DRAFT
COLUMBIA RIVER FISH MITIGATION
SYSTEM FLOOD CONTROL REVIEW

RECONNAISSANCE STUDY

Revised
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U.S. Army Corps of Engineers, Northwestern Division

EXECUTIVE SUMMARY

Introduction

The U.S. Army Corps of Engineers (Corps) has initiated the Columbia River Fish Mitigation System Flood Control Review. This reconnaissance-level study identified a range of potential modifications to existing Columbia River flood control systems that would potentially benefit fish species listed under the Endangered Species Act (ESA), while maintaining acceptable levels of protection from damaging floods and recognizing project purposes.

The objectives of this study were based on Congressional language and supplemental language used in the National Marine Fisheries Service (NMFS) 2000 Biological Opinion (NMFS 2000). The objectives are:

- Reduce the effects of system flood control operations on the spring freshet, particularly during average to below-average runoff years, such that spring and summer flow objectives on both the Snake and Columbia rivers, as defined by NMFS (2000) for required salmonid survival and recovery, can be met at an increased frequency both temporally and spatially.
- Minimize flow fluctuations during fall Chinook salmon emergence and rearing.
- Achieve a high probability of reservoir refill, particularly at Dworshak, Grand Coulee, Hungry Horse, and Libby Dams, which are the largest U.S.-managed projects in the Columbia River Basin (Figure 1).
- Provide acceptable levels of flood protection for developed areas within the active floodplain.

The analyses conducted during the study were used to determine if there is a Federal Interest in pursuing a more detailed feasibility analysis of modifying current system flood control operations to benefit ESA-listed fish species.

Flood Control Operations in the Columbia River Basin

The Columbia River forms the second-largest river basin in the United States. Over the past century, this basin has been altered considerably from a free-flowing river to one that is characterized by multiple water resource projects such as dams, irrigation systems, and municipal/industrial water supply systems. These projects provide numerous uses such as water supply, hydropower, recreation, navigation, and flood control.

Federally operated projects in the Columbia River Basin are known as the Federal Columbia River Power System (FCRPS). The Corps and U.S. Bureau of Reclamation (USBR) operate the Federal facilities and the Bonneville Power Administration (BPA) is responsible for the marketing and transmission of power generated from the FCRPS. Collectively, these three agencies are known as the “Action Agencies”.

The Corps, in cooperation with other Federal, state, and local agencies and the Canadian government, has developed a complex operating system in the Columbia River Basin that moderates or prevents flood damage to property and infrastructure (e.g., roads, railroads, pipelines, housing, and other structures). This operating system includes large storage reservoirs that can hold water and release it at a later time, levees that confine large runoff events to the main channel, and forecasting and operating procedures that allow a degree of control and predictability of flow patterns.

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Changes in Flow Affecting Fish Species Listed Under the ESA

The Columbia River floods are due to snowmelt, large rain events, or a combination of both. The development of water resource projects to reduce damage from these potential flood events and to utilize water from the basin rivers for irrigation, navigation, hydropower, and municipal/industrial have changed the runoff patterns considerably. As a consequence, these changes have altered river flow patterns and the original habitat for many species, some of which are now listed under the ESA. Among these are several species of salmon, steelhead, bull trout, and Kootenai River white sturgeon.

In 2004, NMFS compared the system survivals of anadromous salmon and steelhead Evolutionarily Significant Units (ESUs) resulting from the Action Agencies *Final Updated Proposed Action for the FCRPS Biological Opinion Remand* (UPA) (Corps, et al., 2004) operations against a reference operation they developed that represented the best operations scenario of the FCRPS they assumed possible for salmonid passage and production. The analysis resulted in increases of average ESU in-river survivals of about four percent for Snake River fall Chinook salmon and Snake River and Mid-Columbia River steelhead. The analysis also resulted in about a three percent increase for Snake River fall Chinook salmon. These increases are based on the assumption there is a positive flow/survival relationship. Without this assumption, the increase would only be one percent for all species. The reference operation considered here makes shifts to available summer augmentation water during July through September in the Columbia River arm of the basin to meet or exceed the summer flow objective of the 2004 Biological Opinion.

Regulatory Conditions

The National Marine Fisheries Service (NMFS - also called National Oceanic and Atmospheric Administration [NOAA] Fisheries), in its 2000 Biological Opinion (NMFS 2000) for operation of the FCRPS, identified 199 key "Action Items" that should be taken by the Action Agencies in order to avoid the FCRPS from jeopardizing salmon and steelhead species listed under the ESA. Action 14 of the opinion established seasonal flow objectives in both location (spatial) and timing/duration (temporal) terms to assist downstream migration of juvenile salmonids that occurs during the spring and summer months. The flow objectives cannot always be met during average to below-average runoff years because large storage reservoirs in the Columbia River Basin (particularly Grand Coulee, Dworshak, Hungry Horse, Libby, Duncan, Keenleyside, and Mica) are capturing inflows in order to refill reservoirs and to provide flood damage reduction. Action 35 of the opinion identifies the need for the Corps to evaluate whether existing operations can be altered to allow more consistent spring runoff that would meet the Action 14 flow objectives for downstream migrating juvenile salmonids, particularly during average to below-average discharge years.

The NMFS 2000 Biological Opinion was challenged in the case *National Wildlife Federation v. NMFS*, CR 01-640-RE (D. Oregon, *filed* May 5, 2001). The District Court found the 2000 Biological Opinion invalid and remanded it to NMFS on June 2, 2003 to consider revisions consistent with the Court's opinion of May 7, 2003. The Action Agencies proposed the *Final Updated Proposed Action for the FCRPS Biological Opinion Remand* (UPA) (Corps, et al., 2004). The review of the system flood control operations called for in Action 35 in the NMFS 2000

EXECUTIVE SUMMARY (CONTINUED)

Biological Opinion has been carried over as part of the Action Agencies' UPA and coordinated with NMFS in development of the NMFS 2004 Biological Opinion.[1]

In 2004, NMFS compared the system survivals of ESUs resulting from the UPA operations agains a reference operation they developed that represented the best operations scenario of the FCRPS they assumed possible for salmonid passage and production. The analysis resulted in increases of average ESU in-river survivals of about four percent for Snake River spring Chinook salmon and Snake River and Mid-Columbia River steelhead. The analysis also resulted in about a three percent increase for Snake River fall Chinook salmon. These increases are based on the assumption there is a positive flow/survival relationship. Without this assumption, the increase would only be one percent for all species. The reference operation considered here makes shifts to available summer augmentation water during July through September in the Columbia River arm of the basin to meet or exceed the summer flow objective of the 2004 Biological Opinion.

<u>Federal Interest in Conducting a Feasibility Study</u>

The Corps must determine if there is a Federal Interest in pursuing feasibility level studies to investigate changes in water storage and movement seasonally through the basin rivers to achieve a higher frequency of meeting the ESA flow objectives in response to Action 35 (NMFS 2000, NOAA Fisheries 2004). The changes in the magnitude (spatial) and timing (temporal) of water movement and storage could affect existing procedures for flood damage reduction, including adjustment of operations (e.g., changing the timing and/or volume of storage and releases in reservoirs) or structural changes (e.g., increased height of levees). This report is a reconnaissance-level evaluation that addresses the Federal Interest in identifying a potential way that flow objectives might be met during years when runoff is average to below-average.

<u>Plan Formulation</u>

The reconnaissance-level evaluation was initiated with a workshop in Seattle, Washington. The main purpose of the workshop was to examine a wide range of potential measures that might be used to change the existing operations to improve the ability to meet flow objectives for juvenile salmon migration during average to below-average discharge years. Representatives from the Walla Walla, Portland, and Seattle Districts and the Northwestern Division of the Corps participated in the workshop. Each of these districts and the Division has a key role in the operation of the FCRPS. The Northwestern Division Office, located in Portland, Oregon, is responsible for directing the operation of the FCRPS and implementation of Biological Opinions.

During the workshop, a wide range of potential measures for changing the current operations and structures to meet UPA flow objectives was identified. These measures were categorized as follows:

- Purchase Land and Water,
- Develop New Storage Dams,
- Review the Status of Existing Levees and Determine Need for Upgrades,
- Transfer Storage,

[1] The outcome of the review and actions to be taken by the court are unknown at this time. As decisions regarding the remand are made, the Corps will need to take appropriate actions, to modify, if necessary, the approach to the overall feasibility study.

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- Improve the Use and Reliability of Weather and Runoff Forecasts Systemwide,
- Improve Operational Efficiency,
- Provide Alternative Storage Regulation Systemwide, and
- Evaluate Other Structural and Non-Structural Measures.

From this list, several categories were selected to formulate an alternative plan that could meet the project purpose and objectives. These categories include:

- Improve the Use and Reliability of Weather and Runoff Forecasts Systemwide,
- Provide Alternative Storage Regulation Systemwide,
- Review the Status of Existing Levees and Determine Need for Upgrades, and
- Re-define acceptable levels of flood damage reduction (one of the measures under the Non-Structural Measures category).

Feasibility Study Funding

In accordance with the *Planning Guidance Notebook* (ER 1105-2-100), a reconnaissance-level evaluation typically includes identification of a non-Federal entity willing to serve as a non-Federal sponsor and enter into a cost-sharing agreement for feasibility studies. However, a non-Federal sponsor is not being identified for this project because this evaluation involves investigation of Columbia River flood control operations, which is a Federal responsibility, and the identification of alternative measures to reduce the impacts of these operations on ESA-listed fish species. The responsibility for system operations and compliance with the ESA belongs to the Federal government. This reconnaissance-level report was developed in response to the NMFS 2000 and 2004 Biological Opinions for the FCRPS. If feasibility studies are pursued as a result of this evaluation, they will be 100 percent Federally funded.

Findings of this Reconnaissance Study

This reconnaissance study finds that there is a Federal interest in pursuing a feasibility level study to determine if the System Flood Control Review objectives can be met. The assessment presented in this document indicates there is an alternative plan that can provide acceptable levels of flood control and the desired fisheries benefits, is environmentally acceptable, would likely be supported by the Pacific Northwest region, and would be consistent with Corps policies. This alternative plan to meet the objectives of this system flood control project includes the following components:

1. Improve the use and reliability of seasonal volume forecasts systemwide.
2. Change systemwide storage regulation to manage for more storage/flows and flood control.
3. Update capabilities of existing Federal levees and upgrade as needed to meet new flows.
4. Re-define acceptable levels of damage reduction.

Improving the use and reliability of forecasts systemwide could benefit outmigrating juvenile salmonids and could also help enhance control of potential flood conditions. In addition, improvements to forecasting could help the Corps more reliably meet existing objectives such as flow needed for resident fish; reservoir refill targets; water quality; navigation; recreation; irrigation and other water supply needs; and power production.

Changes in systemwide storage regulation could have a number of potential environmental, social, and economic effects, including effects to reservoir fish and water quality, recreation use,

EXECUTIVE SUMMARY (CONTINUED)

downstream fish resources, wildlife, vegetation, water supply, navigation, and other uses. Changes to Federal levees could result in a wide range of environmental effects that would need to be evaluated in the feasibility study. Levee removal or reconfiguration could, for example, result in new areas for habitat (e.g., wetlands, riparian zones, and side-channels), but could also result in removal of areas from current uses (e.g., urban and industrial development). Re-defining acceptable levels of flood control could also result in a range of environmental, social, and economic effects that would need to be evaluated as part of the feasibility study.

Variable Q, where Q represents discharge, (VAR Q) is a flood control method designed with the potential to better ensure reservoir refill in years with slightly below to slightly above-average seasonal volume runoff forecasts, while maintaining authorized flood protection as measured as The Dalles, OR. Flood control operational changes, such as VAR Q, have been successfully studied and recently implemented on an interim basis in the upper Columbia River, with a decision forthcoming on long-term implementation. Expanding alternative flood control studies and procedures to the entirety of the Columbia River Basin would produce an implementable alternative in the feasibility study that could result in significant increases toward ESA salmon survival and recovery.

This Federal interest determination is based on the responsibilities that the Corps (and other Federal agencies) have in the operation of the FCRPS, including flood control. This interest is also based on the need to ensure that operation of the FCRPS meets requirements of the ESA and the NMFS 2004 and USFWS 2000 Biological Opinions, while maintaining project authorized purposes. The report concludes that a feasibility level study is warranted by these requirements.

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FIGURES

USEFUL ENGLISH TO METRIC CONVERSION FACTORS

To Convert From	**To**	**Multiply by**
LENGTH CONVERSIONS:		
Feet	Meters	0.3048
Miles	Kilometers	1.6093
AREA CONVERSIONS:		
Acres	Hectares	0.4047
Acres	Square meters	4047
Square miles	Square kilometers	2.590
VOLUME CONVERSIONS:		
Acre-feet	Hectare-meters	0.1234
Acre-feet	Cubic meters (m^3)	1234
Cubic feet (cu ft)	Cubic meters (m^3)	2.832×10^{-2} or (0.02832)
OTHER CONVERSIONS:		
Feet/mile	Meters/kilometer	0.1894
Cubic feet/second	Cubic meters/sec	0.02832
Degrees Fahrenheit	Degrees Celsius	(Deg F –32) x (5/9)

LIST OF ACRONYMS

ASA (CW)	Assistant Secretary of the Army (Civil Works)
BPA	Bonneville Power Administration
CCRS	Coordinated Columbia River System
CEAA	Canadian Entitlement Allocation Agreement
CENWD	Corps Northwestern Division
cfs	cubic feet per second
CRFM	Columbia River Fish Mitigation
CRITFC	Columbia River Intertribal Fish Commission
Corps	U.S. Army Corps of Engineers
EA	Environmental Assessment
EIS	Environmental Impact Statement
ER	Engineer Regulations
ESA	Endangered Species Act of 1973, as amended
ESU	Evolutionarily Significant Unit
FCRPS	Federal Columbia River Power System
FERC	U.S. Federal Energy Regulatory Commission
FONSI	Finding of No Significant Impact
FPC	Fish Passage Center
FR	Federal Register
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HTRW	Hazardous, Toxic, or Radioactive Waste
IJC	International Joint Commission
kcfs	thousand cubic feet per second
MAF	million acre-feet
m^3/s	cubic meters per second
NMFS	National Marine Fisheries Service
NOAA Fisheries	National Oceanic and Atmospheric Administration Fisheries (also called NMFS)
PIT tag	Passive Integrated Transponder tag
PL	Public Law
PMP	Project Management Plan
PPL Montana	Pennsylvania Power and Light, Montana
PUD	Public Utility District
RCC	Reservoir Control Center
SOR	System Operation Review
SPF	Standard Project Flood
SRDs	Storage Reservation Diagrams
TDG	total dissolved gases
TMT	Technical Management Team

LIST OF ACRONYMS (continued)

UPA	Updated Proposed Action
USBR	U.S. Bureau of Reclamation
USC	United States Code
USFWS	U.S. Fish and Wildlife Service
VARQ	Variable Q (Q represents discharge)

1. Study Authority

The authority for the Columbia River Basin projects operated by the Corps is established by the following legislation and related documents:

- Section 9 of Public Law (PL) 43-83d Congress (68 Stat. 303)
- Section 7 of the Flood Control Act approved December 22, 1944 (58 Stat. 890; United States Code [USC] 709)
- The Federal Power Act, approved June 10, 1920, as amended (41 Stat. 1063; 16 USC 791 [a])
- Flood Control Act of 1950, House Document 531
- The Fish and Wildlife Coordination Act of 1958, PL 85-624
- The Federal Water Pollution Control Act Amendments of 1972, PL 92-500 (86 Stat. 816, 33 USC 1251)
- The Federal Power Commission Order No. 540, issued October 31, 1975 and published November 7, 1975 (40 Federal Register [FR] 51998), amending Section 2.9 of the Commission's General Policy and Interpretations prescribing Standardized Conditions (Forms) for Inclusion in Preliminary Permits and Licenses issued under Part I of the Federal Power Act
- Engineering and Design – Water Control Management [Engineer Regulation (ER) 1110-2-240], published October 8, 1982

Project-specific authorizations are identified in Section 5.2 of this report.

In Fiscal Year 2003, a Senate Committee recommendation identified using funds appropriated as part of the Columbia River Fish Mitigation (CRFM) Program to initiate an investigation of flood control operations. The Committee language states, "Within the funds provided, the Committee recommendation includes $300,000 for a reconnaissance-level investigation of the Columbia River flood control operations to determine what changes, if any, would benefit endangered species, particularly salmon. Evaluation beyond the reconnaissance phase is subject to agency review and congressional notification." This Committee language supports the intent of Action 35 as presented in the NMFS 2000 Biological Opinion (see Section 2).

2. Background

The Federal Columbia River Power System (FCRPS) is a system of dams and reservoirs located in the Columbia River Basin. This system is operated and maintained by the U.S. Army Corps of Engineers (Corps) and U.S. Bureau of Reclamation (USBR). Congress authorized the FCRPS projects for multiple purposes, including flood control, irrigation, fish and wildlife, power generation, navigation, water quality, municipal and industrial water, and recreation. Bonneville Power Administration (BPA) is responsible for marketing and transmission of power generated from these projects. Collectively, the Corps, USBR, and BPA are referred to as the "Action Agencies".

The National Marine Fisheries Service (NMFS - also called National Oceanic and Atmospheric Administration [NOAA] Fisheries) issued a 2000 Biological Opinion that identified 199 actions as part of the Reasonable and Prudent Alternative to keep the FCRPS operation from jeopardizing salmon and steelhead ("salmonids") listed under the Endangered Species Act of 1973, as amended (ESA). Action 35 of the NMFS 2000 Biological Opinion, quoted below, describes the need to develop and conduct a detailed feasibility analysis of modifying current system flood control operations to benefit the Columbia River ecosystem, including ESA-listed salmonids[2/].

"The Corps shall develop and conduct a detailed feasibility analysis of modifying current system flood control operations to benefit the Columbia River ecosystem, including salmon. The Corps shall consult with all interested state, Federal, Tribal, and Canadian agencies in developing its analysis. Within 6 months after receiving funding, the Corps shall provide a feasibility analysis study plan for review to NMFS and all interested agencies, including a peer-review panel (at least three independent reviewers, acceptable to NMFS, with expertise in water management, flood control, or Columbia River basin anadromous salmonids). A final study plan shall be provided to NMFS and all interested agencies 4 months after submitting the draft plan for review. The Corps shall provide a draft feasibility analysis to all interested agencies, NMFS, and the peer-review panel by September 2005" (NMFS 2000).

It should be noted that the NMFS 2000 Biological Opinion was challenged in the case *National Wildlife Federation v. NMFS*, CR 01-640-RE (D. Oregon, *filed* May 5, 2001). On May 7, 2003, the District Court found the 2000 Biological Opinion invalid and remanded it to the NMFS on June 2, 2003 to consider revisions consistent with the Court's opinion of May 7, 2003.

Since the Action Agencies had already adopted the actions in the NMFS 2000 Biological Opinion, they determined that it would be more appropriate for NMFS to base the remanded Opinion on an updated proposed action reflecting their current and planned future operations. The updated proposed action is presented in the *Final Updated Proposed Action for the FCRPS Biological Opinion Remand* (UPA) (Corps, et al., 2004).

The UPA was considered by NMFS as it drafted the *Revised 2004 Biological Opinion on the Operation of the Federal Columbia River Power System and 19 Bureau of Reclamation Projects* (NMFS 2004 Biological Opinion). In 2004, NMFS compared the system survivals of ESUs resulting from the UPA operations against a reference operation they developed that represented the best operations scenario of the FCRPS they assumed possible for salmonid passage and production. The analysis resulted in increases of average ESU in-river survivals of about four percent for Snake River fall Chinook salmon and Snake River and Mid-Columbia River steelhead. The analysis also resulted in about a three percent increase for Snake River fall Chinook salmon. These increases are based on the assumption there is a positive flow/survival relationship. Without this assumption, the increase would only be one percent for all species. The reference operation considered here makes shifts to available summer augmentation water during July through September in the Columbia River arm of the basin to meet or exceed the summer flow objective of the 2004 Biological Opinion.

NMFS concluded that the collective actions from the UPA would avoid jeopardy to 13 evolutionarily significant units (ESUs) of the Columbia Basin salmonids listed or proposed to be listed under the ESA and the destruction or adverse modification of designated critical habitat.

Action 35 in the NMFS 2000 Biological Opinion has been carried over as part of the Action Agencies' UPA and coordinated with NMFS in development of the NMFS 2004 Biological Opinion. The UPA indicated a reconnaissance-level evaluation would be completed and coordinated with NMFS and the region. Efforts to meet the intent of Action 35 and the intent of the Senate Committee will be referred to as the System Flood Control Review throughout this report.

[2/] The U.S. Fish and Wildlife Service (USFWS) also issued a Biological Opinion in 2000 for operation of the FCRPS. This opinion addressed wildlife, plants, and resident fish species (e.g., Kootenai River white sturgeon and bull trout) that are listed under ESA.

3. Study Purpose and Scope

3.1 Purpose

There is a general principle in the region that flow augmentation should improve juvenile salmonid survival on their migration to the ocean. The purpose of the CRFM System Flood Control Review is to study and evaluate potential modifications to the Columbia River flood control operations and structures for possible modifications that will benefit the Columbia River ecosystem. The study will determine what changes, if any, would benefit ESA-listed fish species, particularly salmonids, while maintaining acceptable levels of protection from damaging floods and recognizing project purposes. The feasibility study will not be limited to evaluating measures/alternatives that will modify federally-controlled elements of the Columbia River the flood control system, but also consider those measures/alternatives that could be performed by private, local, state, or other agencies and organizations.

3.2 Scope

This report presents the background and results of the reconnaissance-level study. The analyses conducted during the study were used to determine if there is a Federal interest in pursuing a more detailed feasibility analysis of modifying current system flood control operations to benefit ESA-listed species, particularly salmonids.

