A COMPREHENSIVE INTEGRATED WATER RESOURCE ASSESSMENT OF POTENTIAL CHANGES TO COLUMBIA RIVER BASIN FLOOD RISK MANAGEMENT POLICY

A Thesis

Presented in Partial Fulfillment of the Requirements for the

Degree of Master of Science

with a

Major in Water Resources Law, Management, and Policy

in the

College of Graduate Studies

University of Idaho

by

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April 2016

Authorization to Submit Thesis

The thesis of Patrick B. Johnson, submitted for the degree of Master of Science with a Major in Water Resources Law, Management, and Policy and titled "A Comprehensive Integrated Water Resource Assessment of Potential Changes to Columbia River Basin Flood Risk Management Policy," has been reviewed in final form. Permission, as indicated by the signatures and dates below, is now granted to submit final copies to the College of Graduate Studies for approval.

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Abstract

The Columbia River Basin, which spans seven U.S. states and two countries, is located in a diverse socio-ecological region of the Pacific Northwest with stakeholders ranging from flood risk managers, irrigators, power utilities, ecological interests, and more. With the governing document of the bi-national management of the Basin, the Columbia River Treaty, under current review, significant flood risk management policy decisions are looming. This research examines historic flow events that exceed the amount deemed to cause flood damages and determines that actual damages at the prescribed threshold flood discharge are minimal in recent events. Additionally, an exploration of the costs and benefits of non-structural flood control measures and an allowance of increased flows shows qualitative and quantitative ecological, social, and economic benefits. This work intends to show the importance and need for further research and examination of flood risk management policy in the Columbia River Basin by applicable stakeholders.

Acknowledgements

When I arrived at the University of Idaho, I wanted to find a way to contribute in a meaningful manner to water resource management in the region through my research. Professor Barb Cosens helped me to identify a project that would accomplish just that, and has been beyond gracious in providing me with her time, energy, and resources ever since. Without her mentorship and guidance, completing this research would have been an even greater challenge. I am forever indebted to her for her kindness and patience.

I also want to acknowledge the other members of my committee, Dr. John Tracy and Dr. Daniele Tonina, for agreeing to help me through this process. They both had time-consuming and life-changing events over the last couple of years, and I cannot thank them enough for still making me and this research a priority.

The United States Geological Survey (USGS) provided substantial funding for this research, and this confidence in me and the research that I was performing helped provide further motivation to produce a useful product for the region. I also want to acknowledge Avista Utilities and the Association of State Flood Plain Managers (ASFPM) for supporting my work through small scholarships.

Lastly, and most importantly, I want to acknowledge my partner and wife Elaine. Her love, support, optimism, laughter, and encouragement is infectious, and makes me a more committed and driven advocate for progressive change.

Dedication

To the humans, plants, and animals of the Columbia River Basin who span the wide range of sociopolitical borders. And to my father, a tireless advocate for intelligent natural resource management who instilled in me the passion needed to pursue my dreams.

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CHAPTER 1: INTRODUCTION AND RESEARCH QUESTIONS

The Columbia River Basin, located in the Pacific Northwestern United States and the southern portion of British Columbia in Canada, is one of the largest and most unique river systems in North America. With seven states, two countries, and numerous Indian tribes residing within its boundaries, management and manipulation for many different uses has been a necessary and complicated proposition. The document governing much of the management in the Basin is the Columbia River Treaty. This Treaty is an agreement between Canada and the United States and primarily discusses flood risk management and power production. It is currently under review due to expiring provisions in 2024, and the United States and Canada disagree on the level of flood risk that should be accepted in the Basin.

Stakeholders on both sides of the border have requested a thorough review of flood risk management as this could potentially bridge the gap between the countries and allow for a more effective document to be implemented moving forward. However, the U.S. Army Corps of Engineers has failed to respond to these requests publicly. In addition to the potential for providing an avenue for the two countries to agree, broad and thorough understanding of flood risk would likely breathe space into the system to accomplish other goals, such as irrigation, hydropower, fish and wildlife, and recreation.

Whereas power production through hydroelectric generators, irrigators, fish and wildlife, and recreation interests are all vital components of system control, flood risk management arguably holds the trump card in the region. Because the Columbia is a hydrological system so reliant on snow melt in an otherwise arid region, maximizing use of the water without putting riparian communities at risk requires detailed research and contemplation between the variety of federal, state, tribal, and local stakeholders. There is a major gap in positions between the United States and Canada in review of the Columbia River Treaty, as the United States seeks much more restrictive regulation of the river to achieve a lower flood risk, and Canada believes that this is unwarranted under the existing Treaty.

Because past flooding events and policy decisions that followed have led to relatively restrictive risk management policy, a comprehensive study is needed to determine the actual flows at which flood damages begin to occur in order for more flexibility to be incorporated in Basin water management. This work seeks to provide the initial stimulation to promote such a comprehensive effort undertaken by multiple agencies in the context of the Columbia River Treaty review.

This interdisciplinary research incorporates the academic disciplines of history, ecology, law, and economics, and attempts to integrate qualitative and quantitative analyses. The broad goal of this work is to start the process of stimulating substantive and thorough research in the Columbia River Basin regarding flood risk management. The first question consulted to achieve this goal is whether the record of high flow and corresponding evidence of flood damage suggest that damage may be limited at higher flows than sought by the United States. The second question examined is whether nonstructural flood control measures can be more cost-effective to implement compared to structural measures. And the third question examined is whether areas in the Basin are available that would allow for benefits without significant economic damage if flows were to increase.

In order to accomplish this goal, background literature was first reviewed. Beginning very broadly, a discussion of flood risk policy by the primary agency tasked with flood risk management, the U.S. Army Corps of Engineers, helps the reader understand the historical context for structural management by the agency and why some hesitation could currently exist for allowing more flexibility. This is critical to understand the context within which these decisions are being made. Following that broad discussion, a slightly focused section includes a discussion of a variety of factors that are leading to a forced transition in the way in which flood risk is managed. In particular, an overview of the legal ramifications of certain types of flood risk management will be provided along with an exploration of non-structural management possibilities and ecological impacts of more flexible flow regimes. This is directly connected to the overall goal of this research, because it provides policy makers and stakeholders in the region with some of the legal requirements that may exist if a failure to fully assess impacts to endangered species occurs, as well as gives context as to other factors, irrespective of the Treaty, that should stimulate further research of flood risk in the Basin.

Once the necessary broad background information is provided, a much narrower discussion follows to explain how these issues apply to the Columbia River Basin, with a particular focus on the Columbia River Treaty. This provides an overview of the source of the differences between Canada and the United States needed to understand the need for a comprehensive flood risk management study.

Following this critical information is the discussion and analysis of historical flood damages in the Columbia River Basin. This will be used to show that past high flow events that have been presumed to cause flood damages have had minimal impacts on the region. Following this discussion, a brief cost and benefit analysis will be discussed, where research may show that current structural management of floodplains may not be the most cost-effective tactic. Then, in order to show that some room does exist for more flexible flows, areas that have floodplains without significant development within the Basin have been identified using site visits and GIS technology. Ultimately the goal of this research is to determine whether more research is needed to ensure that appropriate policy decisions are made regarding flows in the Columbia River Basin.

CHAPTER 2: BACKGROUND

Flood Risk Management

I. U.S. Army Corps of Engineers Flood Risk Policy

As the agency tasked with flood risk management in the Columbia River Basin, this review and analysis of historic U.S. Army Corps of Engineers (Corps) policy will provide a strong starting point in the conceptualization of the premise of the goals of this research, as all flood risk management strategy in the Columbia must be performed within the scope of historical Corps policy. This will help to provide the necessary foundational knowledge needed to understand why some hesitation may exist within the Corps to research whether more flexibility is possible in the region.

The Corps has had a long and complex history of management of the nation's waterways. One of the more imperiled systems, and subsequently one of the more heavily managed, is the Mississippi River Basin. The Mississippi River has the third largest drainage basin in the world, and drains forty-one percent of the forty-eight contiguous states of the United States.[1] The basin covers more than 1,245 million square miles and includes all or parts of thirty-one states and two Canadian provinces.[2] Due to its size in addition to favorable climates and fertile soils, population centers are found throughout the Mississippi River watershed, increasing the frequency of historic flood damages and management responses by the Corps. As a result, this Basin will be used to provide a brief historical background of flooding issues and Corps management strategies leading up to the disastrous impacts of flooding stemming from Hurricane Katrina.

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[1] *Mississippi River Basin*, GREAT RIVERS PARTNERSHIP (June 15, 2015), http://www.greatriverspartnership.org/en-us/northamerica/Mississippi/pages/default.aspx.
[2] *Id.*

As a result of Corps policies, by the 1920's miles of levees had been constructed along the banks of the Mississippi River by the Corps in order to attempt to improve navigation and lessen the impacts of flooding throughout the Basin.[3] In the spring of 1927, this flood control system was put to the test as tremendous rain events throughout the region swelled the rivers to levels that had not been seen in modern times.[4] At high water the river spread and rose even higher, causing the Corps to raise the height of the levees to as much as thirty-eight feet.[5] These levees failed in 145 different places, inundating twenty-seven thousand square miles and causing over $200 million in property damages.[6]

In response to this disaster, Congress passed the Flood Control Act of 1928, declaring that the federal government would take responsibility for the Mississippi River by constructing more levees alongside the development of spillways and reservoirs.[7] Additionally, the Act immunized the federal government from any liability "of any kind . . . for any damage from or by floods or flood waters at any place."[8]

Around the early 1900's, many federal agencies, including the Bureau of Reclamation and the U.S. Geological Survey, had determined that generally, each river must be treated as an integrated unit from source to mouth.[9] Rivers were to be developed "systematically and consistently," with coordination of navigation, flood control, irrigation, and hydro-power.[10] However, according to author Donald Pisani, the Corps did not join the movement toward

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[3] Christina A. Klein & Sandra B. Zellmer, *Mississippi River Stories: Lessons from a Century of Unnatural Disasters*, 60 SMU L. REV. 1471, 1480 (2007).
[4] Stephen Ambrose, *Man v. Nature: Great Flood*, NATIONAL GEOGRAPHIC (May 1, 2001), http://news.nationalgeographic.com/news/2001/05/0501_river4.html.
[5] *Id.*
[6] United States v. James, 478 U.S. 597, 606 (1986).
[7] Pub. L. No. 70-391, 45 Stat. 534 (codified as amended at 33 U.S.C.A. §§ 701-09 (West 2015)).
[8] United States v. James, 478 U.S. 597, 604 (1986) (citing 33 U.S.C.A. § 702).
[9] DONALD J. PISANI, WATER AND AMERICAN GOVERNMENT THE RECLAMATION BUREAU, NATIONAL WATER POLICY, AND THE WEST 1902-1935 285 (Univ. of Cal. Press 2002).
[10] *Id.*

watershed planning, and instead decided to conduct river management in a piecemeal fashion for the benefit of different local interests.[11]

In 1936, Congress passed the Flood Control Act of 1936.[12] This particular statute indicated that for the first time, Congress explicitly recognized federal responsibility for flood control measures nationwide.[13] Congress proclaimed that "destructive floods . . . upsetting orderly processes and causing loss of life and property . . . constitute a menace to national welfare."[14] This Act delegated very broad discretion to the Corps to construct any flood control project it chooses, assuming that the funds were available from Congress.[15] The Corps' discretion was only constrained by a cost-benefit requirement, allowing the Corps to proceed whenever "the benefits to whomsoever they may accrue are in excess of the estimated costs."[16]

As the Corps began the process of building flood control structures as a result of the powers given to them in the 1936 Act, two major floods occurred along the Missouri River.[17] In response, Congress enacted the Flood Control Act of 1944, which authorized five dams and reservoirs in the upper Missouri River and in the Mississippi River.[18]

The new flood control measures were very quickly put to the test when major flooding occurred on the Kansas River in eastern Kansas and the Missouri River in 1951.[19] From the headwaters of the Kansas River to the mouth of the Missouri River into the Mississippi, as high as $2.5 billion in flood-related damages were seen, with nineteen deaths and over one-thousand

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[11] *Id.*
[12] 33 U.S.C.A. § 701a (West 2015).
[13] *Id.*
[14] *Id.*
[15] *Id.*
[16] *Id.*
[17] ROBERT KELLEY SCHNEIDERS, UNRULY RIVER: TWO CENTURIES OF CHANGE ALONG THE MISSOURI (1999).
[18] Flood Control Act of Dec. 22, 1944, Pub. L. No. 78-534, 58 Stat. 887.
[19] Kyle E. Juracek et al., *The 1951 Floods in Kansas Revisited*, U.S. GEOLOGICAL SOC'Y, (2001), http://ks.water.usgs.gov/pubs/fact-sheets/fs.041-01.html.

injuries.[20] In response, more flood-control reservoirs, dams, and levees were constructed on the Kansas and Missouri Rivers.[21] The very next year, in 1952, the Missouri River flooded again, and remains as the greatest flood of record for many communities throughout the Missouri River Basin.[22] Millions of dollars in houses and commercial properties were destroyed, and the area around Omaha, Nebraska was deemed a "disaster area" by President Truman.[23]

Efforts continued into the 1950's and 1960's to manage river systems using structural measures, alongside efforts to create a comprehensive, nationwide flood insurance program.[24] This was stimulated to action by another significant flooding event in New Orleans stemming from Hurricane Betsy in 1965.[25] The hurricane brought a ten foot storm surge to New Orleans, producing the city's worst flooding in decades as a result of significant failure of levees.[26] This flooding event overloaded the city's pumping system, which failed when 90% of the city's electric power was knocked out.[27] Seventy-six total deaths were a direct result of Hurricane Betsy, with a total of $1.42 billion in damages estimated, with most of those damages occurring in Louisiana.[28]

Following the impacts stemming from Hurricane Betsy, Congress passed the Flood Control Act of 1965, which included the Lake Pontchartrain Vicinity Flood Control Project.[29] This particular project authorized the Corps to design and construct hurricane protection that

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[20] *Id.*
[21] *Id.*
[22] *Id.*
[23] *Id.*
[24] Saul Jay Singer, *Flooding the Fifth Amendment: The National Flood Insurance Program and the "Takings" Clause*, 17 B.C. ENVTL. AFF. L. REV. 323, 335 (1990).
[25] *Hurricane Betsy*, HURRICANE SCIENCE (last visited June 15, 2015), http://www.hurricanescience.org/history/storms/1960s/betsy/.
[26] *Id.*
[27] *Id.*
[28] *Id.*
[29] TESTIMONY BEFORE THE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS, U.S. SENATE, U.S. ARMY CORPS OF ENGINEERS (Nov. 12, 2005), http://www.gao.gov/new.items/d06244t.pdf.

could withstand Category Three storms like Betsy, and the Corps originally planned to build a barrier of levees and floodgates along the eastern boundaries of Lake Pontchartrain to prevent storm surge from entering the lake.[30] However, in the mid-1980's, for a variety of reasons, the Corps abandoned the barrier plan in favor of an alternative design that would increase the heights of the levees along the lakefront, the New Orleans outfall drainage canals and the Industrial Canal.[31]

Again these flood control devices that were created and reinforced by the Corps were put to the test, as record-breaking rains occurred in the Mississippi River basin, along with record-breaking river crests, hit the region in 1993.[32] By August of 1993, the upper basin of the Mississippi and its tributaries, including the Missouri River, flooded 17,000 square miles in nine states, breaking flood records for both intensity and duration throughout Missouri, Minnesota, Iowa, and Illinois.[33]

Forty of 226 federal levees and 1,043 of 1,345 non-federal levees were over-topped or breached.[34] The failure of essential infrastructure throughout the Midwest and the release of hazardous substances from inundated Superfund sites and from hundreds of discarded barrels and propane tanks further exacerbated the problem.[35] Fifty deaths were attributed to the flood, 100,000 people were displaced from their homes, and 100,000 buildings were destroyed or severely damaged.[36] Nearly 500,000 acres of agricultural land along the rivers were inundated

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[30] *Id.*
[31] *Id.*
[32] Lee W. Larson, *The Great USA Flood of 1993,* NOAA/NATIONAL WEATHER SERVICE (June 1996) http://www.nwrfc.noaa.gov/floods/papers/oh_2/great.htm.
[33] *Id.*
[34] *Id.*
[35] *Id.*
[36] *Id.*

and about one-fourth of the cropland was covered with sand or scoured out, causing unprecedented crop losses.[37] Estimates of total flood damages ranged as high as $15 billion.[38]

Following this flood, the Corps and other entities again sought the help of congressional funding to rebuild structural measures that had consistently failed over the course of fifty years during major flood events.[39] In testimony presented before the U.S. Senate Environment and Public Works Committee in 1993, Dr. Edward Dickey, Acting Assistant Secretary of the Army for Civil Works stated, "[n]evertheless, the Corps flood-control infrastructure, including flood-control reservoirs, levees, walls, and other structures, performed extremely well during the crisis, preventing billions of dollars in damages."[40] As a result of reassurances from the Corps and the government regarding the relative effectiveness of the levee system during the flooding of 1993, an enormous amount of development occurred throughout the Mississippi River Basin in areas that were inundated in the 1993 floods.[41] This was primarily a result of the growth in popularity and funding within FEMA's National Flood Insurance Program (NFIP) in addition to a renewed sense of confidence in the strength of the levee system throughout the region.[42] The NFIP will be discussed extensively in a later section of this work.[43]

During an assessment of the flooding in 1993 in the Mississippi River Basin, the Corps released a sketch of an example of an optimal floodplain and development. The image can be seen in Figure 1 below.[44]

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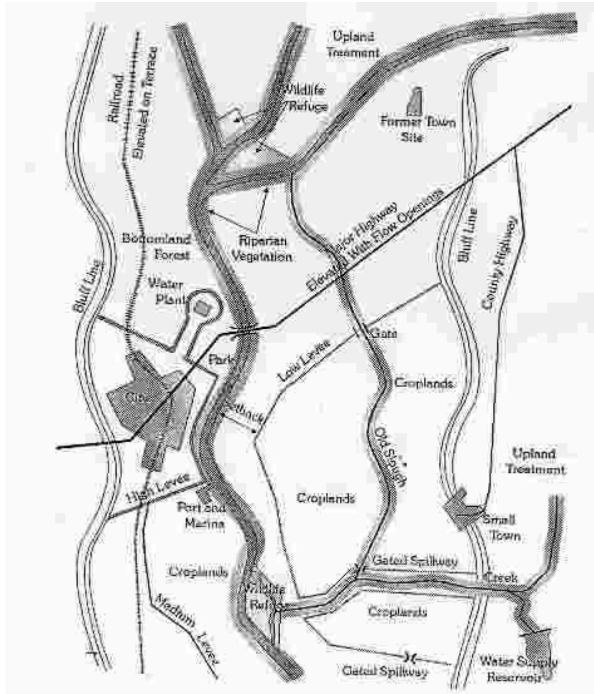
[37] *Id.*
[38] *Id.*
[39] Dan Cassidy & Rickert Althaus, *The Flood of 1993: The Economic Aftermath*, CHOICES (1994) http://ageconsearch.umn.edu/bitstream/131843/2/Floodof1993.pdf.
[40] *Id.*
[41] Susan Saulny, *Development Rises on St. Louis Area Flood Plains*, N.Y. TIMES, May 15, 2007, at A13.
[42] *Id.*
[43] *See infra* FEMA's NFIP and the Endangered Species Act.
[44] *1993 Flood*, U.S. ARMY CORPS OF ENGINEERS (last visited June 15, 2015) http://mvs-wc.mvs.usace.army.mil/papers/93flood/93FLD7.jpg.

Figure 1: 1993 U.S. Army Corps of Engineers Sketch



As can be seen, the Corps' sketch incorporates a combination of structural and non-structural flood risk management measures in addition to some riparian vegetation.[45] This seems to reflect development decisions made immediately following the flooding of 1993.

Following the reinforcement of levees and the growth in participation of the NFIP, another significant flooding event again tested the physical flood prevention infrastructure seen throughout the Mississippi River Basin.[46] The May 1995 Louisiana flood struck the New Orleans metropolitan area, shutting down the city for two days.[47] Six people were killed, and the event was later estimated to have caused more than $3.1 billion in damage.[48] More structural solutions were sought following this catastrophic flood, including the expansion of canals and

[45] *Id.*
[46] *May 1995 Louisiana Flood*, DIGPLANET (last visited June 15, 2015), http://www.digplanet.com/wiki/May_1995_Louisiana_flood.
[47] *Id.*
[48] *Id.*

improving pumping stations.[49] However, despite many decade's worth of structural flood prevention developments in the Mississippi River Basin, the most costly natural disaster in U.S. history struck New Orleans during the aftermath of a relatively mild Category 3 hurricane known as Hurricane Katrina.[50]

As a result of years of development, by 2005, New Orleans rested within a bowl formed by levees, locks, floodgates, and seawalls extending for hundreds of miles, and it was bisected from west to east by the Mississippi River, which was also contained within massive engineered embankments.[51] As was discussed above, this tightly managed system led to a false sense of security, and significant development had occurred within the floodplain and other areas vulnerable to inundation during large rain events.

In order to fully understand the reasons behind the devastation that occurred in New Orleans, a brief assessment of the scientific impacts of these structural measures needs to be performed. Levees and dams constrict the Mississippi River, preventing the transportation of valuable sediments for the nourishment of wetlands and plains at the river's delta, resulting in significant land loss on the delta plains.[52] Additionally, engineered structures, including breakwaters, seawalls, and revetments, interfere with natural sand migration and dune restoration and alter sediment-replenishing currents, leading to coastland beach erosion.[53] Also the dredging of navigation channels, canals, causes a rapid conversion of land and wetlands to

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[49] *Id.*
[50] *Hurricane Katrina: Facts, Damage, & Aftermath*, LIVESCIENCE (last visited June 15, 2015) http://www.livescience.com/22522-hurricane-katrina-facts.html; *Noteworthy Trends of the 2005 Atlantic Hurricane Season,* NOAA (last visited June 15, 2015) http://www.noaanews.noaa.gov/stories2005/s2540b.htm (Five hurricanes in the Atlantic that have made landfall have been stronger).
[51] Klein & Zellmer, *supra* note 3 at 1499.
[52] Robert A. Morton, *An Overview of Coastal Land Loss: With Emphasis on the Southeastern United States,* U.S. GEOLOGICAL SURVEY (2003) http://pubs.usgs.gov/of/2003/of03-337/landloss.pdf.
[53] *Id.*

open water as sediment and water flow patterns are redirected, which leads to less natural flood risk buffer.[54]

In the pre-dawn hours before Katrina made landfall as a Category 3 storm on August 29, 2005, flood waters in the Industrial Canal began to leak into surrounding neighborhoods.[55] By 10:30 a.m., catastrophic failures had occurred on levees surrounding the city, with the levee system breaching in up to thirty places, unleashing floodwaters that continued to rise for several days.[56] At least eighty percent of New Orleans was submerged beneath up to twenty feet of water in the aftermath of the failed levee system, with over 1,200 deaths, 200,000 homes destroyed, and over $108 billion in total economic damages.[57]

Not long after damages were surveyed in the New Orleans area, the Corps responded by establishing what was called "Task Force Guardian" to help rebuild the flood prevention infrastructure in the New Orleans region.[58] This prioritized the rebuilding of levees, floodwalls, and other structural measures that had breached during and after Katrina's landfall.[59]

In the immediate aftermath of Hurricane Katrina, the citizens of New Orleans quickly identified the Corps as the culprit, displaying the slogan "Hold the Corps Accountable" on t-shirts and yard signs and openly blamed the Army Corps in conversations about the storm.[60] Many believed that the Army Corps should be held liable for much of the damage caused by

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[54] *Id.*
[55] Bob Marshall, *City's Fate Sealed in Hours,* NOLA.COM (May 14, 2010) http://www.nola.com/katrina/articles/citys_fate_sealed_in_hours.html.
[56] *Id.*
[57] *Id.;* Jennifer Welsh, *Meteorologist Predicts Sandy Could Cost More than Katrina*, BUSINESS INSIDER (Oct. 31, 2012) http://www.businessinsider.com/meteorologist-predicts-sandy-could-cost-more-than-katrina-2012-10.
[58] *Background Information*, U.S. ARMY CORPS OF ENGINEERS: NEW ORLEANS DISTRICT (last visited June 15, 2015) http://www.mvn.usace.army.mil/Missions/HSDRRS/RiskReductionPlan.aspx.
[59] *Id.*
[60] Michael Abramowitz and Peter Whoriskey, *New Orleans Honors Its Dead,* WASHINGTON POST (Aug. 30, 2006) http://www.washingtonpost.com/wp-dyn/content/article/2006/08/29/AR2006082900515.html.

the failure of the levees.[61] Historically, prior to the enactment of the Federal Tort Claims Act (FTCA) in 1946, which waived the government's immunity for certain tort actions, it was “a well settled rule of law that the government [was] not liable for the nonfeasances or misfeasances or negligence of its officers, and that the only remedy to the injured party in such cases is by appeal to Congress.”[62] The FTCA’s waiver of government immunity, however, has an exception called the “Discretionary Function Exception” and it shields the federal government “whether the allegedly tortious decision was ‘based on considerations of public policy”’ or “incorporates considerable ‘policy judgment.”[63]

This exception became extremely important during litigation following the aftermath of Hurricane Katrina when a suit was filed by local residents for negligence actions against the United States and the Corps under the FTCA’s waiver of immunity.[64] The heart of the complaint was that the Corps was liable for damage because the levee system was negligently “designed, constructed, and maintained”, and assertions were made that the injury to the Plaintiff's resulted from a highly predictable and preventable disaster.[65] In the district court case, the Judge found the Corps negligent and liable for the damages sought by the Plaintiff’s, ruling that the exception articulated above did not apply because “[i]n the event the Corps’ monumental negligence here would somehow be regarded as “policy” then the exception would be an amorphous incomprehensible defense without any discernable contours”.[66]

On appeal, the Fifth Circuit applied a de novo standard of review to the district court's finding, and initially affirmed the district court's finding that the government negligently

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[61] *Id.*
[62] German Bank v. United States, 148 U.S. 573, 579 (1893).
[63] Berkovitz v. United States, 486 U.S. 531 (1988).
[64] In re Katrina Canal Breaches Consol. Litig., 647 F.Supp.2d 644 (E.D. La. 2009).
[65] *Id.*
[66] *Id.* at 717

maintained the levee system by failing to provide timely foreshore protection.[67] This victory for the plaintiffs was short-lived, however, as six months after finding that the government was not immune from suit, the Fifth Circuit abruptly withdrew the previous opinion.[68] In this opinion, the Court determined that the Corps was immune from suit, and dismissed the claim.[69] Legal scholar's claim that this reversal was "confusing, unprincipled, and lacks reasoned analysis."[70] Regardless of the decision, however, this high-profile case captured the public's attention, placing Corps' decision-making regarding flood risk squarely in the spotlight.

Like all federal and state agencies, the Corps has to make decisions regarding project implementation and risk management in the context of budgetary constraints. As a result, the planning and application of project ideas has to be performed in a manner that acknowledges the potential problems with securing adequate funding to complete the project in a holistic manner that ideally treats entire systems as connected rather than constructing projects using a non-systems approach. However, even with budget constraints, non-systems management approaches are not always a necessity. In order to understand the Corps and the management strategies that they invoke, an assessment of these strategies in this context will be performed with an attempt to see if an evolution is occurring within the agency to move away from non-systems approach management, within and outside of the Mississippi River Basin.

Corps wetland permitting process is directly related to flood risk management, as wetland degradation can exasperate the impacts of high flow events by destroying natural buffers that mitigate major flooding. As a result, a case involving wetland permitting that

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[67] In re Katrina Canal Breaches Consol. Litig., 673 F.3d. 381, 386 (5th Cir. 2012).
[68] In re Katrina Canal Breaches Litig., 696 F.3d 436, 441 (5th Cir. 2012).
[69] *Id.* at 454.
[70] Christopher R. Dyess, *Off With His Head: The King Can Do No Wrong, Hurricane Katrina, and the Mississippi River Gulf Outlet*, 9 NW J. L. & SOC. POL'Y 302, 324 (2014).

occurred prior to Hurricane Katrina will be used as a tool to indicate the Corps' interest in non-systems approaches to management decisions impacting flood risk.[71] In this case, the Corps granted three separate permits for a three-phase project by a developer that involved the filling of wetlands in central California.[72] Environmental groups sued, claiming the Corps had violated the National Environmental Policy Act (NEPA) by separating the three projects and assessing individual impacts rather than assessing them in a more cumulative fashion.[73] The Ninth Circuit allowed this non-systems approach to wetland permitting and management in this particular case despite longstanding precedent suggesting a cumulative analysis was necessary.[74] More importantly for this discussion, however, is that the Corps failed to consider the wetland permitting as a holistic system in their analysis of the total environmental impact, reflecting a non-systems approach to wetland permitting that has very little to do with funding constraints.

In the New Orleans area leading up to Katrina, scholars indicate that a piecemeal approach to flood risk management was invoked by the Corps.[75] According to these scholars, compromises in the ability of this system to perform adequately started with the decisions regarding the fundamental design criteria for the development of the system, then were propagated through time as alternatives for the system were evaluated and engineered.[76] As a result, the design, construction, operation, and maintenance of the system in a piecemeal fashion allowed the introduction of additional flaws and defects, trading efficiency for quality.[77] Thus, while individual parts of this particular system could have been adequate, when these parts were

[71] Wetlands Action Network v. U.S. Army Corps of Engineers, 222 F.3d 1105 (9th Cir. 2001).
[72] *Id.* at 1110–1111.
[73] *Id.*
[74] *Id.* at 1123; Keith H. Hirokawa, *The Gap Between Informational Goals and the Duty to Gather Information: Challenging Piecemealed Review Under the Washington State Environmental Policy Act*, 25 SEATTLE U. L. REV. 343, 367–68 (2001).
[75] Daniel A. Farber et al., *Reinventing Flood Control*, 81 TUL. L. REV. 1085, 1104 (2007).
[76] *Id.*
[77] *Id.*

joined together to form an "interactive-interdependent-adaptive system", unforeseen but foreseeable failures developed.[78] According to these scholars, it was evident that insufficient attention was given to creation of an integrated series of components to provide a reliable flood risk management system in New Orleans.[79] This is another example of Corps management that occurred using a non-systems approach rather than viewing the system in a holistic fashion.

According to other scholars, the Corps is very reluctant to participate in the process of setting priorities for its projects, leaving to Congress to decide through the appropriations process the projects that will and will not receive funding.[80] This "agnosticism", as the scholars put it, on priorities deprives congressional decision makers of crucial contextual information regarding the relative seriousness of proposed projects.[81] This encourages non-systems approach, project-by-project congressional decision making, when a more comprehensive approach is required that "integrates flood control, hurricane protection, coastal restoration, ecosystem preservation, and mitigation projects within a single framework."[82] The full information needed regarding one of the major canal projects in New Orleans was difficult to perceive, according to these scholars, when its implications were analyzed only using a non-systems approach.[83]

In an effort to assess whether the Corps has evolved following Hurricane Katrina, a brief look at a few case studies will be assessed. The first, coming from the Chesapeake Bay, involves

[78] *Id.*
[79] *Id.*
[80] Douglas A. Kysard & Thomas O. McGarity, *Did NEPA Drown New Orleans? The Levees, the Blame Game, and the Hazards of Hindsight*, 56 DUKE L.J. 179, 231–232 (2006).
[81] *Id.*
[82] *Id.*
[83] *Id.*

an oyster restoration plan developed by the Corps in 2012.[84] While this does not directly involve flood risk management, it still is helpful in assessing any change in mentality by the agency. The study took a scientific look at where limited resources can have the most impact and provides recommendation for future work.[85] Scientists in the region, at least at that time, differed on the best way to restore oysters in the Chesapeake, which have seen significant declines.[86] Water depth, industrial uses around the Bay, substrate restoration, and salinity levels are all factors in improving the health of the species.[87] Perhaps most importantly for this discussion, the Corps directly communicated that this management plan is a bay-wide, holistic plan that moves past piecemeal efforts and selects targets for large-scale efforts.[88] While this is just one small example, it is important to acknowledge that the Corps has begun to communicate about these issues in a different manner.

By contrast, along the Allegheny River outside of Pittsburgh during the same time period, the Corps was accused of managing the locks system using a non-systems approach, leading to closures in locks for recreational boat usage.[89] While the Corps indicated that this management decision was based solely on funding, it still created significant economic problems in the region.[90] While certainly there are components of the project not represented in this article, the general public sentiment towards the Corps in the region is reflective of non-systems approach management.

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[84] Alex Dominguez, *Chesapeake Oysters Restoration Plan Unveiled by Army Corps of Engineers*, HUFFINGTON POST (Apr. 11, 2012), http://www.huffingtonpost.com/2012/04/11/chesapeake-oysters-restoration-plan_n_1417362.html.
[85] *Id.*
[86] *Id.*
[87] *Id.*
[88] *Id.*
[89] Brigid Beatty, *Allegheny River Locks 6 and 7 Closed for Recreational Boating*, TRIBLIVE (Oct. 12, 2012) http://triblive.com/news/armstrong/2759509-74/lock-locks-river-recreational-allegheny-commercial-corps-hawk-boats-changes#axzz3cW43oVAQ.
[90] *Id.*

Two years later, in the portion of the Mississippi River between St. Louis and the Ohio River, local citizen groups again accused the Corps of taking a non-systems approach to management of a river system.[91] The Corps in this region proposed four projects to reduce dredging costs and keep the river navigable.[92] The structures used have been linked to increased flood heights by some academics, and the citizens groups filed a suit accusing the Corps of not taking new studies and information into account when preparing impact studies for projects.[93] In the suit, the groups requested the judge to order the Corps to expand the scope of its studies and look at the entirety of its activities on the Mississippi River, rather than using a non-systems approach.[94] The Court determined that the injunctive relief that the plaintiffs pursued would be too costly to the Corps, and that "merely establishing a procedural violation of NEPA does not compel the issuance of a preliminary injunction".[95] Thus, the District Court did not agree with the notion that a more holistic assessment of the system was necessary in order to appropriately move forward with the project.[96]

Prior to Hurricane Katrina, the Corps had seemingly developed a reputation of pursuing project development using a non-systems management approach, rather than at a holistic level. Some commentators have expressed that this tactic was a large contributing factor to the destruction seen in New Orleans in 2005. While a slow evolution could be occurring, it is important to recognize the history of relatively slow management changes and how this understanding applies to Columbia River Basin management.

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[91] Jacob Barker, *Environmental Groups Sue Army Corps of Engineers*, ST. LOUIS POST-DISPATCH, (May 22, 2014), http://www.stltoday.com/business/local/environmental-groups-sue-army-corps-of-engineers/article_54ad7071-ee72-5d8f-a406-986b7971c3eb.html.
[92] *Id.*
[93] *Id.*
[94] *Id.*
[95] Nat'l Wildlife Fed'n v. U.S. Army Corps of Engineers, 2014 WL 6685235, NO. 14-590-DRH-DGW (S.D. Ill. 2014).
[96] *Id.* at *16.

The historical prioritization by the Corps of implementation of structural measures in an effort to take away opportunities for natural flows to cause damages was a direct result of floodplain development and legislative mandates to protect riparian communities as a part of the agency's mission. This attempt to control the river through these measures, however, has led to concerns expressed by the public about the role that the Corps perhaps has had in exasperating flood events to magnitudes that otherwise would not have been seen. Regardless of the validity of this position, this section was intended to show why hesitancy could exist within the Corps to allow for higher flows, in fear that this could lead to more damages and negative publicity. The seemingly safer and more confident management tactic from the Corps' perspective is to keep flows at a more restrictive level, even at the expense of other water resource needs. As an important player in the Columbia River Treaty review, this unwillingness to further research the possibilities of flexibility is a deterrent to future compromise between the two countries.

II. Factors Pushing Changes in Flood Risk Management

In order to understand why flood risk management policy is likely going to change irrespective of the information gathered in this research, several factors will be discussed that are pushing these changes. This section is useful in the context of this research because it outlines the importance and value of further research in the Basin to determine the flow at which flood damages actually begin to occur because flood risk management is being influenced by other factors. Even without the pressing need to develop compromises between divisive positions among the United States and Canada in the context of the Columbia River Treaty, the United States government and its agencies have other factors to consider as to why this type of study is necessary. Among these are legal, non-structural risk management opportunities, and an improved understanding of the ecological benefits of more "natural" flow regimes.

A. FEMA's NFIP and the Endangered Species Act

While past examples of flood damages stemming largely from structural management could be considered factors pushing agencies and stakeholders towards an interest in more flexible flood risk management decisions, it is clear that prior to structural flood risk development, flooding in more unmanaged systems was the initial stimulation for structural implementation. In order to provide a more nuanced reason as to why a flow study is necessary by the Corps in the Columbia River Basin, an analysis will follow of a critically important judicial opinion that made a clear and unequivocal connection between flood risk management decisions and the health of endangered species.

Even in the face of a nearly six-fold increase in flood damages over the past century despite billions of dollars in investments in flood control measures, floodplain development continues to rapidly grow throughout the United States.[97] While these management decisions are having significant economic and social impacts throughout the country, the lack of access to floodplains for many species is contributing significantly to a decline in health and survivability.[98] Besides providing very important contributions to broad ecosystem health, healthy floodplains provide refuge for juvenile salmon to avoid high flow volume and velocities, allowing them to rear as long as necessary and conserve energy for their entry to the ocean.[99] They also inundate and create access to spawning and rearing habitat during high flow

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[97] *No Adverse Impact Floodplain Management*, Association of State Floodplain Managers, http://www.floods.org/index.asp?menuID=349&firstlevelmenuID=187&siteID=1 (last visited Feb. 27, 2015).
[98] National Oceanic Atmospheric Administration, *The Importance of Healthy Floodplains to Puget Sound Salmon*, (2011) https://www.fema.gov/pdf/about/regions/regionx/importance_of_healthy_floodplains_by_NMFS.pdf.
[99] *Id.*

seasons, and the groundwater storage and recharge process reduces the likelihood of high-energy flood events that can scour away salmon nests during the winter months.[100] Decisions made regarding floodplain development impact salmon populations significantly, and the interaction between these decisions and ecological health cannot be understated.

The Endangered Species Act, one of the most influential pieces of environmental legislation in United States history, has wide-ranging impacts across the spectrum of policy decisions that the original authors undoubtedly could not have foreseen. One such example is the Federal Emergency Management Agency's (FEMA) National Flood Insurance Program. As a direct result of claims brought by environmental organizations in the Pacific Northwest, a program focused on the anthropocentric impacts of flooding has to consider the impacts to species that rely heavily on floodplain habitat for survival and proliferation.

i. Endangered Species Act

During the 1970's, the United States saw a wave of interest in environmental protection and federal legislation responded accordingly.[101] One piece of legislation that remains remarkably relevant today is the Endangered Species Act of 1973 (ESA).[102] Supreme Court Chief Justice Burger called the ESA "the most comprehensive legislation for the preservation of endangered species ever enacted by any nation."[103] Congress found that species' possessed "esthetic, ecological, educational, historical, recreational, and scientific value to the Nation and its people"[104] and enacted the ESA "to provide a means whereby the ecosystems upon which

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[100] *Id.*
[101] Davina Kari Kaile, *Evolution of Wildlife Legislation in the United States: An Analysis of the Legal Efforts to Protect Endangered Species and the Prospects for the* Future, 5 GEO. INT'L ENVTL. L. REV. 441, 444–45 (1992).
[102] Pub. L. No. 93-205, 87 Stat. 884 (codified as amended at 16 U.S.C. §§ 1531-34 (1988)).
[103] Tennessee Valley Auth. v. Hill, 437 U.S. 153, 176 (1978).
[104] Pub. L. No. 93-205 Sec. 2(A)(3).

endangered species and threatened species depend may be conserved . . . ."[105] This policy was to be pursued "whatever the cost."[106]

The Secretary of the Interior is required to determine whether any species is "endangered" or "threatened" and to designate critical habitat for such species.[107] The ESA requires all federal agencies, in consultation with the Secretary of the Interior, to carry out programs for the conservation of endangered and threatened species.[108] These agencies must insure that any "agency action" is "not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification" of such species' critical habitat.[109] If the Secretary concludes, after consultation, that the proposed action will likely jeopardize the species, then the Secretary may suggest "reasonable and prudent alternatives" that the Secretary believes will not result in violations of the ESA.[110]

Additionally, the ESA makes it unlawful for any person to "take" any wildlife or fish that are listed.[111] The term "take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct."[112] Additionally, the United States Supreme Court has determined that the definition of "harm," within the meaning of ESA provision defining "take," as including "significant habitat modification or degradation that actually kills or injures wildlife" is reasonable.[113]

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[105] Pub. L. No. 93-205 Sec. 2(B).
[106] Tennessee Valley Auth. v. Hill, 437 U.S. at 184.
[107] *Id.* at 160.
[108] *Id.*
[109] *Id.*
[110] *Id.*
[111] *Id.* at 184–85.
[112] *Id.*
[113] Babbitt v. Sweet Home Chapter of Communities for a Greater Oregon, 515 U.S. 687, 706 (1995).

