
21	The Dam's Tribal Impacts Part 1	Video	Colville Tribes	http://www.colvilletribes.com/the_dam_s_tribal_impacts__1_.php
22	The Dam's Tribal Impacts Part 2	Video	Colville Tribes	http://www.colvilletribes.com/the_dam_s_tribal_impacts__2_4_.php
23	The Dam's Tribal Impacts Part 3	Video	Colville Tribes	http://www.colvilletribes.com/the_dam_s_tribal_impacts__3_4_.php
24	The Dam's Tribal Impacts Part 4	Video	Colville Tribes	http://www.colvilletribes.com/the_dam_s_tribal_impacts__4_40.php
25	The Kettle Falls Fishery	Video	Colville Tribes	http://www.colvilletribes.com/the_kettle_falls_fishery__1_2_.php
26	The Kettle Falls Fishery Part 2	Video	Colville Tribes	http://www.colvilletribes.com/the_kettle_falls_fishery__2_2_.php
27	The Complete Seymour	Book/ Interviews	Colville Tribes	http://www.colvilletribes.com/mattina.php
28	Nez Perce Tribe	Website	Nez Perce Tribe	http://www.nezperce.org/
29	Umatilla Indian Reservation: History & Culture	Website	Umatilla Tribes	http://ctuir.org/history-culture
30	Importance of Buffalo	Video	Umatilla Tribes	https://www.youtube.com/watch?v=PgydxFplABM
31	Resume Bison Hunting Traditions	Video	Umatilla Tribes	https://www.youtube.com/watch?v=DtTUOZSvlIo
32	The Confederated Tribes of the Warm Springs Reservation of Oregon	Website	Warm Springs Tribes	https://warmsprings-nsn.gov/
33	Plateu Peoples' Web Portal	Videos	Plateu Tribes	http://plateauportal.wsulibs.wsu.edu/
34	The Confederated Tribes and Bands of the Yakama Nation	Website	Yakima Nation	http://www.yakamanation-nsn.gov/
35	Warbonnet Ceremony	Video	Yakima Nation	http://plateauportal.wsulibs.wsu.edu/digital-heritage/warbonnet-ceremony
36	Traditional Dip Net Fishing	Video	Yakima Nation	https://www.youtube.com/watch?v=oy8HhnCEcEo
37	Burns Paiute Tribe	Website	Burns Paiute	http://www.burnspaiute-nsn.gov/

#	TITLE	TYPE	TRIBE	LINK
38	Burns Paiute Legends	Website	Burns Paiute	http://www.burnspaiute-nsn.gov/index.php?option=com_content&view=category&id=35&Itemid=59
39	Fred Townsend, Burns Paiute member, 78	Video	Burns Paiute	https://www.youtube.com/watch?v=qTi8uP5F3S8
40	Shoshone Paiute Tribe of the Duck Valley Indian Reservation	Website	Shoshone Paiute	http://shopaitribes.org/spt-15/
41	Culture	Videos	Shoshone Paiute	http://www.shopaitribes.org/culture/
42	Shoshone-Bannock Tribes	Website	Shoshone-Bannock Tribes	http://www.shoshonebannocktribes.com/
43	Upper Snake River Tribes Ceremonial Salmon Fishery Videos, Events and Photos	Website	USRT Member Tribes	http://www.uppersnakerivertribes.org
44	Cowlitz Indian Tribe	Website	Cowlitz	https://www.cowlitz.org/
45	Confederated Salish and Kootenai Tribes of the Flathead Nation	Website	Salish & Kootenai Tribes	http://www.csktribes.org/
46	Salish-Pend d'Oreille Culture Committee	Website	Salish-Pend d'Oreille (Kalispel)	http://www.salishaudio.org/

Appendix I

Existence Value Model and Detailed Methodology

Following Richardson and Loomis (2009), we estimate willingness-to-pay for existence value using the double log model. The following table lists the significant variables in the model, their coefficients, the parameters used in this study, and the results of the model. For methodological variables, such as "Mail", we took the sample mean as shown in Richardson and Loomis (2009) as the parameter. Under current conditions, we took the change size variable as zero, since salmon have been in decline and no additional restoration would come about. Under the future scenario, the addition of salmon above Chief Joseph dam would increase runs of chinook, sockeye, coho, and steelhead by as much as 26 percent, and populations in the lower river could increase by as much as 25 percent, for a total increase of about 51 percent. This parameter is used in the future scenario.

Table 40. Existence Value Detailed Methodology

VARIABLE	COEFFICIENT	DEFINITION	FUTURE SCENARIO PARAMETERS	COEFFICIENT X FUTURE SCENARIO PARAMETERS	CURRENT SCENARIO PARAMETERS	COEFFICIENT X FUTURE SCENARIO PARAMETERS
Constant	-153.231		1	-153.2310	1	-153.2310
ln change size	0.87	Natural log of the percent change in species population size	3.932	3.4207	0.000	0.0000
Visitor	1.256	Dummy variable	0.231	0.2901	0.231	0.2901
Fish	1.02	Dummy variable	1	1.0200	1	1.0200
Marine	0.772	Dummy variable	0	0.0000	0	0.0000
Bird	0.826	Dummy variable	0	0.0000	0	0.0000
ln response rate	-0.603	Natural log of the survey response rate	3.894	-2.3481	3.894	-2.3481
Conjoint	2.767	Dummy variable	0.075	0.2075	0.075	0.2075
Mail	-0.903	Dummy variable	0.851	-0.7685	0.851	-0.7685
Charismatic	1.024	Dummy variable	0	0.0000	0	0.0000
Sutdyyear	0.078	Year of value estimate	2016	157.2480	2016	157.2480
ln WTP				5.84		2.42
WTP (2006 USD/ household)				343.37		11.22
WTP (2015 USD/ household)				403.69		13.19

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