The reconnaissance-level study focused primarily on identifying potential alternatives to better meet flow objectives for juvenile salmon migration (see Section 4.1) while considering flood control and other multiple uses of the system. The study did not include any detailed analysis of the potential impacts of modifying the existing system on the various other elements of the human and physical environment, such as hydropower, transportation, fish and wildlife, recreation, or other uses of the system. This type of impact analysis will occur in a detailed feasibility analysis phase of the study.

3.3 Problems and Opportunities

3.3.1 Problems

Adequate river flows, as defined by the flow objectives for the Columbia and Snake Rivers in recent NOAA Fisheries Biological Opinions, have been provided for the spring runoff and summer periods since the early 1990s and are intended to aid juvenile salmonid survival in their downstream migration to the ocean (Corps, et al., 2004). Under current operations, river flows are often not adequate, especially in average to below-average water years, to meet the established flow objectives, which could adversely affect fish passage and survival. This problem is partly as a consequence of current flood control storage rules, frequency of climatic low flow years and within-year seasonal flows, water withdrawals for irrigation and industrial uses, and required flow and storage requirements from other Biological Opinions and agreements for all tributaries of the basin.

For example, the requirement for modified water storage and release timing flow augmentation for Kootenai River white sturgeon and bull trout, as recommended in the USFWS 2000 Biological Opinion (USFWS 2000), can result in less water available from Libby Dam for salmon flow augmentation during July and August. As another example, modified storage and release timing is required during average to below-average water years to conform to the Vernita Bar Agreement for the middle Columbia River or the Hells Canyon Agreement in the Snake River for fall Chinook salmon spawning and emergence.

The main purpose of existing flood control operations is to reduce significant flood damages in the region. This requires a system of levee structures that are critical for dam operation. Modifying flood control operations to increase the likelihood of achieving fish flow objectives may increase flooding risk. Therefore, a potential problem that could result from modifying current flood control operations would be an increase in the risk of flooding and possible associated property damage and/or loss of life. This problem is further complicated by the desire to achieve these spring flow guidelines on a more consistent basis, while also reducing flow fluctuations, ensuring reservoir refill, increasing connectivity to the floodplain and maintaining flood protection and other beneficial uses of the hydrosystem (e.g., power generation, recreation, water supply, navigation, and fish and wildlife).

Another problem is that much of the data used for determining flood damages is outdated. Growth within the floodplains, changes in floodplain land uses, and the condition of existing levee systems may have changed the level of flood damages prevented by the system, therefore the need to update the hydrology and resultant stage-frequency and stage-damage relationships.

3.3.2 Opportunities

The primary opportunity is to increase seasonal flows in the Columbia River system. Changing the spring flood control operations will have the greatest impact to changing spring flow. The intent is to improve ESA-listed salmon smolt passage and survival. The Corps will evaluate increasing the frequency of flows to greater than 80-90% of meeting or exceeding the stated kcfs of the seasonal flow objectives that have been considered important to decrease the long-term risk of extinction of ESA-listed salmonid ESUs and maximize the survival and production probability needed for recovery of ESA-listed salmonid ESUs. NOAA Fisheries (2004) FCRPS BiOp estimated in their reference operation comparison to the UPA that increasing the frequency of meeting or exceeding the 55 kcfs past Lower Granite Dam and 200 kcfs past McNary Dam from 0-10% to approximately 80% of the time during August could result in an absolute 3-4% increase in in-river survival in addition to the UPA survival estimated for each year in the 10 years analyzed (1994-2003) for Snake River fall and spring Chinook salmon and steelhead. This increase in in-river survival during low flow years could be significant to fall Chinook salmon and steelhead stocks in relative comparisons considering that the in-river survival of steelhead from Lower Granite to Bonneville dams was 4.2% during the critically low flow year of 2001 (NOAA Fisheries 2004d).

Another opportunity is to update the prediction and evaluation tools used in the basin, including a reevaluation of the levee system. This is not only important for this study, but a positive for the region by accounting for the developmental changes that have occurred.

3.4 Objectives

The objectives of this study were based on Congressional language and supplemental language used in the NMFS 2000 Biological Opinion (NMFS 2000). The objectives are:

Reduce the effects of system flood control operations on the spring freshet, particularly during average to below-average runoff years, such that spring and summer flow objectives on both the Snake and Columbia rivers, as defined by NMFS (2000) for required salmonid survival and recovery, can be met at an increased frequency both temporally and spatially.

- Minimize flow fluctuations during fall Chinook salmon emergence and rearing.
- Achieve a high probability of reservoir refill, particularly at Dworshak, Grand Coulee, Hungry Horse, and Libby Dams, which are the largest U.S.-managed projects in the Columbia River Basin (Figure 1).
- Provide acceptable levels of protection for developed areas within the active floodplain.

3.4.1 Constraints on System Flows

- Maintain acceptable flood damage reduction in the system.
- Physical (hydrologic) amount of storage in the system to meet flow requirements.
- Alternatives must fully consider Congressionally authorized project purposes.
- Maintain acceptable navigation in the system.
- Currently authorized and regulated summer season water withdrawals from the Columbia River for agriculture, municipal, industrial, etc affects the available storage.

4. Major Projects in the Study Area/Congressional Districts

4.1 General Description of Study Area

The Columbia River Basin is the study area for this report. The Columbia River originates at Columbia Lake in the Rocky Mountains of British Columbia, Canada and flows 1,214 miles to the Pacific Ocean. Three large tributaries of interest are the Kootenai and Pend Oreille rivers, which join the Columbia River near the U.S./Canada border, and the Snake River, which joins the Columbia River about 330 miles upriver from the mouth. The Columbia River Basin, which drains over 259,000 square miles, extends south from British Columbia and encompasses parts of seven U.S. states: Washington, Oregon, Idaho, Montana, Utah, Wyoming, and Nevada (Figure 1).

The annual flow patterns of the Columbia River underwent a substantial transformation during the twentieth century. At the beginning of the century, the river's flows exhibited great seasonality, with roughly 75 percent of the annual flows occurring during summer months (April-September) and roughly 25 percent of annual flows occurring during winter months (October-March). The pattern of annual flows changed in response to the construction of numerous mainstem and tributary impoundments and the subsequent operations of this water control system. A major component of the system is known as the Federal Columbia River Power System (FCRPS), and the principal original purposes underlying its construction were to provide hydroelectric, irrigation, and flood control benefits. Construction of some of the system's large mainstem projects, such as Grand Coulee and Bonneville dams, began in the 1930s. The post-World War II period saw a burst in project authorization and construction of additional large projects. Other projects were built in connection with the Canada-U.S. Columbia River Treaty signed in 1961. The hydrological implications of the system's construction were tremendous. As the system's water control projects came on line, annual flows of the Columbia became and less and less seasonal, as the differences between summer and winter flows were reduced in order to provide reliable year-round hydropower generation and distribution. In the late 1970s, the Columbia's annual flows had been modified such that they were divided roughly evenly between summer and winter, as compared to the 75:25 ratio that had existed at the beginning of the twentieth century. In addition to this "flattening" of the annual Columbia River hydrograph, other key impacts of the construction and operations of the hydropower system were a decrease in water velocities, a change in the size and orientation of the river's plume (a physical zone in the Pacific Ocean that extends from the Columbia's mouth into marine waters), and major changes to limnology and nutritional pathways in the river's estuary and food web. All these changes have likely had significant effects on the early ocean survival of juvenile fish leaving the Columbia River. Passage of such legislation as the National Environmental

Policy Act (1969) and the Endangered Species Act (1973) resulted in consideration of changes in operational patterns and priorities. "Flow objectives" have been established by Federal and state agencies as one component of efforts to sustain and recover salmon habitat and populations (NMFS 1995, 2000 and 2004).

Despite construction and operations of the hydropower system, the river still exhibits considerable flow variations on daily, seasonal, and annual timescales. Under current conditions, less than 1 percent of total annual withdrawals are made during January. By contrast, during July—the month of highest withdrawals—about 18 percent of annual withdrawals from the Columbia River in the State of Washington are made. The seasonality of water withdrawals for irrigation and industry and storage for flood control and recreation is important when considering how the river's water withdrawals affect salmon survival rates.

The basin's salmon and steelhead populations have been in steady decline over the past century. Currently, 13 evolutionarily significant units (ESUs) of salmon and steelhead have been listed as threatened or endangered under the Endangered Species Act (Table 1). Critical habitat within the basin has been designated for 12 of these ESUs. The threatened and endangered fish and their designated critical habitat occur throughout the currently accessible parts of the basin (i.e. the mainstem Columbia River and its tributaries downstream of Chief Joseph Dam near Bridgeport, Washington, and the mainstem Snake River and its tributaries downstream of Hells Canyon Dam along the Oregon/Idaho border).

Table 1. Threatened and Endangered Evolutionarily Significant Units of Salmon and Steelhead in the Columbia River Basin

Species	ESU	Designated Status	Critical Habitat
Chinook salmon (*Oncorhynchus tshawytscha*)	Snake River Fall	Threatened	designated
	Snake River Spring/Summer	Threatened	designated
	Upper Columbia River Spring	Endangered	designated
	Lower Columbia River	Threatened	designated
	Upper Willamette River	Threatened	designated
Chum salmon (*O. keta*)	Columbia River	Threatened	designated
Sockeye salmon (*O. nerka*)	Snake River	Endangered	designated
Coho (*O. kisutch)*	Lower Columbia	Threatened	*n/a*
Steelhead (*O. mykiss*)	Snake River	Threatened	designated
	Upper Columbia River	Endangered	designated
	Middle Columbia River	Threatened	designated
	Lower Columbia River	Threatened	designated
	Upper Willamette River	Threatened	designated

Prior to large-scale habitat degradation, intensive harvest activities, and construction of dams throughout the basin, the total numbers of returning adults comprising the different ESUs counted in the millions.[3] Even considering improvements in adult returns in recent years, the numbers of wild and hatchery adult salmon currently returning to spawn each year are substantially lower than historical returns. Additionally, natural-origin adults of specific tributary stocks that comprise the various ESUs are typically well below targets identified by fishery managers as necessary for conservation and recovery of the listed ESUs (West Coast Biological Review Team 2003). Considering updated information on abundance, growth rate/productivity, spatial distribution, and

[3] Using harvest rates during the nineteenth century, Chapman (1986) estimated peak-period runs of 2.6 million sockeye salmon, 4.3 million Chinook salmon, 620,000 coho salmon, 550,000 steelhead, and 750,000 chum salmon—8.8 million adults altogether.

diversity, a recent status review concluded that all currently-listed salmon and steelhead ESUs in the Columbia River basin continue to be either in danger of extinction or likely to become endangered (West Coast Biological Review Team 2003).

Scientific evidence demonstrates that environmental and biological thresholds important to salmon—such as critical low flow during summer that results in excessive water temperature—are being reached or in some cases exceeded (NRC 2004). Salmon are more likely to be imperiled during late summer on the Snake and Columbia rivers, as they experience pronounced changes in migratory behavior and survival rates when river flow becomes critically low or water temperature becomes too high (ISAB 2004). Further decreases in flows or increases in water temperature are likely to reduce survival rates (NRC 2004, ISAB 2004). Trends such as human population growth in the region and prospective regional climate warming further increase risks regarding salmon survival (NRC 2004).

The Columbia River estuary has changed greatly since the early 1800s. Total volume of the estuary has declined by about 12 percent since 1868, and diking and filling have converted 40 percent of the original floodplain to various human uses (Sherwood et al., 1990). The annual spring freshet has been greatly diminished, thereby reducing organic and sediment inputs. The standing crop of organisms that feed on macrodetritus is only about one-twelfth as great as it once was (ibid.). The Northwest Power Planning Council's ISAB (1996) assumed that a reduction in the food web supported by phytoplankton macrodetritus has negatively affected salmon. Changes in food web production have resulted in a more favorable environment for herring, smelt, and shad. Estuarine degradation and potential mitigation are further discussed in Bottom et al. (2002), Jay and Naik (2000), and Kukulka and Jay (2003). Hatchery-produced salmon and steelhead now pass through the estuary in large quantities, in temporal patterns dissimilar to historical patterns of the passage of wild fish. Effects of these large hatchery releases on estuarine ecology are not fully understood and quantified. Taken together, the various changes in estuarine dynamics could result in cumulative negative effects on wild anadromous fish because of the diminished ecological opportunities offered by a smaller estuary that has experienced pronounced hydrologic and related changes.

For this study, the Columbia River Basin was divided into four smaller subbasins (A, B, C, and D) for the purpose of analysis (see Figure 1). A number of factors were considered in the identification of these subbasins, including:

- Dams operated by the USBR on the upper/middle Snake River have relatively smaller flood control utilization than other areas of the Columbia River Basin because of the major influence of irrigation withdrawals.
- Dividing the basins into areas that are too small might affect the development of alternatives.
- Using larger subbasins could ignore some local flood damage areas.

Subbasins include established monitoring sites for flow objectives (NMFS 2000) and flood reduction assessments that have biological significance. The Salmon and Grand Ronde watersheds were not included in any of the subbasins because they are essentially uncontrolled flow systems that affect the lower Snake River at Lower Granite Dam.

1. Bonneville
2. The Dalles
3. John Day
4. McNary
5. Priest Rapids
6. Wanapum
7. Rock Island
8. Rocky Reach
9. Wells
10. Chief Joseph
11. Grand Coulee
12. Keenleyside
13. Revelstoke
14. Mica
15. Duncan
16. Corra Linn
17. Albeni Falls
18. Libby
19. Hungry Horse
20. Kerr
21. Ice Harbor
22. Lower Monumental
23. Little Goose
24. Lower Granite
25. Dworshak
26. Hells Canyon
27. Oxbow
28. Brownlee
29. Lucky Peak
30. Arrowrock
31. Anderson Ranch
32. Minidoka
33. American Falls
34. Palisades
35. Jackson Lake

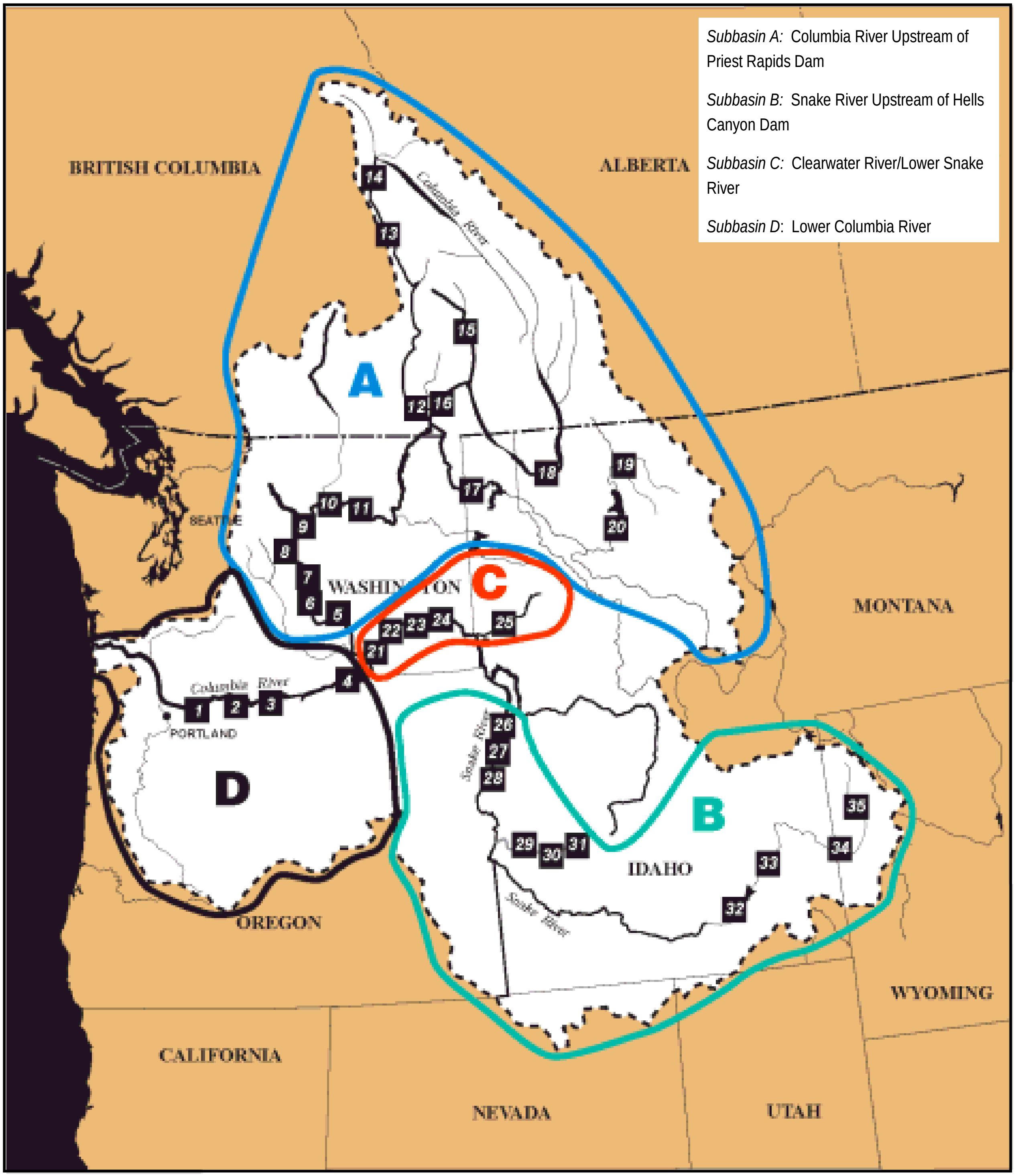

Figure 1. Columbia River Basin, Subbasins, and Hydro Projects Identified for Analysis

<u>Flow Objectives -</u> The UPA (Corps, et al., 2004) defined flow objectives for spring runoff and summer periods with implementation dates for operational releases to be measured at specific monitoring locations that correlated with high estimates for salmon and steelhead smolt survival for particular reaches of the Snake and Columbia rivers. Performance measures resulting in non-jeopardy survival and population production indices leading to recovery have been established by NMFS (NMFS 2004). The NMFS flow objectives for spring and summer flows are identified in Table 2.

The locations of measurements for the flow objectives were generally incorporated into the subbasin designations for this study, with some modification based on system flood control and other regulatory constraints. Under current operations, these flows are not always achieved, partly as a consequence of flow and storage requirements for other biological opinions and agreements for all tributary arms of the basin, and especially in average to below-average water years. The following performance measurement targets for this reconnaissance-level study (i.e., sites where flow monitoring would occur) were established for each subbasin:

Subbasin A - Columbia River Upstream of Priest Rapids Dam: measurement target at Priest Rapids Dam. Vernita Bar Settlement Agreement, U.S. Federal Energy Regulatory Commission (FERC) and Grant, Chelan, and Douglas Public Utility Districts (PUDs), December 9, 1998. The Vernita Bar Agreement, which applies through 2005, defines flow target discharges, water surface elevations, and dates of operational releases through Priest Rapids Dam, to be measured at Vernita Bar, that correlate with high estimates of Hanford Reach fall Chinook salmon spawning and emergence production.

Subbasin B - Snake River Upstream of Hells Canyon Dam: measurement target at Hells Canyon Dam. Hells Canyon Agreement, FERC and Idaho Power Company, July 1992. The Hells Canyon Agreement applies annually at least through completion of the Hells Canyon Hydroelectric Complex relicensing. It defines flow target discharges, water surface elevations, and dates of flow releases from Brownlee Dam storage, and releases through Hells Canyon Dam to be measured through the extent of the spawning grounds utilized below Hells Canyon Dam that influence Snake River fall Chinook salmon spawning and rearing production.

Subbasin C - Clearwater River/Lower Snake River: measurement targets at Lower Granite Dam and at Ice Harbor Dam (NMFS 2000).

Subbasin D - Lower Columbia River: measurement targets from the head of the McNary pool to the mouth of the river, with principal target flows below Bonneville Dam and at The Dalles Dam.

Table 2. Seasonal Flow Objectives (kcfs1/) and Planning Dates for the Mainstem Columbia and Snake Rivers

Location	Spring		Summer	
	Dates	Objective	Dates	Objective
Snake River at Lower Granite Dam	4/03 – 6/20	85-100[2/]	6/21 – 8/31	50 – 55[2/]
Columbia River at McNary Dam	4/10 – 6/30	220-260[2/]	7/01 – 8/31	200
Columbia River at Priest Rapids Dam	4/10 – 6/30	135	N/A[3/]	N/A
Columbia River at Bonneville Dam	11/1 – chum emergence	125-160[4/]	N/A	N/A

[1/] kcfs = thousand cubic feet per second
[2/] Objective varies according to water volume forecasts.
[3/] N/A indicates no dedicated target flows established for this month.
[4/] Objective varies based on actual and forecasted water conditions
Source: Table 3 in the UPA (Corps, et al., 2004)

The maximum amount of flood control storage that can be used to reduce spring flooding is about 39 MAF (48.0 billion m^3), which includes "on-call" storage in Canadian projects [4/]. Without "on-call" storage, the maximum amount of flood control storage in the Columbia River system is about 27 MAF (33.3 billion m^3). Flood control space is used to operate to a regulated flow target at The Dalles, Oregon. Storage in upstream reservoirs to meet flood control objectives at The Dalles generally results in adequate control at other flood damage areas in Canada and the United States. Not all projects in the basin have storage space for flood control. The use of storage for all sub-basins is shown in Tables 5-8.

4.2 U.S. Congressional Districts

The Columbia River Basin includes all or part of a number of U.S. Congressional Districts, which are identified in Table 3 and shown in Figure 2. U.S. Senators for the states that include portions of the Columbia River Basin are identified in Table 4.