1. The Requirement of Federal Consultation

In the present case, the most pertinent section of the ESA is section 7(a)(2), which states that "[e]ach Federal agency shall, in consultation with and with the assistance of the Secretary, insure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered species or threatened species."[114] Section 7(a)(2) imposes a procedural duty on the "action agency"[115] to consult with the "consultation agency" if the agency's action "may affect" a listed species.[116] However, no formal consultation is required if, as a result of the preparation of a biological assessment[117] or as a result of informal consultation with the National Marine Fisheries Service,[118] the action agency determines, with the confirmation of the National Marine Fisheries Service, that the proposed action may affect but "is not likely to adversely affect" the listed species.[119] If the consultation agency finds the action is likely to jeopardize the species, the regulations require that formal consultation be undertaken.[120]

The action agency initiates formal consultation through a written request to the consultation agency[121] and as part of this process, the consultation agency prepares a biological opinion to determine whether the action is likely to jeopardize the continued existence of a listed species.[122] In making its jeopardy determination, the consulting agency evaluates "the

[114] Pub. L. No. 93-205 Sec. 7.
[115] Generally, the United States Fish and Wildlife Service is responsible for terrestrial and freshwater aquatic species while the National Marine Fisheries Service is responsible for listed marine mammals, anadromous fish, and other living marine resources. U.S. Fish and Wildlife Service, *Chapter 1 Endangered Species Act and Incidental Take Permits* 1-3, available at http://www.fws.gov/endangered/esa-library/pdf/HCPBK1.PDF.
[116] Turtle Island Restoration Network v. Nat'l Marine Fisheries Serv., 340 F.3d 969, 974 (9th Cir. 2003).
[117] 50 C.F.R. § 402.1215
[118] 50 C.F.R. § 402.13
[119] 50 C.F.R. § 402.14(b)(1).
[120] Pacific Rivers Council v. Thomas, 30 F.3d 1050, 1054 (9th Cir. 1994).
[121] 50 C.F.R. § 402.14(c).
[122] 50 C.F.R. § 402.14(g)(4).

current status of the listed species or critical habitat," the "effects of the action," and "cumulative effects."[123] "Effects of the action" include both direct and indirect effects of an action "that will be added to the environmental baseline."[124] The environmental baseline includes "the past and present impacts of all Federal, State or private actions and other human activities in the action area" and "the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation."[125] If the biological opinion concludes that jeopardy is not likely and that there will not be adverse modification of critical habitat, or that there is a "reasonable and prudent alternative" to the agency action that avoids jeopardy and adverse modification and that the incidental taking of endangered or threatened species will not violate section 7(a)(2), the consulting agency can issue an "Incidental Take Statement" which, if followed, exempts the action agency from the prohibition on takings.[126] If a jeopardy finding is made, the consultation agency will describe "reasonable and prudent alternatives" that the agency can take to avoid a likelihood of jeopardy.[127]

Agency actions are subject to Section 7(a)(2)'s consultation requirements only if "there is discretionary Federal involvement or control."[128] "[W]here ... the federal agency lacks the discretion to influence the private action, consultation would be a meaningless exercise; the agency simply does not possess the ability to implement measures that inure to the benefit of

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[123] 50 C.F.R. § 402.14 (g)(2)–(3).
[124] 50 C.F.R. § 402.02.
[125] *Id.*
[126] Aluminum Co. of America v. Bonneville Power Admin., 175 F.3d 1156, 1159 (9th Cir. 1999).
[127] 50 C.F.R. § 402.14(g)(5).
[128] 50 C.F.R. § 402.03.

the protected species."[129] In other words, "[w]here there is no agency discretion to act, the ESA does not apply."[130]

2. Listing

As stated above, the Secretary of the Interior is required to determine whether any species is "endangered" or "threatened" and to designate critical habitat for such species.[131] The ESA requires all federal agencies, in consultation with the Secretary of the Interior, to carry out programs for the conservation of endangered and threatened species.[132] In the specific case being analyzed in this section, the species at issue was the Puget Sound Chinook salmon.[133] The reasons for listing and the habitat requirements for this particular species are relevant to many anadromous fish species, and thus are important to assess for future applicability to other cases involving endangered anadromous fish species and floodplain development.[134]

3. Impacts of Floodplain Management on Chinook Salmon

Access to a healthy, viable floodplain is key to the survival of many anadromous fish species. The specific management decisions that have occurred within floodplains have been

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[129] Sierra Club v. Babbitt, 65 F.3d 1502, 1509 (9th Cir. 1995).
[130] Natural Resource Defense Council v. Houston, 146 F.3d 1118, 1125–26 (9th Cir. 1998). However, this language has had some controversial applications. The National Marine Fisheries Service used what the Ninth Circuit characterized as a "novel" and unsupportable "analytical sleight of hand" in defining the environmental baseline in a jeopardy analysis in a later case in which the agency was attempting to apply this discretion test. NMFS included in its environmental baseline the existence of dams on the Columbia River along with what it determined were nondiscretionary dam operations, and all past and present impacts from discretionary dam operations. Importantly, the NMFS concluded that certain aspects of these dam operations were nondiscretionary, given the existence of the dams and the obligations of the Army Corps of Engineers and the Bureau of Reclamation under federal flood control, irrigation, and power generation statutes. The Ninth Circuit rejected this approach, and ruled that the "ESA does not permit agencies to ignore potential jeopardy risks by labeling parts of an action nondiscretionary." Nat'l Wildlife Fed'n v. Nat'l Marine Fisheries Serv., 481 F.3d 1224 (9th Cir. 2007).
[131] Bennett v. Spear, 520 U.S. 154, 157 (1997).
[132] *Id.*
[133] Nat'l Wildlife Fed'n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d 1151, 1153–54 (W.D. Wash. 2004).
[134] Nat'l Marine Fisheries Serv., U.S. Dep't of Commerce, *NMFS Tracking No. 2006/00472, Endangered Species Act--Section 7 Consultation: Final Biological Opinion And Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation Puget Sound Region* (2008), available at http://online.nwf.org/site/DocServer/NMFS_Puget_Sound_nfip-final-bo.pdf?docID=10561 [hereinafter Final Bi-Op].

damaging to these species. One particularly damaging floodplain management process is the construction of levees.[135] Levees serve to diminish floodplain storage of water during floods by pushing the flooding farther downstream, confining the river within a walled in channel and adding pressure to extend the levee.[136] The channelization of the river prevents it from moving across the floodplain, which does not allow for the support of the natural processes of channel migration that create the areas that shelter juvenile salmon.[137]

Additionally, barriers to fish passage and adverse effects on water quality and quantity resulting from dams, the loss of wetland and riparian habitats, and agricultural and urban development activities in efforts to manage and control floodplain development have contributed and continue to contribute to the loss and degradation of various fish habitats.[138] The modification of these fundamental natural processes that allow habitat to form and recover from severe natural disturbances has been devastating to anadromous fish populations.[139] Many scientists believe that salmonid conservation can be achieved only by maintaining and restoring natural floodplain regimes at their natural rates.[140] In addition to the impacts of levees and other riparian modifications, development within the floodplain results in significant impacts to salmon habitat by channelizing the stream, removing important vegetation, and creating point and non-point source pollution.[141] All of these developments cause hydrologic instability, which provides a direct link to biological losses.[142]

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[135] *Id.* at 4.
[136] *Id.*
[137] *Id.*
[138] Final Bio-Op, *supra* note 134 at 4.
[139] *Id.* at 51.
[140] Washington Department of Fish and Wildlife, *Land Use Planning for Salmon, Steelhead, and Trout: A Land Use Planner's Guide to Salmonid Habitat Protection and Recovery* 66 (2009), http://wdfw.wa.gov/publications/00033/wdfw00033.pdf.
[141] Final Bi-op, *supra* note 134 at 63.
[142] *Id.* at 95.

Functional floodplains moderate high flows by substantially increasing the area available for water storage, by allowing water to seep into the "groundwater table during floods, recharging wetlands, off-channel areas, shallow aquifers, and the hyporheic zone."[143] Wetlands, aquifers, and the hyporheic zone then give back to the aquatic system by releasing water to the stream during the summer months through a process called hydraulic continuity.[144] This process is crucial because it ensures adequate flows for salmonids during the summer months, and reduces the possibility of high-energy flood events that can destroy salmonid nests during the winter months.[145] Floodplains generally contain side-channels and other features that provide important "spawning habitat, rearing habitat, and refugia during high flows, and may be used by rearing salmonids for long periods of time depending upon the species."[146] Off-channel areas provide habitat for juvenile salmonids to hide from predators and conserve energy and contain an abundance of food with fewer predators than would typically be found in the river.[147] Examples of this reliance can be found in the Skagit and Stillaguamish Basins, where more than half of the total salmonid habitat is contained within the floodplain and estuarine deltas while this habitat encompasses only ten percent of the total basin area.[148] Poor floodplain management has led to an overall decline in quality freshwater habitat, which is the primary reason for the listing of the Chinook salmon on the ESA.[149]

ii. <u>FEMA National Flood Insurance Program</u>

FEMA is the federal agency charged with administering the National Flood Insurance Program (NFIP), a federal flood insurance program that was created by Congress in 1968 by

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[143] *Id.* at 55.
[144] *Id.*
[145] *Id.*
[146] *Id.* at 103.
[147] Final Bio-Op, *supra* note 134 at 103.
[148] *Id.*
[149] *Id.* at 53.

the National Flood Insurance Act (NFIA), later amended by the Flood Disaster Protection Act of 1973 and again in 1994 by the National Flood Insurance Reform Act.[150] The purposes of the flood insurance program are to make flood insurance "available on a nationwide basis through the cooperative efforts of the Federal Government and the private insurance industry" and to base flood insurance "on workable methods of pooling risks, minimizing costs, and distributing burdens equitably among those who will be protected by flood insurance and the general public."[151]

The three basic components of the NFIP are: (1) the identification and mapping of flood-prone communities, (2) the requirement that communities adopt and enforce floodplain management regulations that meet certain minimum eligibility criteria in order to qualify for flood insurance, and (3) the provision of flood insurance.[152] As part of the NFIP, FEMA also implements a Community Rating System ("CRS"), which provides flood insurance premium discounts in communities that establish floodplain management programs that go above NFIP's minimum eligibility criteria.[153]

Use of flood insurance has grown under the NFIP, from approximately $30 billion in floodplain insurance coverage nationwide in 1978, to approximately $1.2 trillion in floodplain insurance coverage in 2008.[154] The NFIP is a voluntary program, but participation is heavily encouraged using extreme incentivizing measures.[155] These incentives include ensuring that "[m]ortgages that are federally insured or from regulated banks are unavailable for properties

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[150] 42 U.S.C. § 4001 (2014).
[151] 42 U.S.C. § 4001(d).
[152] Nat'l Wildlife Fed'n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d at 1155.
[153] *Id.*
[154] BergerABAM et al., *Floodplains and Fish–Endangered Species Act and the National Flood Insurance Program* (2011) http://www.washington-apa.org/assets/docs/stateconferencepresentations/floodplains_and_fish.pdf.
[155] *Id.*

in the Special Flood Hazard Area (SFHA) in non-participating communities", a "[p]rohibition of federal loans and grants for construction in the SFHA in non-participating communities", and "[l]imitations on disaster assistance for non-participating communities".[156]

Congress authorized FEMA "to identify and publish information with respect to all flood plain areas, including coastal areas located in the United States, which have special flood hazards" and "to establish or update flood-risk zone data in all such areas, and make estimates with respect to the rates of probable flood caused loss for the various flood risk zones for each of these areas."[157] In order to carry out this authorization, FEMA assesses the flood risk within each flood-prone community by conducting a Flood Insurance Study that typically employs the use of models and techniques, and presents the results of the study on a map referred to as a Flood Insurance Rate Map and also in a narrative format.[158] The flood risk information presented in the developed report serves as the technical basis for the administration of the NFIP by FEMA.[159] As part of the original federal legislation creating the NFIP, FEMA is required to review flood maps at least once every five years to assess the need to update all floodplain areas and flood risk zones.[160] In addition, FEMA has promulgated regulations governing the development and revision of flood maps.[161]

iii. <u>Application of Statutory Interaction to Cases</u>

The intersection between the ESA and NFIP is the source of the controversy in the case at hand, and the specificity of this connection will be discussed to show the breadth of the issue.[162] Three primary elements of the NFIP (floodplain mapping, minimum eligibility criteria,

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[156] *Id.*
[157] 42 U.S.C. § 4101(a)(1) (2014).
[158] Nat'l Wildlife Fed'n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d at 1155.
[159] *Id.*
[160] 42 U.S.C. § 4101(e) (2014).
[161] *See e.g.,* 44 C.F.R. § 65.5 (2014).
[162] Nat'l Wildlife Fed'n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d at 1153–54.

and the CRS) are most impactful to the ESA, and these will be discussed at length.[163] These elements will be discussed in the context of a chronological timeline involving court and agency decisions. The development of these claims help to provide the basis for future floodplain management and the interactions that will inherently occur with ecosystem functions.

1. 2004 NWF v. FEMA

The National Wildlife Federation (NWF) and Public Employees for Environmental Responsibility (PEER) brought an Endangered Species Act (ESA) lawsuit against the Federal Emergency Management Agency (FEMA), alleging that FEMA had violated Section 7(a)(2) of the ESA by not consulting with the National Marine Fisheries Service (NMFS) on the impacts of the National Flood Insurance Program (NFIP) on the Puget Sound Chinook salmon, a threatened species.[164] The NWF is "a voice for wildlife, dedicated to protecting wildlife and habitat and inspiring the future generation of conservationists . . ." and PEER "works nation-wide with government scientists, land managers, environmental law enforcement agents, field specialists and other resource professionals committed to responsible management of America's public resources."[165]

These co-plaintiffs sought a declaration that FEMA violated the ESA and an injunction requiring formal consultation with NMFS as a result of FEMA's implementation of the NFIP because some aspects of the program allegedly encourage development in the floodplains, and the floodplains of the Puget Sound provide important habitat for the salmon.[166] The suit was brought in the Western District of Washington, with the claim for relief originating in the Puget

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[163] Final Bio-Op, *supra* note 134 at 83.
[164] Nat'l Wildlife Fed'n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d at 1154.
[165] National Wildlife Federation, *Who We Are*, (Nov. 29, 2014) http://www.nwf.org/Who-We-Are.aspx; Public Employees for Environmental Protection, *About Us*, (Nov. 29, 2014) http://www.peer.org/about-us/.
[166] Nat'l Wildlife Fed'n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d at 1155.

Sound region.[167] This region contains Puget Sound Chinook salmon, which are listed on the Endangered Species list and are thus subject to federal protection.[168] As was discussed earlier, Chinook salmon and many other anadromous fish species rely on floodplains during juvenile life stages.[169] Functional floodplains moderate high flows by substantially increasing the area available for water storage, by allowing water to seep into the "groundwater table during floods, recharging wetlands, off-channel areas, shallow aquifers, and the hyporheic zone."[170] Wetlands, aquifers, and the hyporheic zone then give back to the aquatic system by releasing water to the stream during the summer months.[171] This crucially important process ensures adequate flows for salmonids during the summer months, and reduces the possibility of high-energy flood events that can destroy the nests of salmonids during the winter months.[172] The plaintiffs claim that "through its implementation of the National Flood Insurance Program, FEMA promotes, encourages, and influences human development in Puget Sound floodplains, impairing essential habitat functions of imperiled Chinook salmon."[173] The defendants of course "deny that FEMA's implementation of the NFIP promotes or encourages human development in Puget Sound floodplains and thereby impairs habitat for Puget Sound Chinook salmon."[174]

a. "Discretionary Agency Action"

The first section of the Court's analysis discussed whether the National Flood Insurance Act (NFIA), which created the NFIP, allows FEMA sufficient discretion in order to invoke the

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[167] *Id.* at 1154.
[168] Final Bi-op, *supra* note 134 at 27.
[169] *Id.* at 22.
[170] *Id.* at 55.
[171] *Id.*
[172] *Id.*
[173] Complaint, Nat'l Wildlife Fed'n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d 1151 (W.D. Wash. 2004) (No. CV03-2829), 2003 WL 23955269.
[174] Answer of Intervenor Defendants National Association of Home Builders, et al., Nat'l Wildlife Fed'n v. Federal Emergency Mgmt. Agency, 345 F.Supp.2d 1151 (W.D. Wash. 2004) (No. CV03-2824Z), 2004 WL 2994225.

"discretionary agency action" requirement of section 7(a)(2) of the ESA.[175] This is considered to be a critically important facet of the decision, and is given significant space and time in the opinion.[176] As was discussed, agency actions are subject to Section 7(a)(2)'s consultation requirements only if "there is discretionary Federal involvement or control."[177] The Court assessed 9th Circuit precedent to determine whether the facts indicate that NFIP allows for discretionary agency action by FEMA.[178] The Court discusses how the NFIP influences the management of an entire ecosystem on an ongoing basis, which is similar to the facts from a case where an agency was found to have discretion.[179] In that case, an environmental group brought action against the United States Forest Service, alleging violation of ESA respecting impact of forest activities on Chinook salmon and the Court of Appeals held that Forest Service's land resource management plans for timber sales, range activities, and road building projects in forests constituted "ongoing agency action" throughout their duration for purposes of ESA requirement that Forest Service consult with NMFS on effect of agency action on chinook salmon once NMFS listed Chinook salmon as threatened species.[180] The Management Plans were considered actions that "may affect" the protected salmon because the plans set forth criteria for harvesting resources within the salmon's habitat.[181] The Court concludes that the present case involves a continuing agency action similar to the *Pacific Rivers Council* case because FEMA's passage of the minimum eligibility criteria, the mapping of floodplains, and the implementation of the CRS have ongoing effects extending beyond their mere approval.[182]

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[175] Nat'l Wildlife Fed'n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d at 1168–69.
[176] *Id.*
[177] 50 C.F.R. § 402.03.
[178] Nat'l Wildlife Fed'n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d at 1168–1175.
[179] Pacific Rivers Council v. Thomas, 30 F.3d 1050, 1054 (9th Cir. 1994).
[180] *See generally id.*
[181] *Id.* at 1055.
[182] Nat'l Wildlife Fed'n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d at 1169–1170.

Additionally, similar to the *Natural Resources Defense Council* case, the Court states that a stated environmental purpose is not necessary if the action agency otherwise has discretion to act in such a way that could benefit the endangered and threatened species.[183] The Court then states that "[i]ndeed, most federal agency actions would not be subject to the formal consultation process under Section 7(a)(2) if the ESA only applied to agency actions where the agency was already compelled by statute to protect listed species."[184] Additionally, a narrow interpretation of the section of the ESA would directly contradict with the interpretation of the section by the United States Supreme Court and the Ninth Circuit.[185] Furthermore, the Court determines that the issue is whether the NFIA gives sufficient discretion to FEMA so that FEMA *could* implement the NFIP to benefit the Puget Sound Chinook salmon, not whether FEMA *must* implement the NFIP to benefit the fish.[186] The Court then states that one of the purposes of the NFIP is to preserve natural floodplain functions that benefit salmon, as it authorizes FEMA to guide development away from locations threatened by flood hazards.[187]

The Court then looks at language in the NFIA that states that FEMA "shall consult with other departments and agencies of the Federal Government . . . in order to assure that the programs of such agencies and the flood insurance program authorized under this chapter are mutually consistent."[188] It is determined that the "shall consult" language gives FEMA discretion and appears to require FEMA to consult with other agencies, such as NMFS, to ensure that the NFIP is implemented in a manner that is "mutually consistent" with NMFS's programs.[189] As a result, the Court held that FEMA has discretion to act for the benefit of the

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[183] *Id.* at 1172; Natural Resource Defense Council v. Houston, 146 F.3d at 1118.
[184] Nat'l Wildlife Fed'n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d at 1172.
[185] *Id.*
[186] *Id.*
[187] *Id.*; 42 U.S.C. § 4001(e)(2).
[188] Nat'l Wildlife Fed'n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d at 1172; 42 U.S.C. § 4024.
[189] Nat'l Wildlife Fed'n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d at 1173.

Puget Sound Chinook salmon in implementing the NFIP and thus consultation with the NMFS is ordered.[190] Due to the complexity of the NFIP and the vagueness of "implementation of the NFIP" as a way to describe the agency action at issue, the Court examined the component parts of the NFIP to determine whether FEMA has discretion with respect to each part.[191] To gain a better understanding of the Court's decision and to understand at a deeper level the intimate interaction between the two statutes, an analysis of each component follows.

FEMA argued that its mapping of a floodplain is based solely on a technical evaluation of the base flood elevation.[192] The Court, however, disagrees with this self-assessment, and claims that "FEMA has used its discretion to map the floodplain in a way that allows persons to artificially fill the floodplain to actually remove it from its floodplain status, and thus from regulatory burdens."[193] The increased development from the FEMA decisions in flood risk areas provides a short-term economic benefit with potentially long-term adverse consequences to the floodplain and providing channel function for salmonid habitat.[194] FEMA acknowledged that fill placed in the floodplain removes the property from a mapped flood area through a "Letter of Map Revision Based on Fill", thus incentivizing property owners to place sufficient fill to elevate their buildings above the base flood elevation because property within the floodplain can be "mapped out" of the floodplain and thereby removed from the jurisdiction of the NFIP's insurance requirements.[195] This mapping process is done almost entirely based on topography, meaning that virtually any increase in elevation using fill can lead to an exclusion

[190] *Id.*
[191] *Id.*
[192] *Id.*
[193] *Id.*
[194] Final Bi-Op, *supra* note 134 at 84.
[195] *Id.*

of certain areas from being considered within the floodplain.[196] Through this process, FEMA rarely considers the dynamic nature of the area or the effect of development, which can be deeply detrimental to the ecosystem.[197]

As was discussed above, placing fill to elevate properties and building levees to trigger floodplain map revisions are "detrimental to floodplain and channel function, as lands that are periodically flooded provide safe off-channel refugia for rearing juvenile salmonids during periods of high flow when mainstem channels cannot be occupied, functions essential to decrease mortality in juvenile salmonids."[198] FEMA's mapping program also does not "identify and protect the channel migration zone which provides important functions for salmonids."[199] According to the reasons outlined, the Court determines that there is nothing in the NFIA authorizing FEMA to allow filling activities to change the contours of the natural floodplain, and with the process of mapping that is strictly based on topography with no distinctions for artificially created topography, the process actually incentivizes the filling of floodplain habitat.[200]

According to the Court, in developing the minimum eligibility criteria, the NFIA authorizes FEMA to guide development of proposed construction away from locations threatened by flood hazards and to "otherwise improve the long-range land management and use of flood-prone areas."[201] As has been discussed, to participate in the NFIP, a community

[196] *See generally* Ashley Williams, *Floodplain Delineation Methodology Utilizing LiDAR Data with Attention to Urban Effects, Climate Change, and Habitat Connectivity in Lapwai Creek, Idaho*, (2011), http://wrp.nkn.uidaho.edu/lapwaicwis/pdf/Williams_Thesis.pdf.
[197] Larry Larson & Doug Plasencia, *No Adverse Impact: A New Direction in Floodplain Management Policy*, Natural Hazards Review, 2(4), 167-181 (2001).
[198] Final Bi-Op, *supra* note 134 at 84.
[199] *Id.*
[200] Nat'l Wildlife Fed'n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d at 1173.
[201] 42 U.S.C. § 4102(c)(2).

must adopt minimum floodplain management criteria established by FEMA.[202] Some minimum criteria encourages activities that are ecologically harmful, and result in conditions that adversely affect salmon and their habitat.[203] For example, the NFIP allows unlimited development across the floodplain, except in the floodway, as long as the developed areas are either at or above the level of the 100-year flood or protected by levees with at least 100-year protection.[204] As a result, the Court determined that FEMA must consult on its minimum eligibility criteria because FEMA has discretion to amend its regulations and those regulations have an ongoing impact on the use of floodplains in the area.[205]

As discussed previously, CRS is a voluntary program through which Congress has mandated that FEMA provide discounts on flood insurance premiums to communities that have made the decision to implement flood management regulations that exceed FEMA's minimum criteria.[206] Though the program is voluntary, it is "authorized" and "carried out" by a federal agency in a way that may adversely affect the Puget Sound Chinook salmon.[207] The influence of the CRS on the development in floodplains is unclear although some evidence suggests that the impact of the CRS may be confined largely to minimizing flood damage, reducing repetitive claims, and increasing awareness of flood risk and strategies for structural mitigation rather than salmon habitat protection.[208] For example, CRS credit is given for the construction of "barriers, including levees, berms, and floodwalls, channel modifications, including enlarging

[202] Nat'l Wildlife Fed'n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d at 1156.
[203] Final Bi-Op, *supra* note 134 at 88.
[204] *Id.*
[205] Nat'l Wildlife Fed'n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d at 1174.
[206] Final Bi-Op, *supra* note 134 at 89.
[207] *Id.*
[208] *Id.*

bridges and culverts . . .” among other structures, all of which can be harmful to salmon floodplain habitat.[209]

As a result of this component-by-component analysis of the NFIP, the Court held that the NFIA confers discretion on FEMA to implement the NFIP in a manner that would consider the well-being of the Puget Sound Chinook salmon, with the exception of the part of the program that deals with the actual sale of flood insurance.[210] Thus, the Court held that “FEMA's implementation of the NFIP, with the exception of the actual sale of flood insurance, is a discretionary “agency action” for the purposes of Section 7(a)(2) of the ESA.”[211]

b. Agency action that “may affect” listed species

The next issue the Court analyzes in determining whether the NFIP triggers the ESA's formal consultation requirement is determining whether the implementation of the NFIP “may affect” the Puget Sound Chinook salmon.[212] “Any possible effect, whether beneficial, benign, adverse, or of an undetermined character, triggers the formal consultation requirement.”[213] FEMA contends that there was not a reason to believe that the NFIP “may affect” Chinook salmon.[214] In response, NWF points to a 1998 letter from NMFS to FEMA which NMFS itself opined that the NFIP may lead to increased development that negatively affects salmon: “NMFS . . . believes it is appropriate for FEMA to consult with NMFS regarding [FEMA's disaster assistance] programs, as required by Section 7 of the Endangered Species Act. In particular, we are aware that the National Flood Insurance Program (NFIP), as currently

[209] *Id.*
[210] Nat’l Wildlife Fed’n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d at 1174.
[211] *Id.*
[212] *Id.*; 50 C.F.R. § 402.14(a).
[213] 51 Fed. Reg. 19,926, 19,949 (June 3, 1986) (final rule 50 C.F.R. pt. 402).
[214] Federal Defendant’s Combined Cross-Motion for Summary Judgment and Opposition to Plaintiffs’ Motion for Summary Judgment, Nat’l Wildlife Fed’n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d 1151 (W.D. Wash. 2004) (No. 203CV02824) 2004 WL 5562407.

implemented by FEMA, could result in increased development in flood-prone areas with consequent impairment of floodplain functions of salmon bearing waters."[215] The Court determines that FEMA's argument has little validity, and states that "there is substantial evidence in the administrative record showing that FEMA's implementation of the NFIP "may affect" the Puget Sound Chinook salmon, thus triggering the formal consultation requirement of Section 7(a)(2) of the ESA."[216]

In summary, the Court concluded that FEMA had "violated Section 7(a)(2) of the ESA by failing to consult with NMFS to ensure that: (1) the regulations establishing the minimum eligibility criteria for the NFIP, (2) the mapping of the floodplains, and revisions thereof, and (3) the CRS are not likely to jeopardize the continued existence of the Puget Sound Chinook salmon."[217] Additionally, the Court determined that "FEMA must initiate consultation with NMFS on the impacts of its implementation of the NFIP—specifically on the impacts of the minimum eligibility criteria, the mapping of the floodplains, and revisions thereof, and the CRS—on the Puget Sound Chinook salmon, within 60 days of the entry of this Order. FEMA need not initiate consultation with NMFS on the impacts of the actual sale of flood insurance, either directly or through third parties, on the Puget Sound Chinook salmon."[218]

The opinion by the Court was thorough and well-reasoned, which was a necessity considering the complexity of the claim due to the intersection between two relatively dense statutes. The NFIP was undoubtedly promoting development in the floodplain throughout Western Washington, and this development was clearly having detrimental impacts on listed fish species in the region. This claim helped to clarify how these two statutes were interacting,

[215] Nat'l Wildlife Fed'n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d at 1175–76.
[216] *Id.* at 1176–77.
[217] *Id.* at 1177.
[218] *Id.*

and the opinion helped to determine the importance of ESA consultation in future implementation of the NFIP. The main two disputed facets of the claim, whether the action was an "agency action" for ESA purposes and whether the action was a direct enough cause of potential harm to the listed species were correctly decided by the Court, and it provides much guidance for future NFIP implementation and for other agencies, such as the Army Corps of Engineers, who are working in floodplains.

c. Causation for purposes of standing

Standing must be found in order for a claim to move forward, so this determination is critical. Because causation is a valuable component of future applicability to flood risk managers, it will be briefly discussed. This component of the decision further judicially cements the clear legal connection between floodplain management and the health of endangered species articulated in the "may affect" analysis seen above.

The second facet of standing under the *Lujan* Court's Article III standing analysis requires that there must be a causal connection between the injury and the conduct complained of.[219] In the present case, this component of the standing analysis is arguably the most important facet of the Court's analysis, as it was likely the largest barrier for the plaintiffs to gain the recovery that they sought. In this analysis, a "federal court can only redress injury that fairly can be traced to the challenged action of the defendant, and not injury that results from the independent action of some third party not before the court."[220] In other words, it is futile to tie up court time with cases where there is no possible solution for the person or entity harmed. In this particular case, one argument that could be made regarding the lack of causation is that the harm is caused by private development, not FEMA. Another argument that could be made for

[219] Lujan v. Defenders of Wildlife, 504 U.S. 555 (1992).
[220] Simon v. Eastern Ky. Welfare Rights Org., 426 U.S. 26, 41-42 (1976).

a lack of causation is that FEMA causes the harm but cannot do anything about it because Congress has not left it with any discretion to reduce the harm.

To meet the causation requirement of the standing analysis, the injury must be fairly traceable to the actions of the defendant.[221] In one case, ranchers and irrigation districts sufficiently alleged that their injury from reduced water for irrigation was fairly traceable to United States Fish and Wildlife Service's (FWS) biological opinion proposing use of reservoir water relied on for their water supply to protect endangered species of fish.[222] In that case, the Court determined that despite the wide use by environmentalists of the expanded standing doctrine, plaintiffs attempting to restrict environmental regulation also have access to the utilization of the doctrine.[223]

As discussed above, the injury-in-fact must be "fairly traceable to the challenged action of the defendant."[224] This causation requirement is the second prong of the analysis that stems from the *Lujan* standing test.[225] During the Court's discussion of whether the causation prong was met, it focused primarily on comparing the facts to a case involving an injury to birds that was held to be "fairly traceable" to a ban on the use of leghold traps because the removal of the traps would likely lead to a larger population of predators, which would subsequently decrease the local population of birds.[226] In that case the Court held that the length of chain of causation is not the issue, but rather the plausibility of the links that comprise the chain in determining causation.[227] Using these facts, the Court concluded that NWF had provided sufficient evidence showing that the injury to salmon caused by third party developers of floodplains is not too

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[221] Pritikin v. U.S. Dep't of Energy, 254 F.3d 791, 797 (9th Cir. 2001).
[222] Bennett v. Spear, 520 U.S. 154, 166 (1997).
[223] *Id.*
[224] Friends of the Earth v. Laidlaw Envtl. Services, 528 U.S. at 180–81.
[225] Lujan v. Defenders of Wildlife, 504 U.S. at 562.
[226] Nat'l Audubon Soc'y v. Davis, 307 F.3d 835, 849 (9th Cir. 2002).
[227] *Id.*

tenuously connected to the acts of FEMA in implementing the NFIP.[228] This was crucially important, because FEMA claimed that the actions being taken that were harming the endangered species present were out of their control, which would have caused a failure of standing for the plaintiffs.[229] During this analysis, the Court pointed to acknowledgement by FEMA that communities that do not participate in the NFIP may experience "severely restricted" economic development to show that the community that made the decision to develop in the floodplain was under pressure from the defendants, helping to show that the link between the NFIP and the development was not too tenuous to meet the requirements for standing.[230]

The Court again appropriately applied this prong of the standing analysis. The chain of causation in this case is extremely plausible, as the impacts of the NFIP in the region were significant and the floodplain developments have been scientifically proven to have significant impacts on the Chinook salmon. Without FEMA making the discretionary decision to promote floodplain development, the frequent and destructive development would have been much less likely to have occurred, as financial incentives existed to actually develop areas that would otherwise be extremely expensive and impractical. The Court correctly used a case with arguably a less traceable causal link that was found to be enough to satisfy the second prong of the standing analysis to indicate that this chain of causation was plausible. Additionally, the analysis in this case helped to continue to establish precedent that allows claims to survive lack of standing assertions as long as the action and result are relatively closely connected.

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[228] Nat'l Wildlife Fed'n v. Fed. Emergency Mgmt. Agency, 345 F.Supp.2d at 1165.
[229] *Id.* at 1163.
[230] *Id.*

iv. Implementation Following NWF v. FEMA

Following the decision in 2004 by the Western District of Washington federal court, FEMA implemented a biological opinion, which was created by the NMFS and outlined the reasonable and prudent alternatives that could be implemented by FEMA to avoid future ESA issues.[231] The implementation of these alternatives was challenged by National Wildlife Federation in 2014, and the implementation by FEMA was upheld by the same Court.[232] Thus, the types of changes that were required can be conceivably relied upon in future floodplain management decisions. Also important was the settlement between NWF and FEMA that occurred in another U.S. state in the Columbia River Basin, where FEMA essentially agreed to implement the alternatives in the biological opinion stemming from the decision in Washington federal court in the state of Oregon.[233] This is critically important, because it continued to show the recognition by the federal government of the link between flood risk management and endangered species.

While this case and the cases that followed involved some nuance and creativity by the plaintiffs, it did send a clear message to all agencies and entities involved in flood risk management. Courts have explicitly recognized the intimate link between floodplain management and the impacts on endangered species, causing all future decisions to consider the impacts of decisions on these species.[234] This certainly includes flow management as determined by the U.S. Army Corps of Engineers and other state and federal agencies in the

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[231] Final Bi-Op, *supra* note 134 at 3.
[232] Nat'l Wildlife Fed'n v. Fed. Emergency Mgmt. Agency, No. C11–2044–RSM, 2014 WL 5449859 at *5 (W.D. Wash. Oct. 24, 2014).
[233] Settlement Agreement and [Proposed] Order, Audubon Soc'y of Portland v. Fed. Emergency Mgmt. Agency, No. 3:09-cv-729-HA at *2 (D. Or. July 9, 2010).
[234] This was expanded to also include some terrestrial species as well, so fish are not the only endangered species that can be impacted by floodplain development. *See* Florida Key Deer v. Stickney, 864 F.Supp. 1222 (S.D. Fla. 1994).

region. This factor will undoubtedly be strongly considered moving forward, and stimulates further need to research whether flows could have more flexibility in the Columbia River Basin, irrespective of the need to develop opportunities for compromise in the context of the Treaty.

B. Non-structural flood control possibilities

Another factor pushing for changes in flood risk management are the opinions and perspectives of scholars and experts on the potential for implementation of non-structural measures around the globe. Similar to the above discussion regarding the lawsuit between FEMA and the NWF, this belief that non-structural flood control possibilities can be effective flood risk management tools is a factor irrespective of the Treaty review process that should stimulate the Corps to desire further research and analysis in the Columbia Basin. Gone are the days when structural measures are considered the only way to avoid flood damages, and research further developing and describing potential alternatives is extremely relevant to the goals of this research.

In order to fully understand the possibilities for non-structural flood control measure implementation and the considerations that should exist in the Columbia River Basin to diversify flood risk management, an assessment of international and domestic research will be briefly performed. Some experts in the field consider non-structural flood approaches to flood management to naturally fall into two categories.[235] The first of these categories includes those anticipatory measures which can be assessed, defined and implemented in the floodplains to reduce the risk to property from identifiable future floods.[236] This can include solutions such as improved flood forecasting, control of floodplain development, and flood proofing

[235] J. (Hans) Van Duivendijk, *The systematic approach to flooding problems*, 55(S1) IRRIGATION AND DRAINAGE S55–S74 (2006).
[236] *Id.*

structures.[237] The second of these categories, and perhaps the less preferred, is those planned emergency response measures which are applied when a damaging flood is forecast, imminent or under way, to help mitigate its damaging effects.[238] This can include actions such as flood fighting, and ensuring that these measures are well prepared to appropriately mobilize resources, train and prepare personnel, and ensure public participation well in advance of an actual flood event.[239] The Columbia River Basin is a finely managed system, but as research indicates, "abatement of all floods is not economically feasible."[240] Additionally, researchers have said that "[f]requently flooded areas have been affected by the over-reliance on structural measures, which usually have the goal of changing the direction of water flow along natural and artificial channels with the aim of minimizing extreme water flow."[241] This can lead to "risk transference", which essentially postpones or transfers potential risks to the future, exchanging short-term benefits for long-term problems.[242] Due to these limitations, non-structural flood control measures should be prioritized to limit the amount of economic harm seen throughout the Basin. In order to successfully implement these measures partnership building, improvement of riparian health, and improved planning technologies seem to be a necessity.

i. Cohesive partnerships and collaboration across diverse sectors and entities seem to lead to more successful and holistic implementation of non-structural flood control measures.

A common theme throughout the research involving non-structural flood control measure implementation in flood-prone areas was the prioritization of cohesive partnerships

[237] *Id.*
[238] *Id.*
[239] *Id.*
[240] Bahram Saghafian et al., *Monte Carlo analysis of the effect of spatial distribution of storms on prioritization of flood source areas*, 66(2) NATURAL HAZARDS 1059 (2013).
[241] Richard Ingwe, *Flood Resilience and Sustainable Development in Urban Nigeria: Integrating Traditional and Non-structural Methods of Mitigating and Adapting to Flooding in Cross River State, South-Eastern Nigeria*, XI(11) RISCURI ŞI CATASTROFE 127, 138 (2012).
[242] *Id.*

across sectors and levels of government in order to ensure consistent applications of successful measures. In particular, some research indicates that public-private partnerships are a fundamental component of successful implementation of non-structural flood control measures.[243] In one study, researchers in Nigeria concluded that community institutions and non-government/civil society organizations should lead public institutions in promoting flood resilience using non-structural measures, and that this would lead to more successful environmental governance.[244] Partnerships across sectors and levels of government are important in lots of natural resource management policy decision-making, but the widespread impact and importance of buy-in at all levels seems to make it particularly important in the implementation of non-structural flood control measures. In the context of the Columbia River Basin, this would involve increase collaborative efforts between federal agencies like the U.S. Army Corps of Engineers coordinating efforts with local flood control districts.

ii. Improving riparian health is a crucial non-structural flood control measure that can have significant impacts on improvement of areas prone to flooding.

Of the non-structural flood control measures discussed in the peer-reviewed research, managing floodplain development and improving riparian health is seemingly the most effective and impactful method of reducing flood damages in flood-prone regions. Some research emphasized the importance of preventing urbanization and farmland development in floodplains, as this led to significant increases in economic losses from high flow events.[245] In this example, a watershed in Iran is selected as a case study, and the authors determine that the system reacts well to riparian development that includes forestation and range vegetation

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[243] ABHAS K. JHA ET AL., CITIES AND FLOODING: A GUIDE TO INTEGRATED URBAN FLOOD RISK MANAGEMENT FOR THE 21ST CENTURY 513 (The World Bank, 2012).
[244] Ingwe, *supra* note 241.
[245] Ghanbarpour M. Reza, *Evaluation of flood mitigation alternatives using hydrological modeling*, 11(4) JOURNAL OF APPLIED SCIENCES AND ENVIRONMENTAL MANAGEMENT 113, 113-117 (2007).

cover.[246] The importance of land-use control and intelligent floodplain development is confirmed in a research study performed in Bangladesh.[247] In this case study, the authors indicate that structural engineering has been given too much emphasis in flood risk management, and that non-structural flood control measures should be provided more emphasis.[248] In this example, the authors actually indicate that farmers and communities that embraced high flows and planned for their arrival could actually reap the rewards of nutrient increases from deposited sediment into the floodplain for improved yields.[249] While the idea of intelligent floodplain design and restricted development could lead to decreased economic damages might not be revolutionary, it is important to confirm these ideas through peer-reviewed research. These ideas help to guide floodplain managers and allow for an increased emphasis on non-structural proactive flood risk measures.

iii. The ability to accurately predict and understand flood risk will promote resiliency and develop an ability to quickly respond to high flow events.

Another common theme throughout the peer-reviewed research was the perceived need to improve flood mapping and other planning technologies. In a study performed in another watershed that connects Canada and the United States, reactions to major flooding in the Red River Basin led to an assessment of priorities to ensure that similar events do not repeat themselves in the future.[250] In this case, the researchers indicated that improved mapping with more precise topographical information was important, along with making this information more publicly accessible for use.[251] While the topography of the Red River Basin is certainly

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[246] *Id.*
[247] Frederico Neto, *Alternative approaches to flood mitigation: a case study of Bangladesh,* 25(4) NATURAL RESOURCES FORUM 285, 285-297 (2001).
[248] *Id.*
[249] *Id.*
[250] Slobodan P. Simonovic & Richard W. Carson, *Flooding in the Red River Basin – Lessons from Post Flood Activities*, 28 NATURAL HAZARDS 345, 345–365 (2003).
[251] *Id.*

different than that of the Columbia, this research does emphasize the importance of the most modern, effective mapping technologies to ensure appropriate measures are taken in the floodplain. In China, researchers identified flood mapping and risk area delineation as a crucially important step in the process of decreasing flood-related damages in the floodplain.[252] This study placed more of an emphasis on prevention of deaths in rural river basins throughout China, which is slightly different than contemporary Columbia Basin flood risk management, but the emphasis placed improved flood prediction technologies is still relevant. Additionally, some researchers emphasize that "the role of nonstructural measures in flood control planning depends upon the scale of the problem, the nature of the measure, the degree of protection desired, and whether damage is to existing or future property."[253] This study indicates the importance from an engineering perspective of compatible technology and research with local infrastructure plans to ensure the creative, effective use of non-structural flood control measures in any basin.[254] Generally, this research seems to suggest that non-structural measures can be effective and important tools for flood risk management and economic loss reduction, but careful planning and improved technology must be a priority.