Table 3. U.S. Congressional Districts within the Columbia River Basin

Congressional District	Representative (April 2005)
Washington	
3rd District	Brian Baird
4th District	Doc Hastings
5th District	Cathy McMorris
Oregon	
1st District	David Wu
2nd District	Greg Walden
3rd District	Earl Blumenauer
4th District	Peter DeFazio
5th District	Darlene Hooley
Idaho	
1st District	C.L. "Butch" Otter
2nd District	Michael Simpson
Montana	
At Large	Dennis Rehberg
Nevada	
2nd District	Jim Gibbons
Utah	
1st District	Rob Bishop
Wyoming	
At large	Barbara Cubin

State	District	Representative	State	District	Representative
Washington:	3. 4. 5.	Brian Baird Doc Hastings Cathy McMorris	Idaho:	1. 2.	C.L. "Butch" Otter, Michael Simpson
			Montana:	1.	Dennis Rehberg
Oregon:	1. 2. 3. 4. 5.	David Wu, Greg Walden, Earl Blumenauer, Peter DeFazio, Darlene Hooley	Nevada:	2.	Jim Gibbons
			Utah:	1.	Rob Bishop
			Wyoming:	1.	Barbara Cubin

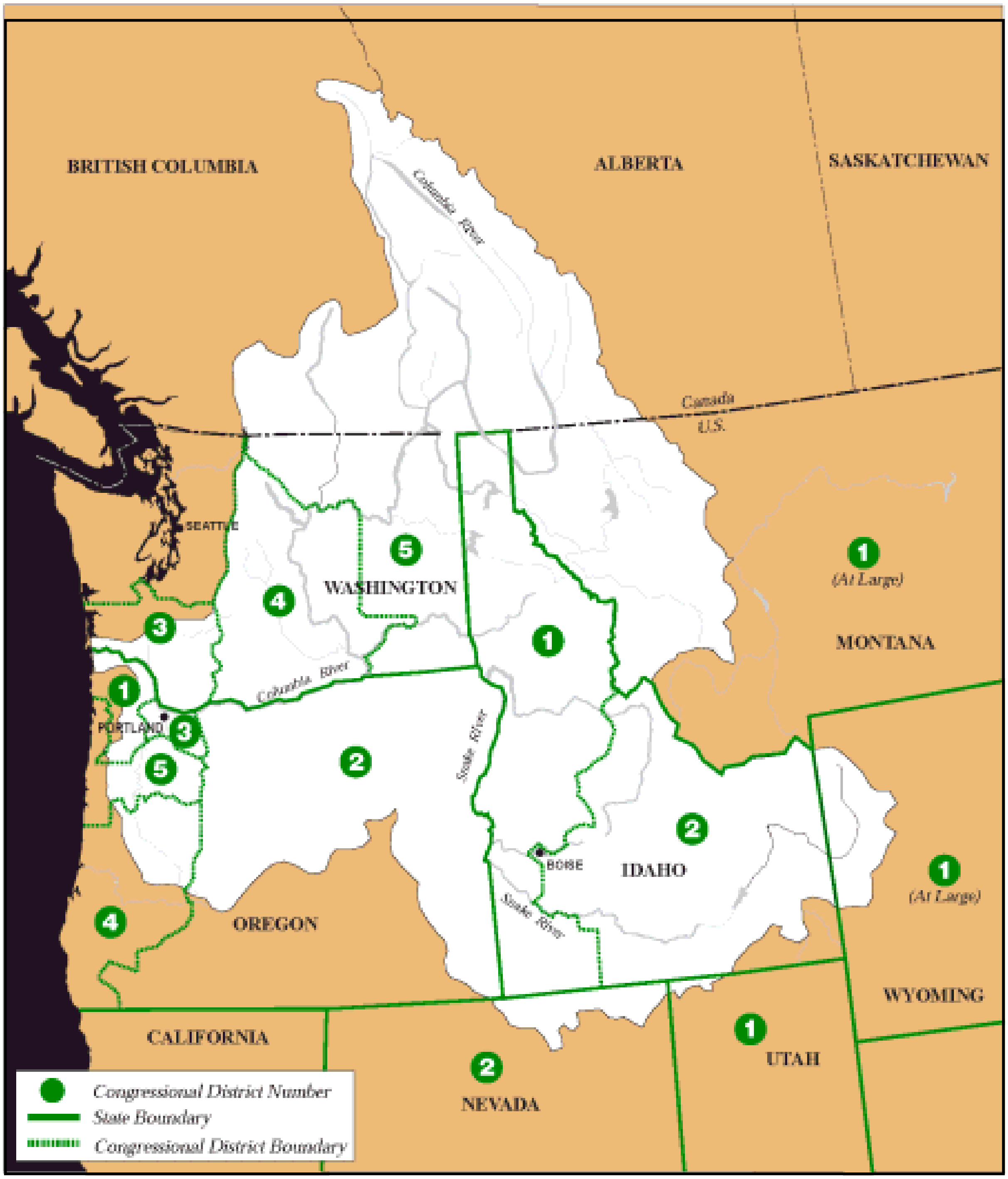

Figure 2. U.S. Congressional Districts in the Columbia River Basin

Table 4. U.S. Senators within the Columbia River Basin

State	Senators	
Washington	Patty Murray	Maria Cantwell
Oregon	Gordon Smith	Ron Wyden
Idaho	Larry Craig	Michael Crapo
Montana	Max Baucus	Conrad Burns
Nevada	John Ensign	Harry Reid
Utah	Robert Bennett	Orrin Hatch
Wyoming	Michael Enzi	Craig Thomas

5. Prior Studies, Reports, and Existing Water Projects

5.1 Prior Studies and Reports

The Corps and other Federal agencies have prepared a number of studies and reports that directly pertain to the issue of modifying current system flood control operations to benefit ESA-listed fish species, particularly salmonids. Some of the most relevant of these studies and reports are identified and briefly discussed in this section. These studies and reports are organized into the following broad categories: projects and their operation, systemwide operations, and project-specific flood control.

5.1.1 Projects and Their Operation

Two major sources of information about projects and their operation are water control manuals and operating plans for each project. Water control manuals provide detailed information about each project, including: authorization and scope; history of the project; location; physical components; watershed characteristics; data collection and communication; organization and coordination for reservoir regulation; hydrologic forecasts; water control plans including flood control, hydropower operations, water quality, sedimentation, and low-flow contingency plans; and the effects of water control plans. Operating plans contain principles of flood control regulation; flood control storage space requirements; flood protection objectives; system flood control operation; operation of each storage reservoir in the system; and implementation of the operating plans including drawdown, refill, and Canadian storage.

In addition to the water control manuals and operating plans, the following document provides other information about projects and their operations:

- *Summary Report, Proposed Reallocation of Flood Control Space, Mica and Arrow Reservoirs. United States Entity, Columbia River Treaty.* Prepared by the North Pacific Division, U.S. Army Corps of Engineers. April 1995. Summarizes work done by the Corps at the request of the Canadian Government to evaluate the flood control effects of reducing the maximum allowable flood control draft from 5.1 MAF (6.3 billion m^3) to 3.6 MAF (4.4 billion m^3) at Arrow Reservoir and increasing the maximum allowable flood control at Mica Reservoir to 4.08 MAF (5.0 billion m^3). System flood control was unaffected. This request was made as Canada prepared to retrofit hydropower generating units for Keenleyside Dam (Arrow Reservoir). The flood control allocation currently used is the 3.6 MAF / 4.08 MAF combination for Arrow and Mica, respectively. Many of the system flood control and hydropower reports listed in the following section were based on the 5.1 MAF / 2.08 MAF allocation.

5.1.2 Systemwide Operations

In addition to the NMFS 2000 and 2004 Biological Opinions and the UPA (see Section 1.0), a large number of reports provide information on studies that evaluated the entire Columbia River Basin on a systemwide basis. These reports include:

- *Columbia River Treaty Documents*. Official documents of the U.S. and Canada regarding the Columbia River Treaty (signed in 1961 and put into effect in 1964).
- *Columbia River Treaty Flood Control Operating Plan*. Prepared by North Pacific Division, U.S. Army Corps of Engineers for the United States Entity. October 1972. Sets forth the basic principles of system flood control operations as ratified in the U.S.-Canada Treaty. The first update was issued in 1999 with a subsequent update issued in May 2003. This is the fundamental system flood control document that explains the procedure currently used for determining system flood control requirements. This document will have significant revisions if and when a new flood control procedure is developed.
- *Columbia River Damage Curves*. Portland District, U.S. Army Corps of Engineers. 1970s-1980s. Presents a series of stage-damage and discharge-damage curves for all lower Columbia River damage reaches. These curves are used in the annual calculation of the benefits of Corps projects. Lower Columbia basin conditions have changed since the time these curves were developed.
- *Lower Columbia River Flood Control Study. River Mile 0 to 145. Summary Report. Volume 1*. December 1988. Presents status of flood risk areas along the Columbia River below Bonneville Dam.
- *Review of Flood Control, Columbia River Basin. Columbia River and Tributaries Study, CRT-63.* North Pacific Division, U.S. Army Corps of Engineers. June 1991. Publishes work undertaken by the Corps to review flood control draft requirements at all system flood control projects with the intent of not drafting as much space in lower water years. One of the reasons for initiating CRT-63 was to address the then Northwest Power Planning Council's Fish and Wildlife Program which requested studying the feasibility of improving fish flows throughout the Columbia River Basin. The Standard Project Flood (SPF) was also recomputed. Proposed changes to the operation of some projects were based on the assumption that the existing level of flood protection at The Dalles should remain unchanged.
- *Columbia River Salmon Flow Measures Options Analysis, Final Environmental Impact Statement.* U.S. Army Corps of Engineers, Bonneville Power Administration (BPA), and U.S. Bureau of Reclamation. 1992. An analysis of the effects of various alternative operationchanges and water management options for 1992 operations, for dams and reservoirs on the lower Columbia and Snake rivers, to improve salmon migration conditions.
- *Interim Columbia and Snake Rivers Flow Improvement Measures for Salmon Supplemental Environmental Impact Statement.* U.S. Army Corps of Engineers, Bonneville Power Administration (BPA), and U.S. Bureau of Reclamation. March 1993. An analysis of water management activities for 1993 and future years until results of several ongoing studies were incorporated into a long-term water management plan.

- *Columbia River System Operations Review (SOR), Final Environmental Impact Statement (EIS) and Technical Reports*. U.S. Army Corps of Engineers, Bonneville Power Administration (BPA), and U.S. Bureau of Reclamation. November 1995. An analysis of future operations of the Columbia River system and river use issues is presented, but no specific measures to modify the flood control system operations were developed.
- *Columbia River Basin System Flood Control Review Preliminary Analysis Report*. North Pacific Division, U.S. Army Corps of Engineers. Portland, Oregon, February 1997. Presents the results of a review of current Columbia River system operations to determine if it would be feasible to implement changes to make more water available for fish. The review determined that increased flows at The Dalles, Oregon would cause increased average annual flood damages. Determination of feasibility was inconclusive due to limited information. Damage curves developed in the 1970s and 1980s were used for this analysis.

- *2000 Biological Opinion - Effects to Listed Species from Operations of the Federal Columbia River Power System.* U.S. Fish and Wildlife Service. December 20, 2000. Interagency consultation on the FCRPS operations pursuant to Section 7(a)(2) of the ESA. This opinion addresses bull trout and Kootenai River white sturgeon.
- *Conservation of Columbia Basin Fish, Final Basinwide Salmon Recovery Strategy*. Federal Caucus. December 2000. Presents Federal government recommendations for actions needed to recover threatened and endangered salmon and steelhead in the Columbia River Basin.
- *The Columbia River System Inside Story.* Bonneville Power Administration, Northwestern Division, U.S. Army Corps of Engineers, and U.S. Bureau of Reclamation. April 2001. A general overview of how the FCRPS is operated.
- *Lower Snake River Juvenile Salmon Migration Feasibility Report/EIS.* U.S. Army Corps of Engineers, Walla Walla District. February 2002. This comprehensive study focused on the relationship between the four dams on the lower Snake River (collectively called the Lower Snake River Project) and their effects on juvenile fish traveling toward the ocean. The Final FR/EIS explored the potential region-wide implications of four alternatives for improving salmon migration through those dams: continue the existing conditions at the dams, maximize transportation of juvenile salmon, make major system improvements (adaptive migration approach), and breach the dams. The preferred alternative selected was the adaptive migration approach because its implementation allowed flexibility in optimizing the mainstem seasonal flow regimes for more "normative" fish routing through the dam structures, such as developing spill routing like removable spillway weirs (RSWs) that were both biologically and economically beneficial. The preferred alternative was the most consistent alternative with the NMFS' 2000 FCRPS BiOp and the only alternative that adequately allowed for a "spread-the-risk" operation deemed necessary by NMFS in their Section 7 of the ESA consultation for salmonid ESU survival, acceptable risk of extinction, and recovery.

5.1.3 Project-Specific Flood Control

Flood control is a key component of the operation of the FCRPS. The following reports specifically address flood control operations and management. Although the reports listed below provide background information and contain elements that may be applicable to the System Flood Control Review, they cover a relatively small portion of the entire Columbia River basin. A number of these reports directly pertain to the variable discharge strategy (also called variable Q or VARQ, with Q representing engineering shorthand for discharge) for flood control at Libby and Hungry Horse Dams, which was implemented on an interim basis in 2003.

VARQ is designed to better ensure reservoir refill in years with slightly below to slightly above-average seasonal runoff forecasts, while maintaining equal flood protection as measured at The Dalles, Oregon. The Libby and Hungry Horse reservoirs may be more full under a VARQ flood control operation than they would have been under a standard flood control operation at the end of April. Therefore, the flow releases from these headwater reservoirs are greater than minimum flow releases during a standard reservoir refill in May and June. The amount of the outflow that is greater than minimum flow is dependent upon the remaining expected inflow and the remaining storage to fill at the respective reservoirs.

Reports or operations that address project-specific flood control include:

- The Lake Pend Oreille Lake Level Experiments, starting in 1997, manipulate the fall/winter level of the lake between elevations 2,051 and 2,055 feet in concert with monitoring of kokanee salmon spawning success, fry survival, and year-class abundance. While these experiments are focused on resident fish in Lake Pend Oreille and do not change flood control requirements and operating strategies, manipulation of Lake Pend Oreille level affects fall/winter discharges at Albeni Falls Dam and the resulting downstream flows in the system, including flows that potentially affect migrating and spawning salmonids (such as chum salmon) in the lower portions of the Columbia River Basin. This report may be relevant to changes in system flood control storage at Albeni Falls Dam.
- *Kootenai River Flood Control Study: Analysis of Local Flood Control Impacts of the Proposed VARQ Flood Control Plan*. U.S. Army Corps of Engineers. 1998. Summarizes a preliminary analysis of the potential impacts of VARQ flood control implementation at Libby Dam on local flood control in the Kootenai River. Information from this report is included in one section of the 1999 Status Report (see next bullet).
- *Status Report: Work to Date on the Development of the VARQ Flood Control Operation at Libby Dam and Hungry Horse Dam*. U.S. Army Corps of Engineers. 1999. Documents work undertaken to develop a modified flood control operation called VARQ at Libby Dam and Hungry Horse Dam. This report is divided into four sections: system flood control, Kootenai basin local flood control, Flathead basin local flood control, and system hydropower effects. All four aspects have since been re-evaluated and documented in other reports listed below.
- *Interim Operation of the VARQ Flood Control Plan at Hungry Horse Dam, Montana: Voluntary Environmental Assessment (EA), FONSI 02-02*. U.S. Bureau of Reclamation. 2002. Documents the potential impacts of implementation of VARQ flood control at Hungry Horse Dam on an interim basis prior to completion of an EIS to evaluate potential permanent VARQ implementation.
- *Upper Columbia Alternative Flood Control and Fish Operations Interim Implementation at Libby and Hungry Horse Dams: Final EA.* U.S. Army Corps of Engineers. 2002. Documents potential impacts of implementation of VARQ flood control at Libby Dam on an interim basis prior to completion of an EIS to evaluate potential permanent VARQ implementation.
- *Hydrologic Analysis of Upper Columbia Alternative Flood Control and Fish Operations on Columbia River System including the VARQ Flood Control Plan at Libby and Hungry Horse Projects.* U.S. Army Corps of Engineers. 2002. Assessed the system-wide hydrologic impacts of the VARQ flood control strategy to the Columbia River in support of the 2002 Final Environmental Impact Assessment for interim VARQ implementation at Libby Dam.
- *Hydrologic Analysis of Upper Columbia Alternative Operations: Local Effects of Alternative Operations at Libby Dam.* U.S. Army Corps of Engineers. 2002. Assessed the hydrologic impacts on the Kootenai Basin of the VARQ flood control strategy to the Columbia River in

support of the 2002 Final Environmental Impact Assessment for interim VARQ implementation at Libby Dam.

- *Total Dissolved Gas Exchange at Libby Dam, Montana, June to July 2002*. Coastal and Hydraulics Laboratory, U.S. Army Engineer Research and Development Center. 2003. Summarizes the impacts of spillway releases at Libby Dam during June 24 to July 9 of 2002 on the total dissolved gas (TDG) concentrations in the Kootenai River. Findings from this report are relevant to Libby Dam operations if project outflows exceed the current powerhouse capacity.
- *Summary Report, 31 December Variable Flood Control Draft for Libby Reservoir*. U.S. Army Corps of Engineers, Northwestern Division, Columbia Basin Water Management Division. January 2004. Study evaluates the feasibility of relaxing the end-of-December flood control draft requirement at Libby Dam. This study resulted in a modification to the VARQ storage reservation diagram (SRD) for the month of December. Future studies on VARQ flood control at Libby Dam should be based on this SRD.
- *(Final) EIS Banks Lake Drawdown*. U.S. Bureau of Reclamation. June 2004. This final EIS analyzes the environmental impacts of the proposed action to lower the water surface elevation for Banks Lake from 1,565 feet to 1,560 feet in August of each year.

5.2 Existing Water Projects

There are numerous existing impoundments located throughout the Columbia River Basin that generally fall into two major categories: storage reservoirs and run-of-river projects. The main purpose of storage reservoirs is to adjust the river's natural flow patterns to conform more closely to water and energy-demand uses, and to provide flood control. Run-of-river projects, in contrast, have limited storage and were developed primarily for navigation and hydropower generation.

A few key reservoirs hold most of the storage in the Columbia River Basin. These reservoirs are associated with the Libby, Hungry Horse, Albeni Falls, Dworshak, Brownlee, and Grand Coulee Dams in the United States and the Duncan, Keenleyside, and Mica Dams in British Columbia, Canada. Most storage has been developed on the upper Columbia River. The following subsections focus specifically on storage projects, projects with fish passage, and Federal projects located below the main water storage dams in the Columbia River system.

The main emphasis of this reconnaissance-level study is on the mainstem Columbia River and the larger tributaries upstream of Bonneville Dam (e.g., Snake River, Kootenai River, and the Pend Oreille River). The Willamette River Basin is a major tributary to the Columbia River, downstream of Bonneville Dam. The Corps operates 13 projects in this basin (Figure 4), 11 of which provide a total of 1.7 MAF (2.1 billion m^3) of flood control storage space (includes storage space that can be used jointly with power production). However, the Willamette River Basin is not the focus of this study, except where it may affect flows and fish in the mainstem Columbia River (e.g., flows that may affect fish passage through the estuary downstream of the confluence of the Columbia and Willamette rivers).

The Columbia River Basin, the study area for this project, was divided into four subbasins for the purposes of analysis (see Figure 1 and Section 3.1 for further information). The following subsections present summary information for the major projects that fall into the subbasin designations identified for the System Flood Control Review. This information is summarized further in Table 5 through Table 8. The final subsection below (Section 4.2.5) briefly addresses the Willamette River.

5.2.1 Subbasin A—Columbia River Upstream of Priest Rapids Dam

Subbasin A may be further subdivided into three geographic areas for the purposes of discussion: Canadian, Upper Columbia River, and Mid-Columbia River. Major projects in these areas are summarized in Table 5 and briefly discussed in the following subsections.

Figure 3. Corps Projects within the Willamette River Basin

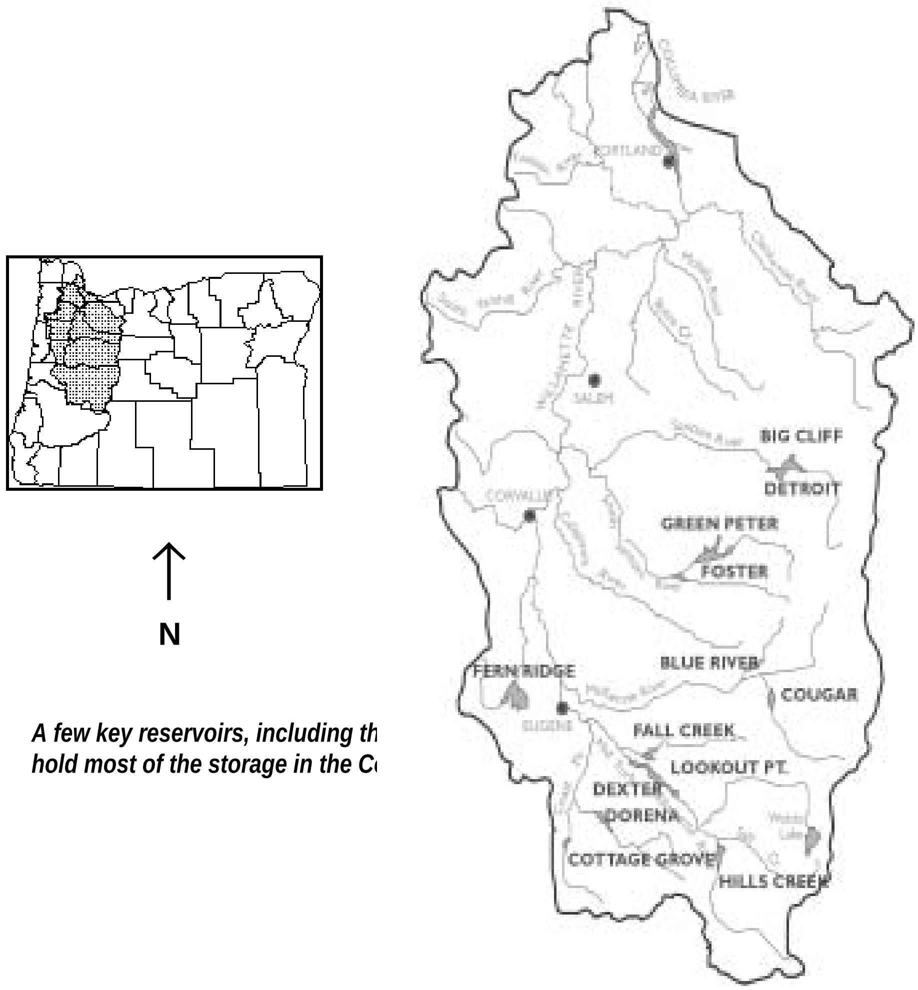

Table 5. Subbasin A – Columbia River Upstream of Priest Rapids Dam, Project Summary Information

Dams	River	Type of Dam[1/]	Purpose and Beneficial Uses	Authorization Law	Year Construction Completed	Operations	Reservoir Name	Useable Capacity (acre-feet)[2/,3/]	Relevance
Canadian									
Mica[3/]	Columbia	S	Flood control, power storage, power	1964 Columbia River Treaty[4/]	1973	BC Hydro	Kinbasket Reservoir	12,000,000 P: 4,080,000 S:7,920,000	Flood control, fish ladders and screens, habitat enhancement
Revelstoke	Columbia	R	Flood control, power	BC Hydro & Power Authority (1964) Amendment Act, 1977 (Bill #4)	1984	BC Hydro	Revelstoke Reservoir	1,500,000	Flood control, fish ladders and screens, habitat enhancement. May be used for emergency storage.
Keenleyside[3/]	Columbia	S	Flood control, power storage, recreation, navigation, irrigation	1964 Columbia River Treaty[4/]	1968	BC Hydro	Arrow Lakes	7,100,000 P: 3,600,000 S: 3,500,000	Flood control, fish ladders and screens, habitat enhancement
Duncan[3/]	Duncan	S	Flood control, power storage	1964 Columbia River Treaty[4/]	1967	BC Hydro	Duncan Reservoir	1,400,000 P: 1,270,000 S: 130,000	Flood control, fish ladders and screens, habitat enhancement
Corra Linn	Kootenay	R	Power		1932	FortisBC.	Kootenay Lake	673,000[A/]	
U.S.—Upper Columbia River									
Hungry Horse	South Fork of the Flathead	S	Irrigation, flood control, navigation, streamflow regulation, hydroelectric generation	PL 329, 78th Congress, 2d Session, approved June 5, 1944 (58 Stat. 270)[5/]	1953	USBR	Hungry Horse	2,980,000	Flood control, flow augmentation
Kerr	Flathead	S	Flood control, power, power storage	FERC Project #5, license issued 1985[6/]	1939	PPL Montana	Flathead Lake	1,219,000[A/]	Flood control
Albeni Falls	Pend Oreille	S	Flood control, power, navigation, recreation	1950 Flood Control Act[7/]	1955	Corps	Lake Pend Oreille	1,155,000[A/]	Flood control, built on natural waterfall location
Libby	Kootenai	S	Flood control, power, fishery, recreation	Flood Control Act of 1950	1973	Corps	Lake Koocanusa	4,979,500	Flood control and flow augmentation
Grand Coulee	Columbia	S	Flood control, navigation, regulation of stream flow, water storage and delivery, power	Rivers and Harbors Act approved August 30, 1935[8/]	1942	USBR	Lake Roosevelt	5,232,000	Flood control, flow augmentation
Chief Joseph	Columbia	R	Power, Recreation	River and Harbors Act of 1946[9/]	1955	Corps	Rufus Woods Lake	116,000[B/]	Upstream limit of anadromous fish migration in Columbia River
U.S.—Mid-Columbia River									
Wells	Columbia	R	Power	FERC Project #2149, license issued 1962[9/]	1967	Douglas Co. PUD 1	Lake Pateros	125,000[C/]	Juvenile fish passage, fish ladder, habitat restoration
Rocky Reach	Columbia	R	Power, recreation	FERC Project #2145, license issued 1957[10/]	1961	Chelan Co. PUD 1	Lake Entiat	120,000[C/]	Juvenile fish passage, fish ladder, habitat restoration

Table 5. Subbasin A – Columbia River Upstream of Priest Rapids Dam, Project Summary Information (continued)

Dams	River	Type of Dam[1/]	Purpose and Beneficial Uses	Authorization Law	Year Construction Completed	Operations	Reservoir Name	Useable Capacity (acre-feet)[2/,3/]	Relevance
U.S.—Mid-Columbia River (continued)									
Rock Island	Columbia	R	Power	FERC Project #973, license issued 1989[9/]	1933	Chelan Co. PUD 1	Rock Island Reservoir	7,500	Notched spillgate for juvenile passage, fish ladder
Wanapum	Columbia	R	Power, navigation	FERC Project #2114, license issued 1959[9/]	1963	Grant Co. PUD 2	Wanapum Lake	500,000	Fish ladder, juvenile fish passage
Priest Rapids	Columbia	R	Power, recreation	FERC Project #2114, license issued 1955[9/]	1959	Grant Co. PUD 2	Priest Rapids Lake	44,000[D/]	Fish survival encouraged through fish ladders, bypass facilities, spill deflectors, transportation, and flow augmentation

1/ S = Storage, R= Run-of-River
2/ Source: Corps 2003. (Useable capacity—water occupying active storage capacity of a reservoir)
3/ Canadian project storage is separated into primary [P] and secondary [S] (on-call) storage. On-call storage is available upon request and payment from the U.S. Government.
4/ Reference: DOE 1980, bchydro.com
5/ Reference: SOR DEIS, www.usbr.gov/power/data/sites
6/ Reference: DOE 1980, FERC.gov. Originally authorized under the 1935 River and Harbors Act
7/ Reference: SOR DEIS, www.nwd-wc.usace.army.mil/PB/oper_planning
8/ Reference: DOE 1980, www.usbr.gov/power/data/sites
9/ Reference: SOR DEIS
10/ Reference: DOE 1980, FERC.gov

BC = British Columbia Hydro and Power Authority
USBR = U.S. Bureau of Reclamation
Corps = U.S. Army Corps of Engineers
FERC = Federal Energy Regulatory Commission
PUD = Public Utility District
PPL Montana = Pennsylvania Power and Light, Montana (formerly Montana Power Company)

A. Total storage. Normally operated to preserve natural lake storage during flood periods.
B. Total storage. May be used for re-regulation of flood flows.
C. Total storage. The maximum allowable for replacement of lost valley storage.
D. Maximum allowable for replacement of lost valley storage, combination of Wanapum and Priest Rapids storage.

Table 6. Subbasin B – Snake River Upstream of Hells Canyon Dam, Project Summary Information

Dams	River	Type of Dam[1/]	Purpose and Beneficial Uses	Authorization Law	Year Construction Completed	Operations	Reservoir Name	Useable Capacity (acre-feet)[2/]	Relevance
Upper Snake River									
Jackson Lake	Snake	S	Irrigation storage, flood control, recreation, and fish and wildlife	Reclamation Act of 1902[3/]	1911	USBR	Jackson Lake	847,000 [A/]	Flood control, habitat enhancement
Palisades	Snake	S	Irrigation, power, flood control, recreation, and fish and wildlife conservation	1950 Flood Control Act[4/]	1957	IWPRS	Pallisades Reservoir	1,400,000 [B/]	Flood control
American Falls	Snake	S	Irrigation, flood control, power generation, improvement of fish and wildlife resources and recreation	Reclamation Act of 1902[3/]	1927	USBR	American Falls	601,000 [A/]	Flood control
Minidoka	Snake	S	Flood control, irrigation and power	Reclamation Act of 1902[3/]	1909	IWPRS	Lake Walcott	95,200 [A/]	Flood control, flow augmentation
Boise River									
Anderson Ranch	South Fork, Boise	S	Irrigation, power, flood and silt control, and minimum stream flows	Reclamation Project Act of 1939 (53 Stat. 1187). [5/]	1950	USBR	Anderson Ranch Reservoir	423,000 [A/]	Flood control. The upper Boise River system has been proposed as critical habitat for bull trout. Minimum releases of 300 cfs from September 15 through March 31 and 600 cfs for the remainder of the year are maintained.
Arrowrock	Boise	S	Irrigation, flood control, recreation, and fish and wildlife	Reclamation Act of 1902[5/]	1915	USBR	Arrowrock Reservoir	286,600 [A/]	Flood control
Lucky Peak	Boise	S	Irrigation, power generation, and flood control	FERC Project #2832, license issued 1980[4/]	1957	Corps	Lucky Peak Lake	988,000 [C/]	Flood control, juvenile bypass system
Hells Canyon Complex									
Brownlee	Snake	S	Power, flood control, power storage	FERC Project #1971, license issued 1955[6/]	1959	IPC	Brownlee Reservoir	975,400[A/]	Flood control, spring and fall flow augmentation for spawning fish and smolts downstream
Oxbow	Snake	S	Power	FERC Project #1971, license issued 1955[6/]	1961	IPC	Oxbow Reservoir		Flood control, spring and fall flow augmentation for spawning fish and smolts downstream
Hells Canyon	Snake	S	Power	FERC Project #1971, license issued 1955[6/]	1967	IPC	Hells Canyon Reservoir		Flood control, spring and fall flow augmentation for spawning fish and smolts downstream

1/ S = Storage, R= Run-of-River
2/ Source: Corps 2003 (Useable capacity—water occupying active storage capacity of a reservoir)
3/ Reference: DOE 1980, www.usbr.gov/power/data/sites
4/ Reference: http://www.idwr.state.id.us/water/stream_dam/dams, FERC.gov
5/ Reference: http://www.usbr.gov/pn/programs/arrorockvalve/feis/FEISChp1.pdf
6/ Reference: DOE 1980, FERC.gov
A. Total storage.
B. Combined requirement for multiple reservoirs. Total Palisades active storage is 1,200,000 acre-feet.
C. Combined requirement for multiple reservoirs. Total Lucky Peak active storage is 278,200 acre-feet.

USBR = U.S. Bureau of Reclamation
Corps = U.S. Army Corps of Engineers
FERC = Federal Energy Regulatory Commission
IPC = Idaho Power Company
IWPRS = Idaho Water & Power Resources Service

Table 7. Subbasin C – Clearwater River/Snake River, Project Summary Information

Dams	River	Type of Dam[1/]	Purpose and Beneficial Uses	Authorization Law	Year Construction Completed	Operations	Reservoir Name	Useable Capacity (acre-feet)[2/]	Relevance
Dworshak	North Fork Clearwater	S	Flood control, power, navigation, fish and wildlife, recreation	PL 87-874, 1962[3/, 4/]	1974	Corps	Dworshak Reservoir	2,016,000	Flow augmentation downstream
Lower Granite	Lower Snake	R	Power, navigation, fish and wildlife, recreation, irrigation, water quality	PL 79-14, House Document 704, 75th Congress 1945[3/]	1975	Corps	Lower Granite Lake	53,000 [A]	Fish survival encouraged through fish ladders, bypass facilities, spill deflectors, transportation, and seasonal flow augmentation
Little Goose	Lower Snake	R	Power, navigation, fish and wildlife, recreation, irrigation, water quality	PL 79-14, House Document 704, 75th Congress 1945[3/]	1970	Corps	Lake Bryan	49,000[A]	Fish survival encouraged through fish ladders, bypass facilities, spill deflectors, transportation, and seasonal flow augmentation
Lower Monumental	Lower Snake	R	Power, navigation, fish and wildlife, recreation, irrigation, water quality	PL 79-14, House Document 704, 75th Congress 1945[3/]	1969	Corps	Lake Herbert G. West	20,000 [A]	Fish survival encouraged through fish ladders, bypass facilities, spill deflectors, transportation, and seasonal flow augmentation
Ice Harbor	Lower Snake	R	Power, navigation, fish and wildlife, recreation, irrigation, water quality	PL 79-14, House Document 704, 75th Congress 1945[3/]	1962	Corps	Lake Sacajawea	25,000 [A]	Fish survival encouraged through fish ladders, bypass facilities, spill deflectors, and seasonal flow augmentation

1/ S = Storage, R= Run-of-River

2/ Source: Corps 2003 (Useable capacity—water occupying active storage capacity of a reservoir)

3/ Reference: SOR EIS, www.nwd-wc.usace.army.mil/PB/oper_planning

4/ Reference: http://www.usbr.gov/pn/programs/arrorockvalve/feis/FEISChp1.pdf

A. Normal power pondage. This may be used for re-regulation of flows.

Corps = U.S. Army Corps of Engineers

Table 8. Subbasin D – Lower Columbia River, Project Summary Information

Dams	River	Type of Dam[1/]	Purpose and Beneficial Uses	Authorization Law	Year Construction Completed	Operations	Reservoir Name	Useable Capacity (acre-feet)[2/]	Relevance
McNary	Columbia	R	Power, navigation	PL 79-14, House Document 704, 75th Congress 1945[3/]	1957	Corps	Lake Wallula	205,000[A]	Fish survival encouraged through fish ladders, bypass facilities, spill deflectors, transportation, and seasonal flow augmentation
John Day	Columbia	R	Flood control, power, navigation, fish and wildlife, recreation, irrigation, water quality	House Bill 531, 81st Congress, Second Session, PL 81-516, 1950[3/]	1971	Corps	Lake Umatilla	535,000	Flood control, fish survival encouraged through fish ladders, bypass facilities, spill deflectors, transportation, and seasonal flow augmentation
The Dalles	Columbia	R	Power, navigation, fish and wildlife, recreation, irrigation, water quality	House Bill 531, 81st Congress, Second Session, PL 81-516, 1950[3/]	1960	Corps	Lake Celilo	53,000 [A]	Flood control, fish survival encouraged through fish ladders, bypass facilities, spill deflectors, transportation, and seasonal flow augmentation
Bonneville	Columbia	R	Power, navigation, fish and wildlife, recreation, water quality	1935 Rivers and Harbors Act[3/]	1938	Corps	Lake Bonneville	100,000 [A]	Fish survival encouraged through fish ladders, bypass facilities, spill deflectors, transportation, and seasonal flow augmentation

1/ S = Storage, R= Run-of-River
2/ Corps 2003 (Useable capacity—water occupying active storage capacity of a reservoir)
3/ Reference: SOR EIS, www.nwd-wc.usace.army.mil/PB/oper_planning
A. Normal power pondage. This may be used for re-regulation of flows.

Corps = U.S. Army Corps of Engineers

Canadian Projects

The Canadian portion of Subbasin A includes five major dams: Mica, Revelstoke, Keenleyside, Duncan, and Corra Linn. Three of the dams (Mica, Keenleyside, and Duncan) were constructed between 1967 and 1984 under authorization of the 1964 Columbia River Treaty. These dams, which are operated by BC Hydro, are used for various purposes including flood control, power generation and storage, irrigation, navigation, and recreation. Revelstoke (completed in 1984) is primarily a run-of-river project, with emergency storage. Corra Linn Dam, located at the outlet of Kootenay Lake, was constructed in 1932 and is operated by Aquila, Inc. (formerly West Kootenay Power and Light Company).

Canadian project storage is separated into primary and secondary ("on-call") storage. Primary storage is the storage space in the Columbia River basin in Canada that is committed for the purpose of flood control for the Columbia River. On-call storage is the additional reservoir storage in the Columbia River basin in Canada that can be operated within the limits of existing facilities as required to meet flood control needs. On-call storage is available upon request and payment from the U.S. Government. The separation into primary and secondary storage is shown in Table 5for Mica, Keenleyside, and Duncan. To date, the United States has never called for use of secondary storage. The use of both the primary and secondary (on-call) storage will be further evaluated in the feasibility report.

Upper Columbia River

The upper Columbia River portion of Subbasin A includes six major dams: Hungry Horse (completed 1953), Kerr (1939), Albeni Falls (1955), Libby (1973), Grand Coulee (1942), and Chief Joseph (1955). All of these dams are used for water storage and flood control except Chief Joseph Dam, which is a run-of-river structure, used for power generation only. Chief Joseph Dam is the current upstream limit for upstream migrating adult salmon and steelhead on the mainstem of the Columbia River. Additional uses at the five storage dams include irrigation, water supply, recreation, navigation, and streamflow regulation.

The Corps operates Albeni Falls (authorized by a Congressional House Bill in 1950), Libby (authorized by the Public Law 516, Flood Control Act of 1950), and Chief Joseph (authorized by the Rivers and Harbors Act of 1946). Lake Koocanusa, located behind Libby Dam, with a storage capacity of almost 5 MAF (6.2 billion m^3), is the largest of the reservoirs associated with these three dams. Water may be released from storage within Libby and Albeni Falls (in addition to normal operations) to increase seasonal downriver flows during critical regulated low flow months to help move migrating juvenile salmonids in downriver areas to the ocean more rapidly. This additional release, termed "flow augmentation," has been either implemented or proposed for both of these dams, and has been coordinated with USFWS 2000 Biological Opinion flow requirements for increasing sturgeon spawning success and productivity.

The USBR operates Hungry Horse and Grand Coulee Dams, which were built under authorization of the Flood Control Act of 1944 and the Rivers and Harbors Act of 1935, respectively. Identified project purposes include irrigation, flood control, power generation, streamflow regulation, and navigation. The reservoirs behind Grand Coulee and Hungry Horse Dams hold approximately 5.2 MAF (6.4 billion m^3) and 3.0 MAF (3.7 billion m^3) of water, respectively. Grand Coulee Dam blocks anadromous fish access to more than 500 miles of the upper Columbia River, with Chief Joseph Dam blocking an additional 52 miles of the mainstem. Flow augmentation has been incorporated into the operation of Hungry Horse Dam and Grand Coulee Dam to improve fish survival in downstream areas.

Kerr Dam, a storage dam built under authorization of the 1935 Rivers and Harbors Act, is operated by Pennsylvania Power and Light, Montana (PPL Montana – formerly Montana Power Company) for the purposes of flood control, power generation, and power storage. A license for Kerr Dam was issued to Montana Power Company and expired in 1980. The current FERC license was issued jointly to the Montana Power Company and the Confederated Salish and Kootenai Tribes of the Flathead Reservation in 1985.

Mid-Columbia River

The Mid-Columbia portion of Subbasin A includes five dams: Wells (completed 1967), Rocky Reach (1961), Rock Island (1933), Wanapum (1963), and Priest Rapids (1959). These dams are all run-of-river structures created for the purpose of generating power under FERC licenses. The dams are operated by county public utility districts (PUDs). Douglas County PUD operates Wells Dam; Chelan County PUD operates Rocky Reach and Rock Island Dams; and Grant County PUD operates Wanapum and Priest Rapids Dams. Efforts to improve anadromous fish survival at these facilities include fish ladders, juvenile bypass systems, and flow augmentation.

5.2.2 Subbasin B—Snake River Upstream of Hells Canyon Dam

Subbasin B may be further subdivided into three geographic areas for the purposes of discussion: Upper Snake River, Boise River, and Hells Canyon Complex. The projects in these areas are summarized in Table 6 and briefly discussed in the following subsections.

Upper Snake River

The upper Snake River includes four storage dams: Jackson Lake (completed 1911), Palisades (1957), American Falls (1927), and Minidoka (1909). The Minidoka, American Falls, and Jackson Lake Dams were authorized by the Reclamation Act of 1902 for the purposes of irrigation supply and power. The Flood Control Act of 1950 added the purpose of flood control to these projects and authorized the construction of Palisades Dam with an active reservoir storage capacity of 1.2 MAF (1.5 billion m^3). Efforts to improve downstream anadromous fish survival include flow augmentation.

Boise River

The Boise River portion of Subbasin B includes three storage dams: Anderson Ranch (1950), Arrowrock (1915), and Lucky Peak (1957). Anderson Ranch and Arrowrock were built for the purposes of irrigation supply, flood control, and power generation under authorization of the Reclamation Act of 1939 and the Reclamation Act of 1902, respectively. Lucky Peak was authorized for irrigation and flood control in 1957. Power generation was placed at Lucky Peak in the 1980s, but not by the Federal government. Efforts to improve downstream anadromous fish survival through the lower Snake River include flow augmentation from the Boise River storage dam operations.

Hells Canyon Complex

The Hells Canyon Complex consists of three dams: Brownlee (completed 1959), Oxbow (1961), and Hells Canyon (1967). Idaho Power built the dams under FERC authorization in 1955 for the purposes of power generation and flood control. The Brownlee reservoir is the only one of the three Hells Canyon Complex reservoirs with significant storage, holding approximately 1 MAF of water (1.2 billion m^3) for system flood control. Efforts to improve downstream anadromous fish survival through the lower Snake River include flow augmentation from the Hells Canyon

Complex. Hells Canyon Dam, the lowermost of the three dams in the complex, blocks upstream passage of adult salmon and steelhead.