C. Ecosystem Impacts of Flexible Flood Risk Management

Another factor pushing for changes in flood risk management is the increasing amount of research and information indicating the ecological benefits of a more flexible flood risk management regime. While the impacts of dams on natural systems has been well-known for years, recent scholarship suggests significant ecological consequences to restricting flows in a

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[252] Dongya Sun et al., *Framework of National Non-Structural Measures for Flash Flood Disaster Prevention in China*, 4(1) WATER 272, 272–282 (2012).
[253] William K. Johnson & Daryl W. Davis, *The Hydrologic Engineering Center Experience in Nonstructural Planning*, 20(1) JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION 15, 15–22 (1984).
[254] *Id.*

significant manner. This section will explore briefly such ecological consequences in an effort to indicate the need for the Corps to explore the possibilities of incorporating more flexibility into flows in the Columbia Basin in order to achieve optimal ecological health.

i. Water Quality Impacts

Water quality impacts stemming from floodplain management decision-making can be significant. It is important to research and understand the negative impacts on water quality from the replacement of grassland or forest cover with agricultural or urban development in floodplains. Additionally, research indicates that certain water quality parameters improve when systems are able to have adequate access to floodplains. While most systems see improved water quality conditions resulting from increased flooding, certain ecological systems can see tremendous water quality degradation from these events.

Current trends throughout the world involve converting grasslands to row crop agriculture, creating a critical need to evaluate the effects of land use on groundwater quality in large river floodplain systems.[255] In a study performed in the Cedar River floodplain in Iowa, the relationship between groundwater hydrology and nutrient infiltration associated with grassland, floodplain forest and cropland cover types were assessed.[256] The objective of the study was to evaluate variations in groundwater hydrology and quality with the goal of quantifying changes in groundwater quality following a land conversion from grassland to row crop in a floodplain.[257] The research indicated that nitrogen levels were significantly higher in groundwater sites beneath cropped sites relative to the sites that were grassland as a primary

[255] Keith E. Schilling et al., *Agricultural conversion of floodplain ecosystems: Implications for groundwater quality*, 153 JOURNAL OF ENVIRONMENTAL MANAGEMENT 74, 74-83 (2015).
[256] *Id.*
[257] *Id.*

result of increased nitrogen usage for the agricultural activities.[258] While it might seem intuitive that increases in nitrogen applications due to transitions from grasslands to agricultural crop land would lead to increased nutrient loads in water quality, it is still crucially important that research exists that confirms this idea. This suggests the importance of management decisions that proactively prevent or reduce the amount of agricultural development in riverine floodplain systems. However, it is important to note that some researchers have found that the type of agriculture practiced in the floodplain can make a significant difference.[259] This can be applied to other development in floodplains as well, such as urban or suburban developments that contribute high amounts of toxic substances into the watershed.

Another study was conducted in a shallow floodplain adjacent to the Coldwater River in Tunica County, Mississippi.[260] This study compared water quality during an artificial flooding period with pre-flood and post-flood periods.[261] Flooding was simulated by pumping water from the river into the upstream portion of the backwater, and water quality parameters were assessed during the different events.[262] Temperature, pH, dissolved oxygen, conductivity and fluorescent chlorophyll decreased within the backwater during flooding events, and are all important parameters in assessing overall stream health.[263] Very generally, the study indicated that artificial flooding in a floodplain stabilized and improved water quality for the entire system and can potentially provide for a viable habitat rehabilitation mechanism in these systems.[264] This is important, as it shows that flooding and access to floodplains for riverine systems has a

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[258] *Id.*
[259] E.S. Brooks, S. Saia & J. Boll, *Assessing BMP Effectiveness and Guiding BMP Planning Using Process-Based Modeling*, 51(2) JAWRA 343-358 (2015).
[260] R.E. Lizzotte, Jr. et al., *Effects of Artificial Flooding on Water Quality of a Floodplain Backwater*, 28(10) RIVER RESEARCH AND APPLICATIONS 1644, 1644-1657 (2012).
[261] *Id.*
[262] *Id.*
[263] *Id.*
[264] *Id.*

crucial ecological function. In this system, it was clear that parameters indicating overall health and quality were improved when the river was given adequate access to its floodplain.

A study performed in floodplains in southwestern Georgia supported the conclusions from the above studies regarding the importance of thoughtful floodplain development and the value of nutrient additions to water quality from allowance of flood events.[265] The watersheds that were studied were human-dominated, with row-crop agriculture and managed forestlands serving as the major land uses in the area.[266] Suspended particles, nitrogen, and soluble reactive phosphorus concentrations, which can be considered undesirable nutrient additions to a stream, were greater during wet and flood periods compared with dry and drought periods for each stream.[267] However, the authors do indicate that lack of floodplain access can lead to a scarcity of biologically important materials, such as organic carbon, originating from floodplain forests.[268] Additionally, the study indicated that although substantial human land use occurred within all of the watersheds studied, water quality was generally adequate, which was attributed to relatively intact floodplain forests.[269] In addition to providing the important inputs such as organic carbon, this intact floodplain reduces and prevents nonpoint-source pollutants from entering the stream through biological and physical absorption.[270] While this study did show an increase in certain types of nutrients from flooding events, it importantly shows the value of prevention of floodplain agricultural development and shows the value of nutrient inputs from these systems.

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[265] Stephen W. Golladay and Juliann Battle, *Effects of Flooding and Drought on Water Quality in Gulf Coastal Plain Streams in Georgia*, 31(4) JOURNAL OF ENVIRONMENTAL QUALITY 1266, 1266-72 (2002).
[266] *Id.*
[267] *Id.*
[268] *Id.*
[269] *Id.*
[270] *Id.*

By contrast, however, some flooding events in certain ecosystems can have detrimental effects on water quality. A study suggesting precisely that was performed after a decade-long drought in southeastern Australia when a series of spring and summer flood events resulted in a large-scale hypoxic blackwater event in the Murray–Darling Basin.[271] These hypoxic blackwater events are characterized by "high levels of dissolved organic carbon in the water column which leads to a decrease in dissolved oxygen, often resulting in fish and crustacean mortality".[272] The causes of these events in this particular system was the inundation of forested and agricultural floodplains that had not been flooded for over a decade, which caused large stores of reactive carbon to gain access to the stream.[273] The findings from this study suggest an exception to the conclusions stemming from the other studies cited above, as particularly arid regions where flood events are extremely rare can actually lead to significant problems related to water quality degradation. This is significant in the relatively arid Columbia River Basin, and should be a potential consideration when determining how quickly flows could be increased.

In conclusion, while studies have been shown to indicate a mix of positive and negative impacts to water quality stemming from increased river access to floodplains, the majority of the studies analyzed indicated that increasing flows would typically lead to improvements in key parameters used often in the hydrologic community to determine stream health. However, it is important to acknowledge and understand the ecological systems that serve as narrow exceptions to these general ideas.

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[271] Kerry L. Whitworth et al., *Drought, floods and water quality: Drivers of a severe hypoxic blackwater event in a major river system (the southern Murray–Darling Basin, Australia)*, 450 JOURNAL OF HYDROLOGY 190, 190-98 (2012).
[272] *Id.*
[273] *Id.*

ii. Fisheries Impacts

The study of freshwater fisheries is crucially important for ecological and economic reasons across the globe. The impacts of floodplain development and management on these often-sensitive ecosystems is important to research and analyze. Fisheries are impacted by floodplain access through a myriad of ways, with entire lifecycles from birth to death being affected by the choices made to either allow or disallow natural flow regimes and flooding events to occur and persist. Numerous studies have been performed to assess these impacts, and will be analyzed in the following section.

A document provided by the Washington Department of Fish and Wildlife helped to start this analysis.[274] This document suggests that salmonid conservation can be achieved only by maintaining and restoring natural floodplain regimes at their natural rates.[275] In addition to the impacts of levees and other riparian modifications, development within the floodplain results in significant impacts to salmon habitat by channelizing the stream, removing important vegetation, and creating point and non-point source pollution.[276] All of these developments cause hydrologic instability, which provides a direct link to biological losses.[277] The Washington Department of Fish and Wildlife recommends the prohibition of new dikes, levees, and other alterations to the floodplain in order to protect sensitive anadromous fish populations throughout the state.[278]

A study performed in the floodplain wetlands of the Xe Champhone River, an important tributary of the Mekong River in southern Lao, indicated that frequent dewatering of floodplains

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[274] *Washington Department of Fish and Wildlife, Land Use Planning for Salmon, Steelhead, and Trout: A Land Use Planner's Guide to Salmonid Habitat Protection and Recovery*, http://wdfw.wa.gov/publications/00033/wdfw00033.pdf (accessed March 8, 2015).
[275] *Id.*
[276] *Id.*
[277] *Id.*
[278] *Id.*

can be destructive to fish communities.[279] In this region, floodplain wetlands are frequently dewatered for the purposes of crop irrigation and fish harvesting.[280] Many wetlands were drained and fished repeatedly in a single dry season, with catches declining by 72% on average between consecutive dewatering events.[281] This research indicates that floodplain manipulation that disallows river access significantly impacts fisheries, as the quantity of fish found prior to the floodplain dewatering was significantly higher than following consecutive dewatering events.

Another study showcased the significant impacts that flow regimes and floodplain access can have on fisheries. This study analyzed the Atchafalaya River Basin in south-central Louisiana, which functions as a tributary for the Mississippi River to the Gulf of Mexico.[282] In this study, the impact of the annual flood regime on fisheries production was assessed.[283] The authors modelled flood duration and magnitude against fishery data on largemouth bass, crappie, blue catfish, buffalofish, gizzard shad and crayfish.[284] When the Atchafalaya River is at flood stage for a lengthy period, the annual relative abundances of largemouth bass, crappie, blue catfish and buffalofish were the healthiest during the fall of the year.[285] However, gizzard shad abundance was at its healthiest during low flow years, when flood duration was less than ten days in a year.[286] Generally the results indicate that annual flood regimes can be managed to optimize the availability of many fish throughout the watershed.[287] While this research shows

[279] Sarah M. Martin et al., *Impacts of fishing by dewatering on fish assemblages of tropical floodplain wetlands: A matter of frequency and context*, 144(1) BIOLOGICAL CONSERVATION 633, 633-640 (2011).
[280] *Id.*
[281] *Id.*
[282] J.B. Alford and M.R. Walker, *Managing the flood pulse for optimal fisheries production in the Atchafalaya River Basin, Louisiana*, 29(3) RIVER RESEARCH AND APPLICATIONS 279, 279-296 (2013).
[283] *Id.*
[284] *Id.*
[285] *Id.*
[286] *Id.*
[287] *Id.*

relative variance in the responses in the fisheries in the river system based on flow and access to the floodplain, it certainly emphasizes the overall impact that these flow regimes can have on fisheries. This study was prepared to assess ways to optimize fisheries for commercial production, but it is certainly applicable to decisions made for ecosystem management purposes as well.

In yet another study indicating the importance of floodplain protection and responsible management, the impact of floodplain manipulation on fish biodiversity was assessed in Bangladesh.[288] The authors indicate that floodplains are nutrient rich and play a significant role as nurseries for many larvae and juvenile fish species.[289] From 1970 to 2003, the annual inundation of approximately 2–3 million hectares of floodplain in Bangladesh had been either prevented altogether, or controlled by gates, pumps or levees.[290] This reduction in floodplain area is often given as one of the reasons for declining floodplain fisheries in Bangladesh.[291] In this case, a dramatic reduction in the volume of water flowing in the three principal river systems in Bangladesh (the Brahmaputra, Ganges, and Meghna Rivers) caused the area of the floodplains to significantly decrease, which led to the decline in fish quantity and biodiversity.[292] This case study again emphasizes and confirms other research conclusions regarding the value of floodplain access and allowance of high flow events to fisheries in the system.

Much of the research cited above has suggested a need to allow a more natural flow regime with less anthropocentric manipulation of these river systems. However, some research

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[288] Gertjan de Graaf and Felix Marttin, *Mechanisms behind changes in fish biodiversity in the floodplains of Bangladesh*, 11(5) WETLANDS ECOLOGY AND MANAGEMENT 273, 273-280 (2003).
[289] *Id.*
[290] *Id.*
[291] *Id.*
[292] *Id.*

exists that actually promotes the use of “artificial” or man-made infrastructure to improve floodplain or wetland access in order to improve survivability and health of fisheries. In the Chehalis River of Washington, research was performed to assess the impacts of “enhanced” and “unenhanced” emergent wetlands in the floodplain on juvenile salmonids.[293] In this study, several species of juvenile salmonids were researched to determine the relative impacts of access to these floodplain areas on survivability.[294] The research determined that the “enhanced” wetlands improved survivability significantly, as they allowed for fish emigration and a longer hydroperiod for rearing.[295] The ability to have access to emigrate is key to survival, because as flows decrease these areas can begin to become uninhabitable for salmonids due to low dissolved oxygen levels among other factors.[296] This is important, because it again supports the notion that floodplain access for salmonids and other fish is crucial for survival. However, this article also differentiates between “enhanced” and “unenhanced” wetlands, suggesting that survivability was much lower in the “unenhanced” wetlands because of lower connectivity to the mainstem, which as mentioned allows for fish emigration when conditions in the floodplain are potentially lethal.[297] This suggests that rather than a system free from manipulation, that improving access to these floodplain areas using development of ecologically-thoughtful engineering can lead to improved survivability and health for certain types of fisheries. With a shifting climate impacting flow regimes throughout the Basin, this type of recognition is even more critically important.

[293] Julie A. Henning et al., *Juvenile Salmonid Use of Freshwater Emergent Wetlands in the Floodplain and Its Implications for Conservation Management*, 26(2) FISHERIES MANAGEMENT 367, 367-376 (2006).
[294] *Id.*
[295] *Id.*
[296] *Id.*
[297] *Id.*

While small-scale research articles focusing on specific components of the impacts of floodplain development and poor management techniques are important and can collectively have significant impacts on the larger problem, it is also important to consider macro-level solutions that can effectively create positive, substantive change. An example of such a program was thoroughly analyzed by researchers in Bangladesh.[298] The Community Based Fisheries Management program is a project that allows communities to rally together to help make decisions regarding fisheries management to ensure long-term sustainability of the species.[299] In particular in countries such as Bangladesh where government structures have failed to adequately manage fisheries to ensure high rates of survivability, programs that empower communities and individuals to take control over decisions help to move forward ever-important dialogue about the future of the resource. In the past, similar to most floodplains around the globe, agricultural and other forms of development in this region have been prioritized over fisheries protection, which has led to a decline in overall fisheries health.[300] In order to attempt to reverse this trend, a collaborative effort by governmental agencies, non-governmental organizations, and an international research center attempted to empower local communities through several actions, most notably creating local fishery management bodies that prepared plans and undertook actions to better manage their local fisheries.[301] While the actual results of this improved dialogue and increased empowerment on actual survivability of fish stocks was not significant, it still seems to be a step towards a more productive and inclusive management mechanism, components of which should be emulated in floodplain communities

[298] Paul M. Thompsona et al., *Lessons from community based management of floodplain fisheries in Bangladesh*, 69(3) JOURNAL OF ENVIRONMENTAL MANAGEMENT, 307, 307-321 (2003).
[299] *Id.*
[300] *Id.*
[301] *Id.*

around the globe. Perhaps the phenomenon of "too many cooks in the kitchen" contributed to the lack of actual fisheries improvements in this scenario.

As can be seen from the variance in locations and specific subject matter being researched, floodplains have significant impacts on overall fisheries health and quantity of stock. Much of the research cited indicates that allowing the river adequate, uncontrolled access to its floodplain can provide significant improvements in survivability of juvenile salmonids and other fish. In addition to allowing a more natural flood regime, some managed flows have been shown to actually improve survivability through the allowance of emigration from potentially lethal areas during lower flows. Additionally, it is also important to assess and analyze creative mechanisms that allow for localized control over fisheries systems to ensure that the individual communities most impacted by floodplain management decisions have an opportunity to be involved in the decision-making process.

iii. Waterfowl Impacts

In addition to the impacts on water quality and fisheries, floodplain management can significantly affect waterfowl populations that rely on these freshwater systems for survival. De-channelization and increasing flows have shown to improve waterfowl habitat, leading to increases in survivability of adolescents and an increase in total individuals present in surveyed plots. While increased flows certainly is not the only solution to improved waterfowl populations, it provides significant support to the creation of healthy, viable populations.

The first article analyzed on this subject comes from a restoration project on the Kissimmee River in Florida.[302] This research performed comes in the midst of a multi-year

[302] Michael D. Cheek et al., *Interim Response of Wading Birds (Pelecaniformes and Ciconiiformes) and Waterfowl (Anseriformes) to the Kissimmee River Restoration Project, Florida, U.S.A.*, 22(3) RESTORATION ECOLOGY 426, 426-434 (2014).

project attempting to improve the aquatic health of the freshwater ecosystem using controlled construction techniques to reestablish historic vegetation communities, naturally fluctuating water levels, and seasonal hydroperiods.[303] At the time of the published research, multiple aerial surveys had been performed following significant de-channelization efforts, and abundance and species richness of waterfowl had shown a positive restoration response.[304] Additionally, the authors indicate that undesirable non-native species have been negatively impacted by the initial restoration efforts, which will help to improve native waterfowl populations further.[305] This study shows that by restoring the system to a semblance of its original floodplain hydrology, waterfowl populations will respond virtually immediately in a positive manner.

In a research study focusing on a specific species coming out of the Mississippi River in southeastern Missouri, mallard ducks were found to be significantly impacted by flooding regimes during certain times of the year.[306] In this particular aquatic system, flooding events seemingly triggered ecologically valuable events for mallard ducks, increasing forage abilities and improving other components of wintering habitat.[307] While this study also analyzed mallard duck evolutionary reactions to different changes in events, for purposes of this paper the most impactful component of the research focuses on the value of floodplain access by the river for survivability of mallard ducks.[308] This emphasizes the importance of floodplain management that prioritizes the ability for natural flow regimes to occur in these systems.

To continue to emphasize the value of floodplain management decisions that allow for natural flood regimes to waterfowl, a study published in 1967 was assessed to diversify

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[303] *Id.*
[304] *Id.*
[305] *Id.*
[306] Mickey E. Heitmeyer, *The Importance of Winter Floods to Mallards in the Mississippi Alluvial Valley Full Access*, 70(1) JOURNAL OF WILDLIFE MANAGEMENT 101, 101–110 (2006).
[307] *Id.*
[308] *Id.*

geographically and temporally the range of studies confirming these conclusions.[309] In the Ottawa River, a permanent rise of six feet in water level led to significant changes in the floodplain ecology.[310] In addition to significant changes in vegetation, breeding waterfowl pairs increased six-fold per mile following the higher water levels.[311] This shows that for decades research indicates that increased flows in river systems lead to improved ecological systems, which promotes breeding and survivability for waterfowl.

The last study briefly analyzed regarding the impacts to waterfowl from proper floodplain management was performed by a civil engineer in California.[312] This perspective is important, because it broadens the scope of expertise from scientists strictly looking at ecological impacts of flooding and increased access to floodplains on ecological systems to one that also encompasses the anthropocentric impacts of these events. In this article, the author showcases from the perspective of an engineer the value of access to floodplains for river channel capabilities, but also emphasizes the value of floodplains to waterfowl.[313] This recognition of the importance of relatively natural flood regimes to natural systems from the perspective of an engineer is a crucially important addition to this conversation, and should not be undervalued.

As can be seen throughout this brief review of floodplain management impacts on waterfowl, a relatively clear connection between increased flows and improved access to floodplains for river systems leads to improved habitat and survivability for waterfowl. This is

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[309] William T. Munro, *Changes in Waterfowl Habitat with Flooding on the Ottawa River*, 31(1) THE JOURNAL OF WILDLIFE MANAGEMENT 197, 197-99 (1967).
[310] *Id.*
[311] *Id.*
[312] Jay R. Lund, *Flood Management in California*, 4 WATER 157, 157-169 (2012).
[313] *Id.*

a crucially important component of floodplain management and should be considered in decision-making regarding flow regimes.

This study of the ecological impacts of floodplain management and development sought to provide an overview of the impacts to water quality, fisheries, and waterfowl from allowance and disallowance of access to floodplains through natural and managed flow regimes. Frequently parameters used to measure water quality, fisheries health, and waterfowl proliferation are improved through improved floodplain access and higher flows in river systems.

Columbia Basin History and the Columbia River Treaty

I. Columbia Basin History

In order to provide the context and background needed to fully understand flood risk management in the Columbia River Basin and to develop further the understanding of the differences in perspective between Canada and United States, a brief background of the Basin and an update on the current Columbia River Treaty review will follow. This will help the reader gain a more nuanced view of the importance of this research, and the value of further stimulation of research to determine actual flows at which damages will occur.

On the morning of May 30, 1948 in Vanport, Oregon, residents received notice of flyers being distributed throughout the community by the Housing Authority of Portland and the United States Chief of Engineers that stated "DIKES ARE SAFE AT PRESENT. YOU WILL BE WARNED IF NECESSARY. YOU WILL HAVE TIME TO LEAVE. DON'T GET EXCITED."[314] This was an attempt to quell the fears of local residents who had heard and seen

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[314] Dale Skovgaard, *Oregon Voices: Memories of the 1948 Vanport Flood*, 1 *Oregon Historical Quarterly* 97 (2007).

the quickly rising waters along the banks of the Columbia River.[315] By 5:00 PM that same day, the city of Vanport was under ten to twenty feet of water with an eventual death toll of at least fifteen with more than 18,000 people losing their homes.[316] Beyond the immeasurable trauma and grief caused by this natural disaster to the locally impacted communities, the desire to manage and control the Columbia River system as a result of the flood of 1948 has had lasting social and environmental impacts in the region. This section will seek to briefly discuss the basic background information needed to understand the current review to provide context for the research performed.

The U.S. government first formally identified in the early 19th Century a desire to develop and manage river systems with the passage of the 1902 Reclamation Act, which sponsored federal reclamation projects.[317] Drawn to the Western states by the prospect of striking it rich, an increasing number of private companies and individuals diverted water from western streams and applied it to various beneficial uses.[318] The most effective method of utilizing the substantial tracts of land in the west for agricultural purposes required the construction of large water projects costing millions of dollars.[319] At the turn of the century the public favored federally-funded reclamation projects, and all major political parties endorsed such a federal program.[320] As a result Congress determined that the sale of public lands in the Western United States should be used for reclamation projects within those same states as part of the Reclamation Act of 1902.[321]

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[315] *Id.*
[316] Vanport Flood begins on Columbia River on May 30, 1948, Historylink.org, last modified August 30, 2013, http://www.historylink.org/index.cfm?DisplayPage=output.cfm&file_id=10473.
[317] 43 U.S.C. § 383 (2015).
[318] Timothy J. Beaton, *Breathing New Life Into Section 8 of the 1902 Reclamation Act: California v. United States*, 50 U. COLO. L. REV. 207, 209 (1979).
[319] *Id.*
[320] *Id.*
[321] *Id.*

Following this piece of legislation, in 1920 the Federal Water Power Act was passed.[322] While this Act has been amended multiple times, the general premise of ensuring federal control over any sort of hydroelectric projects on waters of the United States has remained a constant.[323] This gave the federal government the power to manage and develop systems such as the Columbia in a manner that best fit the nation's interests at the time, rather than allowing unfettered private control over these projects.

At the same time, on the other side of the border, Canada was tracking virtually the same course in efforts to make power production publicly controlled. As an example, in 1897 the province of British Columbia enacted a water law confirming provincial authority over all rivers with an effort to maximize efficiency and social utility.[324] Not long thereafter, the authority and oversight by the B.C. government was expanded with the passage of the B.C. Water Act of 1909, which established a water commission that granted licenses and adjudicated water claims to ensure appropriate and efficient economic development of water resources.[325] As stated by B.C. Premier Richard McBride in 1914 , "[i]f it be for the purposes of power, let us see that the laws are so carried out as to get from the investment and from the water conservation, the very best and most profitable results."[326]

During the 1930's, U.S. President Franklin D. Roosevelt set a course for development of the Columbia River's abundant potential for hydroelectric power production.[327] "Armed with

[322] Federal Water Power Act (FWPA) of 1920, ch. 285, 41 Stat. 1063 (codified as amended at 16 U.S.C. §§ 791a-828c (2015)).
[323] Beth C. Bryant, *FERC's Dam Decommissioning Authority Under the Federal Power Act,* 74 WASH. L. REV. 95, 102–103 (1999).
[324] David R. Percy, *Responding to Water Scarcity in Western Canada,* 83 TEX. L. REV. 2091, 2093 (1995).
[325] *Water 101*, BRITISH COLUMBIA (last visited December 2015),http://engage.gov.bc.ca/watersustainabilityact/water-101/.
[326] *The Columbia River Treaty Revisited: Transboundary River Governance in the Face of Uncertainty* 119 (Barbara Cosens ed. Oregon State University Press 2012) [hereinafter Transboundary River Governance].
[327] *Columbia River History - Dams: History and Purpose*, NW. POWER AND CONSERVATION COUNCIL, (last visited Nov. 3, 2015) http://www.nwcouncil.org/history/damshistory.asp.

a faith that applied science could control nature for maximum profit and welfare for regional residents, along with the idea that public power would provide greater benefits than private power had achieved, federal planners and engineers sought to put the Columbia River to work."[328] As populations began to move into the Columbia Basin, the need for more power increased significantly, promoting further the desire to proactively attempt to manage the system in an effective manner.[329] In order to do this entities needed to be created that would appropriately implement this mission.

One of the more influential entities that was created to attempt to manage these goals was the Bonneville Power Administration (BPA).[330] BPA was created by Congress in 1937 to help deliver and sell the power from the Bonneville Dam that was completed in 1938.[331] Initially BPA's service area was in close proximity to the dam itself, but it has expanded to manage about one-third of all of the power consumed in the Pacific Northwest, according to BPA.[332]

Another initiative that was created to fulfill the needs identified by the U.S. was known as the Columbia Basin Project.[333] This was an enormous irrigation project, and sought to meet the agricultural needs of the Basin.[334] According to some scholars, this Project did not take into account the needs of Canada, such as the impacts of certain projects on Canadian access to anadromous fish that use U.S. waters to migrate into the headwaters that are located in Canada.[335]

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[328] Transboundary River Governance, *supra* note 326 at 120.
[329] *Id.*
[330] *Id.*
[331] *History*, BONNEVILLE POWER ADMINISTRATION (last visited December 2015), http://www.bpa.gov/news/AboutUs/History/Pages/default.aspx.
[332] *Id.*
[333] John Harrison, *Columbia Basin Project*, NW. POWER AND CONSERVATION COUNCIL, (Oct. 31, 2008), http://www.nwcouncil.org/history/ColumbiaBasinProject.
[334] *Id.*
[335] Transboundary River Governance, *supra* note 326 at 121, 123.

In 1932, the first United States government research study of the Columbia River and its capabilities was presented to Congress on behalf of the Chief of Engineers.[336] Despite a major flood in 1894 occurring just forty years prior, there was no mention of flood control management of the system, as the focus was primarily placed upon ensuring that the system was adequately managed for the benefits of improving navigation and resulting commerce in the Columbia.[337] A few years later, the United States and Canada jointly requested that the International Joint Commission, an entity established by the Boundary Waters Treaty of 1909 to investigate and report on the feasibility of cooperative development of the Columbia River system, to examine issues in the Basin.[338] In 1944, the International Joint Commission created the International Columbia River Engineering Board, whose mandate was to support the investigation and conduct technical studies throughout the Basin.[339] Commissioners from both countries apparently were interested in a wide range of topics, with flood control included in addition to power generation during the initial research.[340] The flood of 1948 mentioned earlier, however, was great cause for the increased prioritization of flood control alongside the ever-important goal of producing adequate hydroelectric power in the Basin. As a result, both sides were pushed into action.

A report issued in 1950 by the Chief of Engineers of the U.S. Army to Congress, sometimes referenced as the 531 Report because of its congressional document designation, was a crucially important document that was formative in the creation of the flood control

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[336] House Committee on Rivers and Harbors, *Columbia River, Oreg. Letter from the Secretary of War transmitting report from the Chief of Engineers of preliminary examination and survey of Columbia River at St. Helens, Oreg.* 72nd Cong., 1st sess. 1932, H. Doc. 235.
[337] *Id.*
[338] Historical Highlights, *International Joint Commission*, last modified 2015, http://www.ijc.org/en_/IJC_History.
[339] *Id.*
[340] *Id.*

system that remains largely in effect in contemporary times.[341] The document called for a system of dams that would provide flood control, aid navigation on the Columbia and Snake rivers, and generate power throughout the Basin.[342] However, for purposes of this section the focus will remain primarily on the data, findings, and recommendations regarding flood control. The report indicates that "major" flood events generally impact 300,000 acres throughout the Columbia River Basin, including damages on the tributaries from "backwater", with particularly severe impacts on the far lower portion of the Columbia due to an increase in urbanization in this area.[343]

According to the study, between 1858 and 1948 twenty-four floods had met or exceeded 714,000 cubic feet per second at The Dalles dam.[344] The document indicates that a flow of 600,000 cubic feet per second at The Dalles leads to corresponding flow depths of twenty-two feet at Vancouver, Washington and about twenty-one feet at Portland. This can be compared to the flow during the flood at Vanport in 1948, which reached just over thirty feet in Vancouver with a corresponding flow of over 1,000,000 cubic feet per second at The Dalles.[345] The Chief of Engineers then suggest that flood stage at the Vancouver gage is fifteen feet, with damages beginning to occur at twelve feet.[346] However, the damages that are outlined at these levels are extremely minimal, affecting only the agricultural lands located directly next to the river and some docks.[347] Importantly, the study indicates that, prior to 1950, only when the gage at

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[341] *House Committee on Columbia River and tributaries, northwestern United States, Letter from the Secretary of Army transmitting a letter from the Chief of Engineers*, 81st Cong., 1st sess. 1950, H. Doc. 531.
[342] *Id.*
[343] *Id.* at 2558.
[344] *Id.* at 2559.
[345] *Id.*
[346] *Id.*
[347] *Id.*

Vancouver reaches twenty-five feet are low-lying industrial areas affected and other higher-damage impacts seen, with damages increasing "rapidly" at stages above twenty-five feet.[348]

Later in the 1950 document, the Chief of Engineers indicate that a flow of 800,000 cubic feet per second at The Dalles is the maximum flow that "present and future" levees could withstand, and that discharges at higher levels than that cause significant flooding damages in the lower Basin.[349] The report then proceeds to provide specific recommendations regarding locations of levees and other structural flood control measures and the subsequent costs of the implementation of these measures.[350] It does not, however, appear to give any firm recommendations, other than generally discussing 800,000 cubic feet per second at The Dalles as a number that avoids significant damages.

Following the publication of this report, conversations continued in the Basin regarding the possibilities for collaboration between Canada and the United States to achieve power generation and downstream flood control while sharing some of the benefits of the projects between the two nations. In January of 1959, the Canadian and United States governments requested the International Joint Commission to determine the bilateral benefits of cooperative use of Columbia River Basin storage waters and hydropower, and apportionment of these benefits with regard to electrical generation and flood control.[351] The document outlines very general flood control principles that stipulate that benefits should be based on previously agreed-upon flood regulations, that the monetary value of flood control benefits should be the estimated annual value of the flood damage prevented by upstream storage, and that the

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[348] *Id.*
[349] House Committee, *Columbia River and tributaries, northwestern United States*, *supra* note 341 at 2798.
[350] *Id.*
[351] International Joint Commission, *Report on Principles for Determining and Apportioning Benefits in Columbia River System,* (1959), 26-28.

upstream country should be paid one-half of this value, to be determined in advance of storage project construction.[352] Many of these principles found their way into the Columbia River Treaty, which was signed just a few years later.[353] The United States and the International Joint Commission directly and by implication indicated 800,000 cubic feet per second was the target flow at The Dalles to avoid damages, with a preferred goal of meeting the 600,000 cubic feet per second flow.[354]

The official Canadian "Presentation" document of 1964 suggests that after 2024 that "on-call could be triggered only if U.S. facilities could not control floods to 600,000 cfs at The Dalles.[355] However, the same document also refers to the relevant degree of protection as being 800,000 cfs.[356] At no point does the publication refer to a higher level of protection such as a 450,000 cfs threshold.[357] Second, and perhaps of even greater significance, are the comments of Lieutenant General Itschner during the Senate Ratification Hearings in which he stated that flood control to an 800,000 cfs level is: "[A]n acceptable and desirable immediate goal for flood regulation. Regulation to a flow of 600,000 cubic feet per second is desirable for a further goal in view of the trends of future flood plain use as well as the possibility that a considerably larger flood than the record flood of 1894 might occur."[358]

General Itschner referred to these targets as the initial and the ultimate goals.[359] He goes on to say: "[o]f the 15,500,000 acre-feet of Canadian storage, 8,450,000 acre-feet will be useful

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[352] *Id.*
[353] Treaty Between Canada and the United States of America Relating to Cooperative Development of the Water Resources of the Columbia River Basin ("Columbia River Treaty"), U.S.-Can., Jan. 17, 1961. (Also found in the Appendix to this thesis).
[354] International Joint Commission 1959, *supra* note 351.
[355] Nigel Bankes, *Flood Control Regime of the Columbia River Treaty: Before and After 2024*, 2 WASH. J. ENVTL. L. & POL'Y 1, 45 (2012).
[356] *Id.*
[357] *Id.*
[358] *Id.* at 46.
[359] *Id.*

for the immediate objective of controlling floods equivalent to that of 1894 to 800,000 acre-feet."[360] The balance of the storage, the on-call storage, is referred to under the heading of: "[c]ontrol to 600,000 cubic feet per second" and with the notation that "[s]uch additional storage will be requested only when there is a threat of a very large flood."[361] This implies that the on-call storage should not be used to control down to 600,000 cfs but simply to manage the very large floods down to just below 800,000 cfs.[362]

The Columbia River Treaty (Treaty), which was signed in 1964, called for two "entities", one from Canada and one from the United States.[363] The U.S. Entity, created by the President, consists of the Administrator of the BPA and the Northwestern Division Engineer of the U.S. Army Corps of Engineers (Corps).[364] The Canadian Entity, appointed by the Canadian Federal Cabinet, is the British Columbia Hydro and Power Authority (B.C. Hydro).[365] The Treaty also established the Permanent Engineering Board (PEB), which was set up by the two governments to monitor and report on the results being achieved under the Treaty.[366] The board also assists in reconciling differences concerning technical or operational matters that may arise between the Entities.[367] The U.S. Secretaries of Army and Energy each appoint a PEB member and the governments of Canada and British Columbia each appoint a Canadian member.[368]

A main component of the Treaty called for Canada to develop reservoirs sufficient to provide 15.5 million acre-feet of water storage, which led to the development of three dams:

[360] *Id.*
[361] *Id.*
[362] *Id.*
[363] *Id.*
[364] *Id.*
[365] *Id.*
[366] *Id.*
[367] *Id.*
[368] *Id.*

Duncan (1968), Hugh Keenleyside (also referred to as Arrow) (1969) and Mica (1973).[369] The Treaty also allowed the United States an option to build Libby Dam on the Kootenai River, a tributary of the Columbia River, in Montana, which was completed in 1973.[370] The BPA markets power from the federal projects in the Columbia Basin in the United States, while the Corps is responsible for the operation of its dams and oversees flood risk management and other multipurpose uses of Corps projects.[371] Under the provisions of the Treaty, B.C. Hydro is responsible for the operation of the three Canadian Treaty dams.[372]

Flood control under the Treaty is implemented under a Flood Control Operating Plan developed jointly by the United States and Canadian Entities, and additional measures can be taken when runoff exceeds levels manageable under the plan.[373] However, actual implementation by the Entities includes development of an AOP each year for six years in advance, followed by a Detailed Operating Plan (DOP), prepared each year for the following year to update the AOP and to provide more details on operations including updating runoff operations.[374] A Treaty Storage Regulation (TSR) study is done during the actual operating year and is based on both the DOP and current conditions, and defines storage and draft requirements for treaty reservoirs.[375] Finally, Supplemental Operating Agreements may be used to vary from the TSR if mutual benefits in power, flood control fisheries, or other values may be achieved.[376]

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369 *Id.*
370 *Id.*
371 *Id.*
372 *Id.*
373 Columbia River Treaty, *supra* note 353 at art. II, IV, VI.
374 Barbara Cosens, *Resilience and Law as a Theoretical Backdrop for Natural Resource Management: Flood Risk Management in the Columbia River Basin*, 42 ENVTL. L. 241, 260 (2012).
375 *Id.*
376 *Id.*

In addition, in actual practice, weekly and even daily conference calls occur among the Entities to make adjustments to operations as needed.[377]

A threshold question to be resolved is when the United States is entitled to trigger an on-call request after 2024. The Treaty and the Protocol taken together provide both a general and a specific threshold for the trigger but both are silent on the most important element--the flood control target that is to be used. The first clause of Article IV(3) of the Treaty, which can be found in the Appendix of this document, establishes a general threshold: the United States can only require Canada to provide a flood control operation if "the flows of the Columbia River in Canada continue to contribute to potential flood hazard in the United States of America."

Either Canada or the United States can terminate most of the provisions of the Treaty any time on or after Sept. 16, 2024, with a minimum 10 years' written advance notice.[378] The terms for flood control under the Treaty, however, will change automatically in 2024.[379] After 2024, Canada will still be required to provide some operations for flood control in the United States whether or not the Treaty is terminated, but the United States will be required to provide additional reimbursement to Canada for their lost power benefits and operational costs due to the requested flood control operations.[380] If the Treaty is terminated, the United States will no longer be obligated to pay Canada its entitlement to one-half of the downstream power benefits realized in the United States.[381] However, some things continue even in a termination scenario.

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[377] *Id.*
[378] U.S. Army Corps of Engineers, Bonneville Power Administration, and BC Hydro, *Columbia River Treaty 2014/2024 Review: Phase 1 Report* (2010) available at http://www.crt2014-2024review.gov/.
[379] *Id.*
[380] *Id.*
[381] *Id.*

Stemming from this agreement, there were decisions made that determined that flooding in the Columbia River begins when the river reaches elevation 17.8 feet at Vancouver, Washington, with a corresponding flow measured at The Dalles at approximately 450,000 cubic feet per second.[382] Also stemming from the Columbia River Treaty Flood Control Operating Plan was the determination that significant damage begins at elevation 24 feet, with the corresponding flow at The Dalles at approximately 600,000 cubic feet per second.[383] Additionally, the report indicated that "the desired goal is to control major floods to 600,000 cubic feet per second in the lower Columbia River at The Dalles." The determination of the value of the 450,000 cubic feet per second seems to have developed without any publicly accessible research, but the impacts of this decision are significant in the Basin.

As the entire Columbia is managed as a finely controlled system, the determination of maximum flows at The Dalles significantly impacts decisions regarding the refill of upstream storage reservoirs in a manner that provides the desired controlled flow at The Dalles.[384] While a discharge of 450,000 cubic feet per second is considered a bank-full level, higher controlled flows are used for high magnitude floods to prevent storage space from filling too soon, thus resulting in potentially uncontrolled flows in the lower Columbia.[385] As Canada contains much of the storage capacity in the Columbia Basin, the management of their reservoirs on the mainstem and tributaries are deeply impacted by the flow restrictions established by the United States and British Columbia Entities to prevent flood damage in the United States.

As can be seen from the contradictions above, the actual figures that have been established are relatively unsupported by publicly accessible research, and are certainly archaic

[382] United States Army Corps of Engineers, *Columbia River Treaty Flood Control Operating Plan*, (2003): 16.
[383] *Id.*
[384] *Id.*
[385] *Id.*

in their establishment. Figures compiled from studies in the 1940's and 1950's should not govern decision-making in the twenty-first century, especially when they hold the importance that this information contains. Despite virtually all of the information stemming from the 531 congressional reports and the 1959 International Joint Commission report discussing 800,000 and 600,000 cubic feet per second as the target flows at The Dalles, the United States Army Corps of Engineers has consistently applied 450,000 cubic feet per second as the parameter that the agency is seeking to meet when managing the system.[386] However, over 250 days since the Columbia River Treaty was signed have experienced flows exceeding 450,000 cubic feet per second at The Dalles, and the damages have been so minimal that the Army Corps does not account for actual flood damages, but only flood damages prevented.[387] This suggests that the calculation of this figure to signify the beginning of damages was perhaps arbitrary and not well-researched.

Perhaps feeling morally and professionally obligated to ensure that a similarly destructive event like the flood of 1948 would not occur again in the future, the United States set highly restrictive flows that were well-below figures presented by prominent reports. However, these flows have not adequately taken into account the impacts on Canada's storage reservoir management, the possibilities for non-structural flood control management options, the impacts on the ecosystem such as anadromous fish and waterfowl from decreased flows throughout the Basin, nor an attempt to balance the costs and benefits of this regime. The review process for the Columbia River Treaty has highlighted some of the ambiguities in the Treaty that may lead to differences in interpretation if assured flood control provisions are allowed to

[386] United States Army Corps of Engineers 2003, *supra* note 382.
[387] United States Geological Survey 14105700 Columbia River at The Dalles, OR, last modified 2015, http://waterdata.usgs.gov/nwis/dv?cb_00060=on&format=html&site_no=14105700&referred_module=sw&period=&begin_date=1965-12-01&end_date=2014-12-18.

expire in 2024. The ambiguities relate to language in the Treaty addressing expiration of the assured flood control provisions that retains the United States' ability to call upon Canada for storage for flood control when needed. The provisions fail to define "called upon"[388] storage, and Treaty provisions that apply up to 2024 require the use of "all the related storage" in the United States prior to exercising the call.[389] It is not clear what is meant by "all the related storage," nor is it clear whether the level of flood protection required by the Treaty is the same as that for the "called upon" flood control prior to 2024 (600,000 cubic feet per second), or the level at which the Corps estimates that minor flood damage begins (450,000 cubic feet per second). If flow measured at The Dalles must be kept below 450,000 cubic feet per second to avoid flood damage as opposed to a higher flow, expiration of assured flood control will result in deeper drafts of reservoirs in the United States than historically experienced and reduced flexibility for fish management will be seen.[390]

II. Columbia River Treaty Present Review

For the past several years the United States and British Columbia have undertaken significant efforts to review and seek consultation on Treaty modernization review. Numerous stakeholders have provided input, leading to a complex and arduous review process. This section intends to provide an overview of the reviews as they have progressed over the past several years.

A. U.S. Entity Recommendations

The organizations from the United States that form the United States Entity, the BPA and the Corps, made a regional recommendation to the U.S. Department of State for the future

388 Columbia River Treaty, *supra* note 353 at Annex 1.
389 *Id.*
390 U.S. Army Corps of Engineers, Bonneville Power Administration, and BC Hydro, *Columbia River Treaty 2014/2024 Review: Phase 1 Report* (2010) available at http://www.crt2014-2024review.gov/.

of the Treaty in December of 2013 after extensive stakeholder engagement and research.[391] While the U.S. Regional Recommendation was developed and delivered by the U.S. Entity, the Sovereign Review Team (SRT) contributed to the language of the document as part of an effort to develop regional consensus for the Recommendation.[392] It met from October 2010 through December 2013, and the Treaty Coordinators chaired the SRT on behalf of the U.S. Entity and also represented the Corps and BPA.[393] The SRT also included representatives from nine additional federal agency, five tribal representatives for 15 of the Tribal Nations in the basin, and state representatives from Idaho, Montana, Oregon, and Washington.[394] In the recommendations, the U.S. Entity discusses many issues contained within seven broad categories. While the intimate details of each categorical recommendation should be explored independently, this subsection is intended to provide a broad overview and summary of these recommendations in order to provide the reader with a general sense of the issues of importance that have been identified during the Columbia River Treaty review process by the region.

The first topic outlined by the regional review is the issue of hydropower, which is one of two main topics that stimulated the initial Treaty negotiations in the 1960's. While there is a clear interest in both countries maintaining a viable power supply using hydroelectricity in addition to increased flexibility, it is believed by the U.S. Entity that the modernized treaty should pursue rebalancing the power benefits between the two countries to reflect the "actual

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[391] *U.S. Entity Regional Recommendation for the Future of the Columbia River Treaty* (2013), http://www.crt2014-2024review.gov/Files/Regional%20Recommendation%20Final,%2013%20DEC%202013.pdf [hereinafter U.S. Recommendation].

[392] Kim Ogren, Water Governance Process Assessment: Evaluating the Link between Decision Making Processes and Outcomes in the Columbia River Basin 194 (July 17, 2015) (unpublished PhD. Dissertation, Oregon State University) (on file with author).

[393] *Id.*

[394] *Id.*

value of coordinated operations."[395] The Canadian Entitlement, as mentioned previously, is a calculated amount of power in the Actual Operating Potential (AOP), but changes to operations to, for example, comply with the Endangered Species Act are not included in the calculation. Thus, when the US spills water for fish it not only loses the power it could have produced, it pays Canada as if the power was produced. As a result, the U.S. Entity believes that "Canada is deriving substantially greater value from coordinated power operations than the United States."[396] Additionally, for the Treaty to be sustainable after 2024, the "United States should only provide benefits to Canada equivalent to one-half of the actual U.S. downstream capacity and energy benefits received from coordinated operations as compared to a non-coordinated operation."[397]

The other major topic from the original Treaty, flood control, is the next topic that the U.S. Entity discusses in its recommendation. The U.S. Entity wants to work with the B.C. Entity to identify reasonable compensation to Canada for economic losses and operating costs associated with "Called Upon" flood control.[398] In order to do this, the U.S. Entity identifies that "any payments for Columbia River flood risk management should be consistent with the national flood risk funding policy of federal funding with applicable local beneficiaries sharing those costs as appropriate."[399] Additionally the U.S. Entity wants to prioritize the incorporation of flexibility into flood risk management and wants to define and determine what "Called Upon" flood risk would look like in the event that that is a necessity.[400]

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[395] U.S. Recommendation, *supra* note 391.
[396] *Id.*
[397] *Id.*
[398] *Id.*
[399] *Id.*
[400] *Id.*

The balance of the Flood Control Operating Plan (FCOP), which was discussed previously, and actual operating practice confirms that the assured operation is designed to meet a flood control target of 450,000 cfs at The Dalles.[401] The FCOP represents subsequent practice of the Parties under the Treaty and suggests that Canada has accepted 450,000 cfs at The Dalles as the applicable flood control objective, at least for the assured operation.[402] The FCOP is "subsequent practice in the application of the treaty which establishes the agreement of the parties [the United States and Canada]" that the flood control objective for the assured operation is 450,000 cfs.[403]

The flood control objective for the additional storage that Canada is obliged to commit under the terms of an on-call operation before 2024 is 600,000 cfs at The Dalles.[404] In other words, the United States can only make a call if operation of existing or under construction U.S. storage in 1961, storage at Libby, and assured storage space will still result in a flow at The Dalles greater than 600,000 cfs.[405] Thus, there is broad agreement by the B.C. Entity that prior to 2024, the United States is only entitled to make a call to supplement assured storage space where it anticipates unregulated flows at The Dalles in excess of 600,000 cfs.[406] However, the Americans disagree on what "all related storage" in the U.S. is, with the U.S. Entity considering it to be only those federal dams with authorized flood control space, and the B.C. Entity considering it to be all U.S. dams.

In addition to discussing the two primary topics contained within the original Treaty, the U.S. Entity also outlined new topics, including ecosystem function. The U.S. Entity believes

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[401] Bankes, *supra* note 355.
[402] *Id.*
[403] *Id.*
[404] *Id.*
[405] *Id.*
[406] *Id.*

that a modernized Treaty should provide stream flows from Canada with appropriate timing, quantity, and water quality to promote productive populations of anadromous and resident fish and provide reservoir conditions to promote productive populations of native fish and wildlife.[407] While recognizing existing Treaty obligations, a modernized Treaty should: "(a) incorporate existing Treaty flow augmentation operations and accommodate post-2024 modifications to flow augmentation; (b) incorporate a dry-year strategy; and (c) gain long-term assurance of ecosystem-based functions rather than negotiating for these functions on an annual basis."[408] In addition, the U.S. believes that a modernized Treaty should recognize and minimize adverse effects to tribal, First Nations, and other cultural resources in Canada and the United States.[409] A modernized Treaty should be "designed to be adaptable to meeting ecosystem-based function requirements as new information becomes available or conditions change on the management priorities of both countries."[410] Additionally, the United States Entity wants to pursue a joint program with Canada, with shared costs, to investigate and, if warranted, implement restored fish passage and reintroduction of anadromous fish on the main stem Columbia River to Canadian spawning grounds.[411]

In addition the U.S. Entity mentions water supply, navigation, recreation, and climate change in the recommendation. Regarding water supply, the primary recommendation by the U.S. Entity is to simply incorporate irrigation needs into the modernized Treaty to ensure that a primary industry in the Basin can remain viable.[412] Operations under a modernized Treaty should recognize navigation as an important authorized purpose in the Basin and provide river

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[407] U.S. Recommendation, *supra* note 391
[408] *Id.*
[409] *Id.*
[410] *Id.*
[411] *Id.*
[412] *Id.*

flows that do not "undermine safe navigation, efficient cargo movement, or the ability of navigation infrastructure to be maintained."[413] The U.S. Entity wants to ensure that recreation needs are recognized in the modernized Treaty, and also believes that an understanding of the impacts of climate change also needs to be a priority by allowing for adaptive management.[414]

Additionally, the U.S. Entity recognizes the value of a review process domestically, with consideration given to assuring a composition and membership that is best suited to effectively and efficiently implement the Treaty post-2024.[415]

B. British Columbia Recommendations

Prior to the recommendations put forward by the United States Entity, B.C. Hydro, the B.C. Entity, produced a summary of the perceived benefits of the Columbia River Treaty to both the United States and Canada.[416] Again, while many more details can be found through B.C. published research and studies, this subsection is intended to give a broad overview of the B.C. Entity's perspectives on the varying issues.

Similar to the U.S. Entity, power production is mentioned as an important component of Treaty modernization for the B.C. Entity. According to the B.C. Entity's Public Consultation Report, most of the residents in the Basin on the Canadian side of the border do not feel that power should be a priority in the Treaty modernization, as the perceived benefit to Canada is minimal.[417] Perhaps reflective of these feelings and sentiments, the B.C. Entity does not place

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[413] *Id.*
[414] *Id.*
[415] *Id.*
[416] *U.S. Benefits from the Columbia River Treaty: Past, Present, and Future: A Province of British Columbia Perspective*, B.C. MINISTRY OF ENERGY AND MINES (2013), http://www.crt2014-2024review.gov/Files/Canadian%20Entity%20Report%20on%20Benefits%20to%20US%20from%20CRT,%20June%2025%202013.pdf [hereinafter B.C. Perspective].
[417] *Columbia River Treaty Review: Public Consultation Document*, B.C. HYDRO (March 2014), http://blog.gov.bc.ca/columbiarivertreaty/files/2013/09/Columbia-River-Treaty-Review-Public-Consultation-Report-_March-2014.pdf [hereinafter Public Consultation].

as much emphasis on the importance of meeting specific power needs, but does indicate a desire to accurately and appropriately determine the amount of money required to appropriately compensate Canada for the power production benefits seen in the U.S.[418]

Regarding flood control, the B.C. Entity implies that the payment by the U.S. that has been provided to Canada in exchange for the downstream benefits did not accurately reflect the actual benefits incurred over the period.[419] The report indicates "[i]n 2012 alone, USACE estimates of flood damage prevented (by Treaty and non-Treaty facilities) was approximately $2 billion."[420] This amount is compared to the assured annual flood control operation that was purchased by the United States for 60 years for $64.4 million in the original Columbia River Treaty.[421] In addition, the B.C. Entity confirms that the "Called Upon Flood Control" measures will take place starting in 2024, and suggests a coordinated flood risk management approach that maximizes the benefits and mitigate impacts and risks to multiple U.S. interests.[422]

Regarding ecosystem function, the Canadian Entity expresses that the "[p]rovince will explore ecosystem based improvements recognizing that there are a number of available mechanisms inside and outside the Treaty."[423] However, it clearly indicates that salmon migration and fish passage should be issues that remain outside of the Treaty and should be handled separately by the two nations.[424]

[418] B.C. Perspective, *supra* note 416.
[419] *Id.* at 4–5.
[420] *Id.* (citing a February 2013 Permanent Engineering Board Meeting).
[421] *Id.*
[422] *Id.* at 6–7.
[423] *Id.*
[424] *Id.*

The issues of climate change and adaptive management are mentioned by the Canadian Entity as priorities, in addition to an increased interest in continued collaboration with First Nations throughout the region in a government-to-government consultation process. [425]

C. Summary

In summary, the current Treaty review process presents an extremely valuable opportunity for both sides to improve the management of flows to achieve all of the goals in the region. Providing more room for flexible flows will allow for the other uses in the region, including hydropower, irrigation, and fish, to hold a higher priority. With an appearance of divergence between the two sides on some critical issues surrounding flood control, it seems likely that if it were to be found that flood damages began at a much higher flow in the lower portion of the Basin, upper Basin reservoirs could be managed with more local priorities rather than needing to be highly restrictive in order to ensure that flooding damages did not occur in the lower Basin. This opportunity for review should be viewed as stimulation for further research and discussion about appropriate flow management, with this research showing that current figures relied upon may not be appropriate.

Critically important to acknowledge as considerations are made regarding future flood risk management is the disproportionate impact that these decisions have on disenfranchised communities. Indigenous populations on both sides of the border were entirely left out of the discussions regarding the Columbia River Treaty in the 1960's, and the ramifications that resulted from this document continue to cause pain and suffering due to spiritual, economic and ecological connections to fish and wildlife that have been negatively impacted by the current management regime. While the indigenous community is often cited by scholars in the region,

[425] *Id.*

it is also important to recognize that African-American communities were devastated by past flooding events, and poor communities of color continue to be located in high risk flood areas vulnerable to life-altering events. It is perhaps ironic that the document and management decisions attempting to respond to the devastation put forth to one disenfranchised community led directly to the devastation put forth to another. Systemic racism and classism is difficult to overcome, but a simple recognition of the disproportionate impacts and subsequent slow recovery from damages is important for stakeholders in the region as decisions are made.

CHAPTER 3: GOALS

Hypothesis-driven research is the norm across a variety of disciplines, and is quite often the best and most effective approach to framing research methodology in order to produce the results desired. However, after contemplation and discussion it was determined that rather than taking this more traditional approach in this research, a goal-oriented approach would allow for flexibility in the research direction and was more closely aligned with the mission of this work, which is to provide information to stakeholders and policy makers regarding flood risk management in the Columbia River Basin in the context of the Columbia River Treaty review. Replacing the traditional hypothesis approach with goals should also provide more clarity and direction for the reader.

The broad goal of this research is to start the process of stimulating more substantive and thorough research in the Columbia River Basin regarding flood risk management as a result of outdated policy. This includes determining what the quantitative impacts of flows over 450,000 cubic feet per second, determining some of the qualitative benefits of an increase in allowable flows at The Dalles, and identifying some of the areas in the Basin that could benefit from increased flows. This combination of quantitative and qualitative analyses, while perhaps nontraditional, has significant value. When taken side-by-side they provide meaningful comparisons that allow for substantive conclusions to be drawn, even though they are not discussed using the same units. While this research is not intended to cover all possible issues related to quantitative and qualitative impacts, one of the goals is to determine whether more research is needed to ensure that appropriate policy decisions are made regarding flows in the Columbia River Basin.

Flood Damages

The first section of the research has a goal of assessing and attempting to quantitatively and qualitatively determine the amount of flood damages that have been seen in the Columbia River Basin in past flow events that have exceeded the flow amount that has been selected as the point at which damages occur in the Basin.

Non-structural flood control costs and benefits

The second section of the research has a goal of determining both qualitatively and quantitatively some of the costs and benefits of implementation of non-structural flood control measures in the Columbia River Basin.

Areas in Basin with floodplain access opportunities

The third and last section of the research has a goal of identifying some areas in the Columbia River Basin that could potentially benefit from the implementation of non-structural flood control measures.

CHAPTER 4: METHODOLOGY

Flood Damages

As was discussed at length in the literature review, flow targets at The Dalles have been set at 450,000 mean daily cubic feet per second in an attempt to avoid damages that are believed to begin at this flow.[426] This flow amount stemmed from an arbitrary interpretation of documents indicating that much higher flows were actually necessary for flood damages to occur. As discussed, this is critically important because this restriction causes all of the other reservoirs to be managed in a more restrictive manner, limiting the opportunities for other uses to maximize efficiency.

In order to determine if this flow actually is the threshold at which significant damages occur, an assessment of past flow events that have exceeded this number needed to be performed. While The Dalles gage[427] is only one of hundreds of gages throughout the lower Columbia River Basin, its value and impact on basin-wide management cannot be understated, as flows at this gage are used to manage the entire Basin by agencies. A map with The Dalles is seen below in Figure 2.[428] As such, every day that met or exceeded 450,000 mean cfs since 1915 at The Dalles was counted and assessed as a part of this study.

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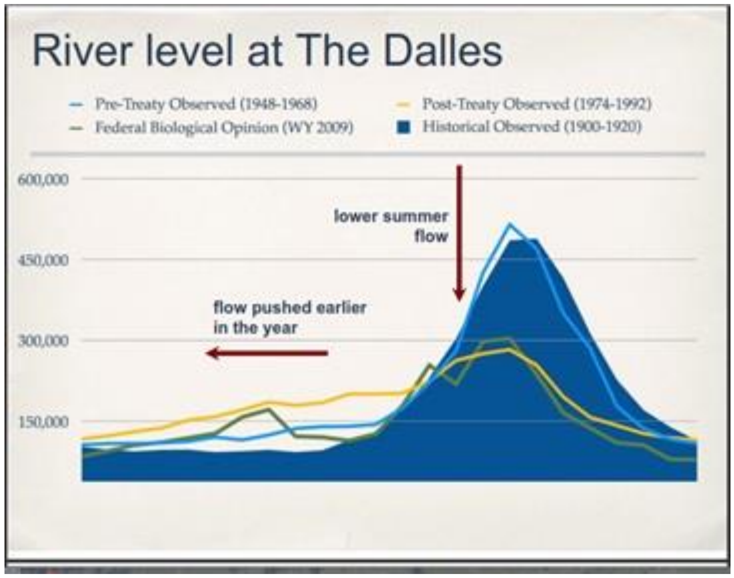
[426] *See supra* Columbia Basin History and the Columbia River Treaty.
[427] United States Geological Survey 14105700 Columbia River at The Dalles, OR, last modified 2015, http://waterdata.usgs.gov/nwis/dv?cb_00060=on&format=html&site_no=14105700&referred_module=sw&period=&begin_date=1915-1-01&end_date=2014-12-18.
[428] *Columbia River on Map,* Daily Kos, (Feb. 13, 2016) https://www.bing.com/images/search?q=map+of+columbia+river+basin+the+dalles+dam&view=detailv2&&id=A59D3207F3F76DFDCE3D7DE317CE9ADE7E4BD052&selectedIndex=4&ccid=EVeew%2fiI&simid=608007635876384549&thid=OIP.M11579ec3f888a49e9943484aacea3fddo0&ajaxhist=0.

Figure 2: Map of Columbia River Basin

Significant flow differences exist between the various eras of policy and management in the system. Prior to the construction of dams in the mid-20th century on the mainstem of the Columbia, flows at The Dalles were much less predictable, with higher flows occurring during the wetter portions of a typical year, and lower flows during the portions of the year that are much drier. Following the construction of the dams that were a part of the Columbia River Treaty, the flows became much less volatile in an attempt to maximize energy production and minimize flooding. The difference in flows can be seen visually in Figure 3 below.[429]

[429] Jim Heffernan, *Tribal Perspectives on the Columbia River Treaty*, CRITFC (Sept. 13, 2015), http://www.usea.org/sites/default/files/event-/CRITC_Overview.pdf.

<u>Figure 3: Flow Changes at The Dalles</u>



While significant differences between the eras certainly exist, it remains helpful to assess the damages that were found prior to the construction of the Treaty dams, as following this construction relatively few days exceeded the mean flow threshold that has been identified. In fact, as can be seen in Table 5 in the Appendix, from 1974-present, eighty-six total days exceeded 450,000 mean cfs. By comparison, from 1915-1974, 1354 days exceeded the 450,000 mean cfs threshold.

After these flow figures were compiled from the USGS gage, research attempted to then quantify approximate flood damages in the lower Basin that coincided with the flow events that exceeded 450,000 mean cfs. The process of gathering these data proved time-intensive in addition to not providing the clear, quantitative results that were desired at the outset of the research. A centralized database could not be found that contains comprehensive flood damage figures that allow for quantifiable damages from specific flood events. This provided difficulties in developing and analyzing information that would directly answer the question of when flood damages begin. Agencies such as the U.S. Army Corps of Engineers compile data on "damages prevented" from flood control projects[430], FEMA attempts to prevent major disasters through flood insurance mapping[431], and the National Weather Service provides some large-scale flood damage estimates by state on an annual basis.[432] However, no single agency is tasked with compiling flood damage data on a Basin-level with small flooding events.[433] The research that was performed provided some fruitful insight nonetheless, and it can be relied upon in future flood management decision-making.

The sources of data for the quantification of flood damages in the lower Columbia River Basin came virtually entirely from two sources: newspapers found throughout the region and a flood damages research study performed by the Environmental and Societal Impacts Group with the National Center for Atmospheric Research. Newspapers, while sometimes providing conflicting or inconsistent information between sources, do allow for a strong qualitative assessment of damages and perceived damages in a region caused by flooding or other disasters. Sometimes they do provide quantitative flood damage figures, but in small-scale high-flow events this is less common. But similar to the value of high volumes of media attention to determine actual damages of a flow event, a lack of newspaper reports or media coverage is also a good indication of the severity of the flow event.

In areas with large newspapers that have invested significant amounts of resources to archiving, newspaper reports can be relied upon for determining qualitative and quantitative flood damages during virtually the entire era being assessed. However, many media sources

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[430] Martie Cenkci, *Army Corps of Engineers projects prevent $13.3 billion in flood damages*, (Sept. 4, 2015), http://www.army.mil/article/155014/Army_Corps_of_Engineers_projects_prevent__13_3_billion_in_flood_damages/.
[431] *The National Flood Insurance Program,* FEMA (Sept. 13, 2015), http://www.fema.gov/national-flood-insurance-program.
[432] *Hydrologic Information Center - Flood Loss Data*, NATIONAL WEATHER SERVICE, (Sept. 13, 2015), http://www.nws.noaa.gov/oh/hic/.
[433] The only exception is when an area is deemed a "federal disaster area" due to flooding.

that were analyzed during this research did not have archived sources available prior to contemporary times. As a result, newspapers and other media sources were helpful in the contemporary analyses, but did not provide much support for the high flow events that occurred prior to the construction of the Treaty dams. The media sources that were researched were not contained to just those found in communities downstream from The Dalles, but instead were expanded to sources found throughout the Columbia River Basin. While higher flows coming from The Dalles will most directly impact downstream communities such as Portland, Vancouver, and Astoria, it is important to acknowledge that managing the entire system to ensure that flows do not exceed 450,000 cfs at The Dalles impacts communities and management throughout the entire Basin. As a result, a larger range of media sources were consulted.

The sole study that was found that provided a significant amount of support in the effort to specifically quantify historic flood damages in the Columbia River Basin came from research compiled by the Environmental and Societal Impacts Group with the National Center for Atmospheric Research.[434] This study was a reanalysis of flood damage estimates collected by the National Weather Service (NWS) between 1925 and 2000, which were estimates of direct physical damage due to flooding that resulted from rainfall or snowmelt.[435] They were obtained from diverse sources, compiled soon after each flood event, and not verified by comparison with actual expenditures.[436] Therefore, a primary objective of the study was to examine the scope, accuracy, and consistency of the NWS damage estimates to improve the data sets.[437] The

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[434] Roger A. Pielke, Jr. et al., *Flood Damage in the United States, 1926–2000: A Reanalysis of National Weather Service Estimates*, NATIONAL CENTER FOR ATMOSPHERIC RESEARCH (June 2002), http://www.flooddamagedata.org/flooddamagedata.pdf.
[435] *Id.*
[436] *Id.*
[437] *Id.*

study provides updated data sets for: estimated flood damage in the U.S. (1926–1979 and 1983–2000, by fiscal year; estimated flood damage for each state in the U.S. (1955–1979, by calendar year, and 1983–2000, by fiscal year); and estimated flood damage, by river basin, for the U.S. (1933–1975, by calendar year).[438]

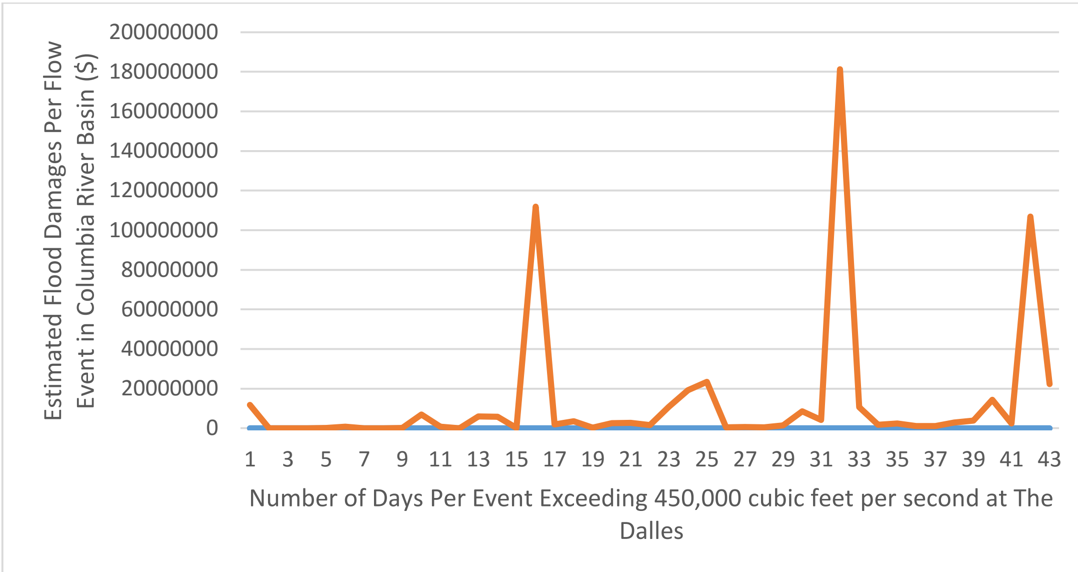
For purposes of this research, the flood damage data by river basin for the United States was the most applicable. The data for the Pacific Northwest region was combined between all rivers and streams found within the Columbia River Basin and those that are not. As a result, the flood damages per year that are found in Table 5 in the Appendix are stemming from those just found within the Columbia River Basin, and the study only provided data from 1933-1975. While the 450,000 cfs figure at The Dalles most directly impacts the mainstem of the Columbia Basin, all of the tributaries were included in this analysis because of the widespread impacts of management at The Dalles to this figure.

As can be seen in Table 1 below, a directly correlative relationship does not seem to exist between flood damages and the number of days that exceeded 450,000 mean cfs at The Dalles. This Table shows flow events that exceeded 450,000 mean cfs and how the number of days that these events stayed above this figure impacted total damages. Some expectations are fulfilled, such as the high damages seen in correlation with the extremely high peak flows over a sustained period of time in 1948, but generally the figures do not seem to be directly related. This is likely a result of weather events that lead to high volumes of flow occurring throughout the Basin, and the series of flood control reservoirs managing these flows prior to reaching The Dalles, but not before damages are already seen in upstream communities. The source of the flooding damages could also be the Willamette River, which flows into the Columbia below

[438] *Flood Damage in the United States, 1926-2003: A Reanalysis of National Weather Service Estimates,* (Sept. 14, 2015), http://www.flooddamagedata.org/.

The Dalles. Additionally, in the contemporary high flow events, some of the damages seen are not occurring during the same time as the damages that are incurred.

Table 1: Flood Damages per Length of High Flow Event



While the authors of the flood damage study and this author recognized the inconsistencies that could exist between a "calendar year" and "water year", it is important to acknowledge the problems that this can create in accurately calculating damages. The term U.S. Geological Survey "water year" in reports is defined as the 12-month period October 1, for any given year, through September 30 of the following year.[439] The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1999 is called the "1999" water year.

Non-structural flood control costs and benefits

In order to determine the possible economic benefits of non-structural measures, numerous studies were consulted. Assessments were performed to identify the types of possible

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[439] *Explanations for the National Water Conditions*, U.S. GEOLOGICAL SURVEY, (Sept. 14, 2015), http://water.usgs.gov/nwc/explain_data.html.

non-structural measures that could be undertaken, the potential economic benefits of these measures, and formulas that could be applied in order to determine quantifiable costs and benefits for communities on a local level.

In order to assess potential economic gains from the ecosystem improvements seen if the Columbia Basin would be able to reaccess its floodplain, studies were consulted that broadly quantified the economic value that is reaped in the Basin from ecosystem services.

Areas in Basin with floodplain access opportunities

While the Columbia River Basin is filled with dramatic gorges and canyons due to its geology and the nature of its climate, there are still some areas that could reap the benefits of the implementation of non-structural flood control measures and the allowance of more flexibility in flows. In order to identify these areas, GIS imagery and topographical maps were consulted among the significant tributaries and the mainstem of the Columbia River. Each river was tracked from its confluence upstream to its source. Images from the analysis are inserted in the appendix and are referenced in the results and discussion section. Specific GPS coordinates are included in the images in attempt to allow the reader to easily access the locations referenced.

The first and most critical component of this analysis required an analysis of topographical information throughout the Columbia River Basin. Every mile of the Columbia River and its major tributaries was analyzed to look for areas where floodplains appeared to be present based on the immediacy of significant topographical shifts. While a technical analysis of the exact elevations needed in relation to flow was not performed, the process undertaken allowed for a general sense as to the likelihood that floodplain benefits could be seen with slightly increased flows.

Following the identification of areas based solely on topography, this layer was removed to allow for a secondary assessment using solely satellite imagery. In addition to confirming visually what was suggested by the topography, it also allowed for an assessment of the amount and type of development found in the areas identified. This allowed for further analysis regarding the likelihood for structural measures to be needed in the higher flow events. Site visits were also conducted to confirm the evidence obtained using GIS technology, including numerous visits on the mainstem in the far lower reaches.

CHAPTER 5: RESULTS/DISCUSSION

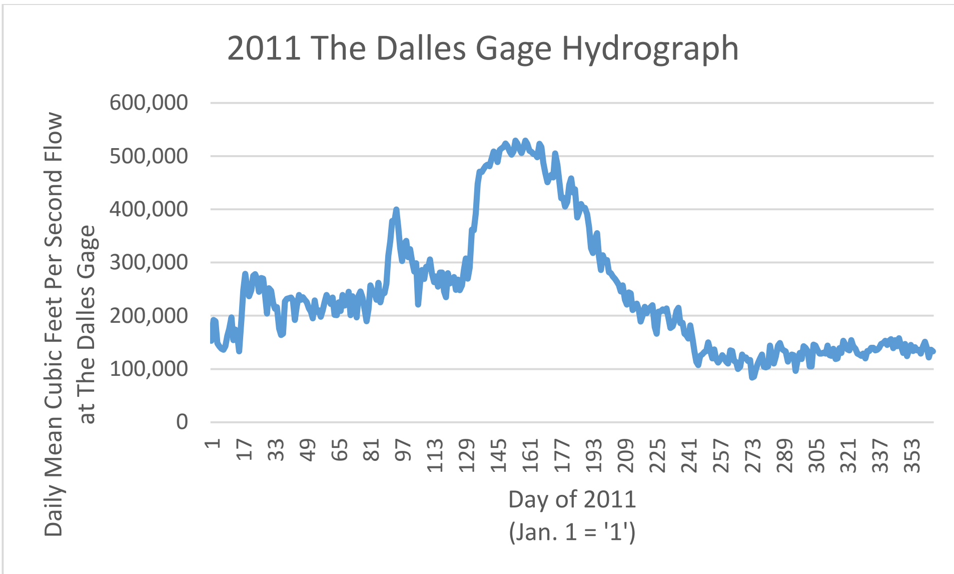
Flood Damages

The flood damage estimates and number of days that exceeded 450,000 daily mean cfs from 1915-2015 can be found in Table 5 in the Appendix. As a result of a lack of available information and data, flood damages from 1915-1933 were left unattained, but the number of days that exceed 450,000 daily mean cfs is included for analysis and future use. As was discussed above, following the construction of the Treaty dams, very few days exceeded the 450,000 cfs threshold, helping to clearly identify the seldom occurrences where this exceedance did occur as important focal points in determining whether these flows caused actual flood damages in the Basin. Three years since 1974 have contained days that have exceeded 450,000 cfs at The Dalles: 1996, 1997, and 2011. These years also provide opportunities for an assessment of flood damages in a contemporary era where floodplain development is similar to what it is today. As a result, a more thorough assessment of these three years will be more useful to modern flood plain managers. The study from the National Center for Atmospheric Research did not assess flooding during these three years, so a quantified figure is not contained in the table. However, a qualitative assessment using the methods described above was performed in order to gain a general sense of flood damages during these events.

I. 2011

The most recent flow event that exceeded the 450,000 mean cfs threshold at The Dalles gage station lasted forty-one days. The maximum mean daily cfs flow amount was 529,000 cfs, which far exceeds the flow at which allegedly flooding damages are seen throughout the region. Due to the relative proximity of the time of this research to the actual flow event, a myriad of information and data would assumedly be available regarding the significant impacts that were seen throughout the Basin regarding flood damages. Therefore, the lack of significant media coverage is just as relevant and telling as a high volume of clear evidence documenting significant regional flood damages. However, some media attention was given to the high flow event, and this will be discussed below.

Table 2: 2011 The Dalles Gage Hydrograph



The communities that will likely be most significantly impacted by high flow events as measured by the gage found at The Dalles are those that are found immediately downstream, including Portland, Astoria, and Vancouver. One of the major newspapers in the region, The Columbian, which is based out of Vancouver, reported during this flow event that there were no real impacts to safety and that the most significant damage seen was the loss of enjoyment of the local beach and trails by the local residents.[440] Additionally "[f]looding has also been observed near Vancouver's Waterfront Renaissance Trail between the Interstate 5 Bridge and Beaches Restaurant & Bar. Residents of the nearby condominiums are asking people not to try

440 Ray Legendre, *Columbia River Levels Remain Near Flood Stage*, THE COLUMBIAN, May 20, 2011.

to complete the trail by trespassing into their hillside gardens and trampling the plants."[441] A few days later, despite the river exceeding flood stage, the local newspaper continued to suggest that the impacts had been and would continue to be minimal in the region.[442]

Another source, The Oregonian, which is based in Portland, discussed the impacts of the rising waters on the number of bridge lifts that needed to be performed in the community.[443] During low water, the Interstate 5 Bridge may only need to be lifted two to three times a month, but between May 15 and May 27, 2011, the bridge had been lifted 52 times according to the Oregon Department of Transportation supervisor for the Steel and Interstate bridges.[444] The supervisor said the "bridgetenders often wait for three or four sailboats to gather before lifting the bridge" and despite the fact that "[l]ifts are not made during peak traffic hours between 6:30 a.m. and 9 a.m., and between 2:30 and 6 p.m. . . . the sharp increase in lifts has frustrated motorists, bicyclists and pedestrians who cross the bridge each day."[445] While not a quantifiable expense, this should be considered in future flood risk management decision-making. An assessment was also performed of news reports stemming from the community of Astoria, which is located very close to the mouth of the Columbia where it flows into the Pacific Ocean, and little was reported on local damages. Outside of the stories discussing the minimal impacts seen from the flow events, very little coverage was given in any of these communities, indicating that despite flows that exceeded 520,000 cfs at The Dalles, the communities were not impacted in a manner that was significant enough to report. While this is not a quantified flood damage figure, the qualitative assessment of these major metropolitan areas is telling.

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[441] *Id.*
[442] *Columbia River Rises Above Flood Stage in Vancouver,* THE COLUMBIAN, May 28, 2011.
[443] Stuart Tomlinson, *Columbia River Remains Under Flood Warning, With a Sharp Increase in Bridge Lifts, Lowland Inundation*, THE OREGONIAN, May 27, 2011.
[444] *Id.*
[445] *Id.*

The flows measured at The Dalles impact many other communities throughout the Basin as well. For example, the Tri-Cities in Washington, located along the banks of the Yakima River, saw road closures during the high flow event.[446] In addition to road closures, individuals had to move mobile home parks and livestock to higher elevations to avoid significant flood damages.[447] Additionally, flooding was seen along another major tributary, the Snake River, as Bingham and Jefferson Counties in Idaho were under a statewide emergency declaration for flooding issues.[448] Other communities were also impacted, but these were the major tributaries contributing to the high flows at The Dalles. It is important to note that while these damages are significant, these tributaries are not directly impacted by Canadian reservoir management. This research only includes the lower Columbia River Basin, so Canadian flooding was not researched.

II. 1997

Prior to 2011, the most recent flow event that exceeded 450,000 mean daily cfs at The Dalles gage occurred in 1997. As can be seen in Table 5 in the Appendix, for 43 days in the 1997 water year the mean daily cfs exceeded 450,000, with a maximum mean daily cfs of 571,000.

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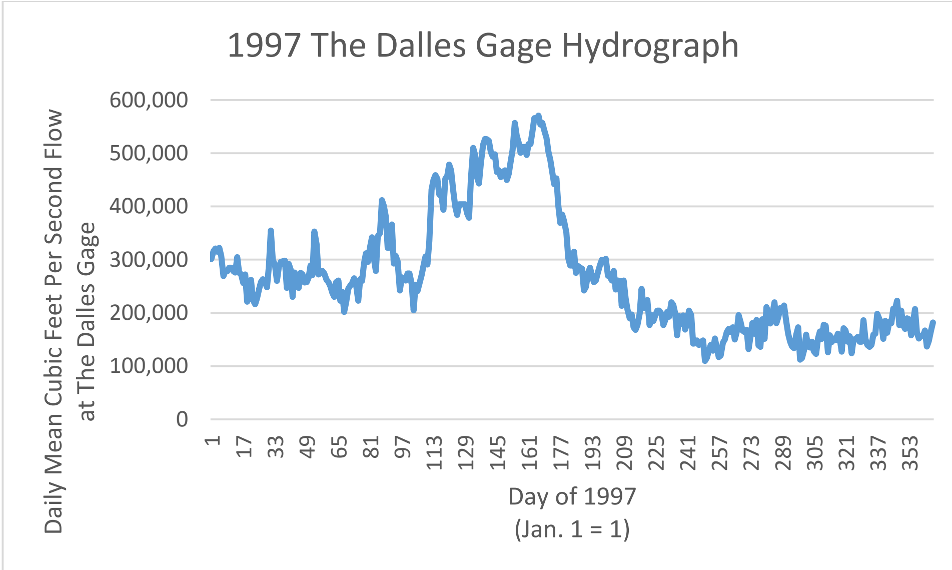
[446] Paula Horton, *Parts of Benton County Still Swamped*, TRI-CITY HERALD, May 19, 2011.
[447] Josh Peterson, *Benton County Declares Flood Emergency as Yakima River Rises*, KVEW, May 17, 2011.
[448] *Idaho Governor Issues Statewide Disaster Declaration over Flooding*, THE OREGONIAN, May 27, 2011.

Table 3: 1997 The Dalles Gage Hydrograph



In the only article that could be found from Portland press, an indication is made that despite some roadways being covered, a hydraulic engineer for the U.S. Army Corps of Engineers indicates that there is nothing to be alarmed about.[449] In Vancouver, a newspaper source indicates that on June 27, 1997, the level of the Columbia River at Vancouver had dropped to 13 feet for the first time in six weeks.[450] Convinced that the river was not again going to reach 19 feet this year, city workers collected most of the "Detour" signs they used periodically to block Columbia Way under the Interstate 5 Bridge, as three times that year the street under the north end of the bridge was closed because of flooding from the river.[451] According to that report, the road was inundated when the river got to 19.5 feet above sea level, which also resulted from flows from the Willamette.[452] Thus, while again there exists an inability to accurately quantify the damages to the Portland and Vancouver metropolitan area, there seems to be relatively minimal reporting from the local press regarding these issues.

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[449] *Willamette, Columbia Rise With Little Alarm*, THE OREGONIAN, June 5, 1997.
[450] Mike Padgett, *In Deep Water No Longer*, THE COLUMBIAN, June 27, 1997.
[451] *Id.*
[452] *Id.*

Beyond the minimal damages seen in the far lower end of the Columbia Basin, the Snake River saw significant flooding during this period.[453] Disastrous spring flooding occurred on the Snake River in eastern Idaho from March 14 to June 30, 1997, prompting a Presidential and FEMA Disaster Declaration for eastern Idaho counties, including: Bingham, Bonneville, Butte, Custer, Fremont, Jefferson, and Madison.[454] No known flood fatalities or injuries resulted, but flood damages were estimated to be over $4 million, while relief totaled $11,365,667 in public assistance, $8,054 in individual assistance, $251,054 from the NRCS, and $1,691,458 in hazard mitigation grants.[455]

III. 1996

In 1996, the first daily mean cfs exceeded 450,000 at The Dalles occurred in over twenty years. While this is significant, the flows only lasted for two days (Table 5 in the Appendix). These flows occurred in mid-June, so an examination of flood damages during that approximate time period was performed, with little to no information coming from Portland or Vancouver media sources. This could have been in part to the significant flooding that was seen only four months prior, as the Willamette River swelled its banks, causing damages throughout its basin.[456] The lack of information surrounding the June high flow event, however, continues to emphasize the possibility that 450,000 mean daily cfs at The Dalles is not the minimum threshold seen for damages.