5.2.3 Subbasin C—Clearwater River/Snake River, Upstream of Ice Harbor Dam

Subbasin C includes one storage dam (Dworshak [completed 1974]) and four run-of-river dams: Lower Granite (1975), Little Goose (1970), Lower Monumental (1969), and Ice Harbor (1962). The Corps operates all these dams. These run-of-river projects were built on the Snake River under 1945 Congressional approval (PL 79-14) for the purposes of irrigation supply, power generation, navigation, recreation, and fish and wildlife. Dworshak Dam was built on the north fork of the Clearwater River under the authority of 1962 Congressional approval (PL 87-874) for the purposes of flood control, power generation, navigation, recreation, and fish and wildlife. Dworshak reservoir has a useable capacity of approximately 2 MAF (2.5 billion m^3).

Efforts to improve anadromous fish survival at the four lower Snake River dams include fish ladders, juvenile bypass and transport systems, spill, and flow deflectors. Flow augmentation managed for increased anadromous fish survival through the lower Snake River occurs from releases at Dworshak Dam as a function of the project's authorized purpose for fish and wildlife. Summary information for these projects is presented in Table 7.

5.2.4 Subbasin D—Lower Columbia River, Downstream of Upper End of McNary Pool

Subbasin D includes four run-of-river dams: McNary (completed 1957), John Day (1971), The Dalles (1960), and Bonneville (1938), all of which are operated by the Corps. The 1935 Rivers and Harbors Act authorized Bonneville Dam for the purpose of power generation and navigation. The Dalles Dam and John Day Dam were authorized by the 1950 Flood Control Act for the purposes of flood control (John Day only), power generation, and navigation. McNary Dam was authorized by 1945 Congressional approval (PL 79-14) for power generation and navigation. Efforts to improve anadromous fish survival at these projects include fish ladders, juvenile bypass and transportation systems, spill deflectors, and flow augmentation. Summary information for these projects is presented in Table 8.

5.2.5 Yakima River

The Yakima River drains an area of nearly 6,000 square miles in Yakima, Kittitas, and Benton Counties in central and south-central Washington. The river basin includes several storage reservoirs that primarily provide water for irrigation to the Yakima Valley. The reservoirs provide other benefits, including recreation, hydropower, fish and wildlife enhancement, and flood control to the extent possible. Several levee systems exist in the Yakima basin to help contain winter floods from rainfall and spring floods from snowmelt. Due to the lack of significant flood control storage in this basin at this time, a re-evaluation of flood control is not planned as part of the system flood control review. If conditions change during the feasibility analysis, flood control storage on the Yakima may be reconsidered at that time.

5.2.6 Willamette River

Although this reconnaissance-level study focuses mainly on the Columbia River and major tributaries upstream of Bonneville Dam, the Willamette River is a major tributary downstream that can affect flows in the lower mainstem Columbia River. In addition, the Columbia River estuary is a major geographical area that may affect flow-related juvenile salmonid survival and production. The Corps operates 13 projects in the Willamette River Basin (see Figure 4) that serve a broad range of beneficial purposes (e.g.,flood control, power production, fishery enhancement, and recreation), with 11 of the projects providing flood control. The remaining two dams are re-regulation dams. The operation of reservoirs on the mainstem Columbia River and Willamette River basins are coordinated to provide flood control for damage centers (see Section 5.1.1) at Portland and Longview-Kelso, and for the levee systems along the lower Willamette and Columbia rivers.

The Willamette River Project generally operates for major flood control season from about 01 November through mid-February. The dams operate to reduce flood stages on the Willamette River and tributaries only. This operation would only have incidental effect on Columbia River stages. By May through July, the Willamette is operated for flow augmentation. This flow augmentation is for the Willamette River only and no direct operation is provided for Columbia River. For this reason, the CRFMFCS evaluations will not include modification to the existing flood control operation on the Willamette. The flood control seasons are different, and the effect by Willamette River projects on springtime flows on the lower Columbia is minimal.

6. Plan Formulation

Plan formulation is the process that the Corps uses to focus its planning efforts and eventually select and recommend a plan for authorization. The following discussion is broken into four general sections: identified problems, potential measures to achieve System Flood Control Review objectives, alternative plan, and preliminary evaluation of alternative components.

6.1 Identified Problems

Biologically adequate flow conditions play a critical role in juvenile salmonid life history by providing conditions that allow juvenile fish to carry out required physiological functions at required times and locations as they move from the freshwater to the saltwater environments. Appropriate flow conditions are also important for adult salmonids from the ocean returning to spawn. A primary problem is evident when adequate seasonal flow objectives cannot be achieved, especially during summer in dry years when naturally low flows can be compounded by 1) seasonally increased anthropogenic demand of river water for agricultural and industrial production, and 2) system and local flood control operations. This System Flood Control Review was requested by NMFS, pursuant to Section 7 of the ESA (NMFS 2000), with the primary objective of evaluating whether the current flood control operations of the FCRPS could be modified to increase the frequency of achieving or exceeding seasonal flow objectives especially during July and August of each year. that are intended to improve survival of juvenile salmonids during their outmigration. Through regional coordination, ongoing research and monitoring, and previous Biological Opinions, NMFS has established flow magnitude and timing/duration objectives for important reaches of the Columbia River system (NMFS 2000 and 2004). The role of the flow contribution to salmonid lifestage survival has been debated for nearly three decades. Recent scientific reviews conclude that a positive flow/survival relationship exists in a general sense for all salmonid stocks, but these reviews have not been able to quantify this relationship. The mechanism likely includes more factors than just the travel time of the water as it influences the migration speed of the fish. Flow provides many secondary and dependent variable mechanisms to salmonid lifestage production. These include water temperature modulation and macroinvertebrate production that define growth rates, energy expenditure rates, and body fitness required increase juvenile survival during outmigration and eventually increase the numbers of mature adults returning to spawn.

Note that there is considerable uncertainty as to the exact flow survival relationship, whether the specific levels established for flow objectives are the right levels, and if research would be able to discern a difference. NOAA –Fisheries stated in the 6 May 2004 Technical Memo titled *Effects of the Federal Columbia River Power System on Salmon Populations*, "We know that salmonid survival will approach zero if flow is at zero, and we know that survival was lower in low-flow 2001 than the more constant survival we've seen with moderate to high flow. But the current data give almost no information for establishing an exact threshold above which survival is "as high as it can get" and below which survival drops off more or less steeply". In their 2003 *Mainstem Amendments to the Columbia River Basin Fish and Wildlife Program*, the Northwest Power Planning Council also recognized the "continuing controversies over the nature, extent of and reasons for the flow survival relationship…" Over time, analysis of the ever-increasing data with sophisticated analysis techniques are providing better discrimination of how the complex relationship between various flow-related variables combine to cumulatively influence juvenile survival. This research is crucial to better identify specific flow thresholds that are important in juvenile survival (ISAB 2004). Recent evaluations of the effects of flow on salmonid survival recognizes that relatively small changes and effects in the salmonid-accessible portions of the river could accumulate with other influences (i.e. water withdrawals, climate change) to yield significant, long-term results (ISAB 2004). The challenge is to develop tools to discern the potential different results accruing from different alternative operations given the complex nature of the flow issue.

Drawdown of storage reservoirs creates seasonal space which is filled by runoff, providing flood damage reduction. The stored water is then released for augmentation flows throughout the downriver reaches for salmonid migrations. This drawdown consistently results in seasonal losses leading to overall ecosystem impacts to productivity in the ESA-listed and non-listed resident fishes and the food webs composed of pelagic and benthic fauna and flora of the reservoir. Following impoundment of these storage reservoirs, state and federal agencies purposely managed the new lakes for resident fish production and other recreational opportunities. Resident fish production and recreation can be dramatically decreased with out-of-season drawdown of these storage reservoirs in order to augment water for increased baseflow downriver needed by migrating anadromous salmonids.

This section of the Reconnaissance Report will provide a descriptive background of the Columbia River basin flood control system in order to further discuss flow regulation effects upon the survival and production of threatened and endangered salmonid ESUs managed for in the Columbia River basin.

6.1.1 Flood Control in the Columbia River Basin

This subsection provides an overview of historical and existing conditions with respect to runoff pathways and flood control operations in the Columbia River Basin. Major current operating requirements with respect to ESA-listed fish species, particularly juvenile anadromous salmonids, are discussed in Sections 5.1.3 and 5.1.4. Section 5.1.5 identifies those conditions that would continue in the future if the Corps does not pursue modification of the current flood control operations during average to below-average flow years.

The Columbia River has an average annual runoff at its mouth of about 198 MAF or 244 billion m^3 (average year-round flows of 275,000 cfs or 7,787 m^3/s), making it second only to the Missouri-Mississippi River system in the United States in runoff. The Canadian portion of the basin generally contributes about 50.2 MAF annually (62 billion m^3). On average, about 25 percent of the Columbia River flow comes from Canada.

Before any mainstem dams were built, natural instantaneous streamflow at the U.S.-Canada border ranged from as low as 14,000 cfs (396 m^3/s) to as high as 550,000 cfs (15,575 m^3/s). This high variation in flow was seasonal. This natural variation has been reduced as a result of upstream storage and regulation. Most of the annual precipitation in the Columbia River Basin occurs in the winter, with the largest share falling in the mountains as snow. The moisture that is stored during the winter in the snowpack is released in the spring and early summer, and about 60 percent of the natural runoff in the basin occurs during May, June, and July.

The Pacific Northwest has two principal flood seasons that correspond to this seasonal flow variation. November through March is the rain-produced flood period. These floods occur most frequently on streams west of the Cascade Mountains. May through July is the snowmelt flood period. East of the Cascades, snowmelt floods dominate the runoff pattern for the Columbia Basin. The most serious snowmelt floods develop when extended periods of warmer weather follow a large accumulation of winter snow. Greater floods result when heavy rains fall during the melting of a large snowpack. The ability to predict the magnitude of a runoff peak and the timing of that peak is limited. This is due primarily to the current inability to reliably predict snowmelt-inducing climatic conditions much beyond three to ten days in advance. Prediction of seasonal runoff volumes start as early as December and have become increasingly reliable.

Historically, peak spring flows in the Columbia River periodically rose to levels that would flood large areas along the river, resulting in loss of life and property damage. Since completion of the FCRPS, many of the areas previously subject to frequent flood damage are now protected by flood control operations, levees, and other measures. Major past and present flood “damage areas” are located on the upper Columbia River (including tributaries), the Clearwater River (below Dworshak Dam), the lower Snake River, and the lower Columbia River (see Figure 5). The basic objective for flood regulation is to operate reservoirs to reduce the stages at all potential flood damage areas, while ensuring with a high level of confidence that storage projects will be refilled at the end of the spring runoff. Table 9 presents information about the current major flood damage areas and the discharge thresholds where either zero damage or major damage may occur.

Flood damage potential is greatest in the lower Columbia River from the damage area at Portland-Vancouver to the mouth of the river (which includes the Longview-Kelso area). Winter rainfall floods from the Willamette River as well as snowmelt floods from the Columbia River can affect this area. The Portland-Vancouver area is the most highly developed and populated reach of the entire Columbia River Basin.

Flood damage in the past has also occurred along the Flathead River near Kalispell, Montana; the Kootenai River between Bonners Ferry, Idaho, and Kootenay Lake; Lake Pend Oreille and the Pend

Figure 4. Major Past and Present Flood Damage Areas in the Columbia River Basin

Figure 5. Major Flood Damage Areas in the Columbia River Basin

Table 9. Flood Damage Areas in the Columbia River Basin

Control Point	River Reach	Zero Damage[1/3/]
Columbia River at Birchbank, BC	Columbia River from below confluence of Arrow Lakes and Brilliant Dam to the U.S. border	225,000 cfs ($6,372\ m^3/s$)
Kootenai River at Bonners Ferry, Idaho[2/]	Kootenai River from Bonners Ferry to Kootenay Lake	1764.0 feet
Flathead River at Columbia Falls, Montana	Flathead River from Columbia Falls, Montana to Flathead Lake	52,000 cfs ($1,473\ m^3/s$)
Flathead Lake at Somers, Montana	Flathead Lake Shoreline	2893.1 feet
Flathead River near Polson, Montana	Flathead River from Kerr Dam to Thompson Falls Dam	28,000 cfs ($793\ m^3/s$)
Pend Oreille Lake near Hope Idaho	Lake Pend Oreille Shoreline	2062.5 feet
Pend Oreille River at Newport, Washington	Pend Oreille River from Albeni Falls Dam to the Columbia River	85,000 cfs ($2,407\ m^3/s$)
Clearwater River at Spalding, Idaho	Clearwater River from Dworshak Dam to the Snake River and then to the Columbia River	112,000 cfs ($3,172\ m^3/s$)
Columbia River at The Dalles, Oregon	Columbia River between Bonneville Dam (river mile 145) and river mile 40	200,000 cfs ($12,743\ m^3/s$)

[1/] Flood damages caused by changes in flow in a river are measured in cfs while flood damages caused by changes in lake level are measured in feet.
[2/] The water surface elevation of this reach of the river is impacted more by the elevation of Kootenay Lake than by the flow of the river. Therefore, damages are identified by lake level elevation.
[3/] Zero damages indicates the stage or flow below which there are no flood damages.
Source: Corps 1997

Oreille River below Albeni Falls; the Columbia River near Kennewick-Pasco-Richland, Washington; the Boise River near Boise, Idaho; the lower Clearwater River near Lewiston, Idaho; and on the Columbia River near Birchbank in British Columbia. Flood damage may also occur in other smaller communities and may be significant to residents in those areas. Although many streams in the basin remain uncontrolled, reservoirs on the major rivers reduce flood damage in most of the major damage areas.

Reservoirs that store a large portion of the runoff for later release were developed in the Columbia River Basin to control peak flows and moderate or prevent flood damage. Operation of these storage reservoirs under the Coordinated Columbia River System (CCRS) has influenced the natural mainstem flows in the Columbia River Basin. (The CCRS refers to projects operated under several separate arrangements: the Pacific Northwest Coordination Agreement, the Columbia River Treaty between the United States and Canada, Federal flood control statutes, and several environmental and fish and wildlife statutes.) In addition, levees have been constructed in many areas to contain peak flows within the main channel. The levees have altered historic channel conditions and habitat.

According to the NMFS 2000 Biological Opinion (NMFS 2000), changes from natural runoff patterns negatively affect juvenile salmonid survival. Levees along the main channel constructed to contain peak flows in the main river channel have disconnected the Columbia River from its historical floodplain and reduced the amount of area within the historical floodplain available to hold floodwaters.

Flood control storage capacity in Columbia River reservoirs is made available only during those two periods when flood risk exists (November through March and May through July) rather than year-round; the amount of space needed depends on how much runoff volume is expected. This approach to system operation makes it possible to use reservoir space for storing water for fish flows, hydropower, irrigation, recreation, and other purposes during periods when there is little or no flood risk, and to use the available storage jointly for flood control and the other purposes during the flood season. This concept of joint-use storage is utilized for the reservoirs of the CCRS.

6.1.2 Operating Objectives for Flood Control

Flood control operations in the Columbia River Basin have two objectives:

1. System Flood Control—operating the total reservoir system to moderate or prevent damaging flows on the lower Columbia River, and
2. Local Flood Control—operating individual reservoirs to moderate or prevent damage to local areas.

6.1.2.1 System Flood Control

System flood control utilizes flood control storage reservoirs (Mica, Arrow, Duncan, Libby, Hungry Horse, Grand Coulee, Jackson Lake, Palisades, Anderson Ranch, Arrowrock, Lucky Peak, Brownlee, Dworshak, and John Day) on the Columbia and Snake rivers and tributaries to reduce peak flood flows in the Lower Columbia in the reach from The Dalles, Oregon, to below Portland. The storage reservoirs are operated as a joint system according to the system and reservoir water control manuals. The water control manual defines the responsible offices and the criteria used for flood control operations.

The system flood control objective in all years is to limit the peak flow at The Dalles, OR to the initial controlled flow (ICF). The ICF also is the trigger indicating when reservoir refill should start. The ICF isdependent on the amount of system flood control reservoir space available before the initiation of refill and the seasonal volume forecast at The Dalles, OR. Historic ICFs have ranged from 200,000 cfs to 600,000 cfs.

Currently, up to about 39 MAF (48 billion m^3) of storage space can be made available for flood control from the CCRS, including about 20.5 MAF (25.3 billion m^3) at the three Canadian Treaty projects (Mica, Keenleyside, and Duncan) (see Table 5). Use and availability of the primary and secondary storage will need to be further addressed in the feasibility phase. This current level of flood protection through managed reservoir storage is supplemented by a variety of levees, floodwalls, and bank protection that were originally organized locally in areas subject to damage from frequent flooding. For example, there are more than 50 levee systems along the lower Columbia River (below Bonneville Dam) with varying protection capabilities. Some are designed to sustain flows of 800,000 cfs (22,656 m^3/s) or more. Other levees in this reach provide less protection. Engineering studies would be required to quantify the capacity of these specific levees.

Control can be accomplished in high runoff years using a combination of available storage in U.S. reservoirs and the approximately 8.4 MAF (10.4 billion m^3) of primary Canadian Treaty storage that is available at no additional cost beyond the original lump-sum payment. To control very large floods, the United States may choose to pay for additional storage in Canadian reservoirs. This "on-call" or secondary storage involves up to about 12 MAF (14.8 billion m^3) that could be utilized (Table 5) and can control the system design flood (1894 hydrograph) to a peak flow of 600,000 cfs at The Dalles. However, to date, the United States has not had to utilize this option.

In addition to levee systems, many areas have adopted other measures to moderate or prevent flood damage potential. Examples include floodplain regulations, land use regulation, and improved land treatment practices.

Reservoirs are operated in accordance with reservoir storage requirements that are represented graphically as curves known as rule curves. Flood control rule curves define the minimum amount of storage space that must be provided at each project to meet system and local flood control needs. Critical rule curves specify reservoir elevations that must be maintained on a monthly basis to ensure that firm hydro energy requirements can be met even if there is a reoccurrence of the worst historical streamflow conditions in the past (Figure 6).

Prior to requirements contained in biological opinions issued in 1995 and replaced in 2000 and 2004, actual reservoir levels tended to be somewhere between the flood control rule curves and the somewhat lower limits established for power generation. FCRPS biological opinions prior to the NMFS 2004 Biological Opinion (NOAA 2004) developed several flow magnitude and frequency enhancement projects that have been carried forward in the Action Agencies UPA (2004), including VARQ studies for upper Columbia River storage projects. These actions are presented in Section 5.1.3. The implementation of these actions, such as system operation shifts between storage projects and USBR water that has been prioritized for flow augmentation, have contributed an estimated 4-8 percent frequency improvement to meeting seasonal flow objectives (NOAA 2004).

The ability to maintain the existing flow improvement actions and the ability of any future developments that result in increasing the frequency of meeting UPA flow objectives (Table 2) during a specific flow season will continue to be coordinated in real-time through the Technical Management Team (TMT) established as a result of consultations on the FCRPS. Achieving established summer flow objectives during the months of August and September will remain the most difficult objective.

The UPA indicates that the FCRPS should fill to April 10 flood control elevations and specifies the percent of time this expectation should be fulfilled at various projects.

Flood control rule curves have a fixed component, which usually defines operation during September through December, when less predictable rainfall floods occur. Evacuation of reservoirs usually begins in this period to ensure that space will be available when needed to control floods. Snowpacks are just beginning to build during this period. As a result, runoff forecasts are not available for most projects, so the curve is based on a statistical analysis of historical events. The variable component of flood control rule curves defines operation from January through April. In January, forecasts of seasonal volume runoff become available. This allows the variable portion of each project's flood control rule curve to be defined. It is based on the runoff volume expected to occur and thus indicates the amount of reservoir storage space needed to control floods through the spring freshet.

The flood control rule curve used as a guide to reservoir evacuation is developed using the project's storage reservation diagram (SRD) (Figure 7), which specifies the amount of storage required to protect against a wide range of runoff forecasts. The target reservoir elevation for flood control is updated monthly as revised forecasts become available.