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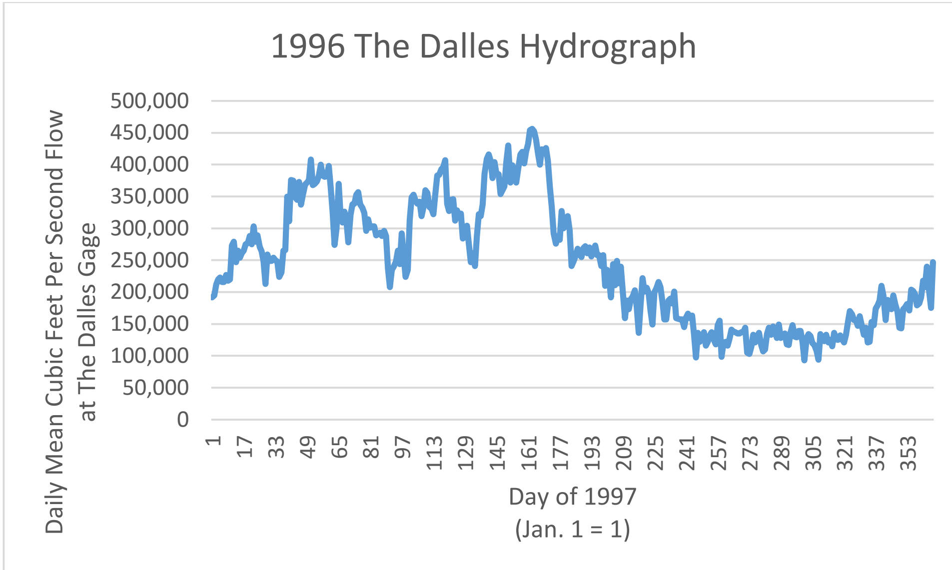
[453] *Flooding in Idaho*, NATIONAL WEATHER SERVICE, (Sept. 21, 2015), http://www.floodsafety.noaa.gov/states/id-flood.shtml.
[454] *Id.*
[455] *Id.*
[456] Don Knapp, *High Water Invades Downtown Portland*, CNN (Feb. 8, 1996) http://www.cnn.com/US/9602/flooding/update/index.html.

Table 4: 1996 The Dalles Gage Hydrograph



IV. Discussion

Despite a lack of quantitative flood damage data, current flood risk management decisions that have been developed on the assumption that 450,000 mean daily cfs at The Dalles leads to flood damages seem to be based on unsupported information. In the three years most recently experiencing flows exceeding this threshold, minimal damage was reported and experienced in communities such as Portland and Vancouver. Some of the upper reaches of tributaries have been more significantly impacted where Canadian reservoirs do not impact flow, but the large municipalities housing millions of people are the areas that flood risk managers are trying to protect with these specific restrictions. Recognizing that further studies need to be performed to accurately determine the actual flow at which damages occur would allow for the entire system to be more effectively optimized for multiple uses and could provide an opportunity to bridge the current gap between the United States and Canada in the Columbia River Treaty modernization discussions.

As was discussed above in the section describing the background to the Columbia River Treaty, one of the more significant sources of conflict between the two sides' positions is the issue of flood control. For over fifty years British Columbia has been obligated to manage their reservoirs in a fashion that prioritizes flood risk reductions throughout the lower portion of the Basin in the United States, in the process sacrificing potential benefits that could be reaped by the citizens of British Columbia. These restrictions are included in the current iteration of the Treaty, and the 450,000 cfs figure has been relied upon by managers on both sides of the border under the assumption that this causes flood risk. While British Columbia has an interest in creating more flexibility in their own management of reservoirs, the United States has a keen interest in ensuring that the reservoirs in British Columbia continue to be managed in a way that reduces flood risk. By determining that 450,000 mean daily cfs at The Dalles does not actually cause significant flood damages in the lower portion of the Columbia River Basin, it allows the United States to also permit more flexibility in management of the upper portion of the Basin. This could provide an opportunity to bridge a gap between the two sides, as the British Columbia reservoirs could be more beneficial and responsive to local needs, while the United States would continue to ensure that flows that actually cause damages in the lower Basin are kept to a minimum.

Non-structural flood control costs and benefits

I. Non-structural economic benefits

Structural flood control measures that have been implemented throughout the Columbia Basin have been costly, and with recent developments, Metro Portland is in the process of determining the potential cost of further construction and improvement.[457] The levee system found near and around the Portland Airport is in need of repair as a result of newly stringent standards for levees, and will cost well into the millions of dollars for the community.[458] Multnomah County Drainage District Director Reed Wagner indicates that levee repairs will cost $11 million a mile, with 26 miles of levee potentially needing replacements or repairs.[459] "Our hope with what we've learned so far system-wide (across all the levees), it'll be under $100 million," Wagner said. "But we've heard stories from across the country."[460]

There is a dire need for the Columbia River and its tributaries to have the ability to access and reconnect with its vast and ecologically important floodplain. Diversifying flood risk management throughout the Basin presents an opportunity to improve this access, which will subsequently lead to increased ecological resilience and numerous anthropocentric benefits.[461] Implementation of non-structural flood control measures will help allow for more flexibility in flows while not increasing flood damages throughout the Basin. Efforts should be undertaken by individuals, communities, and other entities to integrate these measures into broader floodplain management.

When one follows the mainstem of the Columbia River, it is striking the lack of structural development within and around the floodplain and riparian area relative to other major river systems in the United States. This suggests that increasing flow flexibility will have very minimal economic impact on the majority of the Basin. However, Portland and its

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[457] Nick Christensen, *New Standards for Columbia River Levees Could Cost Millions*, METRO NEWS, HTTP://WWW.OREGONMETRO.GOV/NEWS/NEW-STANDARDS-COLUMBIA-RIVER-LEVEES-COULD-COST-MILLIONS-FIX (Mar. 5, 2015).
[458] *Id.*
[459] *Id.*
[460] *Id.*
[461] Cosens, *supra* note 374.

surrounding area are a significant exception to this Basin-wide trend. While downtown Portland is located on the Willamette River, important Portland infrastructure, such as the Portland International Airport, are located directly in the floodplain of the mainstem of the Columbia.[462] Additionally, many structures within Vancouver, Washington are located within the floodplain, as well as parts of the Tri-Cities.[463] The choice to construct an airport in a floodplain of a major river system was land-use planning based on short-term gain against a high maintenance cost later because it creates significant difficulties with implementation of non-structural flood control measures. In fact, if flows are allowed to be more flexible in the Basin, targeted structural measures to prevent large-scale economic losses such as this are likely to be fiscally necessary given the cost of non-structural implementation. However, implementation of non-structural measures in Vancouver and in other parts of Portland could be possible.

Floodplain managers in the lower Columbia River Basin should strongly consider attempting to make decisions based on a concept developed by the Association of State Floodplain Managers (ASFPM) known as "No Adverse Impact".[464] "No Adverse Impact" floodplain management is the idea that actions of one property owner are not allowed to adversely affect the rights of other property owners.[465] This management style can be implemented at a watershed level, a regional level, or a community level, with the adverse effects or impacts being measured in terms of increased flood peaks, increased flood stages,

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[462] *USGS Map Name: Mount Tabor, OR*, TOPOQUEST, https://www.topoquest.com/map.php?lat=45.58689&lon=-122.61010&datum=nad27&zoom=16&map=auto&coord=d&mode=zoomout&size=m.
[463] *Id.*
[464] Association of State Floodplain Managers, *No Adverse Impact* (April 3, 2015) http://www.floods.org/index.asp?menuID=349&firstlevelmenuID=187&siteID=1.
[465] *Id.*

higher flood velocities, increased erosion and sedimentation, or other impacts the community considers important.[466]

One of the most effective nonstructural flood risk mitigation measures is called relocation, which entails physically moving structures and communities out of the floodplain to areas that are either out of the floodplain or a have a much smaller risk of flooding.[467] While this method can be potentially expensive, it inarguably is the best option for reconnecting the river to the floodplain without providing long-term damages and expenses. ASFPM's "No Adverse Impact" discusses and identifies floodplain acquisition and relocation projects as a way to completely eliminate future flood risk to the people and the building because the flood-prone structure is either moved outside of the floodplain or acquired and demolished and perpetual deed restrictions can be placed on the cleared land.[468] One major program that communities can participate in that helps in this regard is the FEMA Hazard Mitigation Assistance program.[469] In order to participate in this program, the grant must demonstrate that the future benefit outweigh the total-project costs as a basic eligibility requirement.[470] In a 2005 study, the Multi-Hazard Mitigation Council's analysis of FEMA mitigation project applications determined that flood hazard mitigation projects returned an average of $4.00 for every $1.00 spent over the lifetime of the project.[471]

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[466] *Id.*
[467] U.S. Army Corps of Engineers, *National Nonstructural Flood Proofing Committee* (April 3, 2015) http://www.usace.army.mil/Missions/CivilWorks/ProjectPlanning/nfpc.aspx.
[468] Association of State Floodplain Managers, *Mitigation: How-To Guide to No Adverse Impact* 13 (2013) available at http://www.floods.org/NoAdverseImpact/NAI_How-to-Guide_Mitigation.pdf.
[469] FEMA, *Hazard Mitigation Assistance* (April 3, 2015) https://www.fema.gov/hazard-mitigation-assistance.
[470] *Mitigation: How-To Guide to No Adverse Impact*, *supra* note 468.
[471] Multihazard Mitigation Council, *Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities* 5 (2005) available at http://c.ymcdn.com/sites/www.nibs.org/resource/resmgr/MMC/hms_vol1.pdf.

Additionally, following the completion of a mitigation project, a Loss Avoidance Study can be completed to determine how much damage was prevented from an actual flood event, and since the acquired land will no longer feature a structure at-risk of being flooded, benefits derived from the project will continue to accrue as future floods occur if the land remains undeveloped in perpetuity.[472] In addition to the economic benefits, social and environmental systems are also improved. The ecosystem benefits have been discussed briefly above, but social benefits can also occur, including peace of mind and lower stress levels for residents that experience concern and trauma from the loss of property or worse.

While the environmental and social benefits of the use of relocation as a nonstructural flood control measure is clear, communities are often concerned about the loss of tax base on the property that is acquired through a program like this, as typically a deed restriction on the property will limit future reuse of the property.[473] While open lands do likely generate less revenue than industrial, residential, or commercial properties, they do not have to provide the same community-based services. A study performed by the American Farmland Trust showed that residential development costs on average $1.15 in expenditures for every $1.00 in revenue generated.[474] This indicates that the tax base loss that would occur from participation in a program like this would not have the negative impact that a community might initially believe. The possibility of relocation is a holistic, economically-sound flood risk management mechanism, and should be considered by communities and other entities in the Basin as a real alternative to more dramatic structural changes, or a reliance on highly restrictive flow regimes.

[472] *Mitigation: How-To Guide to No Adverse Impact*, *supra* note 468.
[473] *Id.*
[474] American Farmland Trust, *Cost of Community Services Studies* (2006) available at http://stjohns.ifas.ufl.edu/documents/CostOfCommunityServicesStudies_8-06.pdf.

In addition to relocation, several other methods of flood risk management are considered "non-structural" and can be implemented on a much smaller scale. One of these methods is the process of elevating buildings in place so that the structure sees a reduction in frequency or depth of flooding during high-water events.[475] This can be done using foundation walls, piers, piles, posts or columns.[476] Fill is also used to map areas out of the floodplain under FEMA's National Flood Insurance Program, but this has proven to be damaging to endangered fish species and should not be recommended.[477] Another small scale nonstructural flood risk management technique is known as wet flood proofing. This involves taking measures that allow floodwater to enter the structure, which allows hydrostatic forces on the inside and outside of the structure to be equalized, reducing the risk of structural damage.[478] This in addition to relocating vulnerable items such as utilities, appliances and furnaces are relocated or waterproofed to higher locations can be effective.[479] When this method is combined with effective, timely flood warning systems that alert inhabitants in flood prone areas of impending high water, inhabitants have the opportunity to evacuate damageable property and themselves from the flood prone area which can prevent damage even further.[480]

The components of non-structural flood control measures that have proven successful around the world can certainly be applied to the Columbia River Basin. While efforts have been made to improve collaboration regarding flood control throughout the Basin, undoubtedly more efforts could be undertaken. Partnerships between different communities, public and private

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[475] U.S. Army Corps of Engineers, *National Nonstructural Flood Proofing Committee* (April 3, 2015) http://www.usace.army.mil/Missions/CivilWorks/ProjectPlanning/nfpc.aspx.
[476] *Id.*
[477] Final Bi-Op, *supra* note 134.
[478] U.S. Army Corps of Engineers, *National Nonstructural Flood Proofing Committee* (April 3, 2015) http://www.usace.army.mil/Missions/CivilWorks/ProjectPlanning/nfpc.aspx.
[479] *Id.*
[480] *Id.*

entities, and incorporation of a more democratic voice in flood risk decision-making could be strengthened significantly throughout the Basin. The idea of allowing more flexibility in flow will lead to improved riparian health and the positive ecological impacts that stem from the improved access for the river into the floodplain. Arguably the most important lesson that can be extracted from the international assessment of successful non-structural flood control measures is the notion of improved predicted technology to determine how to prepare communities for flood events. In the case of the Columbia River, the most important determination should be an assessment of the actual flow where significant flood damages occur to determine precisely how resources should be managed throughout the system. While damages prevented data collected by the United States Army Corps of Engineers is helpful, it does not provide the information needed to make appropriate management decisions.

In order to determine the costs of implementation of the non-structural measures, a variety of analyses may be undertaken. In 1975 the United States Army Corps of Engineers, while acknowledging the value of considering non-structural flood control measures in certain management decisions, through a research project undertaken by a researcher at University of California-Davis, developed a series of formulas that could be used in specific scenarios to estimate the costs and benefits of implementation of these measures.[481] Some of the formulas created will be briefly explained in order for the possibility of future use by floodplain managers and resource development policy makers.

The researcher on behalf of the Corps of Engineers developed a formula for the costs of floodproofing, which is as follows: $C_p = C_d C_2(CRF_p + M_p)M_s hA$, where the variables are as follows: C_p is the annual average cost of floodproofing, C_d is a factor to account for

[481] *Estimating Costs and Benefits of Nonstructural Flood Control Measures,* U.S. ARMY CORPS OF ENGINEERS, (1975) http://www.hec.usace.army.mil/publications/ResearchDocuments/RD-10.pdf.

contingencies (1.3 is suggested), C_2 is the initial cost of floodproofing per foot of flood depth per market value of the structure, CRF_p is a capital recovery factor, M_p is the annual maintenance cost of the floodproofing measures expressed as a fraction of total installation cost, M_s is the market values of all structures to be floodproofed, in dollars per acre, h is the average depth of flooding in feet, and A is the area flooded in acres.[482] This description is an attempt to serve as an overview of the calculation process, with much more in-depth analysis found in the document cited.[483] While this formula might seem complicated on its face, it does attempt to help provide individual property owners a method by which they can evaluate potential costs. This could be applied in a localized community context and could appropriately determine an estimated cost prior to development of a program devoted to promoting this type of measure.

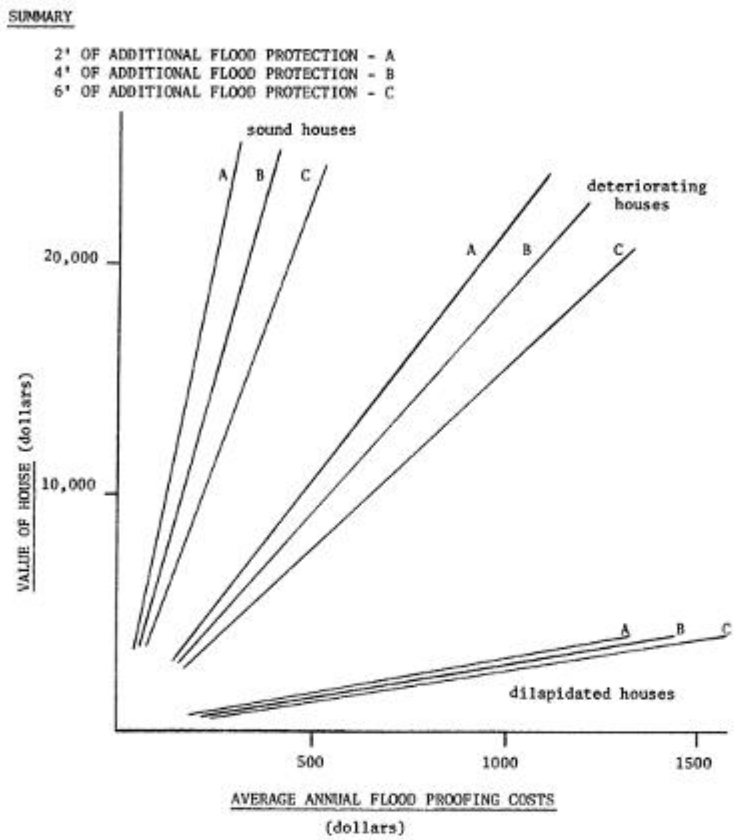
As an example application, the study examined the Tug Fork basin, and by applying the formulas provided developed the chart found below in Figure 4.[484] This type of research and development would be critically important for floodplain managers throughout the Columbia River Basin.

[482] *Id.*
[483] *Id.*
[484] *Id.*

Figure 4: Annual Cost of Floodproofing Formula

II-7

Figure II-2: Annual Cost of Floodproofing and Value of House



[Source: Tug Fork]

In addition to floodproofing costs, the study also discusses the costs of relocating people and structures from the floodplain. According to this report, there are three primary physical components of a relocation program: 1. Movement of existing structures from the flood-prone area to areas that are less flood-prone 2. Providing alternative sites with equivalent public services 3. Restoration of the evacuated floodplain.[485] A formula for determining these costs can be seen below in Figure 5.[486]

Figure 5: Formula for Measuring Non-Structural Costs

A Formula and Table Method for Measuring Costs

The cost of an evacuation-relocation program can be stated as a formula:

$$C_E = E_E + I - I_a - I_p \qquad (II.9)$$

where,

C_E = annual cost of evacuation and relocation;

E_E = the physical costs of administering and carrying through the program (changed to annual terms using an appropriate capital recovery factor);

I = discounted average annual income which could be earned at the floodplain site;

I_a = average annual agricultural income at the floodplain site;

I_p = value of open space or open land which is not reflected in the market.

Here we are ignoring I, I_a and I_p and concentrating on E_E. As in the case of floodproofing, the best way to determine total evacuation costs would be to survey the structures in the area proposed for evacuation, interview moving companies and demolition companies, determine relocation site costs for each move, and add the costs of conforming to PL 91-646. For preliminary planning a less thorough technique would be sufficient.

For this purpose E_E can be further defined[4] as :

$$E_E = CRF[A_m N_m + A_p N_p + A_d N_d + A_f N_f + A_r N_r + (A_i N_i - A_s N_s) + A_a N_a] + M \qquad (II.10)$$

where,

A_m = average moving costs per structure;

N_m = number of structures to be moved;

A_p = average cost of purchasing structures;

N_p = number of structures to be purchased;

A_d = average demoliton and removal costs per structure demolished;

N_d = number of structures to demolish;

A_f = average costs to fill basement;

N_f = number of affected structures with basement;

A_r = average cost to restore floodplain (seeding, grading, etc.);

N_r = number of acres in floodplain to be restored;

A_i = average market price of relocation sites and cost of improving these to make them equivalent to evacuated sites;

N_i = number of relocation sites required;

A_s = average salvage value per acre evacuated (i.e. for parks or agriculture);

N_s = acres evacuated;

CRF = capital recovery factor;

M = annual maintenance cost for preventing future development;

A_a = cost of relocation assistance;

N_a = number of structures receiving assistance.

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[485] *Id.*

[486] *Id.*

In addition to the costs, the report importantly also discusses the benefits of non-structural measures using various formulas. For example:

Figure 6: Formula for Benefits of Non-Structural Measures

$$B = n[(S_f^x - P_f) - (S_u^x - P_u)]$$

where,

B = benefits;

P_f = rental value, in initial equilibrium, of land subject to flooding (floodplain site);

P_u = rental value, in initial equilibrium, of land not subject to flooding (off floodplain site);

S_u^x = earnings of activity (net receipts exclusive of the cost of land) given a location outside the floodplain;

S_f^u = earnings of activity if located on the floodplain;

n = the number of activities.

The research continues to discuss the difficulties with quantifying these measures, but proposes other formulas in an attempt to help floodplain managers come to quantitative figures to balance against the costs of implementation.

In addition, it is important to note that some local flood managers could potentially advocate for the Corps to determine that 600,000 cfs at The Dalles is the appropriate target flow for economic purposes. While flood insurance is designed to lessen floodplain development, it could be feared that local developers, working from the assumption that the Corps is adequately managing flows beneath 450,000 cfs at The Dalles, will pressure local flood managers to allow development in areas that could be impacted by such a flow. However, it is clear that the Corps, despite significant efforts, has failed to manage at this flow in recent years. As such, a determination that 600,000 cfs as the target flow will help avoid potential flood losses from a reliance by developers that the Corps will be able to meet the 450,000 cfs target.

While dated, the formulas stemming from this report could and should be used to assess the costs and benefits of non-structural measures implemented throughout the Columbia Basin. This will allow for an improved and more transparent process of identifying appropriate areas within local communities that could provide opportunities for implementation of non-structural measures.

II. Economic benefits of ecosystem services

Ecological benefits of allowing a river or stream access to the floodplain are significant. Beyond these strictly ecological benefits, however, are the economic benefits that are inextricably tied to these ecological systems that that are found throughout the Pacific Northwest. While quantifying these values and the impacts are extremely difficult, an acknowledgement of the economic value of these systems is critically important when making large-scale management decisions in the Basin.

In a particularly valuable and recent study in the Pacific Northwest, Earth Economics, an organization that "applies new economic tools and principles to the challenges of the 21st century"[487], performed a study to inform the Chehalis Basin Flood Authority's decision-making process and ensure maximum return on future flood protection investments.[488] This report identifies and estimates the economic value of natural systems in the Chehalis River Basin, including flood protection.[489] An asset value is also provided in the study, which allows traditional flood project cost/benefit analysis to include ecosystem services.[490] While this Basin is not within the Columbia River Basin, the asset value for ecosystem services between $43-400 billion annually helps to give a general framework for the potential value of the much larger Columbia River system.[491] Using a 0% discount rate, which treats the value that the ecosystem

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[487] *Our Mission*, EARTH ECONOMICS, http://www.eartheconomics.org/Page23.aspx (last visited Aug. 28, 2015).
[488] Flood Protection and Ecosystem Services in the Chehalis River Basin, *Earth Economics*, http://www.eartheconomics.org/FileLibrary/file/Reports/Chehalis/Earth_Economics_Report_on_the_Chehalis_River_Basin_compressed.pdf (May 2010).
[489] *Id.*
[490] *Id.*
[491] *Id.* at 42.

services will provide to future generations as equal to that of present generations, the present value of ecosystem services could be as much as one trillion dollars.[492]

These numbers, while in a watershed that has obvious differences from the Columbia, still justify significant investments in restoration and conservation throughout the lower Columbia. One of the largest and most valuable resources in the Columbia, salmon, is also found in the Chehalis Basin. As the author's point out in this report, in the 1920's, the best investment to increase salmon production and economic value was to invest in more boats and nets.[493] However, investing in ecosystem services is a more effective and productive investment today.[494]

According to the authors, "if natural flood protection [and] salmon productivity . . .are lost . . .levees [and] hatcheries . . . must be built", which creates the need for real costs to be incurred to replace services that were previously free, often with less efficient systems.[495] As the author's reiterate, in many urbanized watersheds, levees occupy and narrow the transition zone for salmon where the young adjust from fresh to salt water.[496] This can create swift currents that sweep young fish directly from fresh to salt water, resulting in high mortality rates. On the other hand, widening the floodway coupled with restoration investments such as off-channel sloughs, can create salmon habitat while at the same time provide greater flood protection. Generally, this study shows the economic value of allowing floodplain access for salmon populations and the importance of large, multi-municipality basins to prioritize flood risk management that values ecosystem services.

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[492] *Id.*
[493] *Id.*
[494] *Id.*
[495] *Id.* at X.
[496] *Id.* at 13.

In addition to the Earth Economics study that gave general values that the Chehalis River Basin provides, a research study was performed in 2009 estimating the economic value of salmon in the Rogue River in Oregon.[497] In this report, the author's determined that Oregonians received $1.4 million annually associated with commercial salmon fishing, $16 million annually associated with salmon sport fishing, and $1.5 billion annually associated with non-use values.[498] While the Rogue River system is much more unconfined than the Columbia, the figures that are found within a larger river system are indicative of the values that could be found within the Columbia system. Improving survivability through an increase in flexibility with flood risk management and subsequent improved access to the floodplain would have dramatic economic impacts in the region.

As mentioned above, waterfowl also see significant benefits when river systems are allowed access to the floodplain. In order to see the estimated economic impact of waterfowl hunting in the Columbia River Basin, a study performed by the U.S. Fish and Wildlife Service will be briefly discussed.[499] When combining Washington, Oregon, and Idaho in 2001, over $71 million was spent in trip and equipment expenditures, over 1,000 jobs were created, and over $5.6 million in state tax revenues were generated.[500] These figures again reflect the importance for local economies of prioritizing waterfowl habitat through improved floodplain habitat and incorporating flexibility into flood risk management decisions.

In addition to the above economic benefits, clear economic loss could be seen in the region if a lawsuit, similar to that seen in the Western District of Washington as discussed

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[497] *The Economic Value of Rogue River Salmon*, ECONORTHWEST, http://www.americanrivers.org/assets/pdfs/wild-and-scenic-rivers/the-economic-value-of-rogue.pdf (Jan. 2009).
[498] *Id.*
[499] Erin Henderson, *Economic Impact of Waterfowl Hunting in the United States*, U.S. FISH AND WILDLIFE SERVICE, http://www.wlf.louisiana.gov/sites/default/files/pdf/pagehunting/32535-programs/nat_survey2001_waterfowlhunting.pdf (2009).
[500] *Id.* at 11.

above[501], is brought due to the impacts that structural measures and floodplain managing have on other species listed under the Endangered Species Act. While this cost is difficult to quantify due to the wide variance in costs incurred in lawsuits, it is still an economic detriment that should be considered when balancing the costs and benefits of non-structural flood control measure implementation.

Areas in Basin with floodplain access opportunities

Whereas the above analysis indicates the potential need for further examination and research regarding the appropriate ways in which the flows in the Columbia River should be managed, initial conclusions can be made that some flexibility seems to exist in the Columbia River Treaty negotiations in terms of the needs of the U.S. portion of the Basin to rely upon Canada reservoirs. In order for those potentially increased flows to be feasible, however, there must be some areas in the U.S. portion of the Basin that contain relatively undeveloped floodplains that can withstand these flows. The following analysis is not intended to provide concrete areas that should be relied upon without further research, but simply is an effort to identify areas of potential value for this purpose in hopes that future policy research can use this research as a springboard for further analysis. However, much time was spent identifying areas throughout the Columbia River Basin where possible flexibility could be seen, and these areas will be briefly discussed and identified below. Much of the Basin contains deep gorges and canyons, but some portions of the mainstem and its tributaries provide significant undeveloped floodplain opportunities.

The mainstem of the Columbia River was the first stream analyzed, and the analysis started at the mouth where it flows into the Pacific Ocean, and followed upstream to the border

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[501] *See supra* FEMA's NFIP and the Endangered Species Act.

between Washington and British Columbia. From Crims Island to the mouth of the Columbia River significant portions of undeveloped floodplain with relatively little elevation change exists (Figure 7). This portion of the river could likely handle a much higher flow amount without the need for significant flood control measures at all. This was confirmed during a site visit that showed that a significant and undeveloped floodplain exists in this area (Figures 8 & 9). Several miles upstream from the mouth, on Point Adams Road in Oregon, a typical marshy landscape is found between the mouth and Crims Island (Figures 10 & 11).

Just upstream from Crims Island at Longview, WA and Rainer, OR, a combination of structural and non-structural measures would likely need to be undertaken (Figure 12 & 13). Very little elevation change is seen in the floodplain in this area, but significant development in Longview presents some challenges. However, undeveloped floodplain with very little elevation change can be seen from Prescott, OR past St. Helens, OR, as numerous wildlife refuges and lakes are found all of the way to nearly the mouth of the Willamette River (Figures 14 & 15).

However, the portion of the Columbia River that flows near Portland and along the banks of Vancouver, WA is a significant challenge. While some non-structural measures could likely be implemented to mitigate damages, some structural measures would likely be required, especially near the Portland Airport. These limitations for floodplain access for the river exist almost completely from the mouth of the Willamette River to Mosier, OR, other than the Pierce Wildlife Refuge found directly downstream from Bonneville Dam.

Some limited opportunities for floodplain access exist from Mosier, OR to The Dalles, OR, with the possibility of some small-scale structural measures at The Dalles to prevent damages (Figure 16). Due to elevation difficulties, very little accessible floodplain exists from

The Dalles to Arlington, OR. However, from Arlington, OR to Van Skinner Island in Washington floodplain access is available (Figure 17). Limitations due to topography are found from Van Skinner Island to Attalia, WA, however from Attalia to Homestead Island has high potential for increased flows including the McNary Wildlife Refuge islands (Figure 18). However, some structural measures will be required in the Tri-Cities and some concern could be present in the area due to the Hanford facility.

From Homestead Island to Locke Island some difficulties exist due to elevation changes, but just past Locke Island to Priest Rapids Dam along the Saddle Mountain National Wildlife Refuge some opportunities seem to exist (Figure 19). From Priest Rapids Dam to Trinidad, WA seems to be limited, but from Trinidad to Rock Island Dam small areas have some floodplain (Figure 20). From Rock Island Dam to Entiat, WA, limited floodplain access exists, and in portions where it does exist development in Wenatchee has occurred, requiring a mixture of structural and non-structural measures. However, some access seems to be present between Entiat and Chelan Falls, WA (Figure 21). Chelan Falls and Brewster, WA are connected by a deep gorge, but a small window exists between Brewster and Bridgeport, WA (Figure 22). Some small opportunities from Bridgeport to the Canadian border exist with floodplain access, but the majority of the rest of the U.S. portion of the river has deep gorges and canyons typical of the region (Figure 23).

A tributary of the Columbia River that is critically important in the Portland and Vancouver, WA area is the Willamette River. This river flows through downtown Portland and has caused significant flooding issues in the region in the past. From the confluence through Portland there is a highly developed floodplain all of the way to Willow Island. This portion of the stream would likely require creative structural and non-structural measures to mitigate higher flows. However, much of the rest of the Willamette River all of the way to Dexter Reservoir has relatively undeveloped floodplain and very little issue with topographical restrictions (Figures 24, 25, & 26). Communities such as Salem, Corvallis, and Eugene have some floodplain development, but generally the Willamette seems to have the potential for higher flows that could provide the floodplain benefits mentioned previously.

One of the largest and most significant tributaries is also one of most heavily managed through reservoirs and dams. The Snake River has high volumes of canyons and gorges (Figure 28). However, some limited opportunities for floodplain access benefits do exist. From the confluence to Ice Harbor Dam some access to the floodplain is possible (Figure 27). However, from Ice Harbor Dam to Weiser, ID, extreme limitations due to topography exist for floodplain access. Some limited opportunities for undeveloped floodplain access can be found on the Snake River between Weiser, ID and Guffey, ID (Figures 29, 30, & 31). From Guffey to Grand View, ID, topographical restrictions exist, but the Chattin Flat near Grand View provides some floodplain access (Figure 32). The remainder of the Snake River has small scale opportunities, with particular access upstream of Idaho Falls.

Some access opportunity exists in the portion of the Cowlitz River from the confluence to Barrier Dam (Figure 33). However, the remainder of the Cowlitz River is limited by topography.

Another tributary, the Pend Oreille River, has limited access from its confluence to Ione, WA. However, some opportunities exist from Ione, WA to Lake Pend Oreille (Figures 34, 35, & 36). From there, the Clark Fork is relatively limited.

The Yakima River, which is the longest river that flows completely in Washington, is a critically important tributary to the Columbia River. From its confluence to Pomona, WA lots of opportunity through a large stretch of river exists for floodplain access (Figures 37, 38, & 39). From Pomona to Ellensburg, however, limitations exist due to topography. However, from Ellensburg to just past Thorp, WA floodplain access reappears before being extremely limited all of the way to its source.

Another significant tributary is the Boise River in Idaho. While it flows through downtown Boise and Caldwell, some areas, in particular downstream of Boise, have opportunities for floodplain access (Figure 41).

While there are many other tributaries in the Columbia River Basin that were not directly mentioned, the streams that are found above are the most significant rivers in the Basin with floodplain access that are managed by reservoir operations. In order to explain why some of the other tributaries are not as important, a few will be highlighted briefly. The category of streams that are almost entirely gorges and canyons include Deschutes, Clearwater, and the Owyhee. These streams are extremely important in the region regarding flows, but without significant floodplain access, they do not provide the types of benefits outlined in a previous section. Conversely, the Klickitat and Salmon do have some significant floodplain areas, but are not managed by reservoirs. This is important in this context because without the ability to manage these flows through reservoirs, it is unhelpful to recognize and identify areas that could benefit from higher flows. Additionally, tributaries such as the Kootenay and Okanogan have floodplain access in the U.S. but flow into the Columbia River in British Columbia, limiting the effectiveness of autonomous U.S. flow decisions. However, the Okanogan does have opportunities for floodplain access (Figure 40). Additionally, smaller streams such as the John Day were not thoroughly analyzed, as the potential impact is relatively small in the larger flow regime.

While important to reiterate that this research is not as technical as is needed to truly identify areas that could provide flexibility in terms of flow access to floodplains, it does serve the purpose of starting the process of thinking critically about creative ways to manage flood risk. While the Columbia River has some opportunities for flexibility, many of its tributaries have even higher potential and could be managed to decrease reliance on British Columbia for flow restrictions to prevent flood damages.

CHAPTER 6: CONCLUSION

As can be seen from the above analysis, significant research needs and questions have been raised, as current flood risk management policy is seemingly based on decisions made without thorough examination of actual impacts from flow regimes. Additionally, there are clear quantitative and qualitative benefits from increased flows and the implementation of non-structural flood control measures, and there are lots of locations throughout the Columbia River Basin that would allow for this flexibility.

In addition to the general conclusions stemming from this research, the need for a federal agency, perhaps the U.S. Army Corps of Engineers, to quantify actual flood damages by basin in order to adequately equip flood risk managers with the tools needed to effectively manage such risks should be emphasized. Additionally, it is important to briefly reiterate the potential desires of local flood managers to have a more flexible flow target at The Dalles to help minimize local development in areas that could be impacted by flows that exceed the arbitrarily low target flow of 450,000 cfs that has been exceeded many times since the Treaty dams were constructed.

In the current context of the Columbia River Treaty review, the United States should specifically invest research resources into determining the flows at which actual damages begin to occur. This number is likely closer to 600,000 cfs found in early Corps documents rather than 450,000 cfs, and this will allow for more flexibility for the United States and lessen the reliance on British Columbia's reservoirs. Additionally, a more thorough analysis of the actual costs and benefits of more flexible flood risk management, both qualitative and quantitative, would equip policy makers with more critical information regarding the most economically responsible options in the Basin. While some locations were identified for flexibility in this research, more research should also be performed on the mainstem of the Columbia regarding the possibility for floodplain access with increased flows. Flood risk management in the Columbia River Basin is very likely too restrictive and allowing for more flexibility will achieve economic, ecological, and social benefits throughout the region.

APPENDIX

Figure 7: Columbia River at Crims Island

Figure 8: Mouth of Columbia River

Figure 9: Mouth of Columbia River

Figure 10: Columbia River on Point Adams Road several miles upstream from mouth

Figure 11: Columbia River on Point Adams Road several miles upstream from mouth

Figure 12: Columbia River at Longview

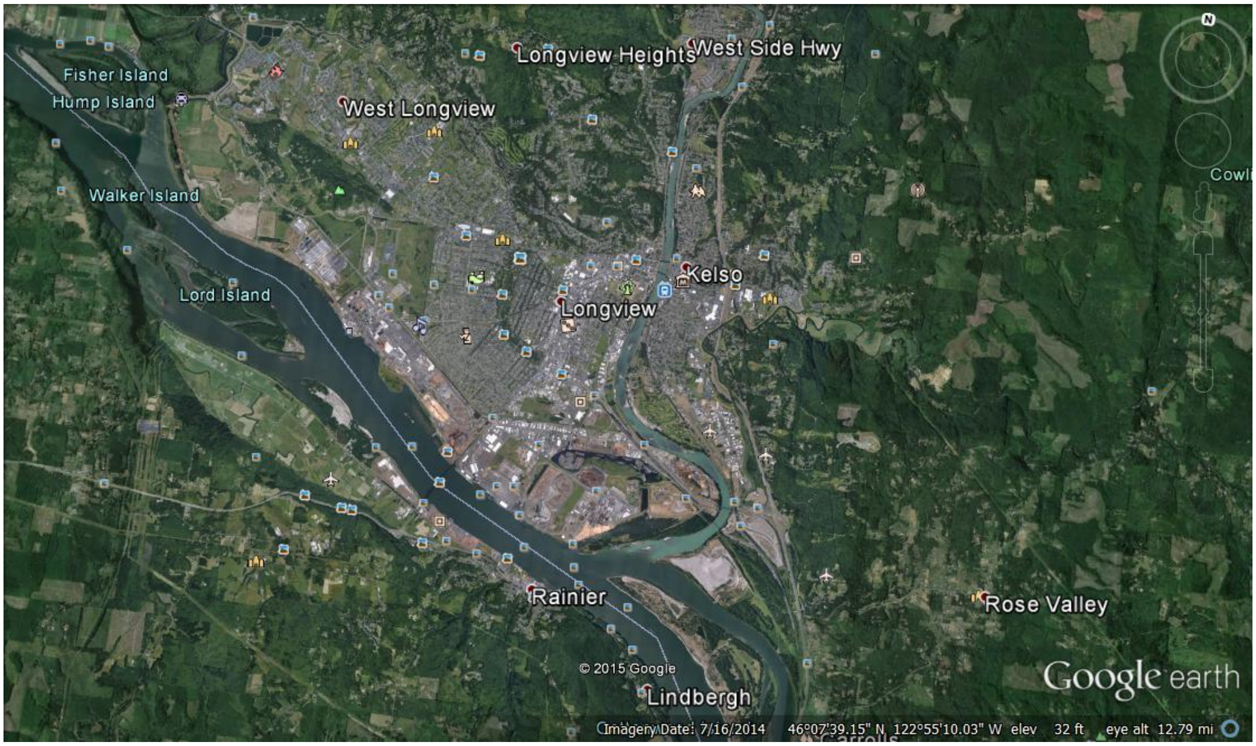

Figure 13: Columbia River at Longview (taken from Oregon)