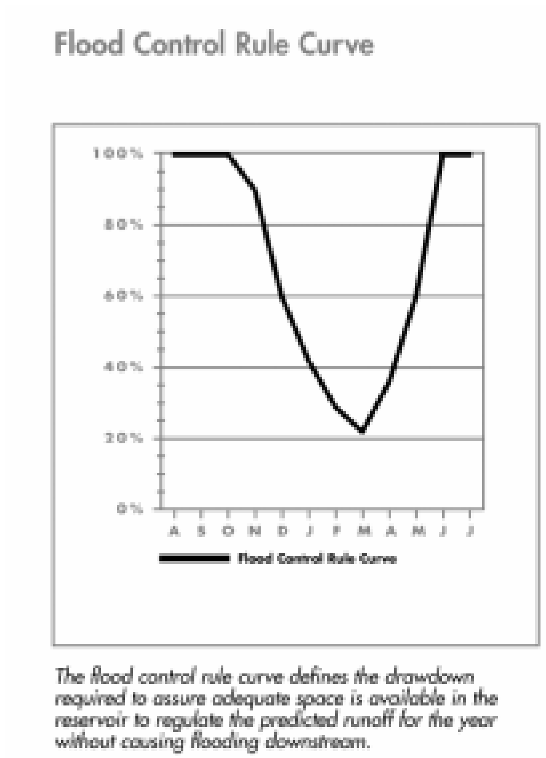

Figure 5. General Schematic of a Flood Control Curve used for Controlling Runoff

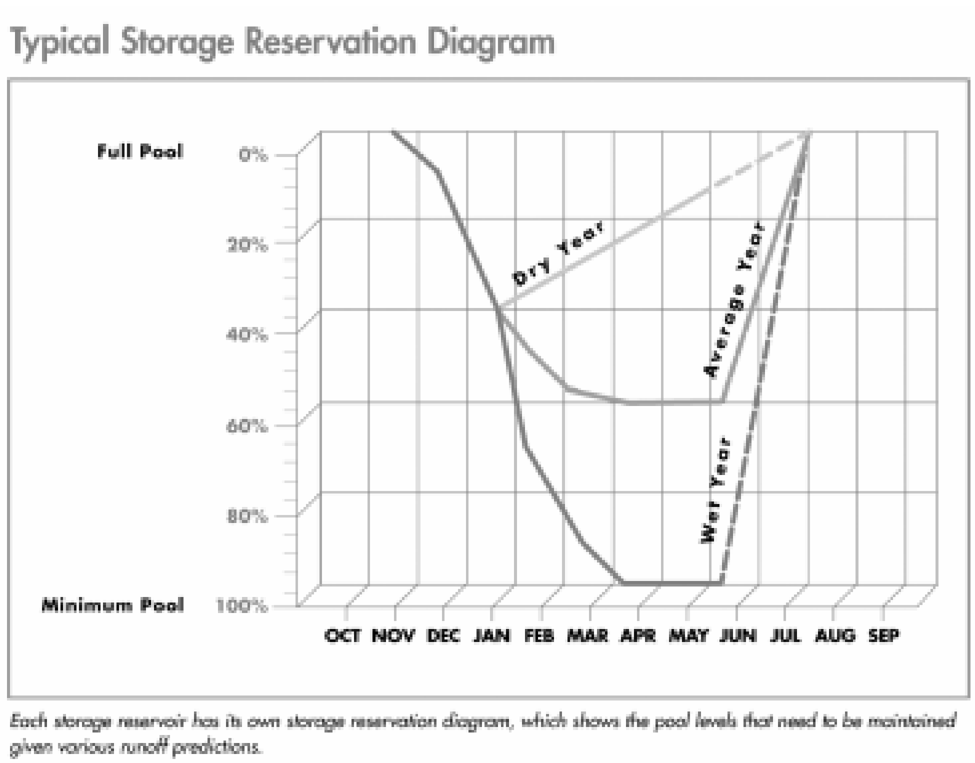

Figure 6. Schematic of Typical Storage Reservoir Levels During Dry, Average, and Wet Years

Once refill begins (usually in April or May, but as late as June or, rarely, in July), reservoirs are allowed to refill gradually at a rate that maintains downstream flows at acceptable levels. To guide this operation, the Corps uses computer models and other tools to simulate reservoir operation on a daily basis in response to forecasted runoff. In moderate to high runoff years, careful monitoring is required to keep potentially damaging flows to a minimum.

In some years, cool weather, low snowpack, and other conditions result in reduced runoff, so the potential for flood conditions is never realized. In those years, considerations such as refill requirements, water releases for fish, and power generation opportunities heavily influence refill operation.

6.1.2.2 Local Flood Control

Local flood control utilizes system flood control reservoirs to reduce flows in the local reaches below each reservoir to protect those areas from flood damages. Thus, the same flood control reservoirs protect both local reaches and distant downstream reaches. Each reservoir's fall and winter drawdown schedule is designed to provide space for controlling local rainfall floods as well as snowmelt floods. Generally, during spring floods, storage of runoff for system control, as currently operated, provides protection for local areas as well. For example, Dworshak Reservoir is a key component for system flood control. In addition, if localized rain events or rapid snowmelt occur in the watershed upstream of Dworshak Dam, operations can be adjusted to moderate or prevent flood damage in areas immediately downstream and in the Lewiston-Clarkston area (Figure 5).

As noted above, the current level of flood protection through managed reservoir storage is supplemented by a variety of levees, floodwalls, and bank protection that were originally organized locally in areas subject to damage from frequent flooding. Many areas have also adopted other measures to moderate or prevent flood damage potential, including floodplain regulations, land use regulation, and improved land treatment practices.

6.1.3 FCRPS Operating Requirements for Salmonids

The major current operating requirements for project operations in the Columbia River Basin that are designed to increase salmonid survival and production are summarized by BPA et al. (2001). These requirements, which could be modified in the future, define the operating strategy currently implemented by the Action Agencies in accordance with the NMFS 2004 and USFWS 2000 Biological Opinions issued under the ESA and are listed as follows:

- Manage reservoir operations during the fall and winter to achieve a high confidence of refill to flood control elevations by early spring of each year to maximize the water available for flow augmentation and spill.
- Provide flow augmentation in the Columbia River and Snake River and manage these flows during the fish migration seasons according to decisions from the in-season management (technical and policy) teams.
- Release the stored flow augmentation water during the migration season in a manner that strives toward specified flow objectives measured at Lower Granite and McNary projects and, during the spring, at Priest Rapids. During the fall and winter, release stored water for chum salmon and fall Chinook salmon.
- Manage spill at mainstem projects to improve fish passage efficiency (non-turbine fish passage) up to specified levels of TDG. Projects in Oregon and Washington are spilling up to 120 percent of TDG, while Montana projects are only allowed to spill up to 110 percent of TDG.

- Transport all juvenile anadromous fish collected at the lower Snake River collector projects during the spring and summer and from McNary Dam in the summer to downstream release sites. This avoids passage through multiple dams. Other periods for transport may be directed through regional in-season management decisions.
- Operate lower Snake River reservoirs within the lower 1 foot (0.3 meter) of the normal operating range from early April through August each year.
- Operate the John Day reservoir at an elevation of 262.5 feet (80 meters), plus or minus 1.5 feet (0.45 meter), from mid-April through September each year.
- Seek to refill storage reservoirs by the end of June to maximize summer flow augmentation.
- Operate turbines within 1 percent of peak efficiency during the juvenile and adult fish migration seasons, initially defined as March 15 through October 31 in the Columbia River and March 15 through November 30 in the Snake River and, as of 2004, defined as April 1 through October 31 for both rivers.
- Operate Libby Dam to provide specified water volumes and flow for Kootenai River white sturgeon and bull trout, and restrict daily flow changes to minimize downstream effects to the riverine environment and to resident fish.
- Manage reservoir elevations at storage projects to moderate or prevent detrimental effects on resident fish, wildlife, and recreational facilities. Summer draft objectives, as defined by NMFS, are to be met at Hungry Horse, Libby, Grand Coulee, Banks Lake, and Dworshak projects while attempting to meet flow objectives for juvenile salmon migration.

While the NMFS 2004 and USFWS 2000 Biological Opinions provide general operating guidelines, the concept of "adaptive management" is also followed in the operation of the FCRPS. This concept allows river managers to learn from actual experience and adapt the resulting operating principles or actions to what is expected to be best for ESA-listed fish species.

In addition to the specific operating guidelines outlined above, the Action Agencies need to comply with a wide number of regulations, agreements, and treaties, including, but not limited to, the following:

- Endangered Species Act of 1973, as amended
- National Environmental Policy Act of 1969, as amended
- Federal Water Pollution Control Act of 1972, as amended (when amended in 1977, this Act became generally known as the Clean Water Act)
- Columbia River Treaty (between the United States and Canada)
- Libby Coordination Agreement
- Pacific Northwest Coordination Agreement
- Columbia Storage Power Exchange
- Canadian Entitlement Allocation Agreements
- Non-Treaty Storage Agreement
- Pacific Northwest Power Planning and Conservation Act of 1980
- Tribal Treaties and Executive Orders
- 1938 International Joint Commission (IJC) Order on Kootenay Lake.

In addition, non-Federal projects (i.e., PUDs, private companies) in the Columbia River Basin are regulated through FERC licenses.

Overall, criteria for flood control in the Columbia River Basin are assumed to remain the same for future without project conditions. There are other planning mechanisms that might alter this condition (e.g., ongoing negotiations with Canada over potential additional releases from Canadian reservoirs during the July/August period).

6.1.4 Effects of Flow on Juvenile Anadromous Salmonid Survival

Prior to the NMFS 2000 Biological Opinion, flow augmentation would be provided during the spring and summer migration period as described in the NMFS 1995 and 1998 FCRPS Biological Opinions (NMFS 1995; NMFS 1998), mainly to increase survival of migrating juvenile fish. The NMFS 2000 Biological Opinion utilized a sliding scale for spring and summer flow objectives (April through August) dependant on annual availability of stored water. The sliding scale approach was incorporated into the 2004 NMFS Biological Opinion.

The timing of flow depends on several factors (e.g., fish abundance, available storage, and river temperature). The priority of flow augmentation for the Snake River is for summer migrating juvenile fall Chinook salmon in July and August, unless doing so would depart markedly from the spring flow objectives. The result is some balance of use for spring and summer flow needs and reservoir refill.

Dworshak reservoir has been used as part of the flow augmentation program. Releases from Dworshak result in cooler water downstream. Depending upon timing of flow releases, these releases can both benefit or work to the detriment of life-stage survival of the juvenile Snake River fall Chinook salmon stocks in the summer, and could be detrimental to the Clearwater River stocks by extending the period before these fish are ready to migrate (Arnsberg and Statler, 1996; Connor et al., 1996). If increased flow increases survival, then optimized flow augmentation by meeting the UPA flow objectives (Table 2) at a high frequency would benefit the Snake River salmonid stocks.

Increased survival of juvenile anadromous salmonids could be satisfied by increasing the frequency of achieving the UPA flow objectives (Corps, et al. 2004) both temporally and spatially in the Snake and Columbia rivers. The NMFS 2004 Biological Opinion, Section 6 on Effects of Proposed Action, and Appendix D, Survival Results Memo, discuss certain biological benefits that can be determined for increasing flow and the frequency of meeting the seasonal flow objectives for survival and recovery of listed salmonids stocks. The following provides a preliminary evaluation of the effects of UPA on flow conditions and juvenile fish migration.

Flow Conditions

Flow influences water velocity and water quantity, the amount of spawning habitat and shallow water rearing habitat below and between dams for some ESUs, as well as the size and physical characteristics of the near-ocean plume at the mouth of the Columbia River. The flows proposed by the UPA and the reference operation upon which the NMFS 2004 Biological Opinion evaluated jeopardy are very similar for seasonal average spring flows in the Snake River and only slightly reduced for the lower Columbia River when juvenile salmon and steelhead are migrating downstream (Table 10).

There is a concern over the summer flows in both the lower Snake and Columbia rivers, where flows are reduced 6.3 percent and 20.0 percent (Table 10), respectively, from reference to UPA operations. This reduction can affect availability of shallow-water rearing habitat during the summer. Fall and winter flows under UPA operations are proposed to be higher compared to reference operations, which would result in a greater quantity of salmonid spawning and egg incubation habitat.

Table 10. Simulated Average Seasonal Flows (and flow ranges) for FCRPS Reference and Proposed UPA Operations During Spring and Summer Time Periods Relevant to Migrating Juvenile Salmon and Steelhead (years 1994 through 2003)

Reach and Season	Reference Operations (kcfs)	UPA Operations (kcfs)	Absolute Difference (Proposed - Reference) (kcfs)	Percent Difference (Absolute Difference ÷ Reference)
Snake River Spring (4/3 – 6/20)	93.0 (47.9 to 148.1)	93.0 (54.0 to 145.7)	+0.0 (+6.1 to-2.7)	+0.0 (+12.8 to –1.6)
Snake River Summer (6/21-9/30)	45.0 (26.9 to 64.8)	42.1 (26.6 to 61.6)	-2.8 (-0.3 to -3.2)	-6.3 (-1.0 to –5.0)
Lower Columbia Spring (4/10 - 6/30)	256.9 (127.5 to 425.0)	255.1 (156.4 to 401.8)	-1.8 (28.9 to –23.2)	-0.7 (+22.7 to –5.5)
Lower Columbia Summer (7/1–9/30)	189.5 (166.2 to 114.7)	151.5 (114.7 to 197.5)	-37.9 (-51.5 to –22.8)	-20.0 (-31.0 to -10.3)
Lower Columbia Fall and Winter (11/1 - 4/15)	162.6 (119.0 to 212.6)	173.5 (121.0 to 236.3)	+10.9 (+1.9 to +23.7)	+6.7 (+1.6 to +11.2)

Source: Table 6.3 in NMFS 2004.

Quantitative estimates of the associated difference in shallow-water rearing habitat below Bonneville Dam (including the estuary) are not available, but the 20.0 percent difference in flow (Table 10) is likely to reduce the availability of shallow-water rearing habitat during the summer. Fall and winter flows associated with the proposed hydro operation are somewhat higher compared to the reference operation, which would result in a greater quantity of habitat for spawning and egg incubation for at least one population of Columbia River chum salmon.

As long as adequate springtime flows during incubation and fry emergence are maintained, it is unlikely that these higher flows would have a significant effect on mainstem spawning of Snake River fall Chinook salmon. Snake River fall Chinook salmon spawning generally occurs during November and December in relatively deep water downstream of the Hells Canyon Dam tailrace, further downstream at alluvial tailouts of major tributaries of the Snake River like the Salmon and Grande Ronde rivers, and secondarily in pockets downstream of the Federal lower Snake River dams. To the extent that there is an effect of higher winter flow frequency on the number of salmon spawning and success of spawning, it would likely be beneficial.

Some water quality conditions associated with the UPA operation could decline with lower flows during summer months, compared to the reference operation[4]. Higher water temperatures during the summer would most likely affect migrating juvenile Snake River fall Chinook salmon and some populations of rearing Columbia River chum salmon and Lower Columbia River Chinook salmon. Additionally, warmer summer temperatures may affect migrating adult Snake River and Lower Columbia River fall Chinook salmon and winter-run populations of several steelhead ESUs. It is unlikely that other water quality factors such as TDG would be higher for the proposed hydro operations relative to the reference operation, since voluntary spill for fish passage should not exceed TDG limits based on state water quality standards in either the reference or proposed operation, and involuntary spill is similar in the two operations.

The results of the NMFS 2004 Biological Opinion evaluation would not change the 8 to 86 percent (Table 11) of flow years (during spring and summer months) at Lower Granite, Priest Rapids, McNary, and Bonneville dams that are expected to meet or exceed specified flow objectives (Table 2). These flow objectives were considered in the No Jeopardy determination for ESA-listed anadromous salmonid stocks in the Snake and Columbia rivers (NMFS 2004). As Table 11

[4] Low summer flows are often associated with higher water temperatures.

illustrates, the summer months are the most difficult to achieve sustained flow objectives identified in the NMFS 2004 Biological Opinion. However, NMFS compared the system survivals of ESUs resulting from the UPA operations against a reference operation they developed that represented the best operational scenario of the FCRPS they assumed possible for salmonid passage and production. The reference operation generally exhibited seasonal flows that met or exceeded the NMFS 2004 BiOp flow objectives around 80% of the time. NMFS' reference operation developed yearly average flows for the spring and summer seasons that were not very different from the yearly average flows proposed in the UPA, with an exception for meeting or achieving the flow objectives at a higher frequency on a monthly or seasonal basis. For example, the summer flows at McNary that met or exceeded the average summer flow target increased from 10% to 78% of the time. NMFS reference operation was unconstrained for irrigation or flood control allowing the hydrology to operate all storage reservoirs as run-of-river projects (e.g., operate at full pool and pass inflow unless winter/spring drafts are needed for salmon flow augmentation or to reduce TDG downstream at mainstem dams) that try to refill by June 30. These shifts to available summer augmentation water during July through September in the Columbia River arm of the basin to meet or exceed the summer flow objective of the 2004 BiOp resulted in increases of average ESU in-river survivals of about 4% for Snake River spring Chinook salmon and Snake River and Mid-Columbia River steelhead, and about 3% for Snake River fall Chinook salmon (if a positive flow/survival relationship is assumed, otherwise only about 1% if no flow/survival relationship is assumed).

Table 11. Percent of Flow Years at Lower Granite, Priest Rapids, McNary, and Bonneville Dams that are Expected to Meet or Exceed Specified Flow Objectives Under the Base Case, Based on 50-year Simulation (1929-1978)

Period	Lower Granite	Priest Rapids	McNary	Bonneville
January	N/A[1/]	N/A	N/A	88
February	N/A	N/A	N/A	78
March	N/A	N/A	N/A	78
April	38	56	48	N/A
May	60	86	64	N/A
June	68	78	50	N/A
July	40	N/A	48	N/A
August	0	N/A	8	N/A
September	N/A	N/A	N/A	8
October	N/A	N/A	N/A	20
November	N/A	N/A	N/A	74
December	N/A	N/A	N/A	90

[1/] N/A indicates no dedicated target flows established for this month.
Source: NMFS 2000

Juvenile Salmonid Survival and Flow During a Low Flow Year - Spring 2001

There exists two temporal/spatial scales for which meeting UPA flow objectives are applicable: 1) the within year measure where every summer period can be critical, and 2) the between year measure where the climate across an entire year causes critical low flows for both the spring and summer periods. Flow year 2001 was a more extreme critical low flow year that can be used for illustration of the effect of compounded low flows due to scale 2) acting to making scale 1) more extremely critical to fish production and survival.

Low river runoff volume and hydrosystem operation decisions in 2001 affected the ability to implement the NMFS 2000 Biological Opinion measures for the 2001 juvenile salmon migration. The July Final Runoff Volume Forecast at The Dalles was 52 percent of average, and at Lower Granite Dam, the volume was estimated at 47 percent of average. Reservoir refill was prioritized in order to provide hydropower. As a result, NMFS 2000 Biological Opinion flow objectives were not achieved. Seasonal average flows for the spring period were 48.9 kcfs at Lower Granite and 126.3 kcfs at McNary compared to the NMFS 2000 Biological Opinion flow objectives of 85-100 kcfs at Lower Granite and 220-260 kcfs at McNary (Table 2).

The Fish Passage Center (FPC) presented survival estimates of the 2001 spring outmigration of juvenile steelhead and Chinook salmon in the Snake and Columbia rivers as these stocks responded to the low run-off volume and BPA energy and financial emergencies that occurred in spring 2001 (incorporated into NMFS 2004 and Williams, et al. 2005) (Table 12). These conditions combined to produce poor migration conditions for juvenile spring/summer Chinook salmon, fall Chinook salmon, and steelhead. An estimated 80 percent of the Snake River stock smolts were transported by barge during the 2001 outmigration season, so the survivals represent about 20 percent of the stock outmigrant populations for those smolts that remained to migrate in-river with low flow and predominantly no spill.

The estimated weekly survival estimates of yearling spring/summer Chinook salmon, in the reach from Lower Granite tailwater to McNary Dam tailwater, using fish that were PIT tagged above Lower Granite were below 60 percent (about 10 percent to 15 percent below normal) in April and declined from mid-May through the remainder of the migration. Estimates of survival by the end of May were lower than 20 percent.

The NMFS 2004 Biological Opinion (NMFS 2004) and Williams, et al. (2005) estimated the reach survivals for the lower Snake and Columbia rivers to derive the system survivals for the flow years 1994-2003. For a reduced flow year such as 2001 where Snake River flows were one-half to one-third of average and above average flow years.

A comparison of survivals to total discharge using the same wild Chinook salmon data in Table 12 showed an increase in survival with increasing flows. Flows in the lower Snake River in 2000 were considerably higher than those in 2001. The time period of the spring outmigration past Lower Granite Dam in 2001 was not greatly different when compared to historic timing. Run timing for both Chinook salmon and steelhead began later and was shorter in 2001 compared to historic timing.

Table 12. Observed Seasonal Average Flows and Estimated Reach Survivals for the Lower Snake and Columbia Rivers for the Flow Years 1994-2003

Migration Year	Lower Snake River Seasonal Average Spring Flow (kcfs)	Lower Columbia River Seasonal Average Spring Flow (kcfs)	Median Travel Time (days) of PIT-tagged yearling Chinook salmon between Lower Granite and Bonneville dams	Reach Survival of Snake River Spring/summer (yearling) Chinook Salmon	Reach Survival of Snake River Steelhead	Reach Survival of Snake River Fall (subyearling) Chinook Salmon
1994	58	186	No estimate	.378	.572	No data
1995	97	249	18.4	.678	.773	.304
1996	138	360	16.2	.568	.647	.232
1997	158	441	14.1	.605	.732	.042
1998	112	285	19.0	.588	.661	.343
1999	116	303	16.1	.710	.617	.242
2000	84	254	16.4	.632	.637	.216
2001	43	120	31.0	.203	.067	.034
2002	80	277	16.9	.626	.372	No data
2003	89	242	14.4	.719	.501	.256

Sources: Columns 1, 2, 3, 5, 6, and 7 from NMFS 2004 Biological Opinion, Appendix D, Attachment 3, Hydro Flow/Survival Memo, compiled from Table 1 (page D3-1), Table 2 (page D3-5), Table 3 (page D3-9), Table 4 (page D3-12), and Table 5 (page D3-16) and Table 6 (page D3-19). Column 4 from Williams, et al., 2005.

System survivals in 2001 for Snake River spring/summer Chinook salmon, Snake River B-run steelhead, and Snake River fall Chinook salmon were 28-35 percent, 9-18 percent, and 10-16 percent, respectively, of the range of system survivals calculated for the average to above-average flow years that meet or exceed a high frequency of the NMFS 2000 or 2004 BiOp flow objectives (Table 12). Estimates of system survival during 2001 for both hatchery and wild Chinook salmon were very similar. For steelhead, early season survivals were near 20 percent and declined to less than 10 percent for hatchery fish, while the wild steelhead faired slightly better with survivals that remained near 20 percent compared to average to above average flow years, when system survivals were between 50-77%.

Low flow river conditions for 2001 produced the poorest survivals since PIT tag survivals have been estimated (1994) (Table 12). Seasonal survival estimates from Lower Granite to McNary Dam for yearling Chinook salmon was estimated at 0.57 and for steelhead at 0.16. Average survival for spring Chinook in this reach from 1995 to 2000 was 0.72, and average survival was 0.70 for steelhead, respectively. The steelhead estimate of 0.16 for 2001 is about 50 percentage points below the lowest seasonal estimate for the last 5 years and probably represents both lower survival as well as increased residualism in smolts de-smoltifying back into rearing and overwintering lifestages.