Figure 14: Columbia River at Prescott, Oregon

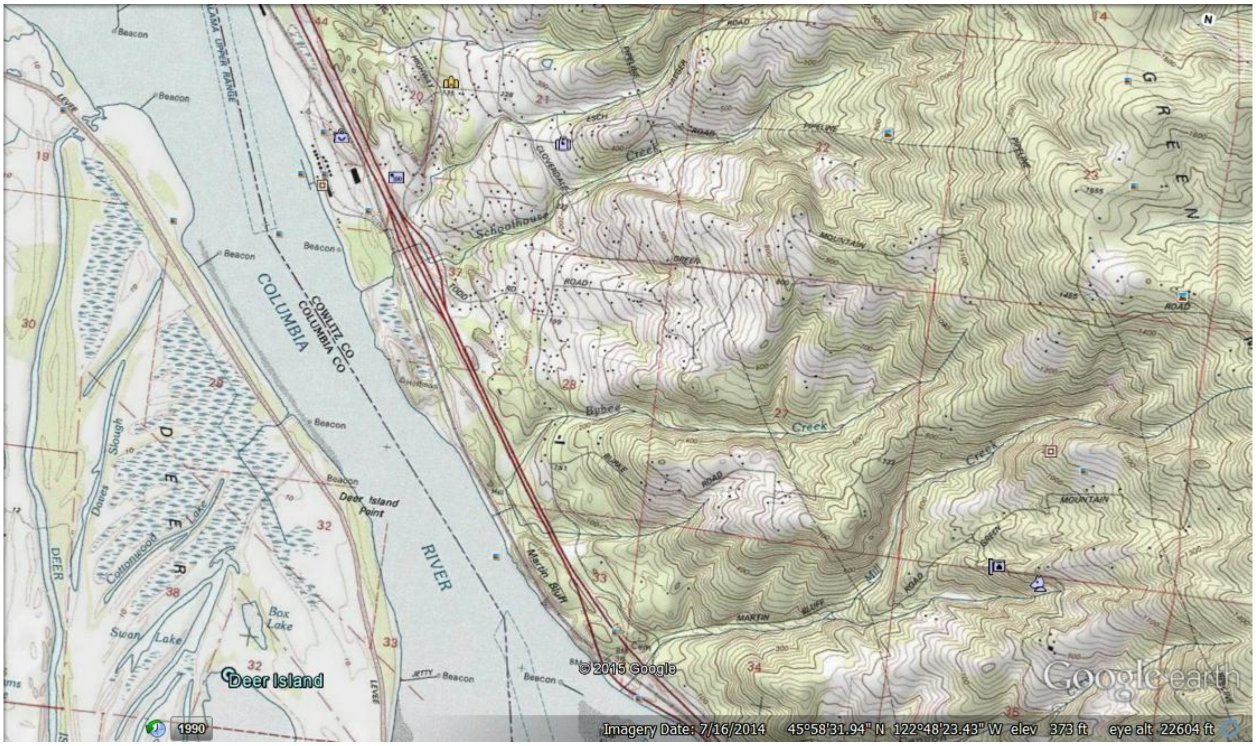

Figure 15: Columbia River at Prescott, Oregon

Figure 16: Columbia River past Mosier, Oregon

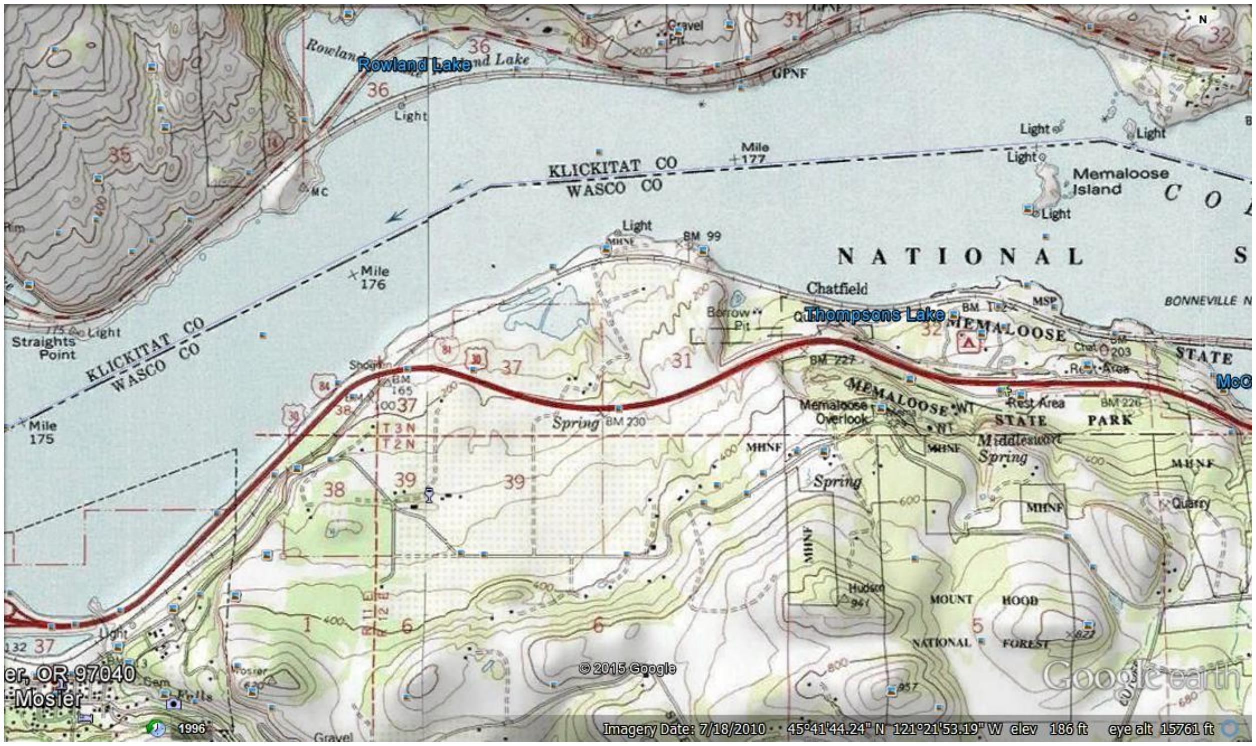

Figure 17: Columbia River between Arlington, Oregon and Van Skinner Island

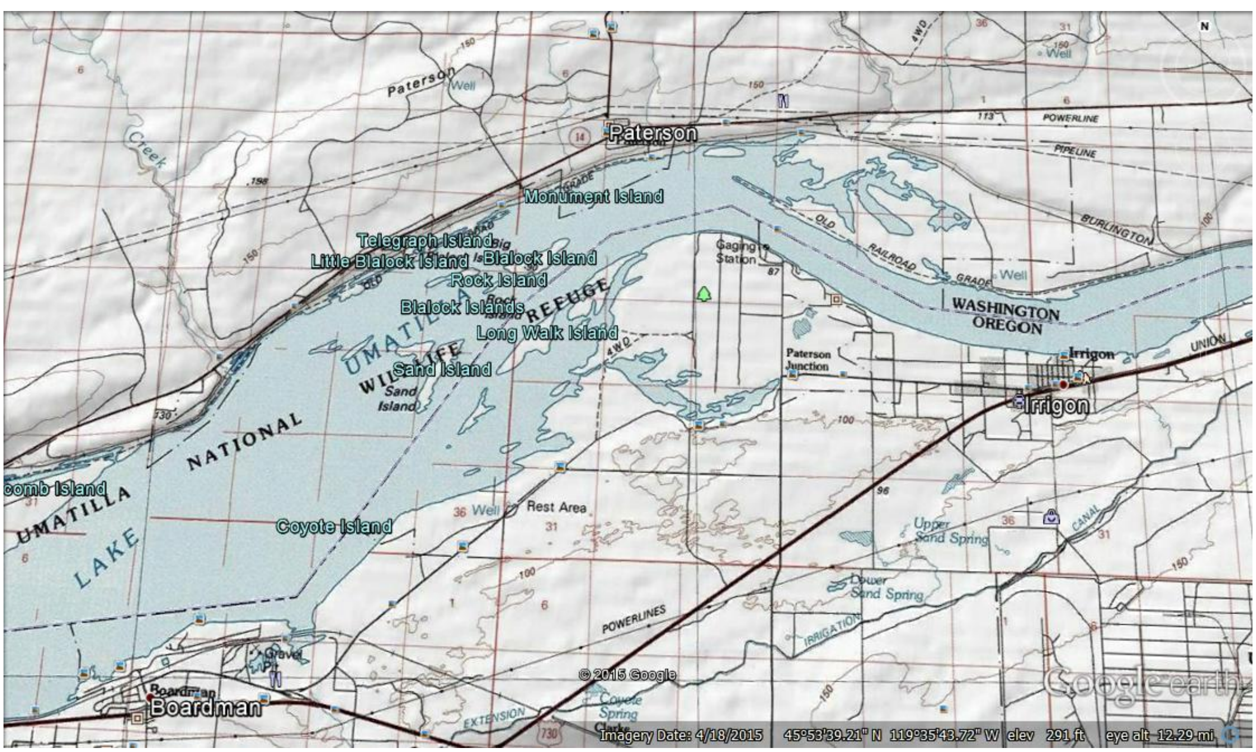

Figure 18: Columbia River at Homestead Island, Washington

Figure 19: Columbia River at Locke Island, Washington

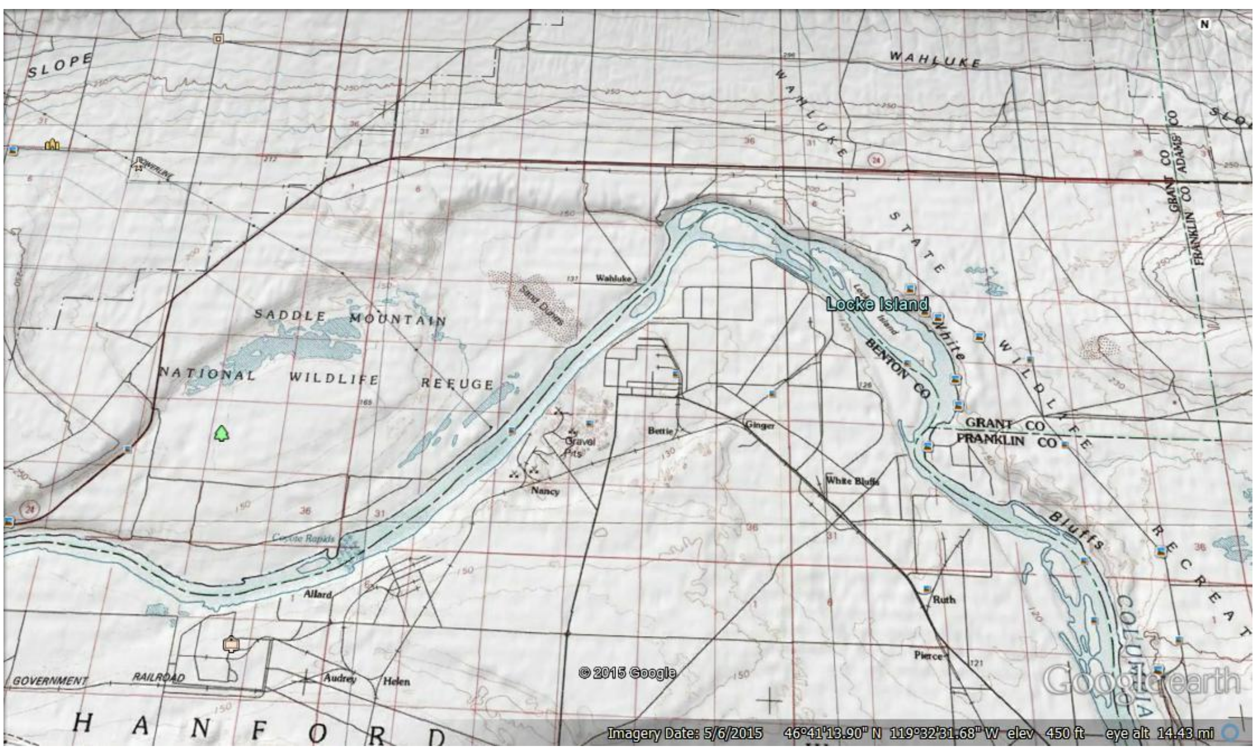

Figure 20: Columbia River just past Trinidad, Washington

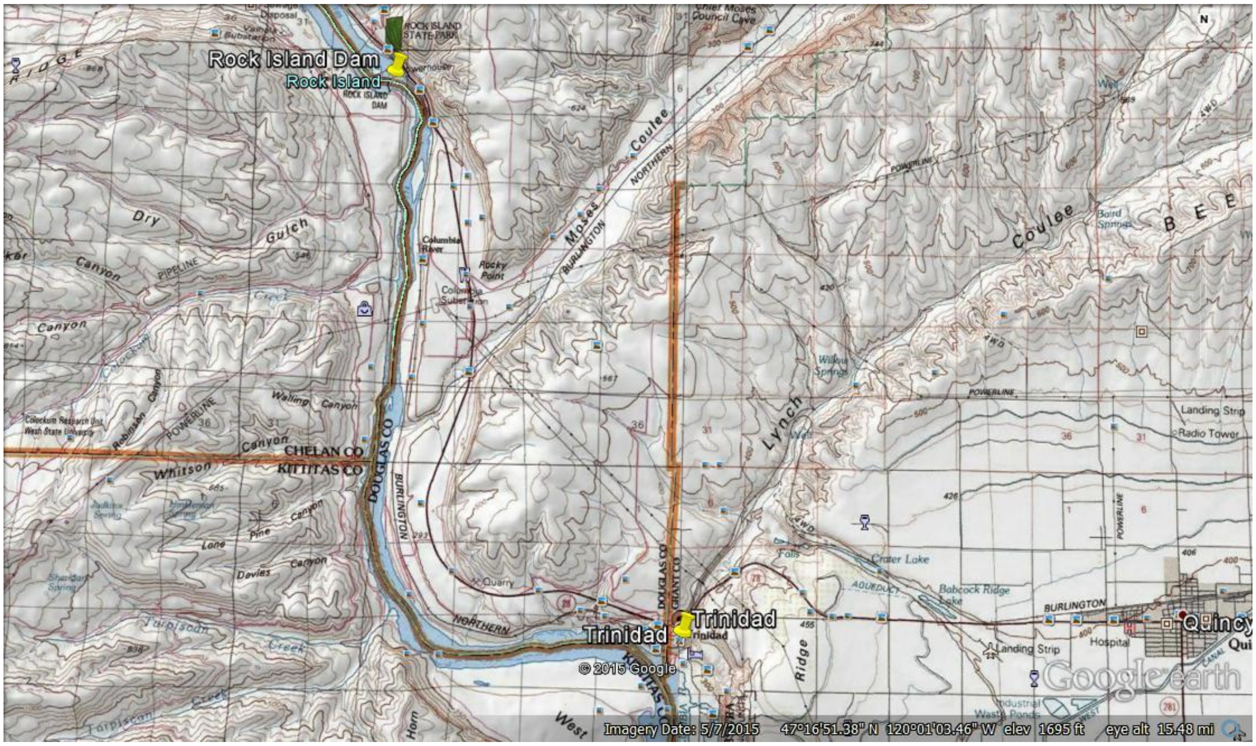

Figure 21: Columbia River between Entiat, Washington and Chelan Falls, Washington