The timing of passage for spring migrants at McNary was more delayed compared to the average historic dates for yearling spring/summer Chinook salmon. For both steelhead and spring/summer Chinook salmon, the timing of the 90 percent passage was more than a week later than average. While it is clear low flow contributed to increase travel times, flows in the lower Columbia River also fluctuated widely over short periods of time; sometimes these fluctuations represented a change of 30 to 40 percent in total river flow.

The mid-Columbia River outmigration was shaped by the cyclic peaking of flows that followed the artificial weekly cycle of power needs. It is evident in passage indices that steelhead were more affected by this type of flow fluctuation than Chinook salmon. Travel times in 2001 were some of the slowest in the 20 years of travel time calculations. The longer travel times were especially noticeable in the lower Columbia River, where flows were near record lows. For yearling Chinook salmon over the years 1996 to 2000, travel time from McNary Dam to Bonneville Dam averaged 5.6 days (average and of median daily travel times), while 2001 travel times average 10.8 days and median travel times were 31.0 days, about twice the median of any average or above-average flow year (Table 12). For steelhead over the same reach the 1996 to 2000 average travel time was 5.0 days compared to an average of 10.0 for 2001.

There are competing scientific hypotheses and models regarding the effects of environmental forces, such as flow, on Columbia River salmon. River velocity and water temperature are of particular interest to fisheries scientists, water managers, and interest groups, as these factors influence the migratory behavior of salmonids. Several computer models have been used to simulate the effects of river flows (especially water velocity) and temperature on the migratory speed and survival of smolt (young salmon ready to migrate from fresh water to the sea). These models ascribe different levels of importance to river discharge and temperature and their effects on migratory conditions for juvenile salmonids. Within the body of scientific literature reviewed as part of this study, the relative importance of various environmental variables on smolt survival is not clearly established. When river flows become critically low or water temperatures excessively high, however, pronounced changes in salmon migratory behavior and lower survival rates are expected (NRC 2004, ISAB 2004).

In 2002, Giorgi et al. reviewed the status of flow augmentation evaluations published to date. The authors emphasized that establishing general relationships between flows and either migration speed or survival provides a rationale for entertaining flow augmentation as a strategy to improve survival. However, an evaluation of the biological benefits of providing additional water in any particular year has many facets and requires a more focused analysis. Few such detailed evaluations have been conducted. Even the 2000 NMFS Biological Opinion offered no assessment of benefits or risks associated with flow augmentation; rather, it specified volumetric (in millions of acre-feet) standards dedicated to flow augmentation and prescribed seasonal flow (in thousands of cubic feet per second, or kcfs) targets. However, no quantitative analysis describing the change in water velocity, smolt speed, or survival improvement was presented that can be attributed to the additional water provided by flow augmentation. Some studies that attempted to focus specifically on evaluating the effects of flow augmentation water delivery are discussed briefly below.

A study in the late 1990s commented on the effectiveness of flow augmentation in changing water velocity and meeting the flow targets which were later specified in the 2000 Biological Opinion (Dreher, 1998). It was found that the volumes of water in storage reservoirs currently earmarked for flow augmentation in the Snake River (1) provide only small incremental increases in average water velocity through the hydrosystem and (2) are insufficient to meet flow targets in all years. This analysis, however, was not intended to specifically evaluate flow augmentation strategies and thus offered no insight with respect to fish responses.

The topic of summer flow augmentation has received increased attention in recent years. For example, Connor et al. (1998) conducted a study that had implications for summer flow augmentation in the Snake River. Using PIT-tagged juvenile fall Chinook that reared upstream from Lower Granite Dam, they regressed tag detection rates at the dam (survival indices) against flow and temperature separately. They found that over four years, the detection rate was positively correlated to mean summer flow and negatively correlated with maximum water temperature.

Risks associated with flow augmentation were addressed by the Independent Science Advisory Board's publication *Return to the River*, which expressed concerns regarding risks associated with summer flow augmentation, in particular (ISAB, 1996):

> "Underscoring these substantial uncertainties in flow augmentation rationale is the fact that summer drawdowns in upstream storage reservoirs, for example Hungry Horse Reservoir in Montana, to accomplish summer smolt flushing in the lower Columbia River has direct and potentially negative implications for nutrient mass balance and food web productivity in Flathead Lake, located downstream from Hungry Horse."

The issue involves balancing expected benefits to anadromous fish with ecosystem functions and potential risks to other species. There is clearly a complex array of water management activities in the Columbia River basin today, and arriving at an appropriate balance among competing and complementary strategies is a venture that contains many considerations and uncertainties.

The ISAB (1996) stressed the importance of the estuary as a key regulator of overall survival and annual variation in abundance of salmon. The estuary (and nearshore Columbia plume and its interface with seawater) provides a physiological transition zone, potential refuge from predators, and forage (Simenstad et al., 1982). Rapid growth of juvenile salmon in this transition zone is important, as increased size lessens vulnerability to predation in this environment. Anthropogenic effects on estuarine and plume dynamics derive from estuarine alterations such as diking and filling, and from flow and water quality alterations upstream (e.g., reductions in turbidity; Junge and Oakley, 1966).

6.1.5 Effects of Current Operations if Continued into the Future

Current FCRPS operations include both ongoing flood control measures (Sections 5.1.1 and 5.1.2) and an adaptive management approach focused on continuous monitoring and implementation of new ways to improve salmonid survival and production. If the Corps does not pursue modification of current flood control operations (Section 5.2) or provide system improvements through the adaptive management approach, the following are the future without-project conditions:

- Reach and system survivals for each ESA-listed species and stock would remain susceptible to seasonal and yearly low flow events that could delay the time to recovery for such stocks.
- Timing and downstream migration rates for juvenile fish would remain within current bounds during average and below-average flow years (i.e., there would be no incremental increase in flow over existing conditions).
- Storage reservoir drawdowns and refills would remain within current bounds.
- Levee configurations would likely remain similar to current standards. Maintenance and inspection of these levees would continue under current operating criteria.

- Recreation activities would occur during periods similar to present-day (i.e., reservoirs would refill according to current schedules).
- Water quality conditions would remain within current bounds (e.g., water temperature, nutrients in reservoirs, and TDG). However, these may be affected by ongoing negotiations and discussions designed to alleviate potential problems at certain projects.
- Other programs (funded by multiple agencies and Tribes) would be continued to improve habitat and fish passage conditions for juvenile and adult migration in the Columbia River Basin (e.g., habitat restoration projects would continue to be developed and transportation of outmigrants from the four lower Snake River dams and McNary Dam would continue).
- Flood control capabilities would remain the same as under current conditions.
- Navigation opportunities would remain within current bounds.
- Economic considerations would remain within current and projected bounds.

Maintenance and operation requirements for municipal and industrial water supply and irrigation would remain the same.

6.2 Potential Measures to Achieve System Flood Control Review Objectives

The Corps held the Columbia River Fish Mitigation System Flood Control Review Formulation Workshop in Seattle, Washington on June 26-27, 2003 to initiate efforts for this reconnaissance study and establish plans for its overall direction and coordination. Workshop participants included resource specialists from the Corps' Walla Walla, Portland, and Seattle Districts and Northwestern Division. A key part of the workshop was the identification of a range of potential modifications to the existing flood control system that could meet the objectives of the System Flood Control Review. This was the first step in identifying an alternative that demonstrates Federal Interest in pursuing a detailed feasibility study.

6.2.1 Identification of Potential Measures

A variety of measures to achieve System Flood Control Review objectives were proposed for consideration during the workshop. Each of these measures will need to be studied in order to formulate the specific details. These are listed by subbasin in Appendix A and briefly summarized in the following paragraphs.

Land and Water Purchase. Rather than protect flood-prone land by active measures, such as levees, certain lands could be purchased and allowed to flood during peak runoff. Purchasing lands currently protected by a levee and removing or altering the levee so that floodwaters could flow onto those lands, would, for example, help reduce peak flood elevations in the main channel. Similarly, water that is currently used for other purposes (e.g., irrigation) might be purchased to supplement flows during the spring runoff period. Water would be purchased for use during average to below-average water years. Higher spring flows would come from modified SRDs as a result of changing acceptable levels and risk for flood control.

New Storage Dams. Higher spring flows might be obtained from either more flood control in the system that is not filled during the spring runoff, or new storage reservoirs that are drafting during the spring (and provide no flood control). Several undeveloped sites have been identified in the upper Columbia River and Snake River basins as having the potential to increase the overall storage capacity of the Columbia River system. These sites could provide additional capabilities to control potential floods. Water stored in any new facilities could also be used to supplement the spring runoff during average to below-average flow years.

Modification of Existing Levee Systems. Existing levee systems could be reconstructed to contain higher flood flows, providing potentially more flexibility for the operation of reservoir projects. Existing Federal and non-Federal levees were designed to control specific flood conditions. If the potential for higher flood peaks increases as a result of other measures designed to meet System Flood Control Review objectives (i.e., the risk of flooding increases), Federal levees could be upgraded and raised to accommodate the higher peaks. Higher spring flows would be derived from modified SRDs that are based on the upgrades in most areas of system flood control.

Transfer Storage. The Federal government currently transfers storage capacity during peak runoff either within the Federal/non-Federal system or between the Federal/non-Federal system and Canadian projects to decrease peak runoff in certain areas. By holding or releasing water in one area of the Columbia River Basin, peak flows can be controlled elsewhere, thus avoiding flood peaks. Releases from Canadian projects, Grand Coulee, or other upper Columbia River projects could, for example, be decreased during high flows in the Snake River Basin to moderate or prevent potential flood conditions in the lower Columbia River. However, expansion of additional transfers would need to be evaluated.

Improve the Use and Reliability of Volume and Runoff Forecasts Systemwide. The Columbia River system has an existing array of monitoring facilities for flow conditions, snow levels, and meteorological conditions. These monitoring facilities coupled with extensive forecasting and modeling capabilities allow control of peak runoff conditions and moderate or prevent potential flood damage. This monitoring system has functioned well over the past 50 years, with very little flood damage occurring in the major flood damage areas. However, a review of current capabilities would determine if upgrades to the existing system might further improve capabilities to control peak runoff. Also, with the technological advancements in remote sensing and forecasting methods in recent years, expansion of the existing system might also help fill any data gaps that could improve forecasting capabilities.

Improve Operational Efficiency. Current operations are designed to be compatible with existing flood control practices and procedures. In addition, current operations reflect regional fish passage needs. These operations would need to be reviewed and potentially revised to accommodate any new changes that could result from other measures, which would meet System Flood Control Review objectives. This review may also identify opportunities to improve the operational efficiency of the existing system. For example, addition of another generating unit at an existing facility might allow more flexibility and efficiency in release patterns for managing flood conditions.

Adjustments in power distribution from different regions in the United States (and Canada) to level energy demand and supply already occur under various regulations, agreements, and treaties. The potential for other adjustments to meet System Flood Control Review objectives would need to be reviewed to determine if they could provide further flexibility over current operations. Other opportunities could include possible revisions to the scheduling for operation and maintenance activities of projects in the Columbia River Basin and for fossil fuel or other generating facilities to allow more flexibility in achieving System Flood Control Review objectives.

Provide Alternative Storage Regulation Systemwide. In addition to possible storage and transfer of water to moderate or prevent flood peaks, existing regulations and procedures to manage potential flood conditions could be reviewed. This review would include evaluating possible approaches for controlling potential flood peaks at each facility. Existing management of storage or releases is patterned in response to existing and forecasted conditions and operating procedures. If new operations are considered for achieving System Flood Control Review objectives (e.g., upgrading levees to accommodate higher flood peaks), existing storage regulation might be revised to allow more late-winter storage during average to below-average flow years.

Other Structural Measures. A wide variety of structural measures might be used to meet System Flood Control Review objectives. For example, increasing the storage of existing reservoirs (i.e., through increased dam height) could be another structural measure for managing flood conditions. Similarly, dredging in certain areas might increase storage or flow capacity. Utilization of irrigation canals during flood conditions to temporarily relieve peak flood conditions might also be another measure.

Other Non-Structural Measures. A wide variety of additional measures that do not require changes in physical structures might also be used to meet System Flood Control Review objectives. Examples of evaluations that might lead to non-structural measures include redefining acceptable levels of flood control or re-evaluation of run-of-river projects for potential additional flood control management capabilities (over existing operations).

6.2.2 Initial Evaluation of Potential Measures

An initial review of the potential measures identified above was conducted to determine whether the specific measure can meet each of the four project objectives (Section 2.3). In addition, the above measures have been evaluated on the probable effect they might have on the resources. This information is summarized in Table 12.

6.3 Alternative Plan

Each of the measures identified in Section 5.2 could potentially be implemented independently or in combination with each other. The objective of this reconnaissance-level study was to formulate at least one alternative plan that has a Federal interest and warrants further study. Some of the measures presented at the workshop are not included directly in the final alternative plan developed for this review. This does not, however, necessarily eliminate them from future consideration in the feasibility study. In addition, the evaluation of system flood control measures is an ongoing process (i.e., even though this report provides a current description for the System Flood Control Study, meetings with various Federal, state, local and Tribal entities are ongoing and may affect the selected alternative plan recommended in this feasibility study).

Table 13. Effects of Potential Measures on Resources and Meeting Project Objectives

	Measures								
	Land and Water Purchase	New Storage Dams	Levee Modifications	Transfer Storage	Improve Forecasts Systemwide	Improve Operational Efficiency	Alternative Storage Regulation	Other Structural Measures	Other Non-Structural Measures
OBJECTIVES									
Meet Spring & Summer Flow Objectives during Average to Below-Average Runoff Years	X	X		X	X		X	X	X
Minimize Flow Fluctuations during Fall Chinook Salmon Emergence and Rearing		X		X			X		
Achieve High Probability of Refill							X		
Provide Acceptable Levels of Protection for Developed Areas	X	X	X	X			X		X
RESOURCES									
Air Quality	○	○	○	○	○	○	○	○	○
Water Resources	○	■	○	○	○	◆	◆	○	◆
Terrestrial Resources	○	■	○	○	○	○	○	○	○
Aquatic Resources (other than anadromous	◆○	■	○	◆	◆○	○	◆	○■	◆
Cultural Resources	○	■	○■	○	○	○	○	○■	○
Transportation	○	○	○	○	○	○	○	○	○
Hydropower	○	○	○	◆	◆	◆	○	◆○	○
Water Supply	○	○	○	○	◆	○	○	○	○
Land Ownership and Use	■	■	○■	○	○	○	○	○	○
Recreation	◆	○	○	○	◆	○	◆	○	○
Social Resources	○■	○■	○	○	○	○	○	○	◆
Aesthetics	○	■	○	○	○	○	○■	○	◆

- ◆ Positive Effect
- ◆○
- ○ Minimal or No Effect
- ○■
- ■ Negative Effect
- X Can Meet Objective

Some of the measures would require cooperation and interaction with private utilities, other agencies, and Canada for evaluation and implementation. This is briefly discussed in the following preliminary evaluation of the alternative plan. The major components of the alternative recommended for detailed analysis in the feasibility study are identified and discussed in the following subsections. Individual measures may or may not apply to all subbasins.

Following consideration of the potential candidate measures (see Section 5.2), one alternative plan that demonstrates a Federal interest was identified. This plan contains four measures:

1. Improve the use and reliability of seasonal volume forecasts systemwide.
2. Change systemwide storage regulation to manage for more storage/flows and flood control.
3. Update capabilities of existing Federal levees and upgrade as needed to meet new flows.
4. Re-define acceptable levels of damage reduction.

These components are discussed in turn in the following subsections. The following descriptions outline the background of each measure, studies that will need to be conducted, and proposed implement able measures.

6.3.1 Improve the Use and Reliability of Weather and Runoff Forecasts Systemwide

Managing the Columbia River Basin to provide maximum benefits requires a detailed understanding of weather forecasts and water conditions. Numerous organizations are involved in a coordinated effort to collect and analyze the information that is used to develop forecasts for managing the hydro system in the Columbia River Basin. Key organizations include:

- Corps
- USBR
- BPA
- British Columbia Hydro and Power Authority
- National Weather Service's Northwest River Forecast Center
- U.S. Geological Survey
- Natural Resources Conservation Service (formerly U.S. Soil Conservation Service)
- Columbia River Water Management Group
- Northwest Power Pool.

The Corps and USBR are primarily responsible for the operation and other non-power uses at their projects. BPA schedules and dispatches the power from the Federal dams. Public and private utilities manage the operation of their facilities (e.g., Grant County PUD, Chelan County PUD, Douglas County PUD, Idaho Power, PPL Montana, and others that operate major hydro facilities in the Columbia River Basin).

Planning for operation of the Columbia River system is conducted through the Pacific Northwest Coordination Agreement, which encompasses Federal agencies, investor-owned companies, municipalities, public utility districts, and private companies involved in the coordination of multiple-use system requirements. This agreement establishes the day-to-day power operations. Coordination of operations with Canadian projects is primarily conducted under the Columbia River Treaty.

The operation of the Columbia River system is highly complex and has developed in detail over many years. As such, there may be areas within the forecasting process that could be evaluated to determine if improvement in their predictive capabilities could be made. Several specific areas of this alternative component that should be evaluated in the feasibility study are noted as follows. While most apply to all subbasins, some are subbasin specific (see Appendix A).

- Re-evaluate SRDs and models.
- Develop new and improved volume forecasts for each reservoir, paying particular attention to improving forecast accuracy in low-water years.
- Use technology to upgrade models used to forecast flows.
- Consider benefits of adding more SNOTEL sites in the upper Columbia River (Canada) to improve water supply forecasting.
- Consider benefits of operating at 70 percent exceedance (exceedance equates to the likelihood of being at or higher than a certain elevation for a given period of time) during below-average water years.
- Seek improvements in forecasting technology and data collection, so that flood control operations will yield expected results with greater reliability.
- Use improvements in forecasting to set flood control targets bi-monthly during evacuation period.
- Develop SRDs that show the 30 percent, 50 percent, and 70 percent exceedance forecasts to allow evaluation of more options, particularly in average to below-average water years.

6.3.2 Provide Alternative Storage Regulation Systemwide

The major Federal storage projects in the Columbia River Basin are Libby, Hungry Horse, Grand Coulee, Albeni Falls, and Dworshak (see Figure 3). In addition, three major Canadian dams (Mica, Keenleyside, and Duncan) have large storage reservoirs. Combined, these eight dams have a relatively large capacity to control flow events and augment downstream flows. Other dams in the basin have limited capabilities for flood control or are run-of-river dams. NOAA Fisheries (2004) reference operation analysis proposed operating the storage reservoirs predominately as run-of-river projects once the reservoir meets full pool in the spring. An extreme scenario such as this would have flood control consequences, whereas other alternative storage regulation scenarios based upon risk analyses may have minor consequences to the Corps ability to provide adequate flood control.

The dispersal of the large storage facilities in the basin currently allows for exchanges of power and water through adjustment of releases (e.g., optimizing releases to moderate or prevent flood damages to local areas). In addition, water can be stored for later use in augmenting flows for both resident and anadromous fish, supporting recreation activities, providing wildlife and wetland habitat, supplying irrigation water, and numerous other uses.

Under current operating procedures, systemwide adjustments are made in storage to accommodate, to the extent possible, the many uses and requirements in the system. Although compliance with key regulatory requirements (such as biological opinion requirements and power production needs) carry a high priority, control or avoidance of potentially damaging floods has an even higher priority. Runoff patterns and flow releases at the major storage dams are managed during the heavy spring and summer snowmelt and during large rainfall events in the winter to moderate or prevent flood damage.

The storage and release at one reservoir is often influenced by what occurs at other reservoirs, both locally and in other parts of the system. For example, the flow released from Grand Coulee in the summer is partly influenced by the flows coming down the Snake River during this same period (which, in turn, are influenced by storage reservoir (e.g., Dworshak) releases in the Snake River system). Also, water released from upper Columbia River reservoirs in the United States is influenced by releases from Canadian reservoirs on this system. Often times what is known as "storage exchange" occurs, where Canada (British Columbia) may release flows at the request of the U.S., with the U.S. releasing more flow later to compensate for earlier Canadian releases. The overall efficiency of this approach relative to the desire for providing higher downstream flows at specific times for anadromous fish will be analyzed in the feasibility study.

Key measures that will be evaluated for alternative selection include:

- Consider storage transfers including:
    1. Libby and Hungry Horse swap.
    2. Systemwide swaps.
    3. Lower Granite and John Day transfer.
    4. Lower Granite and John Day emergency storage in low-water years.
    5. Agreement to purchase additional Canadian storage.
    6. Provide summer flow augmentation from projects other than Hungry Horse, if Hungry Horse is overdrafted in the summer and does not refill in the following year.
    7. Modify IJC to have Duncan (BC reservoir) add more flow to Kootenay Lake by lowering flood control storage requirements (which increases the chance of trapping storage for high flows from April to August).
    8. Transfer storage between Dworshak and Grand Coulee or Brownlee.
- Modify Canadian treaty storage agreements to increase flexibility in flood control.
- Incorporate existing non-Federal dams into overall operational changes to provide additional spring freshet flows.
- Implement new rule curves for Dworshak.
- Implement new flood control requirements in low-water years (VARQ).
- Balance requirements for fish, power, and flood control during average to below-average water years.
- Implement new rule curves for Jackson, Palisades to Boise, and the remainder of the Snake River System to Brownlee to provide more flow in low-water years by reshaping flow as done under VARQ.