Figure 22: Columbia River at Bridgeport, Washington

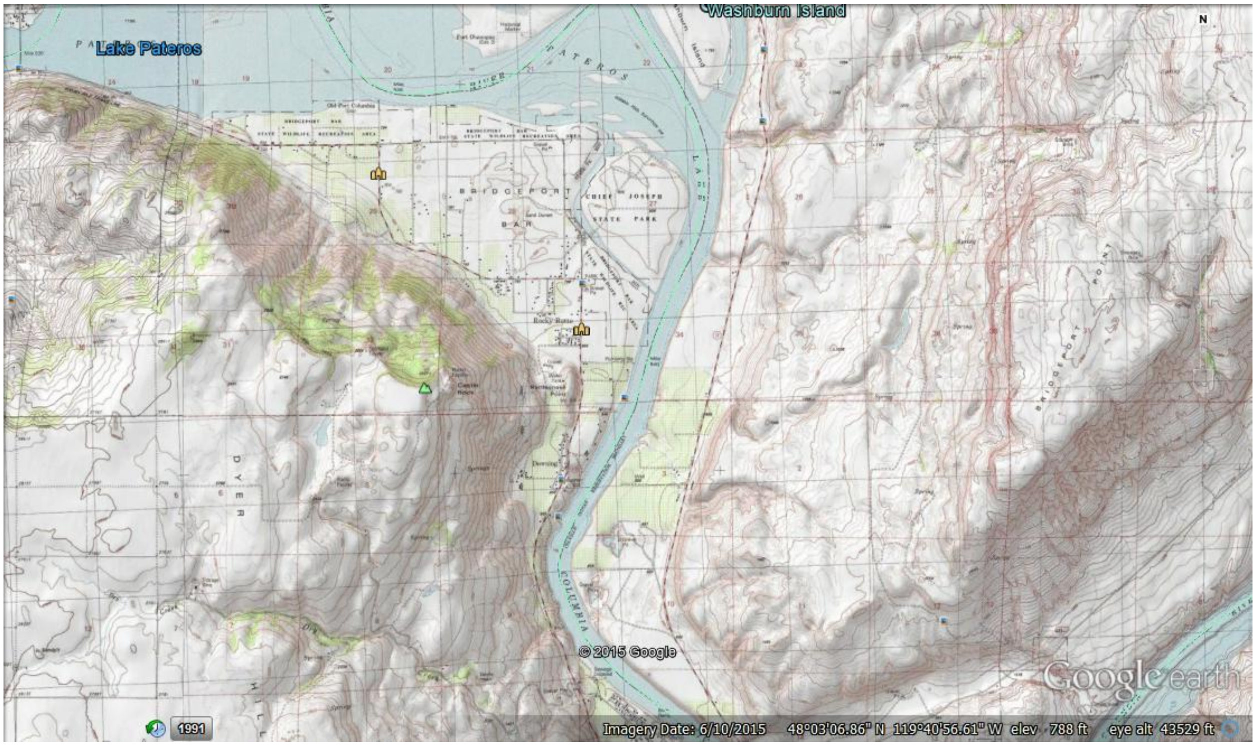

Figure 23: Columbia River past Northport, Washington

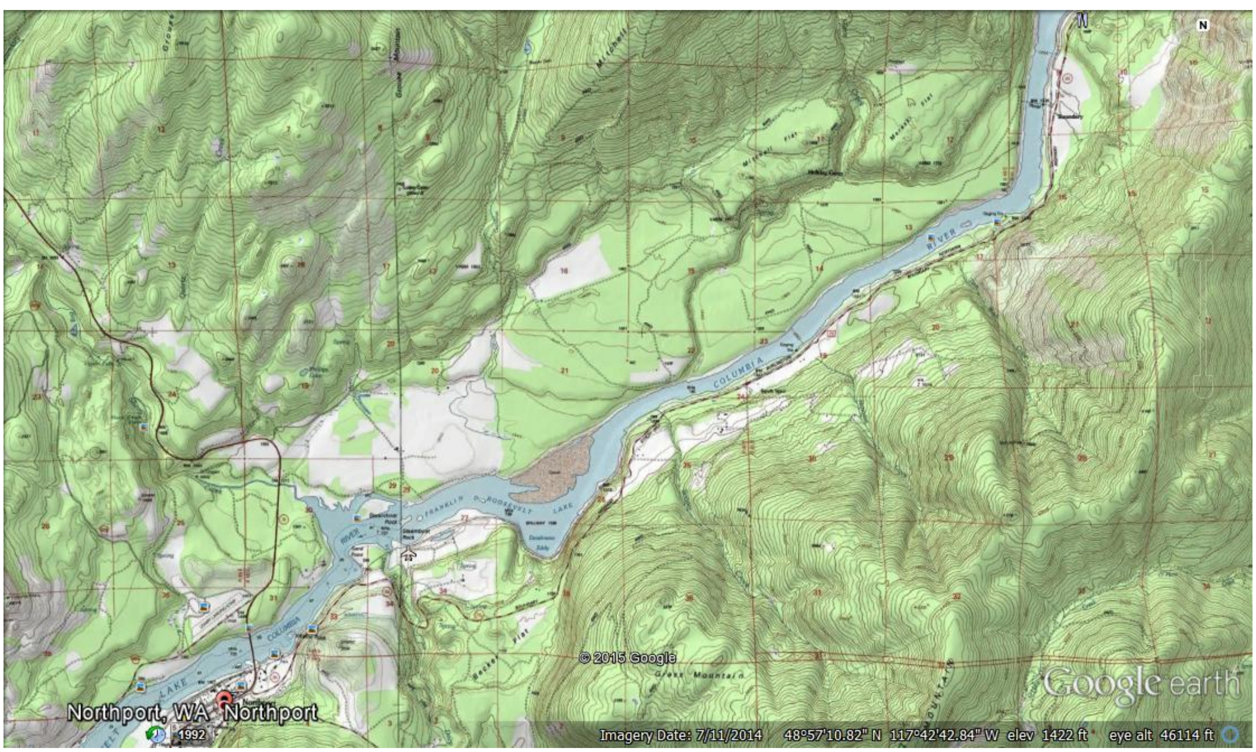

Figure 24: Willamette River between Willow Island and Dexter Reservoir

Figure 25: Willamette River between Willow Island and Dexter Reservoir

Figure 26: Willamette River at North Albany, Oregon

Figure 27: Snake River from confluence to Ice Harbor Dam

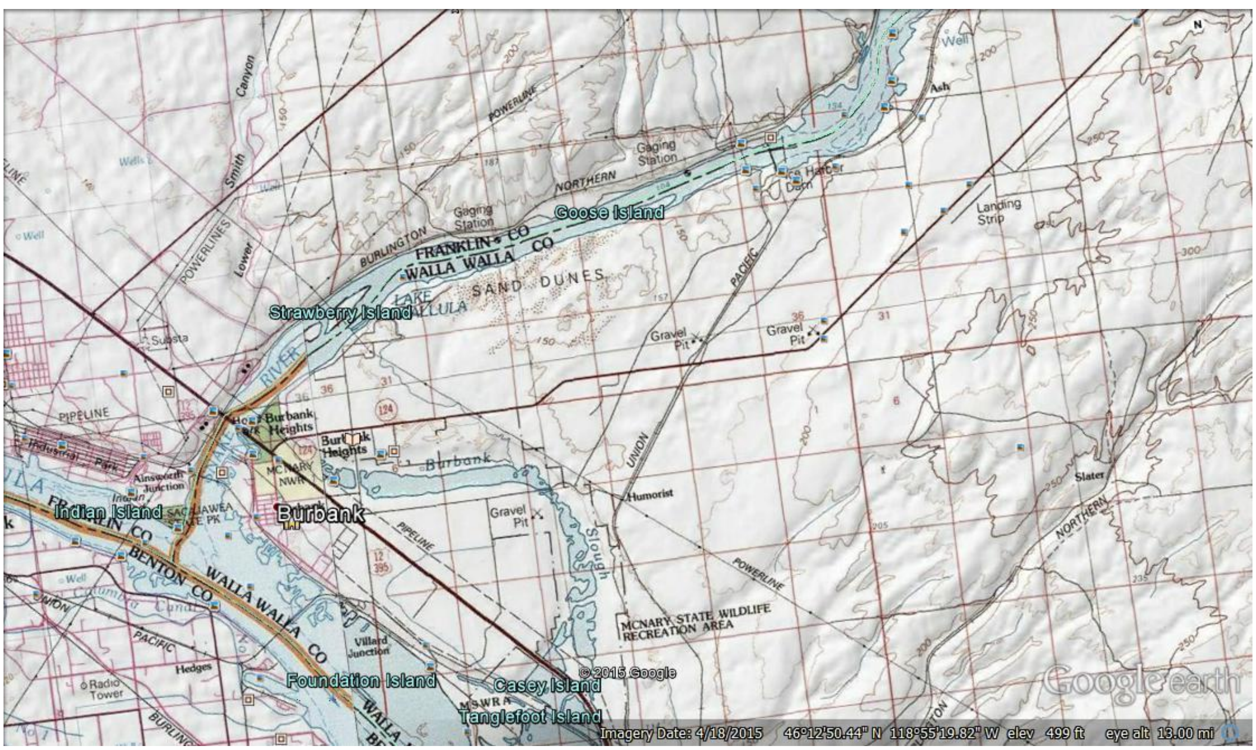

Figure 28: Snake River west of Pullman, Washington

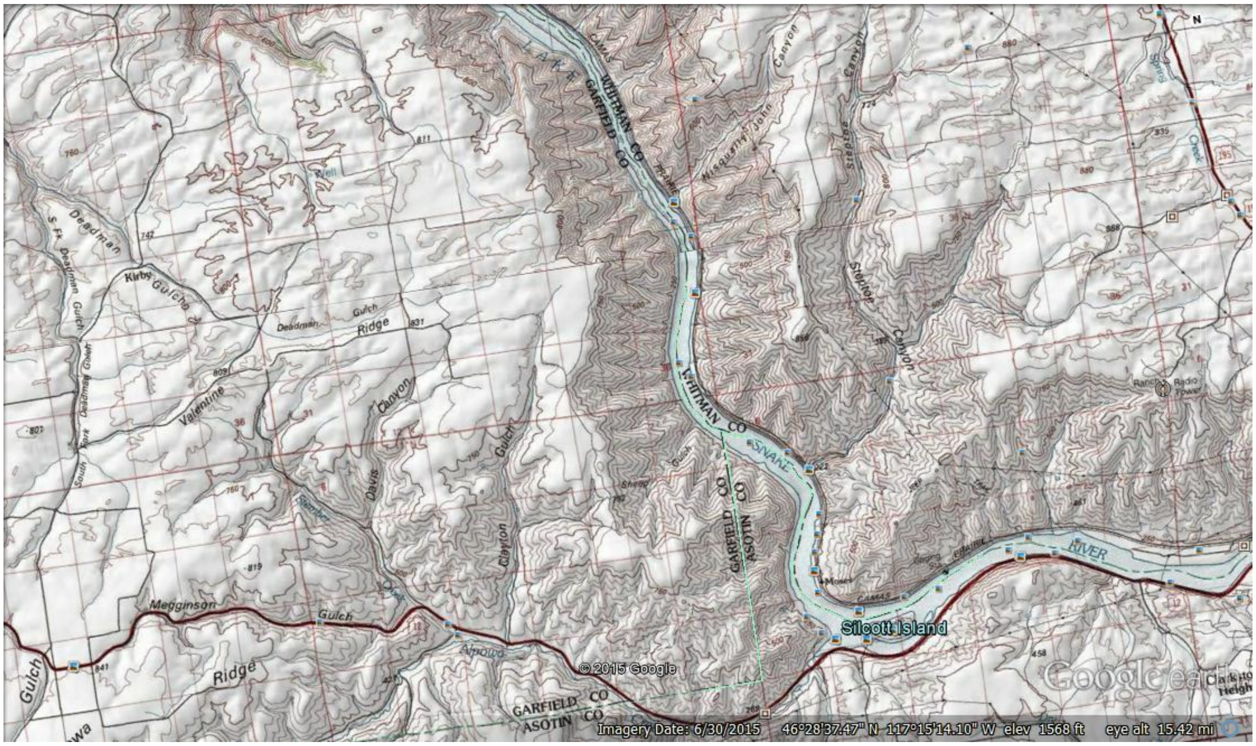

Figure 29: Snake River near Weiser, Idaho

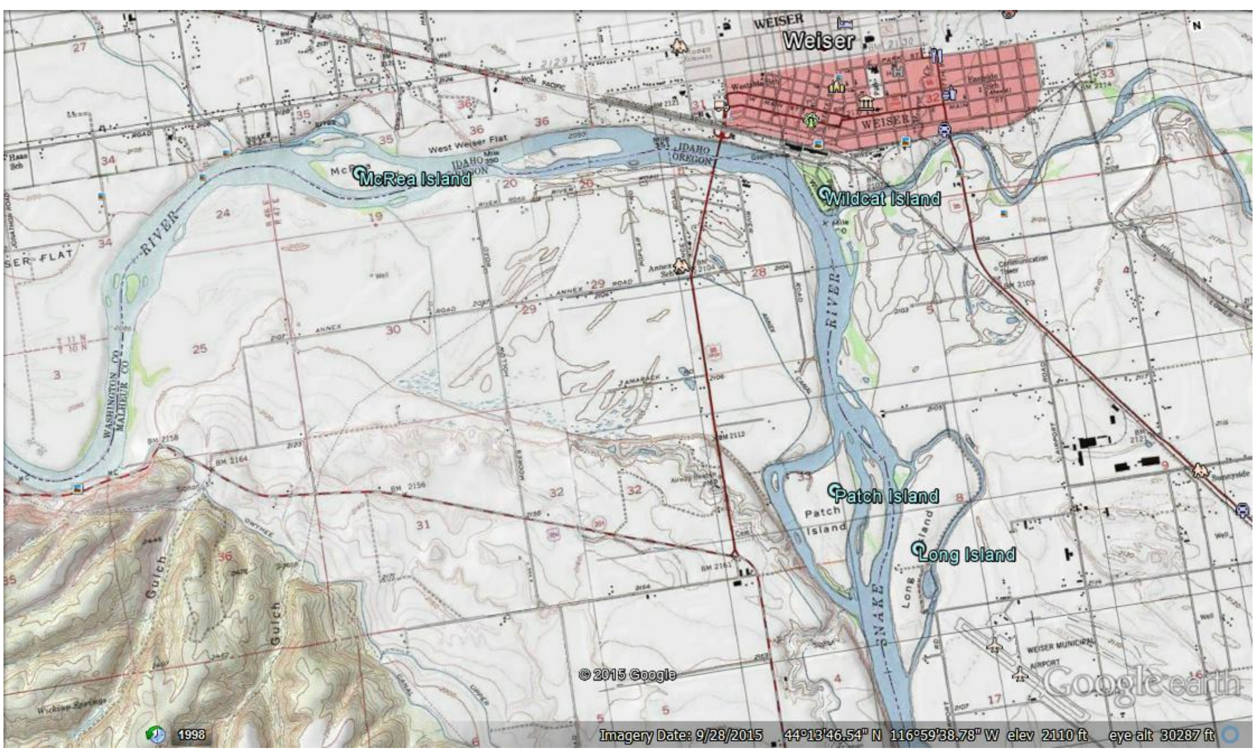

Figure 30: Snake River near Weiser, Idaho

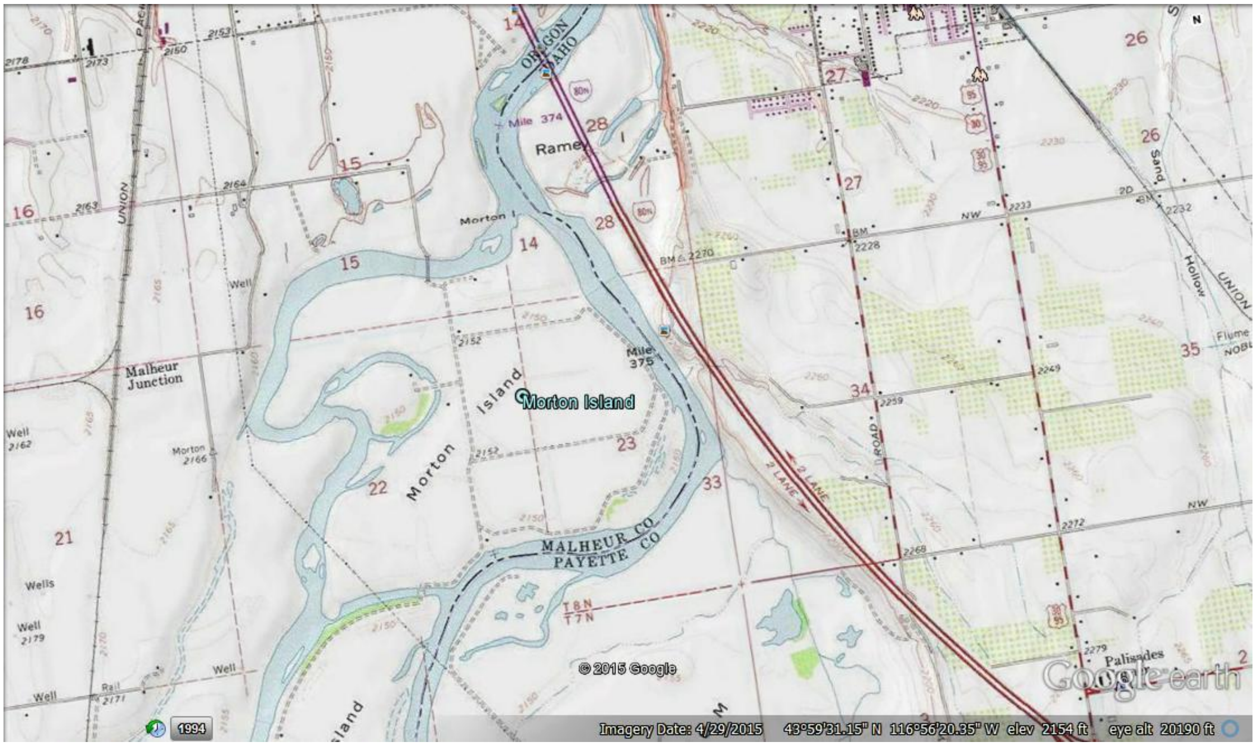

Figure 31: Snake River between Weiser, Idaho and Guffey, Idaho

Figure 32: Snake River near Grand View, Idaho

Figure 33: Cowlitz River

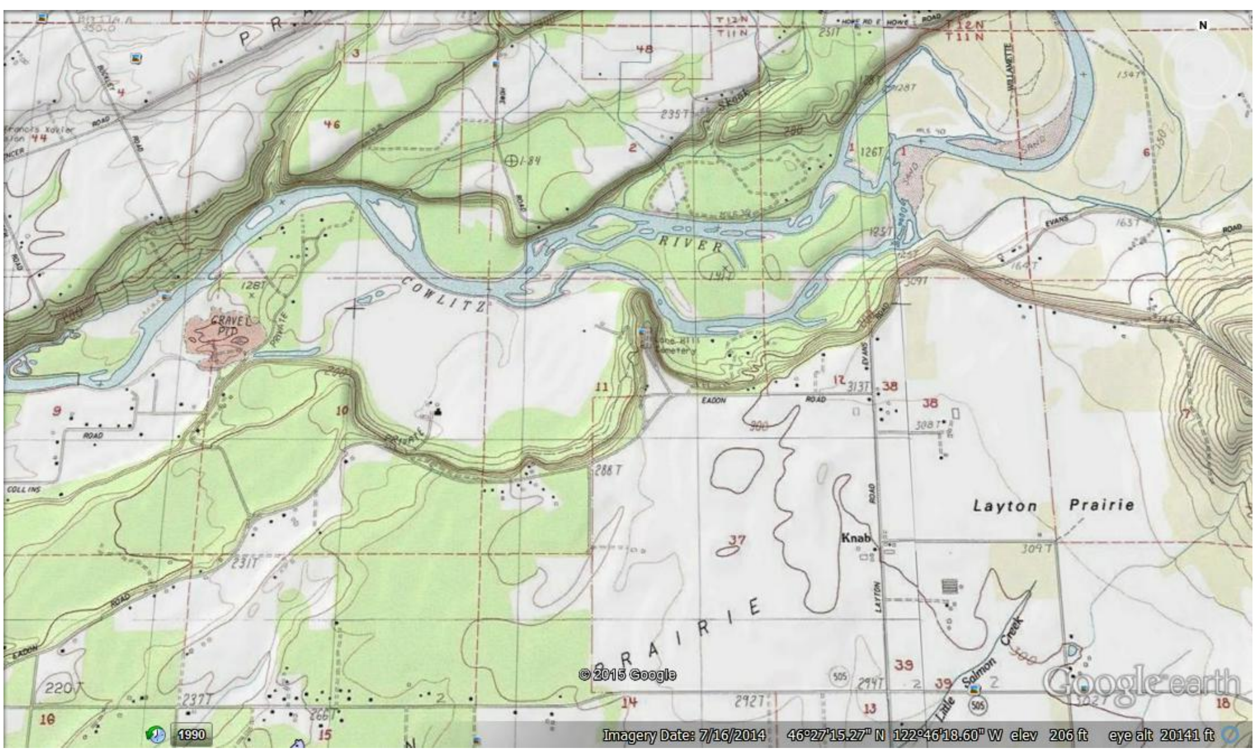

Figure 34: Pend Oreille River at Ione, Washington

Figure 35: Pend Oreille River past Ione

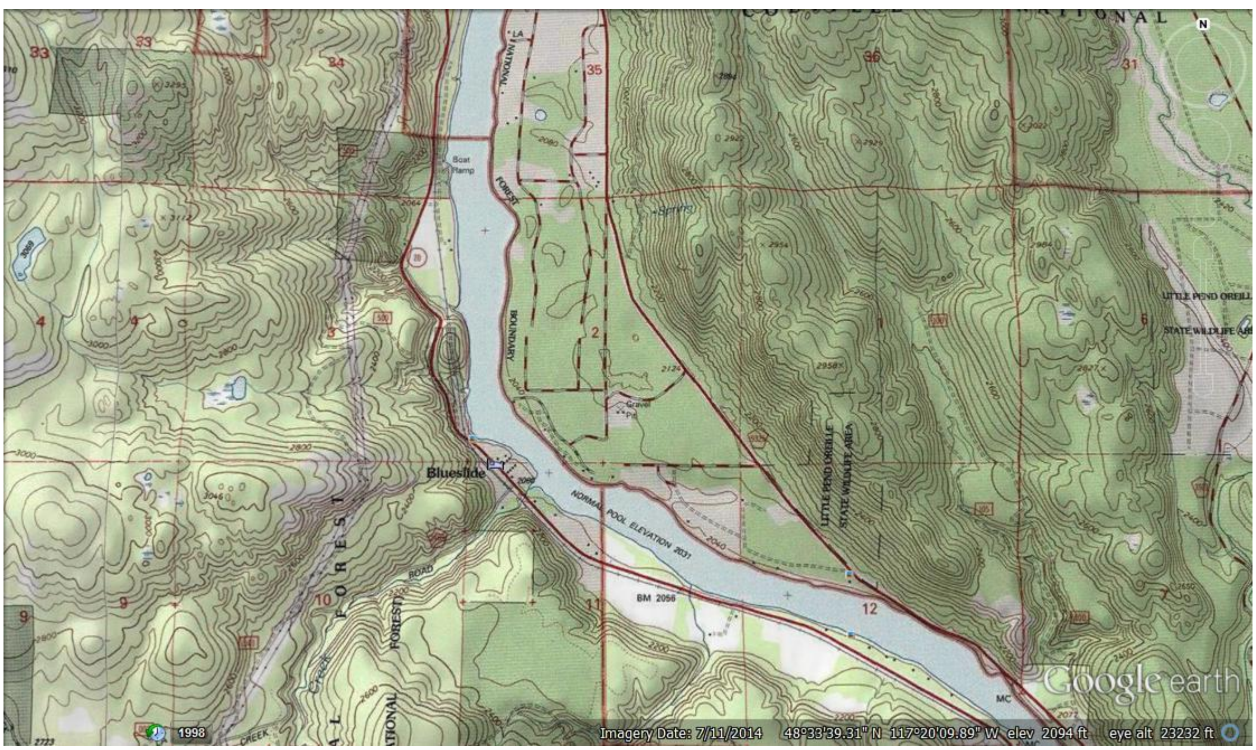

Figure 36: Pend Oreille River past Ione

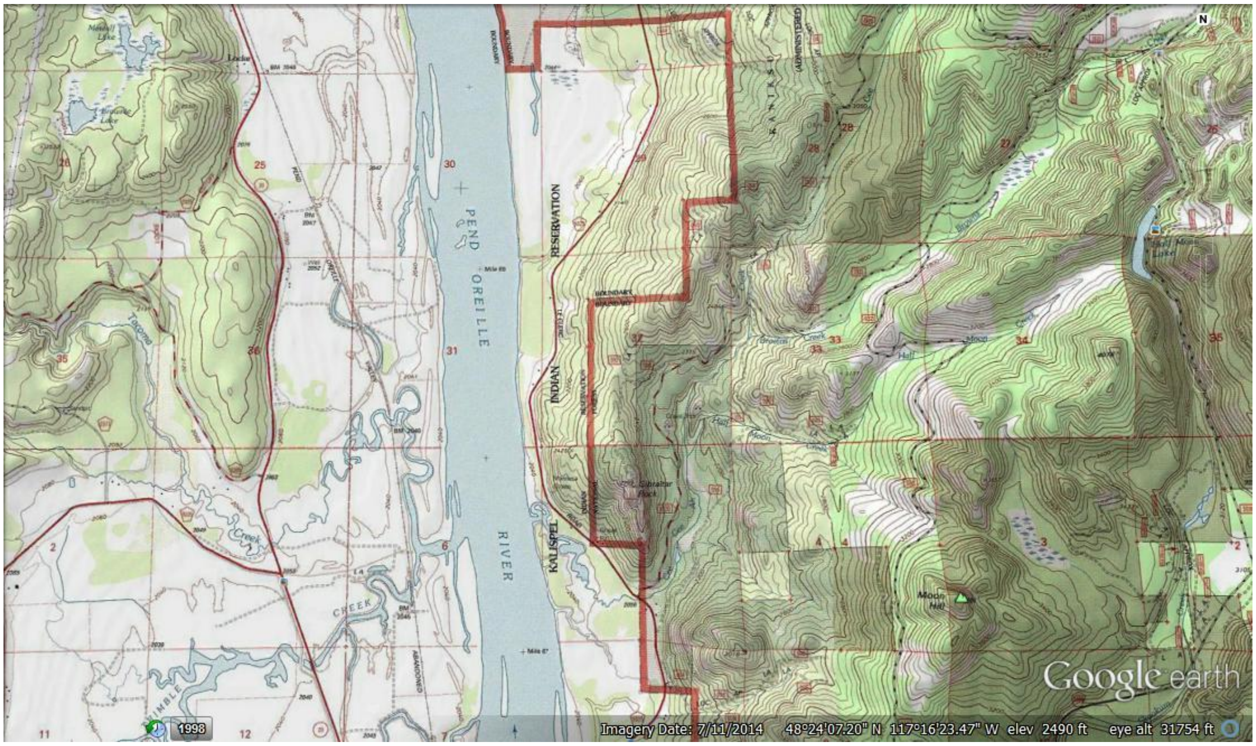

Figure 37: Yakima River between confluence and Pomona, Washington

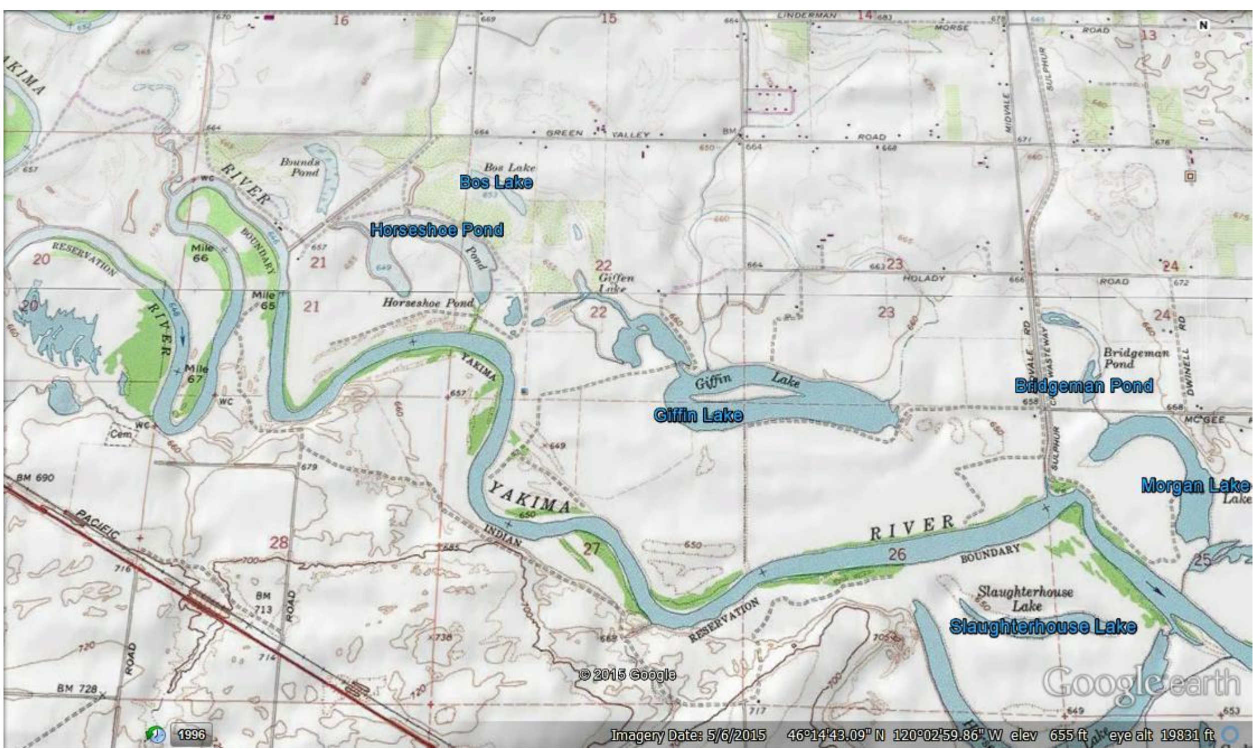

Figure 38: Yakima River near Richland

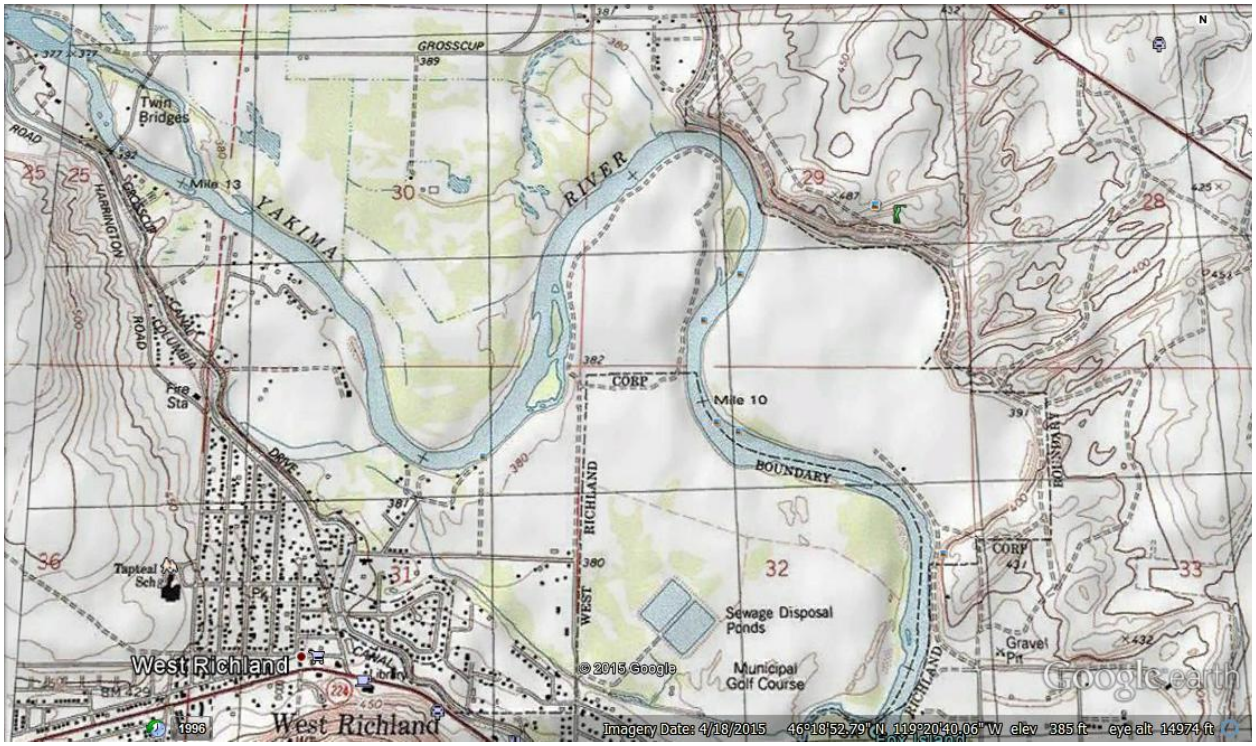

Figure 39: Yakima River near Pomona, Washington

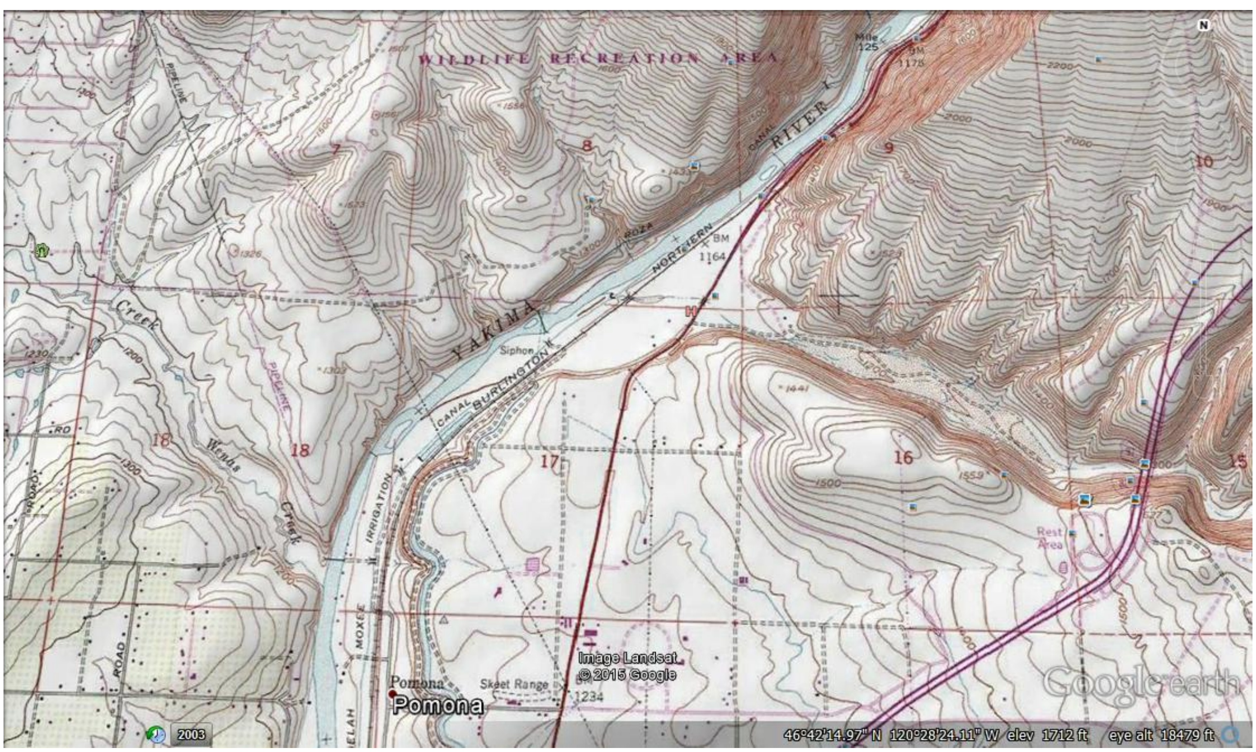

Figure 40: Okanogan River example

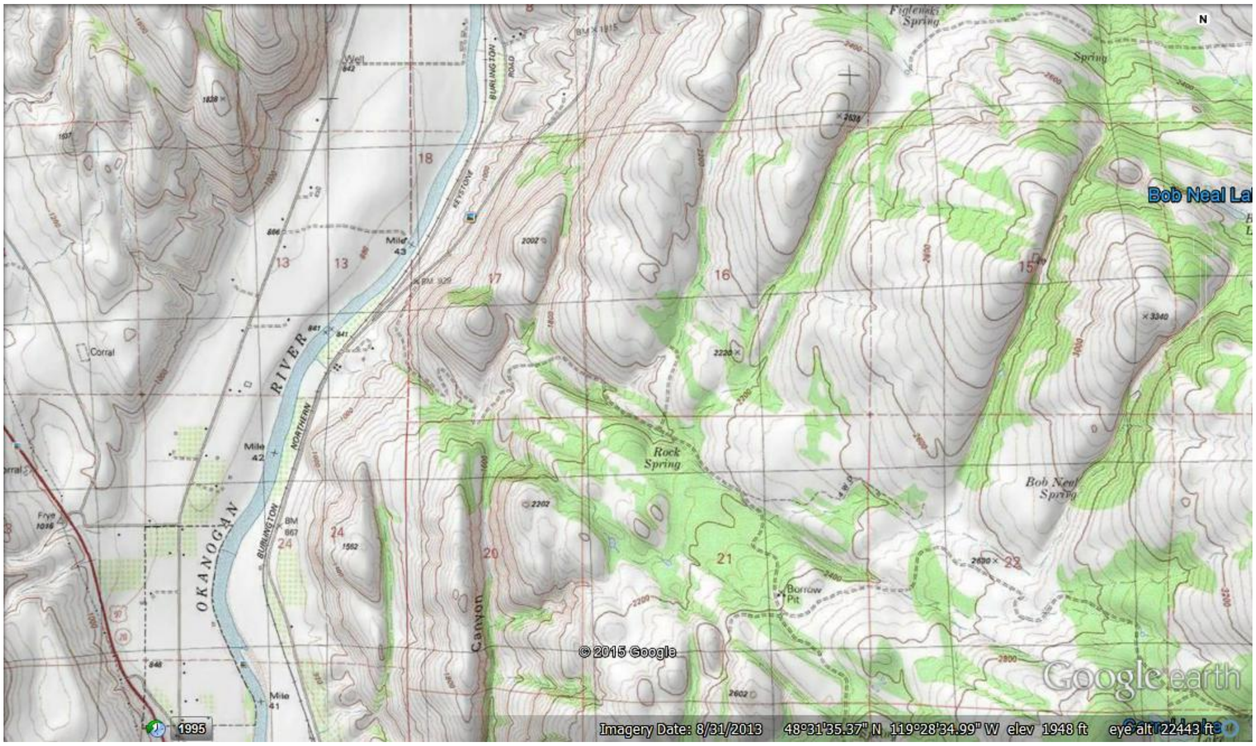

Figure 41: Boise River west of Boise, Idaho

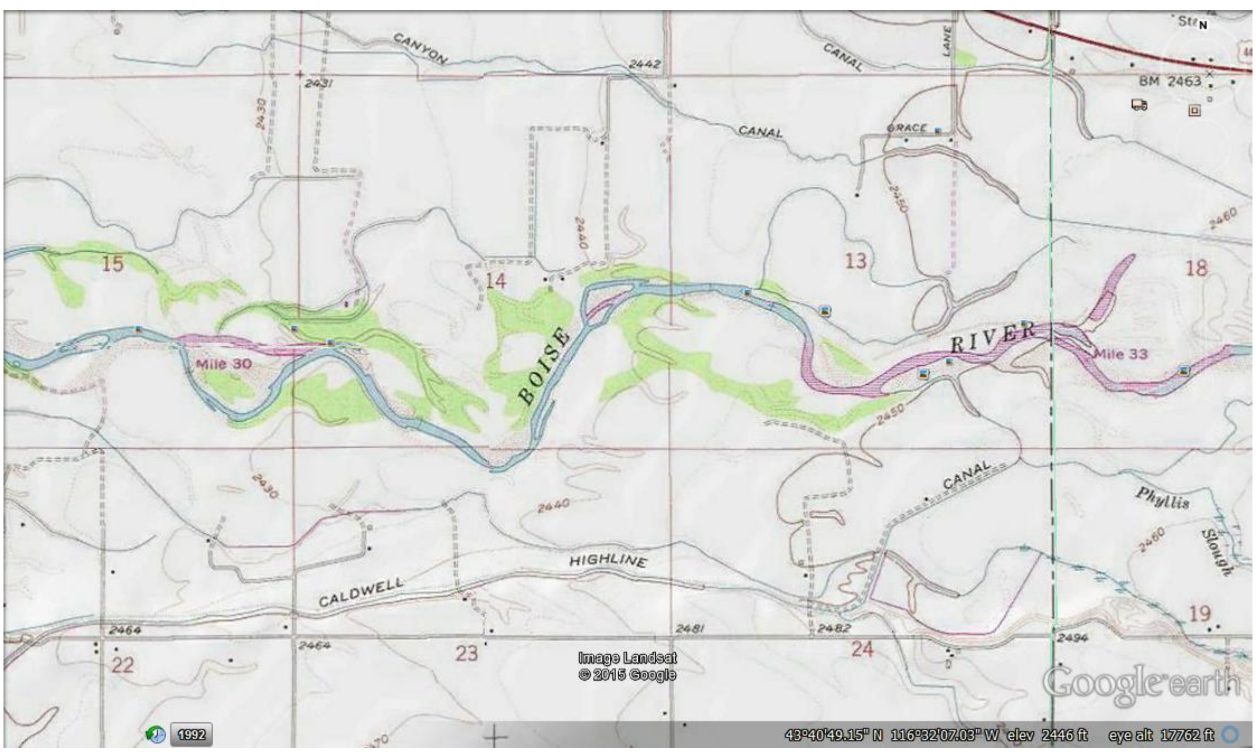

Table 5: Flood Damages Data

Year	# of Days Exceeding 450,000 mean cfs	Maximum Flow (mean daily cfs)	Estimated Flood Damages For Entire Basin ($)
1915	0	N/A	Not Available
1916	52	727,000	Not Available
1917	55	727,000	Not Available
1918	24	578,000	Not Available
1919	10	553,000	Not Available
1920	0	N/A	Not Available
1921	50	773,000	Not Available
1922	34	677,000	Not Available
1923	29	581,000	Not Available
1924	0	N/A	Not Available
1925	27	642,000	Not Available
1926	0	N/A	Not Available
1927	34	690,000	Not Available
1928	35	766,000	Not Available
1929	3	460,000	Not Available
1930	0	N/A	Not Available
1931	0	N/A	Not Available
1932	37	565,000	Not Available
1933	42	722,000	11,731,000
1934	6	453,000	0
1935	10	476,000	0
1936	28	529,000	33,000
1937	0	N/A	137,000
1938	33	605,000	790,000
1939	0	N/A	0
1940	0	N/A	0
1941	0	N/A	145,000
1942	0	N/A	6,894,000
1943	42	541,000	807,000
1944	0	N/A	0
1945	12	505,000	6,000,000
1946	41	581,000	5,714,000
1947	44	536,000	88,000
1948	46	999,000	111,826,000
1949	33	622,000	1,966,000
1950	54	739,000	3,583,000
1951	37	591,000	200,000
1952	31	557,000	2,466,000
1953	22	609,000	2,749,000
1954	52	546,000	1,541,000
1955	26	545,000	10,853,000
1956	54	815,000	19,185,000
1957	40	700,000	23,384,000
1958	29	584,000	401,000
1959	30	552,000	577,000
1960	0	N/A	360,000
1961	34	699,000	1,459,000
1962	1	460,000	8,448,000
1963	0	N/A	4,086,000
1964	31	662,000	181,202,000
1965	28	520,000	10,669,000
1966	0	N/A	1,669,000
1967	35	622,000	2,313,000
1968	0	N/A	1,011,000
1969	3	452,000	1,165,000
1970	0	N/A	2,821,000

Year	# of Days Exceeding 450,000 mean cfs	Maximum Flow (mean daily cfs)	Estimated Flood Damages For Entire Basin ($)
1971	51	557,000	3,796,000
1972	48	619,000	14,396,000
1973	0	N/A	2,325,000
1974	21	588,000	196,787,000
1975	0	N/A	22,227,000
1976	0	N/A	Not Available
1977	0	N/A	Not Available
1978	0	N/A	Not Available
1979	0	N/A	Not Available
1980	0	N/A	Not Available
1981	0	N/A	Not Available
1982	0	N/A	Not Available
1983	0	N/A	Not Available
1984	0	N/A	Not Available
1985	0	N/A	Not Available
1986	0	N/A	Not Available
1987	0	N/A	Not Available
1988	0	N/A	Not Available
1989	0	N/A	Not Available
1990	0	N/A	Not Available
1991	0	N/A	Not Available
1992	0	N/A	Not Available
1993	0	N/A	Not Available
1994	0	N/A	Not Available
1995	0	N/A	Not Available
1996	2	456,000	Not Available
1997	43	571,000	Not Available
1998	0	N/A	Not Available
1999	0	N/A	Not Available
2000	0	N/A	Not Available
2001	0	N/A	Not Available
2002	0	N/A	Not Available
2003	0	N/A	Not Available
2004	0	N/A	Not Available
2005	0	N/A	Not Available
2006	0	N/A	Not Available
2007	0	N/A	Not Available
2008	0	N/A	Not Available
2009	0	N/A	Not Available
2010	0	N/A	Not Available
2011	41	529,000	Not Available
2012	0	N/A	Not Available
2013	0	N/A	Not Available
2014	0	N/A	Not Available
2015	0	N/A	Not Available

Table 6: Historic Flow Data

Dates	Daily Mean Cubic Feet Per Second
5/9/1916	463,000
5/10/1916	461,000
5/11/1916	455,000
6/10/1916	453,000
6/11/1916	465,000
6/12/1916	477,000
6/13/1916	479,000
6/14/1916	477,000
6/15/1916	475,000
6/16/1916	489,000
6/17/1916	520,000
6/18/1916	555,000
6/19/1916	602,000
6/20/1916	638,000
6/21/1916	651,000
6/22/1916	675,000
6/23/1916	664,000
6/24/1916	646,000
6/25/1916	635,000
6/26/1916	644,000
6/27/1916	655,000
6/28/1916	679,000
6/29/1916	695,000
6/30/1916	716,000
7/1/1916	727,000
7/2/1916	720,000
7/3/1916	706,000
7/4/1916	704,000
7/5/1916	709,000
7/6/1916	709,000
7/7/1916	695,000
7/8/1916	688,000
7/9/1916	679,000
7/10/1916	673,000
7/11/1916	673,000
7/12/1916	668,000
7/13/1916	657,000
7/14/1916	642,000
7/15/1916	631,000
7/16/1916	618,000

Dates	Daily Mean Cubic Feet Per Second
7/17/1916	605,000
7/18/1916	596,000
7/19/1916	585,000
7/20/1916	574,000
7/21/1916	562,000
7/22/1916	547,000
7/23/1916	539,000
7/24/1916	532,000
7/25/1916	501,000
7/26/1916	485,000
7/27/1916	467,000
5/25/1917	457,000
5/26/1917	493,000
5/27/1917	522,000
5/28/1917	551,000
5/29/1917	583,000
5/30/1917	611,000
5/31/1917	657,000
6/1/1917	688,000
6/2/1917	673,000
6/3/1917	662,000
6/4/1917	655,000
6/5/1917	640,000
6/6/1917	624,000
6/7/1917	607,000
6/8/1917	594,000
6/9/1917	596,000
6/10/1917	611,000
6/11/1917	653,000
6/12/1917	664,000
6/13/1917	646,000
6/14/1917	622,000
6/15/1917	605,000
6/16/1917	600,000
6/17/1917	620,000
6/18/1917	668,000
6/19/1917	716,000
6/20/1917	727,000
6/21/1917	718,000
6/22/1917	709,000
6/23/1917	700,000

Date	Daily Mean Cubic Feet Per Second
6/24/1917	697,000
6/25/1917	682,000
6/26/1917	677,000
6/27/1917	668,000
6/28/1917	664,000
6/29/1917	660,000
6/30/1917	651,000
7/1/1917	644,000
7/2/1917	627,000
7/3/1917	611,000
7/4/1917	602,000
7/5/1917	596,000
7/6/1917	596,000
7/7/1917	587,000
7/8/1917	576,000
7/9/1917	572,000
7/10/1917	564,000
7/11/1917	553,000
7/12/1917	543,000
7/13/1917	526,000
7/14/1917	503,000
7/15/1917	487,000
7/16/1917	477,000
7/17/1917	463,000
7/18/1917	451,000
5/2/1918	457,000
5/3/1918	481,000
5/4/1918	501,000
5/5/1918	530,000
5/6/1918	560,000
5/7/1918	566,000
5/8/1918	566,000
5/9/1918	564,000
5/10/1918	564,000
6/21/1918	570,000
6/22/1918	574,000
6/23/1918	572,000
6/24/1918	572,000
6/25/1918	578,000
6/26/1918	574,000
6/27/1918	572,000
6/28/1918	564,000

Date	Daily Mean Cubic Feet Per Second
6/29/1918	549,000
6/30/1918	530,000
7/1/1918	518,000
7/2/1918	507,000
7/3/1918	487,000
7/4/1918	467,000
7/5/1918	451,000
5/28/1919	459,000
5/29/1919	471,000
5/30/1919	503,000
5/31/1919	532,000
6/1/1919	553,000
6/2/1919	522,000
6/3/1919	503,000
6/4/1919	479,000
6/5/1919	469,000
6/6/1919	457,000
5/18/1921	465,000
5/19/1921	511,000
5/20/1921	551,000
5/21/1921	587,000
5/22/1921	613,000
5/23/1921	624,000
5/24/1921	640,000
5/25/1921	651,000
5/26/1921	666,000
5/27/1921	677,000
5/28/1921	690,000
5/29/1921	702,000
5/30/1921	690,000
5/31/1921	668,000
6/1/1921	649,000
6/2/1921	649,000
6/3/1921	662,000
6/4/1921	684,000
6/5/1921	700,000
6/6/1921	716,000
6/7/1921	734,000
6/8/1921	743,000
6/9/1921	750,000
6/10/1921	762,000
6/11/1921	773,000

Date	Daily Mean Cubic Feet Per Second
6/12/1921	766,000
6/13/1921	757,000
6/14/1921	746,000
6/15/1921	736,000
6/16/1921	732,000
6/17/1921	713,000
6/18/1921	688,000
6/19/1921	655,000
6/20/1921	631,000
6/21/1921	605,000
6/22/1921	585,000
6/23/1921	570,000
6/24/1921	562,000
6/25/1921	558,000
6/26/1921	555,000
6/27/1921	549,000
6/28/1921	539,000
6/29/1921	528,000
6/30/1921	520,000
7/1/1921	509,000
7/2/1921	501,000
7/3/1921	495,000
7/4/1921	479,000
7/5/1921	467,000
7/6/1921	453,000
5/27/1922	459,000
5/28/1922	479,000
5/29/1922	475,000
5/30/1922	465,000
5/31/1922	455,000
6/1/1922	463,000
6/2/1922	483,000
6/3/1922	511,000
6/4/1922	543,000
6/5/1922	574,000
6/6/1922	607,000
6/7/1922	635,000
6/8/1922	666,000
6/9/1922	677,000
6/10/1922	673,000
6/11/1922	668,000
6/12/1922	653,000

Date	Daily Mean Cubic Feet Per Second
6/13/1922	635,000
6/14/1922	624,000
6/15/1922	622,000
6/16/1922	618,000
6/17/1922	618,000
6/18/1922	624,000
6/19/1922	622,000
6/20/1922	611,000
6/21/1922	598,000
6/22/1922	587,000
6/23/1922	574,000
6/24/1922	555,000
6/25/1922	536,000
6/26/1922	518,000
6/27/1922	495,000
6/28/1922	481,000
6/29/1922	465,000
6/8/1923	453,000
6/9/1923	471,000
6/10/1923	495,000
6/11/1923	518,000
6/12/1923	536,000
6/13/1923	560,000
6/14/1923	581,000
6/15/1923	581,000
6/16/1923	572,000
6/17/1923	560,000
6/18/1923	553,000
6/19/1923	551,000
6/20/1923	549,000
6/21/1923	545,000
6/22/1923	530,000
6/23/1923	524,000
6/24/1923	520,000
6/25/1923	520,000
6/26/1923	524,000
6/27/1923	524,000
6/28/1923	516,000
6/29/1923	516,000
6/30/1923	511,000
7/1/1923	505,000
7/2/1923	501,000

Date	Daily Mean Cubic Feet Per Second
7/3/1923	489,000
7/4/1923	477,000
7/5/1923	469,000
7/6/1923	455,000
5/17/1925	467,000
5/18/1925	491,000
5/19/1925	516,000
5/20/1925	536,000
5/21/1925	572,000
5/22/1925	607,000
5/23/1925	629,000
5/24/1925	642,000
5/25/1925	642,000
5/26/1925	633,000
5/27/1925	629,000
5/28/1925	622,000
5/29/1925	616,000
5/30/1925	616,000
5/31/1925	616,000
6/1/1925	616,000
6/2/1925	598,000
6/3/1925	578,000
6/4/1925	560,000
6/5/1925	547,000
6/6/1925	526,000
6/7/1925	509,000
6/8/1925	495,000
6/9/1925	485,000
6/10/1925	471,000
6/11/1925	463,000
6/12/1925	453,000
6/7/1927	461,000
6/8/1927	491,000
6/9/1927	532,000
6/10/1927	591,000
6/11/1927	638,000
6/12/1927	646,000
6/13/1927	653,000
6/14/1927	660,000
6/15/1927	673,000
6/16/1927	682,000
6/17/1927	688,000

Date	Daily Mean Cubic Feet Per Second
6/18/1927	690,000
6/19/1927	688,000
6/20/1927	682,000
6/21/1927	679,000
6/22/1927	675,000
6/23/1927	668,000
6/24/1927	662,000
6/25/1927	655,000
6/26/1927	655,000
6/27/1927	646,000
6/28/1927	644,000
6/29/1927	642,000
6/30/1927	627,000
7/1/1927	602,000
7/2/1927	587,000
7/3/1927	568,000
7/4/1927	553,000
7/5/1927	539,000
7/6/1927	522,000
7/7/1927	511,000
7/8/1927	497,000
7/9/1927	483,000
7/10/1927	471,000
7/11/1927	453,000
5/13/1928	461,000
5/14/1928	477,000
5/15/1928	491,000
5/16/1928	491,000
5/17/1928	495,000
5/18/1928	501,000
5/19/1928	516,000
5/20/1928	534,000
5/21/1928	562,000
5/22/1928	591,000
5/23/1928	622,000
5/24/1928	653,000
5/25/1928	688,000
5/26/1928	700,000
5/27/1928	723,000
5/28/1928	752,000
5/29/1928	766,000
5/30/1928	764,000

Date	Daily Mean Cubic Feet Per Second
5/31/1928	757,000
6/1/1928	741,000
6/2/1928	720,000
6/3/1928	700,000
6/4/1928	675,000
6/5/1928	660,000
6/6/1928	638,000
6/7/1928	618,000
6/8/1928	598,000
6/9/1928	583,000
6/10/1928	562,000
6/11/1928	545,000
6/12/1928	526,000
6/13/1928	507,000
6/14/1928	495,000
6/15/1928	475,000
6/16/1928	459,000
6/18/1929	455,000
6/19/1929	460,000
6/20/1929	455,000
5/13/1932	452,000
5/14/1932	474,000
5/15/1932	510,000
5/16/1932	525,000
5/17/1932	507,000
5/18/1932	499,000
5/19/1932	485,000
5/20/1932	492,000
5/21/1932	503,000
5/22/1932	514,000
5/23/1932	551,000
5/24/1932	565,000
5/25/1932	536,000
5/26/1932	518,000
5/27/1932	496,000
5/28/1932	478,000
5/29/1932	463,000
6/12/1932	456,000
6/13/1932	467,000
6/14/1932	478,000
6/15/1932	496,000
6/16/1932	514,000

Date	Daily Mean Cubic Feet Per Second
6/17/1932	529,000
6/18/1932	540,000
6/19/1932	540,000
6/20/1932	532,000
6/21/1932	521,000
6/22/1932	514,000
6/23/1932	507,000
6/24/1932	507,000
6/25/1932	510,000
6/26/1932	507,000
6/27/1932	499,000
6/28/1932	492,000
6/29/1932	478,000
6/30/1932	470,000
7/1/1932	456,000
6/1/1933	453,000
6/2/1933	495,000
6/3/1933	514,000
6/4/1933	529,000
6/5/1933	549,000
6/6/1933	577,000
6/7/1933	593,000
6/8/1933	597,000
6/9/1933	597,000
6/10/1933	601,000
6/11/1933	653,000
6/12/1933	676,000
6/13/1933	653,000
6/14/1933	657,000
6/15/1933	676,000
6/16/1933	691,000
6/17/1933	714,000
6/18/1933	722,000
6/19/1933	718,000
6/20/1933	699,000
6/21/1933	676,000
6/22/1933	668,000
6/23/1933	653,000
6/24/1933	641,000
6/25/1933	625,000
6/26/1933	613,000
6/27/1933	601,000

Date	Daily Mean Cubic Feet Per Second
6/28/1933	593,000
6/29/1933	581,000
6/30/1933	573,000
7/1/1933	565,000
7/2/1933	557,000
7/3/1933	541,000
7/4/1933	533,000
7/5/1933	526,000
7/6/1933	518,000
7/7/1933	507,000
7/8/1933	495,000
7/9/1933	480,000
7/10/1933	465,000
7/11/1933	457,000
7/12/1933	450,000
5/1/1934	450,000
5/2/1934	453,000
5/3/1934	450,000
5/8/1934	450,000
5/9/1934	450,000
5/10/1934	450,000
6/2/1935	453,000
6/3/1935	457,000
6/4/1935	457,000
6/5/1935	450,000
6/6/1935	450,000
6/7/1935	453,000
6/8/1935	469,000
6/9/1935	472,000
6/10/1935	476,000
6/11/1935	472,000
6/12/1935	465,000
6/13/1935	465,000
6/14/1935	461,000
6/15/1935	461,000
6/16/1935	461,000
6/17/1935	461,000
6/18/1935	453,000
6/19/1935	450,000
5/14/1936	461,000
5/15/1936	480,000
5/16/1936	507,000

Date	Daily Mean Cubic Feet Per Second
5/17/1936	529,000
5/18/1936	510,000
5/19/1936	488,000
5/20/1936	476,000
5/21/1936	472,000
5/22/1936	465,000
5/23/1936	450,000
6/1/1936	450,000
6/2/1936	457,000
6/3/1936	472,000
6/4/1936	495,000
6/5/1936	522,000
6/6/1936	526,000
6/7/1936	514,000
6/8/1936	507,000
6/9/1936	518,000
6/10/1936	518,000
6/11/1936	503,000
6/12/1936	480,000
6/13/1936	457,000
5/27/1938	469,000
5/28/1938	507,000
5/29/1938	541,000
5/30/1938	589,000
5/31/1938	605,000
6/1/1938	597,000
6/2/1938	585,000
6/3/1938	573,000
6/4/1938	573,000
6/5/1938	585,000
6/6/1938	589,000
6/7/1938	593,000
6/8/1938	601,000
6/9/1938	601,000
6/10/1938	589,000
6/11/1938	565,000
6/12/1938	533,000
6/13/1938	507,000
6/14/1938	495,000
6/15/1938	488,000
6/16/1938	480,000
6/17/1938	476,000

Date	Daily Mean Cubic Feet Per Second
6/18/1938	472,000
6/19/1938	469,000
6/20/1938	457,000
6/21/1938	450,000
6/24/1938	457,000
6/25/1938	469,000
6/26/1938	469,000
6/27/1938	469,000
6/28/1938	465,000
6/29/1938	461,000
6/30/1938	453,000
5/30/1943	468,000
5/31/1943	479,000
6/1/1943	486,000
6/2/1943	501,000
6/3/1943	505,000
6/4/1943	500,000
6/5/1943	484,000
6/6/1943	462,000
6/7/1943	446,000
6/8/1943	442,000
6/9/1943	450,000
6/10/1943	460,000
6/11/1943	472,000
6/12/1943	484,000
6/13/1943	486,000
6/14/1943	476,000
6/15/1943	473,000
6/16/1943	475,000
6/17/1943	465,000
6/18/1943	464,000
6/19/1943	477,000
6/20/1943	510,000
6/21/1943	541,000
6/22/1943	539,000
6/23/1943	534,000
6/24/1943	528,000
6/25/1943	508,000
6/26/1943	501,000
6/27/1943	494,000
6/28/1943	491,000
6/29/1943	490,000

Date	Daily Mean Cubic Feet Per Second
6/30/1943	490,000
7/1/1943	495,000
7/2/1943	497,000
7/3/1943	495,000
7/4/1943	492,000
7/5/1943	493,000
7/6/1943	488,000
7/7/1943	476,000
7/8/1943	469,000
7/9/1943	465,000
7/10/1943	459,000
7/11/1943	455,000
6/4/1945	454,000
6/5/1945	455,000
6/6/1945	464,000
6/7/1945	484,000
6/8/1945	505,000
6/9/1945	502,000
6/10/1945	496,000
6/11/1945	488,000
6/12/1945	483,000
6/13/1945	478,000
6/14/1945	472,000
6/15/1945	459,000
5/11/1946	456,000
5/12/1946	457,000
5/13/1946	459,000
5/14/1946	463,000
5/15/1946	469,000
5/16/1946	467,000
5/17/1946	461,000
5/18/1946	456,000
5/19/1946	461,000
5/20/1946	477,000
5/21/1946	493,000
5/22/1946	500,000
5/23/1946	496,000
5/24/1946	498,000
5/25/1946	504,000
5/26/1946	509,000
5/27/1946	516,000
5/28/1946	535,000

Date	Daily Mean Cubic Feet Per Second
5/29/1946	567,000
5/30/1946	581,000
5/31/1946	578,000
6/1/1946	575,000
6/2/1946	568,000
6/3/1946	564,000
6/4/1946	562,000
6/5/1946	568,000
6/6/1946	572,000
6/7/1946	570,000
6/8/1946	566,000
6/9/1946	557,000
6/10/1946	544,000
6/11/1946	532,000
6/12/1946	519,000
6/13/1946	505,000
6/14/1946	494,000
6/15/1946	485,000
6/16/1946	485,000
6/17/1946	483,000
6/18/1946	474,000
6/19/1946	471,000
6/20/1946	456,000
5/9/1947	471,000
5/10/1947	513,000
5/11/1947	536,000
5/12/1947	529,000
5/13/1947	509,000
5/14/1947	500,000
5/15/1947	493,000
5/16/1947	503,000
5/17/1947	504,000
5/18/1947	495,000
5/19/1947	493,000
5/20/1947	485,000
5/21/1947	486,000
5/22/1947	482,000
5/23/1947	477,000
5/24/1947	473,000
5/25/1947	466,000
5/26/1947	457,000
5/27/1947	469,000

Date	Daily Mean Cubic Feet Per Second
5/28/1947	480,000
5/29/1947	486,000
5/30/1947	484,000
5/31/1947	476,000
6/1/1947	468,000
6/2/1947	467,000
6/3/1947	469,000
6/4/1947	474,000
6/5/1947	472,000
6/6/1947	474,000
6/7/1947	471,000
6/8/1947	471,000
6/9/1947	477,000
6/10/1947	478,000
6/11/1947	507,000
6/12/1947	513,000
6/13/1947	505,000
6/14/1947	495,000
6/15/1947	480,000
6/16/1947	476,000
6/17/1947	477,000
6/18/1947	481,000
6/19/1947	481,000
6/20/1947	478,000
6/21/1947	465,000
5/21/1948	488,000
5/22/1948	535,000
5/23/1948	584,000
5/24/1948	668,000
5/25/1948	675,000
5/26/1948	698,000
5/27/1948	746,000
5/28/1948	806,000
5/29/1948	876,000
5/30/1948	944,000
5/31/1948	999,000
6/1/1948	980,000
6/2/1948	949,000
6/3/1948	934,000
6/4/1948	937,000
6/5/1948	960,000
6/6/1948	958,000

Date	Daily Mean Cubic Feet Per Second
6/7/1948	947,000
6/8/1948	948,000
6/9/1948	949,000
6/10/1948	959,000
6/11/1948	963,000
6/12/1948	969,000
6/13/1948	964,000
6/14/1948	942,000
6/15/1948	915,000
6/16/1948	877,000
6/17/1948	846,000
6/18/1948	831,000
6/19/1948	812,000
6/20/1948	794,000
6/21/1948	766,000
6/22/1948	744,000
6/23/1948	727,000
6/24/1948	708,000
6/25/1948	679,000
6/26/1948	645,000
6/27/1948	626,000
6/28/1948	600,000
6/29/1948	579,000
6/30/1948	562,000
7/1/1948	541,000
7/2/1948	518,000
7/3/1948	498,000
7/4/1948	473,000
7/5/1948	456,000
5/13/1949	474,000
5/14/1949	521,000
5/15/1949	558,000
5/16/1949	594,000
5/17/1949	612,000
5/18/1949	622,000
5/19/1949	613,000
5/20/1949	603,000
5/21/1949	588,000
5/22/1949	601,000
5/23/1949	599,000
5/24/1949	592,000
5/25/1949	578,000

Date	Daily Mean Cubic Feet Per Second
5/26/1949	570,000
5/27/1949	569,000
5/28/1949	571,000
5/29/1949	583,000
5/30/1949	585,000
5/31/1949	578,000
6/1/1949	572,000
6/2/1949	553,000
6/3/1949	532,000
6/4/1949	512,000
6/5/1949	492,000
6/6/1949	479,000
6/7/1949	481,000
6/8/1949	496,000
6/9/1949	501,000
6/10/1949	508,000
6/11/1949	498,000
6/12/1949	485,000
6/13/1949	479,000
6/14/1949	461,000
5/25/1950	463,000
5/26/1950	480,000
5/27/1950	478,000
5/28/1950	469,000
5/29/1950	467,000
5/30/1950	487,000
5/31/1950	488,000
6/1/1950	477,000
6/2/1950	475,000
6/3/1950	478,000
6/4/1950	488,000
6/5/1950	500,000
6/6/1950	512,000
6/7/1950	520,000
6/8/1950	524,000
6/9/1950	530,000
6/10/1950	525,000
6/11/1950	498,000
6/12/1950	480,000
6/13/1950	491,000
6/14/1950	518,000
6/15/1950	553,000

Date	Daily Mean Cubic Feet Per Second
6/16/1950	562,000
6/17/1950	581,000
6/18/1950	630,000
6/19/1950	682,000
6/20/1950	702,000
6/21/1950	712,000
6/22/1950	716,000
6/23/1950	725,000
6/24/1950	737,000
6/25/1950	739,000
6/26/1950	721,000
6/27/1950	705,000
6/28/1950	670,000
6/29/1950	665,000
6/30/1950	671,000
7/1/1950	688,000
7/2/1950	704,000
7/3/1950	704,000
7/4/1950	693,000
7/5/1950	668,000
7/6/1950	649,000
7/7/1950	631,000
7/8/1950	617,000
7/9/1950	601,000
7/10/1950	584,000
7/11/1950	560,000
7/12/1950	530,000
7/13/1950	534,000
7/14/1950	522,000
7/15/1950	496,000
7/16/1950	477,000
7/17/1950	463,000
5/12/1951	467,000
5/13/1951	496,000
5/14/1951	515,000
5/15/1951	522,000
5/16/1951	524,000
5/17/1951	507,000
5/18/1951	510,000
5/19/1951	536,000
5/20/1951	563,000
5/21/1951	570,000

Date	Daily Mean Cubic Feet Per Second
5/22/1951	556,000
5/23/1951	554,000
5/24/1951	565,000
5/25/1951	591,000
5/26/1951	597,000
5/27/1951	591,000
5/28/1951	584,000
5/29/1951	585,000
5/30/1951	597,000
5/31/1951	569,000
6/1/1951	549,000
6/2/1951	533,000
6/3/1951	515,000
6/4/1951	497,000
6/5/1951	480,000
6/6/1951	473,000
6/7/1951	473,000
6/8/1951	471,000
6/9/1951	460,000
6/17/1951	450,000
6/18/1951	475,000
6/19/1951	485,000
6/20/1951	484,000
6/21/1951	479,000
6/22/1951	466,000
6/23/1951	460,000
6/24/1951	452,000
5/11/1952	452,000
5/12/1952	451,000
5/13/1952	455,000
5/14/1952	465,000
5/15/1952	478,000
5/16/1952	508,000
5/17/1952	518,000
5/18/1952	504,000
5/19/1952	496,000
5/20/1952	496,000
5/21/1952	523,000
5/22/1952	550,000
5/23/1952	553,000
5/24/1952	542,000
5/25/1952	535,000

Date	Daily Mean Cubic Feet Per Second
5/26/1952	534,000
5/27/1952	550,000
5/28/1952	557,000
5/29/1952	547,000
5/30/1952	535,000
5/31/1952	521,000
6/1/1952	502,000
6/2/1952	488,000
6/3/1952	478,000
6/4/1952	477,000
6/5/1952	481,000
6/6/1952	487,000
6/7/1952	478,000
6/8/1952	472,000
6/9/1952	461,000
6/10/1952	454,000
6/5/1953	469,000
6/6/1953	486,000
6/7/1953	496,000
6/8/1953	504,000
6/9/1953	520,000
6/10/1953	537,000
6/11/1953	542,000
6/12/1953	542,000
6/13/1953	560,000
6/14/1953	587,000
6/15/1953	607,000
6/16/1953	608,000
6/17/1953	609,000
6/18/1953	604,000
6/19/1953	601,000
6/20/1953	601,000
6/21/1953	588,000
6/22/1953	567,000
6/23/1953	538,000
6/24/1953	512,000
6/25/1953	492,000
6/26/1953	477,000
5/20/1954	456,000
5/21/1954	512,000
5/22/1954	546,000
5/23/1954	561,000

Date	Daily Mean Cubic Feet Per Second
5/24/1954	531,000
5/25/1954	521,000
5/26/1954	529,000
5/27/1954	544,000
5/28/1954	543,000
5/29/1954	530,000
5/30/1954	520,000
5/31/1954	515,000
6/1/1954	513,000
6/2/1954	513,000
6/3/1954	515,000
6/4/1954	517,000
6/5/1954	511,000
6/6/1954	507,000
6/7/1954	505,000
6/8/1954	501,000
6/9/1954	494,000
6/10/1954	495,000
6/11/1954	483,000
6/12/1954	491,000
6/13/1954	505,000
6/14/1954	505,000
6/15/1954	506,000
6/16/1954	514,000
6/17/1954	522,000
6/18/1954	530,000
6/19/1954	521,000
6/20/1954	509,000
6/21/1954	499,000
6/22/1954	486,000
6/23/1954	499,000
6/24/1954	515,000
6/25/1954	510,000
6/26/1954	507,000
6/27/1954	478,000
6/28/1954	473,000
6/29/1954	485,000
6/30/1954	474,000
7/1/1954	453,000
7/9/1954	461,000
7/10/1954	465,000
7/11/1954	470,000

Date	Daily Mean Cubic Feet Per Second
7/12/1954	466,000
7/13/1954	471,000
7/14/1954	467,000
7/15/1954	471,000
7/16/1954	470,000
7/17/1954	458,000
6/11/1955	475,000
6/12/1955	469,000
6/13/1955	488,000
6/14/1955	512,000
6/15/1955	520,000
6/16/1955	516,000
6/17/1955	507,000
6/18/1955	487,000
6/19/1955	492,000
6/20/1955	494,000
6/21/1955	488,000
6/22/1955	504,000
6/23/1955	519,000
6/24/1955	518,000
6/25/1955	540,000
6/26/1955	545,000
6/27/1955	540,000
6/28/1955	533,000
6/29/1955	534,000
6/30/1955	531,000
7/1/1955	534,000
7/2/1955	532,000
7/3/1955	499,000
7/4/1955	483,000
7/5/1955	459,000
7/6/1955	453,000
4/24/1956	522,000
4/25/1956	552,000
4/26/1956	554,000
4/27/1956	539,000
4/28/1956	541,000
4/29/1956	532,000
4/30/1956	512,000
5/1/1956	472,000
5/9/1956	467,000
5/10/1956	484,000

Date	Daily Mean Cubic Feet Per Second
5/11/1956	494,000
5/12/1956	510,000
5/13/1956	491,000
5/14/1956	469,000
5/19/1956	465,000
5/20/1956	520,000
5/21/1956	570,000
5/22/1956	605,000
5/23/1956	626,000
5/24/1956	622,000
5/25/1956	649,000
5/26/1956	680,000
5/27/1956	697,000
5/28/1956	694,000
5/29/1956	711,000
5/30/1956	713,000
5/31/1956	724,000
6/1/1956	757,000
6/2/1956	807,000
6/3/1956	815,000
6/4/1956	807,000
6/5/1956	800,000
6/6/1956	793,000
6/7/1956	788,000
6/8/1956	772,000
6/9/1956	759,000
6/10/1956	739,000
6/11/1956	746,000
6/12/1956	740,000
6/13/1956	718,000
6/14/1956	677,000
6/15/1956	652,000
6/16/1956	631,000
6/17/1956	615,000
6/18/1956	590,000
6/19/1956	540,000
6/20/1956	514,000
6/21/1956	551,000
6/22/1956	545,000
6/23/1956	512,000
6/24/1956	510,000
6/25/1956	494,000

Date	Daily Mean Cubic Feet Per Second
6/26/1956	496,000
6/27/1956	469,000
5/9/1957	454,000
5/10/1957	485,000
5/11/1957	517,000
5/12/1957	505,000
5/13/1957	511,000
5/14/1957	524,000
5/15/1957	546,000
5/16/1957	556,000
5/17/1957	580,000
5/18/1957	591,000
5/19/1957	593,000
5/20/1957	618,000
5/21/1957	668,000
5/22/1957	700,000
5/23/1957	654,000
5/24/1957	641,000
5/25/1957	643,000
5/26/1957	640,000
5/27/1957	633,000
5/28/1957	628,000
5/29/1957	627,000
5/30/1957	620,000
5/31/1957	615,000
6/1/1957	612,000
6/2/1957	620,000
6/3/1957	616,000
6/4/1957	639,000
6/5/1957	639,000
6/6/1957	622,000
6/7/1957	621,000
6/8/1957	622,000
6/9/1957	593,000
6/10/1957	580,000
6/11/1957	565,000
6/12/1957	569,000
6/13/1957	547,000
6/14/1957	525,000
6/15/1957	526,000
6/16/1957	496,000
6/17/1957	459,000

Date	Daily Mean Cubic Feet Per Second
5/20/1958	450,000
5/21/1958	485,000
5/22/1958	514,000
5/23/1958	543,000
5/24/1958	536,000
5/25/1958	534,000
5/26/1958	534,000
5/27/1958	550,000
5/28/1958	562,000
5/29/1958	578,000
5/30/1958	584,000
5/31/1958	583,000
6/1/1958	569,000
6/2/1958	568,000
6/3/1958	573,000
6/4/1958	556,000
6/5/1958	548,000
6/6/1958	540,000
6/7/1958	533,000
6/8/1958	523,000
6/9/1958	506,000
6/10/1958	493,000
6/11/1958	503,000
6/12/1958	501,000
6/13/1958	495,000
6/14/1958	493,000
6/15/1958	505,000
6/16/1958	493,000
6/17/1958	465,000
6/4/1959	456,000
6/5/1959	454,000
6/6/1959	468,000
6/7/1959	496,000
6/8/1959	526,000
6/9/1959	523,000
6/10/1959	525,000
6/11/1959	520,000
6/12/1959	501,000
6/13/1959	494,000
6/14/1959	520,000
6/15/1959	534,000
6/16/1959	539,000

Date	Daily Mean Cubic Feet Per Second
6/17/1959	529,000
6/18/1959	521,000
6/19/1959	519,000
6/20/1959	525,000
6/21/1959	538,000
6/22/1959	552,000
6/23/1959	551,000
6/24/1959	549,000
6/25/1959	542,000
6/26/1959	541,000
6/27/1959	532,000
6/28/1959	535,000
6/29/1959	539,000
6/30/1959	528,000
7/1/1959	514,000
7/2/1959	494,000
7/3/1959	484,000
5/25/1961	458,000
5/26/1961	503,000
5/27/1961	528,000
5/28/1961	552,000
5/29/1961	559,000
5/30/1961	550,000
5/31/1961	556,000
6/1/1961	577,000
6/2/1961	593,000
6/3/1961	614,000
6/4/1961	645,000
6/5/1961	661,000
6/6/1961	664,000
6/7/1961	675,000
6/8/1961	699,000
6/9/1961	693,000
6/10/1961	689,000
6/11/1961	691,000
6/12/1961	681,000
6/13/1961	664,000
6/14/1961	652,000
6/15/1961	641,000
6/16/1961	628,000
6/17/1961	595,000
6/18/1961	584,000

Date	Daily Mean Cubic Feet Per Second
6/19/1961	599,000
6/20/1961	607,000
6/21/1961	586,000
6/22/1961	565,000
6/23/1961	551,000
6/24/1961	521,000
6/25/1961	490,000
6/26/1961	480,000
6/27/1961	463,000
6/5/1962	460,000
6/2/1964	450,000
6/3/1964	456,000
6/4/1964	498,000
6/5/1964	514,000
6/6/1964	511,000
6/7/1964	528,000
6/8/1964	537,000
6/9/1964	545,000
6/10/1964	581,000
6/11/1964	582,000
6/12/1964	576,000
6/13/1964	597,000
6/14/1964	614,000
6/15/1964	618,000
6/16/1964	632,000
6/17/1964	645,000
6/18/1964	662,000
6/19/1964	653,000
6/20/1964	638,000
6/21/1964	625,000
6/22/1964	617,000
6/23/1964	612,000
6/24/1964	610,000
6/25/1964	612,000
6/26/1964	620,000
6/27/1964	602,000
6/28/1964	588,000
6/29/1964	579,000
6/30/1964	555,000
7/1/1964	517,000
7/2/1964	486,000
5/31/1965	464,000

Date	Daily Mean Cubic Feet Per Second
6/1/1965	482,000
6/2/1965	490,000
6/3/1965	493,000
6/4/1965	486,000
6/5/1965	488,000
6/6/1965	504,000
6/7/1965	499,000
6/8/1965	515,000
6/9/1965	520,000
6/10/1965	510,000
6/11/1965	508,000
6/12/1965	511,000
6/13/1965	517,000
6/14/1965	517,000
6/15/1965	500,000
6/16/1965	471,000
6/17/1965	464,000
6/18/1965	483,000
6/19/1965	487,000
6/20/1965	483,000
6/21/1965	486,000
6/22/1965	481,000
6/23/1965	481,000
6/24/1965	487,000
6/25/1965	491,000
6/26/1965	488,000
6/27/1965	474,000
6/3/1967	465,000
6/4/1967	496,000
6/5/1967	517,000
6/6/1967	544,000
6/7/1967	564,000
6/8/1967	602,000
6/9/1967	601,000
6/10/1967	622,000
6/11/1967	619,000
6/12/1967	611,000
6/13/1967	602,000
6/14/1967	601,000
6/15/1967	595,000
6/16/1967	599,000
6/17/1967	605,000

Date	Daily Mean Cubic Feet Per Second
6/18/1967	602,000
6/19/1967	612,000
6/20/1967	616,000
6/21/1967	617,000
6/22/1967	603,000
6/23/1967	598,000
6/24/1967	593,000
6/25/1967	596,000
6/26/1967	605,000
6/27/1967	608,000
6/28/1967	614,000
6/29/1967	601,000
6/30/1967	567,000
7/1/1967	541,000
7/2/1967	521,000
7/3/1967	514,000
7/4/1967	482,000
7/5/1967	468,000
7/6/1967	439,000
7/7/1967	457,000
5/19/1969	451,000
5/25/1969	452,000
5/26/1969	451,000
5/5/1971	470,000
5/6/1971	517,000
5/7/1971	516,000
5/8/1971	532,000
5/9/1971	537,000
5/10/1971	538,000
5/11/1971	549,000
5/12/1971	554,000
5/13/1971	557,000
5/14/1971	556,000
5/15/1971	552,000
5/16/1971	541,000
5/17/1971	526,000
5/18/1971	504,000
5/19/1971	488,000
5/20/1971	477,000
5/21/1971	473,000
5/26/1971	463,000
5/27/1971	489,000

Date	Daily Mean Cubic Feet Per Second
5/28/1971	509,000
5/29/1971	527,000
5/30/1971	521,000
5/31/1971	517,000
6/1/1971	517,000
6/2/1971	512,000
6/3/1971	507,000
6/4/1971	500,000
6/5/1971	487,000
6/6/1971	491,000
6/7/1971	498,000
6/8/1971	503,000
6/9/1971	512,000
6/10/1971	500,000
6/11/1971	510,000
6/12/1971	512,000
6/13/1971	513,000
6/14/1971	512,000
6/15/1971	510,000
6/16/1971	512,000
6/17/1971	513,000
6/18/1971	511,000
6/19/1971	514,000
6/20/1971	504,000
6/21/1971	473,000
6/22/1971	452,000
6/23/1971	451,000
6/24/1971	466,000
6/25/1971	466,000
6/26/1971	465,000
6/27/1971	468,000
6/28/1971	470,000
6/29/1971	455,000
5/17/1972	463,000
5/18/1972	470,000
5/19/1972	482,000
5/20/1972	482,000
5/21/1972	500,000
5/22/1972	495,000
5/23/1972	498,000
5/24/1972	501,000
5/25/1972	492,000

Date	Daily Mean Cubic Feet Per Second
5/26/1972	493,000
5/27/1972	488,000
5/28/1972	492,000
5/29/1972	496,000
5/30/1972	518,000
5/31/1972	544,000
6/1/1972	556,000
6/2/1972	554,000
6/3/1972	557,000
6/4/1972	565,000
6/5/1972	563,000
6/6/1972	568,000
6/7/1972	575,000
6/8/1972	583,000
6/9/1972	593,000
6/10/1972	596,000
6/11/1972	595,000
6/12/1972	599,000
6/13/1972	601,000
6/14/1972	597,000
6/15/1972	605,000
6/16/1972	604,000
6/17/1972	606,000
6/18/1972	614,000
6/19/1972	613,000
6/20/1972	619,000
6/21/1972	605,000
6/22/1972	580,000
6/23/1972	558,000
6/24/1972	556,000
6/25/1972	544,000
6/26/1972	518,000
6/27/1972	491,000
6/28/1972	489,000
6/29/1972	491,000
6/30/1972	487,000
7/1/1972	473,000
7/2/1972	460,000
7/3/1972	451,000
6/15/1974	472,000
6/16/1974	497,000
6/17/1974	535,000

Date	Daily Mean Cubic Feet Per Second
6/18/1974	567,000
6/19/1974	568,000
6/20/1974	588,000
6/21/1974	584,000
6/22/1974	583,000
6/23/1974	585,000
6/24/1974	586,000
6/25/1974	583,000
6/26/1974	580,000
6/27/1974	579,000
6/28/1974	567,000
6/29/1974	530,000
6/30/1974	506,000
7/1/1974	496,000
7/2/1974	482,000
7/3/1974	478,000
7/4/1974	473,000
7/5/1974	453,000
6/11/1996	456,000
6/12/1996	452,000
5/12/1997	453,000
5/13/1997	510,000
5/14/1997	497,000
5/15/1997	455,000
5/16/1997	443,000
5/17/1997	482,000
5/18/1997	516,000
5/19/1997	527,000
5/20/1997	526,000
5/21/1997	523,000
5/22/1997	503,000
5/23/1997	494,000
5/24/1997	498,000
5/25/1997	465,000
5/26/1997	468,000
5/27/1997	455,000
5/28/1997	464,000
5/29/1997	468,000
5/30/1997	450,000
5/31/1997	461,000
6/1/1997	484,000
6/2/1997	506,000

Date	Daily Mean Cubic Feet Per Second
6/3/1997	557,000
6/4/1997	533,000
6/5/1997	520,000
6/6/1997	501,000
6/7/1997	512,000
6/8/1997	512,000
6/9/1997	497,000
6/10/1997	517,000
6/11/1997	517,000
6/12/1997	541,000
6/13/1997	566,000
6/14/1997	564,000
6/15/1997	571,000
6/16/1997	554,000
6/17/1997	557,000
6/18/1997	543,000
6/19/1997	529,000
6/20/1997	503,000
6/21/1997	487,000
6/22/1997	464,000
6/24/1997	453,000
5/17/2011	471,000
5/18/2011	470,000
5/19/2011	476,000
5/20/2011	482,000
5/21/2011	484,000
5/22/2011	481,000
5/23/2011	496,000
5/24/2011	509,000
5/25/2011	505,000
5/26/2011	489,000
5/27/2011	512,000
5/28/2011	515,000
5/29/2011	517,000
5/30/2011	524,000
5/31/2011	519,000
6/1/2011	509,000
6/2/2011	503,000
6/3/2011	509,000
6/4/2011	529,000
6/5/2011	524,000
6/6/2011	513,000

Date	Daily Mean Cubic Feet Per Second
6/7/2011	506,000
6/8/2011	516,000
6/9/2011	529,000
6/10/2011	523,000
6/11/2011	510,000
6/12/2011	508,000
6/13/2011	504,000
6/14/2011	504,000
6/15/2011	498,000
6/16/2011	523,000
6/17/2011	517,000
6/18/2011	488,000
6/19/2011	469,000
6/20/2011	451,000
6/21/2011	460,000
6/22/2011	465,000
6/23/2011	460,000
6/24/2011	505,000
6/25/2011	484,000
6/26/2011	453,000

Figure 42: The Columbia Treaty

The Columbia Treaty

Treaty between Canada and the United States of America relating to Cooperative Development of the Water Resources of The Columbia River Basin

The Governments of Canada and the United States of America

Recognizing that their peoples have, for many generations, lived together and cooperated with one another in many aspects of their national enterprises, for the greater wealth and happiness of their respective nations, and

Recognizing that the Columbia River Basin, as a part of the territory of both countries, contains water resources that are capable of contributing greatly to the economic growth and strength and to the general welfare of the two nations, and

Being desirous of achieving the development of those resources in a manner that will make the largest contribution to the economic progress of both countries and to the welfare of their peoples of which those resources are capable, and

Recognizing that the greatest benefit to each country can be secured by cooperative measures for hydroelectric power generation and flood control, which will make possible other benefits as well.

Have agreed as follows:

ARTICLE I

Interpretation

1.In the Treaty, the expression

(a) "**average critical period load factor**" means the average of the monthly load factors during the critical stream flow period;

(b) "**base system**" means the plants, works and facilities listed in the table in Annex B as enlarged from time to time by the installation of additional generating facilities, together with any plants, works or facilities which may be constructed on the main stem of the Columbia River in the United States of America;

(c) "**Canadian storage**" means the storage provided by Canada under Article II;

(d) "**critical stream flow period**" means the period, beginning with the initial release of stored water from full reservoir conditions and ending with the reservoirs empty, when the water available from reservoir releases plus the natural stream flow is capable of producing the least amount of hydroelectric power in meeting system load requirements;

(e) “**consumptive use**” means use of water for domestic, municipal, stock-water, irrigation, mining or industrial purposes but does not include use for the generation of hydroelectric power;

(f) “**dam**” means a structure to impound water, including facilities for controlling the release of the impounded water;

(g) “**entity**” means an entity designated by either Canada or the United States of America under Article XIV and includes its lawful successor;

(h) “**International Joint Commission**” means the Commission established under Article VII of the Boundary Waters Treaty, 1909, or any body designated by the United States of America and Canada to succeed to the functions of the Commission under this Treaty;

(i) “**maintenance curtailment**” means an interruption or curtailment which the entity responsible therefor considers necessary for purposes of repairs, replacements, installations of equipment, performance of other maintenance work, investigations and inspections;

(j) “**monthly load factor**” means the ratio of the average load for a month to the integrated maximum load over one hour during that month;

(k) “**normal full pool elevation**” means the elevation to which water is stored in a reservoir by deliberate impoundment every year, subject to the availability of sufficient flow;

(l) “**ratification date**” means the day on which the instruments of ratification of the Treaty are exchanged;

(m) “**storage**” means the space in a reservoir which is usable for impounding water for flood control or for regulating stream flows for hydroelectric power generation;

(n) “**Treaty**” means this Treaty and its Annexes A and B;

(o) “**useful life**” means the time between the date of commencement of operation of a dam or facility and the date of its permanent retirement from service by reason of obsolescence or wear and tear which occurs notwithstanding good maintenance practices.

2. The exercise of any power, or the performance of any duty, under the Treaty does not preclude a subsequent exercise of performance of the power or duty.

ARTICLE II

Development by Canada

1.Canada shall provide in the Columbia River basin in Canada 15,500,000 acre-feet of storage usable for improving the flow of the Columbia River.

2. In order to provide this storage, which in the Treaty is referred to as the Canadian storage, Canada shall construct dams:

(a) on the Columbia River near Mica Creek, British Columbia, with approximately 7,000,000 acre-feet of storage;
(b) near the outlet of Arrow Lakes, British Columbia, with approximately 7,100,000 acre-feet of storage; and
(c) on one or more tributaries of the Kootenay River in British Columbia downstream from the Canada-United States of America boundary with storage equivalent in effect to approximately 1,400,000 acre-feet of storage near Duncan Lake, British Columbia.

3.Canada shall commence construction of the dams as soon as possible after the ratification date.

ARTICLE III

Development by the United States of America Respecting Power

1. The United States of America shall maintain and operate the hydroelectric facilities included in the base system and any additional hydroelectric facilities constructed on the main stem of the Columbia River in the United States of America in a manner that makes the most effective use of the improvement in stream flow resulting from operation of the Canadian storage for hydro-electric power generation in the United States of America power system.

2. The obligation in paragraph (1) is discharged by reflecting in the determination of down-stream power benefits to which Canada is entitled the assumption that the facilities referred to in paragraph (1) were maintained and operated in accordance therewith.

ARTICLE IV

Operation by Canada

1. For the purpose of increasing hydroelectric power generation in Canada and in the United States of America, Canada shall operate the Canadian storage in accordance with Annex A and pursuant to hydroelectric operating plans made thereunder. For the purpose of this obligation an operating plan if it is either the first operating plan or if in the view of either Canada or the United States of America it departs substantially from the immediately preceding operating plan must, in order to be effective, be confirmed by an exchange of notes between Canada and the United States of America.

2. For the purpose of flood control until the expiration of sixty years from the ratification date, Canada shall

(a) operate in accordance with Annex A and pursuant to flood control operating plans made thereunder
    (i) 80,000 acre-feet of the Canadian storage described in Article II(2)(a),
    (ii) 7,100,000 acre-feet of the Canadian storage described in Article II(2)(b),

(iii) 1,270,000 acre-feet of the Canadian storage described in Article II(2)(c),

provided that the Canadian entity may exchange flood control storage under subparagraph (ii) for flood control storage additional to that under subparagraph (I), at the location described in Article II(2)(a), if the entities agree that the exchange would provide the same effectiveness for control of floods on the Columbia River at the Dalles, Oregon;

(b) operate any additional storage in the Columbia River basin in Canada, when called upon by an entity designated by the United States of America for that purpose, within the limits of existing facilities and as the entity requires to meet flood control needs for the duration of the flood period for which the call is made.

3. For the purpose of flood control after the expiration of sixty years from the ratification date, and for so long as the flows in the Columbia River in Canada continue to contribute to potential flood hazard in the United States of America, Canada shall, when called upon by an entity designated by the United States of America for that purpose, operate within the limits of existing facilities any storage in the Columbia River basin in Canada as the entity requires to meet flood control needs for the duration of the flood control period for which the call is made.

4. The return to Canada for hydroelectric operation and the compensation to Canada for flood control operation shall be as set out in Articles V and VI.

5. Any water resource development, in addition to the Canadian storage, constructed in Canada after the ratification date shall not be operated in a way that adversely affect the stream flow control in the Columbia River within Canada so as to reduce the flood control and hydroelectric power benefits which the operation of the Canadian storage in accordance with the operating plans in force from time to time would otherwise produce.

6. As soon as any Canadian storage becomes operable Canada shall commence operation thereof in accordance with this Article and in any event shall commence full operation of the Canadian storage described in Article II(2)(b) and Article II(2)(c) within five years of the ratification date and shall commence full operation of the balance of the Canadian storage within nine years of the ratification date.

ARTICLE V

Entitlement to Downstream Power Benefits

1. Canada is entitled to one half the downstream power benefits determined under Article VII.

2. The United States of America shall deliver to Canada at a point on the Canada-United States of America boundary near Oliver, British Columbia, or such other place as the entities may agree upon, the downstream power benefits to which Canada is entitled, less

(a) transmission loss,
(b) the portion of the entitlement disposed of under Article VIII(1), and

(c) the energy component described in Article VIII(4).

3. The entitlement of Canada to downstream power benefits begins for any portion of Canadian storage upon commencement of its operation in accordance with Annex A and pursuant to a hydroelectric operating plan made thereunder.

ARTICLE VI
Payment for Flood Control

1. For the flood control provided by Canada under Article IV(2)(a) the United States of America shall pay Canada in United States funds:

(a) 1,200,000 dollars upon the commencement of operation of the storage referred to in subparagraph (a)(i) thereof,
(b) 52,100,000 dollars upon the commencement of operation of the storage referred to in subparagraph (a)(ii) thereof, and
(c) 11,100,000 dollars upon the commencement of operation of the storage referred to in subparagraph (a)(iii) thereof.

2. If full operation of any storage is not commenced within the time specified in Article IV, the amount set forth in paragraph (1) of this Article with respect to that storage shall be reduced as follows:

(a) under paragraph (1)(a), 4,500 dollars for each month beyond the required time,
(b) under paragraph (1)(b), 192, 100 dollars for each month beyond the required time, and
(c) under paragraph (1)(c), 40,800 dollars for each month beyond the required time.

3. For the flood control provided by Canada under Article IV(2)(b) the United States of America shall pay Canada in United States funds in respect only of each of the first four flood periods for which a call is made 1,875,000 dollars and shall deliver to Canada in respect of each and every call made, electric power equal to the hydroelectric power lost by Canada as a result of operating the storage to meet the flood control need for which the call was made, delivery to be made when the loss of hydroelectric power occurs.

4. For each flood period for which flood control is provided by Canada under Article IV(3), the United States of America shall pay Canada in United States funds:

(a) the operating cost incurred by Canada in providing the flood control, and
(b) compensation for the economic loss to Canada arising directly from Canada foregoing alternative uses of the storage used to provide the flood control.

5. Canada may elect to receive in electric power, the whole or any portion of the compensation under paragraph 4(b) representing loss of hydroelectric power to Canada.

ARTICLE VII
Determination of Downstream Power Benefits

1. The downstream power benefits shall be the difference in the hydroelectric power capable of being generated in the United States of America with and without the use of Canadian storage, determined in advance, and is referred to in the Treaty as the downstream power benefits.

2. For the purpose of determining the downstream power benefits:

(a) the principles and procedures set out in Annex B shall be used and followed;
(b) the Canadian storage shall be considered as next added to 13,000,000 acre-feet of the usable storage listed in Column 4 of the table in Annex B;
(c) the hydroelectric facilities included in the base system shall be considered as being operated to make the most effective use for hydroelectric power generation of the improvement in stream flow resulting from operation of the Canadian storage.

3. The downstream power benefits to which Canada is entitled shall be delivered as follows:

(a) dependable hydroelectric capacity as scheduled by the Canadian entity, and
(b) average annual usable hydroelectric energy in equal amounts each month, or in accordance with a modification agreed upon under paragraph (4).

4. Modification of the obligation in paragraph (3)(b) may be agreed upon by the entities.

ARTICLE VIII
Disposal of Entitlement to Downstream Power Benefits

1. With the authorization of Canada and the United States of America evidenced by exchange of notes, portions of the downstream power benefits to which Canada is entitled may be disposed of within the United States of America. The respective general conditions and limits within which the entities may arrange initial disposals shall be set out in an exchange of notes to be made as soon as possible after the ratification date.

2. The entities may arrange and carry out exchanges of dependable hydroelectric capacity and average annual usable hydroelectric energy to which Canada is entitled for average annual usable hydroelectric energy and dependable hydroelectric capacity respectively.

3. Energy to which Canada is entitled may not be used in the United States of America except in accordance with paragraphs (1) and (2).

4. The bypassing at dams on the main stem of the Columbia River in the United States of America of an amount of water which could produce usable energy equal to the energy component of the down-stream power benefits to which Canada is entitled but not delivered to Canada under Article V or dis-posed of in accordance with paragraphs (1) and (2) at the time the energy component was not so delivered or disposed of, is conclusive evidence that such

energy component was not used in the United States of America and that the entitlement of Canada to such energy component is satisfied.

ARTICLE IX

Variation of Entitlement to Downstream Power Benefits

1. If the United States of America considers with respect to any hydroelectric power project planned on the main stem of the Columbia River between Priest Rapids Dam and McNary Dam that the increase in entitlement of Canada to downstream power benefits resulting from the operation of the project would produce a result which would not justify the United States of America in incurring the costs of construction and operation of the project, Canada and the United States of America at the request of the United States of America shall consider modification of the increase in entitlement.

2. An agreement reached for the purposes of this Article shall be evidenced by an exchange of notes.

ARTICLE X

East-West Standby Transmission

1. The United States of America shall provide in accordance with good engineering practice east-west standby transmission service adequate to safeguard the transmission from Oliver, British Columbia, to Vancouver, British Columbia, of the downstream power benefits to which Canada is entitled and to improve system stability of the east-west circuits in British Columbia.

2. In consideration of the standby transmission service, Canada shall pay the United States of America in Canadian funds the equivalent of 1.50 United States dollars a year for each kilowatt of dependable hydroelectric capacity included in the downstream power benefits to which Canada is entitled.

3. When a mutually satisfactory electric coordination arrangement is entered into between the entities and confirmed by an exchange of notes between Canada and the United States of America the obligation of Canada in paragraph (2) ceases.

ARTICLE XI

Use of Improved Stream Flow

1. Improvement in stream flow in one country brought about by operation of storage constructed under the Treaty in the other country shall not be used directly or indirectly for hydroelectric power purposes except:

(a) in the case of use within the United States of America with the prior approval of the United States entity, and
(b) in the case of use within Canada with the prior approval of the authority in Canada having jurisdiction.

2. The approval required by this Article shall not be given except upon such conditions, consistent with the Treaty, as the entity or authority considers appropriate.

ARTICLE XII

Kootenai River Development

1. The United States of America for a period of five years from the ratification date, has the option to commence construction of a dam on the Kootenai River near Libby, Montana, to provide storage to meet flood control and other purposes in the United States of America. The storage reservoir of the dam shall not raise the level of the Kootenai River at the Canada-United States of America boundary above an elevation consistent with a normal full pool elevation at the dam of 2,459 feet, United States Coast and Geodetic Survey datum, 1929 General Adjustment, 1947 International Supplemental Adjustment.

2. All benefits which occur in either country from the construction and operation of the storage accrue to the country in which the benefits occur.

3. The United States of America shall exercise its option by written notice to Canada and shall submit with the notice a schedule of construction which shall include provision for commencement of construction, whether by way of railroad relocation work or otherwise, within five years of the ratification date.

4. If the United States of America exercises its option, Canada in consideration of the benefits accruing to it under paragraph (2) shall prepare and make available for flooding the land in Canada necessary for the storage reservoir of the dam within a period consistent with the construction schedule.

5. If a variation in the operation of the storage is considered by Canada to be of advantage to it the United States of America shall, upon request, consult with Canada. If the United States of America determines that the variation would not be to its disadvantage it shall vary the operation accordingly.

6. The operation of the storage by the United States of America shall be consistent with any order of approval which may be in force from time to time relating to the levels of Kootenay Lake made by the International Joint Commission under the Boundary Waters Treaty, 1909.

7. Any obligation of Canada under this Article ceases if the United States of America, having exercised the option, does not commence construction of the dam in accordance with the construction schedule.

8. If the United States of America exercises the option it shall commence full operation of the storage within seven years of the date fixed in the construction schedule for commencement of construction.

9. If Canada considers that any portion of the land referred to in paragraph (4) is no longer needed for the purpose of this Article Canada and the United States of America, at the request of Canada, shall consider modification of the obligation of Canada in paragraph (4).

10. If the Treaty is terminated before the end of the useful life of the dam Canada shall for the remainder of the useful life of the dam continue to make available for the storage reservoir of the dam any portion of the land made available under paragraph (4) that is not required by Canada for purposes of diversion of the Kootenay River under Article XIII.

ARTICLE XIII
Diversions

1. Except as provided in this Article neither Canada nor the United States of America shall, without the consent of the other evidenced by an exchange of notes, divert for any use, other than consumptive use, any water from its natural channel in a way that alters the flow of any water as it crosses the Canada-United States of America boundary within the Columbia River Basin.

2. Canada has the right, after the expiration of twenty years from the ratification date, to divert not more than 1,500,000 acre-feet of water a year from the Kootenay River in the vicinity of Canal Flats, British Columbia, to the headwaters of the Columbia River, provided that the diversion does not reduce the flow of the Kootenay River immediately downstream from the point of diversion below the lesser of 200 cubic feet per second or the natural flow.

3. Canada has the right, exercisable at any time during the period commencing sixty years after the ratification date and expiring one hundred years after the ratification date, to divert to the head-waters of the Columbia River any water which, in its natural channel, would flow in the Kootenay River across the Canada-United States of America boundary, provided that the diversion does not reduce the flow of the Kootenay River at the Canada-United States of America boundary near New-gate, British Columbia, below the lesser of 2500 cubic feet per second or the natural flow.

4. During the last twenty years of the period within which Canada may exercise the right to divert described in paragraph (3) the limitation on diversion is the lesser of 1000 cubic feet per second or the natural flow.

5. Canada has the right:

(a) if the United States of America does not exercise the option in Article XII(1), or
(b) if it is determined that the United States of America, having exercised the option, did not commence construction of the dam referred to in Article XII in accordance therewith or that the United States of America is in breach of the obligation in that Article to commence full operation of the storage, to divert to the headwaters of the Columbia River any water which, in its natural channel, would flow in the Kootenay River across the Canada-United States of America boundary, provided that the di-version does not reduce the flow of the Kootenay River at the Canada-United States of America boundary

near Newgate, British Columbia, below the lesser of 1000 cubic feet per second or the natural flow.

6. If a variation in the use of the water diverted under paragraph (2) is considered by the United States of America to be of advantage to it Canada shall, upon request, consult with the United States of America. If Canada determines that the variation would not be to its disadvantage it shall vary the use accordingly.

ARTICLE XIV

Arrangements for Implementation

1. Canada and the United States of America shall each, as soon as possible after the ratification date, designate entities and when so designated the entities are empowered and charged with the duty to formulate and carry out the operating arrangements necessary to implement the Treaty. Either Canada or the United States of America may designate one or more entities. If more than one is designated the powers and duties conferred upon the entities by the Treaty shall be allocated among them in the designation.

2. In addition to the powers and duties dealt with specifically elsewhere in the Treaty the powers and duties of the entities include:

(a) coordination of plans and exchange of information relating to facilities to be used in producing and obtaining the benefits contemplated by the Treaty,
(b) calculation of and arrangements for delivery of hydroelectric power to which Canada is entitled for providing flood control,
(c) calculation of the amounts payable to the United States of America for standby transmission services,
(d) consultation on requests for variations made pursuant to Articles XII(5) and XIII(6),
(e) the establishment and operation of a hydrometeorological system as required by Annex A,
(f) assisting and cooperating with the Permanent Engineering Board in the discharge of its functions,
(g) periodic calculation of accounts,
(h) preparation of the hydroelectric operating plans and the flood control operating plans for the Canadian storage together with determination of the downstream power benefits to which Canada is entitled,
(i) preparation of proposals to implement Article VIII and carrying out any disposal authorized or exchange provided for therein,
(j) making appropriate arrangements for delivery to Canada of the downstream power benefits to which Canada is entitled including such matters as load factors for delivery, times and points of delivery, and calculation of transmission loss,
(k) preparation and implementation of detailed operating plans that may produce results more advantageous to both countries than those that would arise from operation under the plans referred to in Annexes A and B.

3. The entities are authorized to make maintenance curtailments. Except in case of emergency, the entity responsible for a maintenance curtailment shall give notice to the corresponding Canadian or United States entity of the curtailment, including the reason therefor and the probable duration thereof and shall both schedule the curtailment with a view to minimizing its impact and exercise due diligence to resume full operations.

4. Canada and the United States of America may by an exchange of notes empower or charge the entities with any other matter coming within the scope of the Treaty.

ARTICLE XV

Permanent Engineering Board

1. A permanent Engineering Board is established consisting of four members, two to be appointed by Canada and two by the United States of America. The initial appointments shall be made within three months of the ratification date.

2. The Permanent Engineering Board shall:

(a) assemble records of the flows of the Columbia River and the Kootenay River at the Canada-United States of America boundary;
(b) report to Canada and the United States of America whenever there is substantial deviation from the hydroelectric and flood control operating plans and if appropriate include in the report recommendations for remedial action and compensatory adjustments;
(c) assist in reconciling differences concerning technical or operational matters that may arise between the entities;
(d) make periodic inspections and require reports as necessary from the entities with a view to ensuring that the objectives of the Treaty are being met;
(e) make reports to Canada and the United States of America at least once a year of the results being achieved under the Treaty and make special reports concerning any matter which it considers should be brought to their attention;
(f) investigate and report with respect to any other matter coming within the scope of the Treaty at the request of either Canada or the United States of America.

3. Reports of the Permanent Engineering Board made in the course of the performance of its functions under this Article shall be prima facie evidence of the facts therein contained and shall be accepted unless rebutted by other evidence.

4. The Permanent Engineering Board shall comply with directions, relating to its administration and procedures, agreed upon by Canada and the United States of America as evidenced by an exchange of notes.

ARTICLE XVI
Settlement of Differences

1. Differences arising under the Treaty which Canada and the United States of America cannot resolve may be referred by either to the International Joint Commission for decision.

2. If the International Joint Commission does not render a decision within three months of the referral or within such other period as may be agreed upon by Canada and the United States of America, either may then submit the difference to arbitration by written notice to the other.

3. Arbitration shall be a tribunal composed of a member appointed by Canada, a member appointed by the United States of America and a member appointed jointly by Canada and the United States of America who shall be Chairman. If within six weeks of the delivery of a notice under paragraph (2) either Canada or the United States of America has failed to appoint its member, or they are unable to agree upon the member who is to be Chairman, either Canada or the United States of America may request the President of the International Court of Justice to appoint the member or members. The decision of a majority of the members of an arbitration tribunal shall be the decision of the tribunal.

4. Canada and the United States of America shall accept as definitive and binding and shall carry out any decision of the International Joint Commission or an arbitration tribunal.

5. Provision for the administrative support of a tribunal and for remuneration and expenses of its members shall be as agreed in an exchange of notes between Canada and the United States of America.

6. Canada and the United States of America may agree by an exchange of notes on alternative procedures for settling differences arising under the Treaty, including reference of any difference to the International Court of Justice for decision.

ARTICLE XVII
Restoration of Pre-Treaty Legal Status

1. Nothing in this Treaty and no action taken or foregone pursuant to its provisions shall be deemed, after its termination or expiration, to have abrogated or modified any of the rights or obligations of Canada or the United States of America under then existing international law, with respect to the uses of the water resources of the Columbia River basin.

2. Upon termination of this Treaty, the Boundary Waters Treaty, 1909, shall, if it has not been terminated, apply to the Columbia River basin, except insofar as the provisions of that Treaty may be inconsistent with any provision of this Treaty which continues in effect.

3. Upon termination of this Treaty, if the Boundary Waters Treaty, 1909, has been terminated in accordance with Article XIV of that Treaty, the provisions of Article II of that Treaty shall continue to apply to the waters of the Columbia River basin.

4. If upon the termination of this Treaty Article II of the Boundary Waters Treaty, 1909, continues in force by virtue of paragraph (2) of this Article the effect of Article II of that Treaty

with respect to the Columbia River basin may be terminated by either Canada or the United States of America delivering to the other one year's written notice to that effect; provided however that the notice may be given only after the termination of this Treaty.

5. If, prior to the termination of this Treaty, Canada undertakes works usable for and relating to a diversion of water from the Columbia River basin, other than works authorized by or undertaken for the purpose of exercising a right under Article XIII or any other provision of this Treaty, paragraph (3) of this Article shall cease to apply one year after delivery by either Canada or the United States of America to the other of written notice to that effect.

ARTICLE XVIII

Liability for Damage

1. Canada and the United States of America shall be liable to the other and shall make appropriate compensation to the other in respect of any act, failure to act, omission or delay amounting to a breach of the Treaty or any of its provisions other that an act, failure to act, omission or delay occurring by reason of war, strike, major calamity, act of God, uncontrollable force or maintenance curtailment.

2. Except as provided in paragraph (1) neither Canada nor the United States of America shall be liable to the other or to any person in respect of any injury, damage or loss occurring in the territory of the other caused by any act, failure to act, omission or delay under the Treaty whether the injury, damage or loss results from negligence or otherwise.

3. Canada and the United States of America, each to the extent possible within its territory, shall exercise due diligence to remove the cause of and to mitigate the effect of any injury, damage or loss occurring in the territory of the other as a result of any act, failure to act, omission or delay under the Treaty.

4. Failure to commence operation as required by Articles IV and XII is not a breach of the Treaty and does not result in the loss of rights under the Treaty if the failure results from a delay that is not wilful or reasonably avoidable.

5. The compensation payable under paragraph (1):

(a) in respect of a breach by Canada of the obligation to commence full operation of a storage, shall be forfeiture of entitlement to downstream power benefits resulting from the operation of that storage, after operation commences, for a period equal to the period between the day of commencement of operation and the day when commencement should have occurred;

(b) in respect of any other breach by either Canada or the United States of America, causing loss of power benefits, shall not exceed the actual loss in revenue from the sale of hydroelectric power.

ARTICLE XIX
Period of Treaty

1. The Treaty shall come into force on the ratification date.

2. Either Canada or the United States of America may terminate the Treaty other than Article XIII (Except paragraph (1) thereof), Article XVII and this Article at any time after the Treaty has been in force for sixty years if it has delivered at least ten years written notice to the other of its intention to terminate the Treaty.

3. If the Treaty is terminated before the end of the useful life of a dam built under Article XII then, notwithstanding termination, Article XII remains in force until the end of the useful life of the dam.

4. If the Treaty is terminated before the end of the useful life of the facilities providing the storage described in Article IV(3) and if the conditions described therein exist then, notwithstanding termination, Articles IV(3) and VI(4) and (5) remain in force until either the end of the useful life of those facilities or until those conditions cease to exist, whichever is the first to occur.

ARTICLE XX
Ratification

The instruments of ratification of the Treaty shall be exchanged by Canada and the United States of America at Ottawa, Canada.

ARTICLE XXI
Registration with the United Nations

In conformity with Article 102 of the Charter of the United Nations, the Treaty shall be registered by Canada with the Secretariat of the United Nations.

This Treaty has been done in duplicate copies in the English language.

IN WITNESS WHEREOF the undersigned, duly authorized by their respective Governments, have signed this Treaty at Washington, District of Columbia, United States of America, this seventeenth day of January, 1961.

For Canada

John G. Diefenbaker
Prime Minister of Canada

E.D. Fulton
Minister of Justice

A.D.P. Heeney
Ambassador Extraordinary and Plenipotentiary of Canada to the United States of America

For the United States of America

Dwight D. Eisenhower
President of the United States of America

Christian A. Herter
Secretary of State

Elmer F. Bennett
Under Secretary of the Interior