6.3.3 Modify Existing Levees to Increase Flood Damage Reduction Potential.

Storage in large reservoirs has successfully contributed to prevention of damage during flood conditions. However, in certain areas, additional structures have been built to provide needed protection. These structures include levees, floodwalls (e.g., the concrete seawall along the Willamette River in downtown Portland), and bank protection (e.g., revetments, vegetation, and other protective devices).

Levees are a major component of the flood control systems, with their size, location, and conditions influencing the amount of flow that is considered safe to pass down the channel without causing unacceptable flood damage. In some cases, adding height to the levees in certain areas may allow higher flows to occur because the risk of damage would be reduced. Adding more levees in key flood damage areas may provide assurance that greater spring storage could occur. Key locations include:

- Bonners Ferry in Idaho, which would allow greater flexibility of operation at Libby Dam.

- Kootenay River (reducing flood control needs at Libby) and at Cusick (reducing flood control needs at Hungry Horse and Albeni Falls).
- Kalispell in Montana (reducing flood control needs at Hungry Horse).
- Flathead River between Columbia Falls and Flathead Lake (reducing flood control needs at Hungry Horse).
- Lewiston, Idaho to allow increased flows from the upper Snake and Clearwater rivers.
- Idaho Falls (Idaho), Burley (Idaho), and Ontario (Oregon).
- Lower Columbia River development areas to allow for greater flow.
- Lower Columbia River not associated with developed areas to allow restoration and attenuate peak flood elevations.

Key measures that will be evaluated and proposed include:

- Increase levee monitoring during spring freshet flows along the lower Columbia River.
- Upgrade existing flood control structures to provide the authorized protection as needed .

In order to evaluate the existing levee The flood control system is not designed to prevent all flooding, but is intended to manage the risk of damaging flooding. Determine current level of risk and then reconsider both the level of risk (i.e., chance that a certain level of flooding would occur) and what is considered acceptable damage (e.g., flooded farm fields may be acceptable, flooded cities may not be acceptable). Acceptable risk and acceptable damage are two parameters critical in determining how flood control reservoirs are operated. Levels of flood control are based on factors such as system hydrology, available storage, key flood areas, and the status of levees or other control structures.

While other alternative components above (5.3.1 through 5.3.3) are directed at modifying system conditions, this component could result in changes in storage by re-defining what is considered acceptable. For example, if greater risk is considered acceptable, less reservoir storage may be needed during some years in the spring because there would be a reduced need to protect against higher downstream flows from high rain or snow runoff events. Therefore, a re-evaluation of acceptable flood protection may provide benefits to downstream flow needs without actually changing any physical conditions in the system.

Key measures that will be evaluated and proposed include:

- Determine current level of risk and update the level of protection provided by the flood control systems as needed.

6.4 Preliminary Evaluation of Alternative Components

The following provides a preliminary evaluation each of the alternative components discussed in the preceding section.

6.4.1 Improve the Use and Reliability of Weather and Runoff Forecasts Systemwide

A wide array of monitoring instruments, computer programs, and plans are used by a variety of cooperating entities (see Section 5.3.1.) to forecast (both short- and long-term) weather conditions and monitor or control river flows in the Columbia River Basin. However, with the rapid technological advancements in monitoring instruments and remote-sensing capabilities that continue to occur, the potential to improve these capabilities exists. An expanded network could provide more detailed information, monitoring data, and reliability. This would assist in reducing the forecast error and narrowing the changes in river flows while shortening the time frame for making predictions.

The extent of any upgrades and improvements in the data collection or forecasting efforts will need to be evaluated in the feasibility report to determine the need, data gaps, potential improvements, and budget constraints. This would be a systemwide review that would examine the existing monitoring and forecasting capabilities, identify potential upgrades, and evaluate the incremental costs of new system upgrades.

From an environmental perspective, the placement of additional monitoring or forecasting equipment would only result in local disturbances (e.g., placement of an additional weather station would only result in localized impacts). However, the ability to provide more detailed and reliable information and forecasts would assist in meeting the UPA flow objectives (Table 2). This would be a potential benefit to outmigrating juvenile salmonids.

Any improvements in the forecasting system could also help to enhance control of potential flood conditions. This information could decrease the need for additional structures such as new or upgraded levees (i.e., the flood peaks may be better controlled based on upgraded monitoring or forecasting capabilities) and for storage transfers (see below). In addition, upgrades could help to more reliably meet existing regulatory requirements such as flow needed for resident fish (e.g., Kootenai River white sturgeon and bull trout), reservoir refill targets, water quality (e.g., TDG concentrations), navigation, recreation, irrigation and other water supply needs, and power production. This measure by itself will not meet the objectives of the study. This measure could provide improved forecasting abilities, when combined with other measures could allow for flow conditions that meet the study objectives.

6.4.2 Provide Alternative Storage Regulation Systemwide

An objective of the Feasibility Study is to analyze options to existing flood control operations during average to below-average flow years. This could involve higher levels of reservoir storage than previously have been considered or evaluated in detail. It could also involve adjustments to storage between or among projects. Therefore, the feasibility study will need to identify potential alternatives for storage systemwide that could be used to increase reservoir levels during average to below-average water years. The potential effects that these increases and storage alternatives would have on flood control capabilities would also need to be evaluated.

Changes in regulation of storage could result in environmental effects in a number of different ways. For example, changes can affect reservoir fish and water quality, recreation use, downstream fish resources, wildlife, vegetation, water supply, navigation, and other uses. All of these potential effects would need to be evaluated in the feasibility study to identify any cumulative effects that might occur systemwide and on each project. If alternate storage can be achieved systemwide and System Flood Control Review objectives implemented, this could be a benefit to outmigrating juvenile salmonids.

6.4.3 Modify Existing Levees for Increased Flood Damage Reduction Potential.

The existing levee systems need to be evaluated to determine if structural changes (raising, strengthening, etc) would increase local flood damage reduction potential, and result in reservoirs having increased operational flexibility. This will require a full review of the existing levee systems and structures, damage areas, and a consideration of the environmental and socio-economic/cultural impacts of structural modifications. A trade off analysis between reservoir storage and localized flood control structures will be required, incorporating risk factors.

In some areas, levees constrict the historic channel and decrease the capabilities of the former floodplain to temporarily store or decrease the flow of floodwaters. Under these conditions, it may be beneficial to remove or reconfigure the levee to allow expansion of the floodplain, which would decrease the potential flood peak. This could result in new areas for habitat (e.g., wetlands, riparian zones, and side channels), but could also result in removal of areas from current uses (e.g., urban and industrial development). In the feasibility study, the implications of a range of different measures involving the levees and other flood control structures will need to be evaluated for potential environmental impacts and other benefits and costs.

The importance of this measure is to support flood damage reduction by offsetting changes in protection caused by changes in flow and storage within the basin. By itself, this measure will not meet the objectives of the System Flood Control Review, if changes to current operations exceed acceptable levels of protection.

7. Federal Interest

The preliminary assessment presented in this document indicates there is an alternative plan that can provide acceptable levels of flood control and the desired fisheries benefits, is environmentally acceptable, is supported by elements of the Pacific Northwest region, and would be consistent with Corps policies. The plan meets the Corps' Environmental Operating Principles by helping to sustain a number of threatened and endangered fish species and their habitat, balancing flood control and other system uses with fundamental natural processes, and providing prudent use of seasonally limited instream flows in consideration of cumulative impacts and benefits of alternative uses. The plan will help protect fish species of national importance, and will increase fish passage and survival in the Columbia River system. The evaluation of the alternative plan will involve collaboration between Canadian, Federal, local, and private reservoir operators; Federal and local resource agencies; Indian tribes; and local stakeholders, including agricultural, recreation, and commercial interests. This alternative plan includes the following components:

1. Improve the use and reliability of seasonal volume forecasts systemwide.
2. Change systemwide storage regulation to manage for more storage/flows and flood control.
3. Modify existing levees and other structural systems to increase flood damage reduction potential.

Improving the use and reliability of forecasts systemwide would potentially benefit outmigrating juvenile salmonids and could also help enhance control of potential flood conditions. In addition, upgrades could help the Corps more reliably meet existing objectives such as flow needed for resident fish; reservoir refill targets; water quality; navigation; recreation; irrigation and other water supply needs; and power production.

Changes in systemwide storage regulation could have a number of potential environmental, social, and economic effects, including effects to reservoir fish and water quality, recreation use, downstream fish resources, wildlife, vegetation, water supply, navigation, and other uses. Changes to Federal levees could result in a wide range of environmental effects that would need to be evaluated in the feasibility study. Levee removal or reconfiguration could, for example, result in new areas for habitat (e.g., wetlands, riparian zones, and side-channels), but could also result in removal of areas from current uses (e.g., urban and industrial development).

The Corps has an appropriate role in conducting this evaluation. This determination is based on the responsibilities that the Corps and other Federal agencies have in the operation of the FCRPS, including flood control. It is also based on the need to ensure that this system meets requirements of the ESA and the NMFS 2004 and USFWS 2000 Biological Opinions.

8. Preliminary Financial Analysis

In accordance with the Planning Guidance Notebook (ER 1105-2-100), a reconnaissance-level evaluation typically includes identification of a non-Federal entity willing to serve as a non-Federal sponsor and enter into a cost-sharing agreement for feasibility studies. However, a non-Federal sponsor is not being identified in this case because this evaluation involves investigation of Columbia River flood control operations, which is a Federal responsibility, and the identification of alternative measures to reduce the impacts of these operations on ESA-listed fish species. The responsibility for system operations and compliance with the ESA belong to the Federal government. This reconnaissance-level report is being developed in response to continuing consultation with NMFS, including the NMFS 2004 Biological Opinion for the FCRPS. If feasibility studies are pursued as a result of this evaluation, these studies will be 100 percent Federally funded.

The Columbia River Fish Mitigation Project allows for the study and implementation of measures, which will offset passage impacts to fish caused by the FCRPS operating projects. Use of the CRFM Project to study large system issues has been done in the past and Congress included language in the 2003 Appropriations to initiate the reconnaissance level study under CRFM. In addition, the CRFM Program would allow the feasibility level study to begin in Fiscal Year 2007, subject to regional support, agency review, and Congressional notification.

9. Summary of Feasibility Assumptions

From the baseline work that has been accomplished to date, some feasibility study assumptions can be made and are as follows:

- The Project Management Plan (PMP) will be developed to identify the specific studies and issues for the feasibility study.
- The initiation of the feasibility study will be dependent upon favorable agency review and Congressional notification.
- The Action Agencies' UPA has identified the flow objectives for fish. These objectives have been used by NMFS in their analysis of the FCRPS operations and in determination of non-jeopardy survival and population production indices (replacement rates) for satisfying recovery.
- Alternatives formulated in the feasibility study will involve some change in reservoir regulations. Some alternatives may identify potential changes to Canadian storage regulations.
- The base case and all alternatives will be evaluated with analysis of climate change corrections. This will be discussed further in the PMP.
- All authorized project uses will be fully considered when formulating alternatives.
- Development in the Columbia River Basin in previously developed damage areas has changed enough to warrant development of new flood control damage curves.
- There are potential structural or operational modifications that can be made either at operating facilities or elsewhere in the Columbia River Basin to offset some, if not all, of the increased flood risk that could be identified.
- Acceptable levels of flood control risk may be re-defined.
- A non-Federal sponsor will not be identified to help cover the costs of conducting a feasibility study.

- Funding for conducting a feasibility study will be 100% Federal through CRFM which is funding shared among the system purposes of hydropower, flood control, navigation, etc. The portion allocated to hydropower would be reimbursed by BPA to the U.S. Treasury. Current hydropower allocation percent has averaged about 80%, but final allocation will be determined at completion of the feasibility study.
- The proposed work is compatible with other ongoing efforts by Federal, state, and local agencies, as well as other Corps operational purposes, to include actions taken into consideration by NMFS in the 2004 Biological Opinion for the FCRPS.
- The feasibility study will be conducted in accordance with Principles and Guidelines and Corps' regulations and policies.
- The feasibility document will be a combined Feasibility Report and EIS.
- Other feasibility study assumptions will be outlined in the PMP.

These assumptions will be reviewed during the actual feasibility phase.

10. Tentative Feasibility Phase Milestones

During the average to below-average years, the demand for available water by all users is increased because the amount and timing does not meet with the users' need. Therefore, the scope of the feasibility study will be developed around the ability to successfully screen through a large set of storage and release options without over committing financial resources on actions that will not meet the needs of the objectives. A four-phased approach is recommended in the feasibility study. This phased approach will allow the Corps and the region to make decisions at the end of each phase on whether to continue, revise or terminate the study. Each phase will be focused to address specific questions. The following provides a conceptual overview of the process. Key criteria and specific tasks will be further identified and refined during the development of the PMP.

Phase I

The focus of Phase I will be: Is there water available to achieve environmental benefits needed for the fisheries? How much water is available and is it enough to achieve the benefits needed for fish?

This phase will consist of conducting hydrological evaluations, limited economical evaluations and engineering evaluations, scoping of future economic and engineering evaluations, and limited environmental studies. The phase will also include development of the environmental hydrograph with input from the region. In addition there will be activities that will be conducted throughout all study phases, such as, plan formulation project management, independent technical review of models and technical product and public involvement. The following provides additional information for this phase:

- Categorize the majority of Columbia Basin operational storage and release options in such a manner that groups of options can be screened, narrowing the range of alternatives needed for further study.
- A set of screening criteria need to be defined, likely based on fish flow objectives (Table 2) overlaid on average to below-average flow years.
- Develop environmental flows working with a regional group of experts representing fish passage. Benefits need to be linked to screened groups of operational storage and release alternatives.

- Identify the best methodology for economic assessment of baseline damages brought to the current timeline. This methodology will be used in the subsequent phase for comparing flow outputs for various screened alternatives against the baseline damage curves.
- Conduct limited environmental studies that will need to be performed; majority of these studies would be formulated based on work that has already been conducted.
- Better define the goals and objectives for the subsequent phase.
- Revise the PMP based on the knowledge gained in this phase.
- Complete Phase 1 Report
- Independent Technical Review of Phase I Report
- Public/Agency Review
- Submittal to MSC for approval of Phase 1 Report.

Phase II

The focus of Phase II will be: Do the environmental benefits justify the costs associated with changes to the flood control system?

In this phase further hydrology and hydraulic modeling will be conducted in combination with economic and engineering studies. Environmental studies will continue to better refine the environmental benefits while the effects to the flood control system are investigated. Limited cost estimates will be conducted to determine the costs for the benefits that could be achieved with the different alternatives. Fish and wildlife coordination will be initiated. The following provides additional information for this phase:

- Phase II would be based on the results of Phase I evaluations. Review the environmental benefits and further formulate environmental studies.
- Conduct preliminary evaluations which will help to identify necessary economic and engineering studies.
- Perform hydrologic and hydraulic modeling to evaluate the range of alternatives from Phase I that were not screened out.
- Conduct economic surveys of high risk areas to determine the damage curves for those areas. Determine impacts to the flood control structures with the hydrographs developed in Phase I.
- Conduct surveys of the existing flood control structures, such as levees, floodwalls, and other flood control structures to reevaluate the protection that would be provided with the new hydrographs developed in Phase I.
- Prepare a qualitative assessment of what the impact to the flood control system, i.e. cost of implementation, increase in risk of failure, etc., in order to conduct a limited cost effectiveness –incremental cost analysis evaluation.
- Complete Phase II Report
- Independent Technical Review of Phase II Report
- Public/Agency Review
- Submittal to MSC for approval of Phase II Report.

Phase III

The focus of Phase III will be: Are there environmental benefits that can be achieved with low investment and low risk of failure to the flood control system? What early action changes or measures can be recommended?

In this phase the focus will be to prepare an interim feasibility report. The activities associated with this phase include continued hydrology and hydraulic modeling, economic analysis, environmental studies and evaluations, development of alternative plans, along with engineering evaluations and design, real estate coordination that is required, fish and wildlife coordination, HTRW evaluation and cultural resource coordination. The following provides additional information for this phase:

- Conduct additional environmental studies to determine the larger Biological Effects.
- Continue hydrologic and hydraulic modeling to characterize the impacts associated with changes to the existing flood control system.
- Prepare an Interim feasibility report that would recommend changes to the operation of flood control system with limited changes to the existing flood control system.
- Complete Phase II Report
- Independent Technical Review of Phase II Report
- Public/Agency Review
- Submittal to MSC for approval of Phase II Report.

Phase IV

The focus of Phase IV will be to complete a final feasibility report on an alternative that will provide the environmental benefits and require changes to the flood control system.

All studies will be completed in order to develop the final feasibility report that will recommend changes to the flood control system to benefit fish. This includes finalization of hydraulic modeling, economic studies, final engineering design and cost estimates, fish and wildlife coordination, HTRW evaluation, and final cultural resource coordination. The following provides additional information for this phase:

- Prepare a final feasibility report, based on studies conducted in previous phases and additional studies needed to justify implementation of changes to the flood control structures in the system in order to achieve the flow requirements required for environmental benefits.
- Prepare NEPA documentation
- Independent Technical Review of Feasibility Report/NEPA Documents
- MSC Review
- Public/Agency Review/Revisions
- Submittal of final Feasibility Report/NEPA documentation to MSC/HQ.

The tentative milestones for the feasibility study are summarized in Table 14.

Table 14. Feasibility Phase Milestones - Tentative

Description	Target Date
Submit Reconnaissance Report to HQ	June 2006
Complete Project Management Plan	February 2007
Initiate Feasibility Study	February 2007
Public Workshops/Scoping Meetings	April 2007
Prepare Phase I Report	March 2008
Initiate Phase II	May 2008
Prepare Phase II Report	April 2009
Feasibility Scoping Meeting	September 2009
Prepare Interim Feasibility Report	April 2010
Alternative Formulation Briefing	June 2010
Submit Interim Feasibility Report/EIS Public and HQ Review	November 2010
Submit Final Interim FS/EIS to HQ USACE	April 2011
Prepare Draft Final Feasibility Report	June 2012
Alternative Formulation Briefing	September 2012
Draft Feasibility Report and EIS for Public Review	November 2012
DE Presentation	December 2012
Final Report Submittal Package to Corps Headquarters (HQUSACE)	April 2013
File Final EIS with Environmental Protection Agency	April 2013
Chief's Report to Assistant Secretary of the Army, Civil Works (ASA [CW])	June 2013
ASA (CW) Letter to Office of Management and Budget	July 2013

11. Feasibility Phase Cost Estimate

The feasibility phase cost estimate for this project is presented in Table 15. This cost estimate is preliminary, largely based on previous studies of similar scope and size. The estimate will be modified to reflect considerations specific to the scope through development of the PMP.

Table 15. Feasibility Phase Cost Estimate.

Description	Estimated Cost ($)			
	Phase I	Phase II	Phase III	Phase IV
Engineering Studies (Hydrology)	575,000	1,150,000	1,500,000	1,000,000
Socioeconomic Studies	500,000	1,800,000	2,500,000	3,000,000
Engineering Studies (Surveys/ structures)	220,000	770,000	1,020,000	520,000
Real Estate	0	0	20,000	480,000
Environmental Studies	875,000	2,200,000	1,000,000	1,000,000
Fish and Wildlife Coordination Act	0	20,000	100,000	200,000
Hazardous, Toxic, or Radioactive Waste (HTRW) Studies	0	0	20,000	30,000
Cultural Resources	0	0	100,000	150,000
Cost Estimating	0	35,000	25,000	275,000
Public Involvement	275,000	375,000	475,000	700,000
Plan Formulation	100,000	300,000	485,000	925,000
Interim Feasibility Report			1,000,000	
Draft Report	-	0	0	1,000,000
Final Report	-	0	0	600,000
Project Management	200,000	400,000	625,000	775,000
ITR	50,000	100,000	347,500	972,500
Contingency (10 percent)	279,500	715,000	921,750	1,162,750
SUBTOTAL:	**3,074,500**	**7,865,000**	**10,139,250**	**8,270,250**
TOTAL FEASIBILTY STUDY COST:				**29,349,000**

12. Recommendations

The preliminary assessment presented in this document identifies a series of proposed measures to meet the UPA flow objectives (Table 2). The identified planning measures and objectives are in the Federal interest, consistent with the Corps' Environmental Operating Principles, in accord with Administration policy and budgetary priorities, and are generally supported by the Pacific Northwest region. It is recommended that the Columbia River Fish Mitigation System Flood Control Review Project proceed to feasibility stage. It is also recommended that the feasibility stage be 100 percent Federally funded, since the scope of the study outlines responsibilities that belong to the Federal government.

13. Potential Issues Affecting Initiation of Feasibility Phase

Initiation of the feasibility phase could proceed in Fiscal Year 2007 given the ability to reprioritize appropriated CRFM funds. It would be necessary to obtain added appropriated dollars in subsequent years in order to further the feasibility phase and the other required salmon projects being funded from CRFM.

14. Views of Other Resource Agencies

Meetings have been held with representatives from the USBR, the Columbia River Intertribal Fish Commission (CRITFC), Idaho Rivers, Idaho Department of Fish and Game, Idaho Department of Water Quality, Governor of Idaho's Office, and Senator Michael Crapo's Boise Office. In addition, a presentation was made at the Regional Flood Control Workshop sponsored by CRITFC. The workshop was well attended with representatives from some of the previously mentioned agencies, as well as representatives from Representative David Wu's Office, US Fish and Wildlife Service, Warm Springs Tribe, Nez Perce Tribe, Yakama Tribe, U.S. Bureau of Indian Affairs, Federal Emergency Management Agency, Natural Resource Conservation Service, BC Hydro, along with numerous local governments and Non-Government Organizations. In all, there is strong support for what is being proposed.

It is anticipated that meetings and discussions with many of the above listed entities will continue while this report is being reviewed and during the feasibility study. This System Flood Control Review is considered, by the Action Agencies, as an ongoing and interactive process designed to meet this review's study objectives (see Section 2.3)

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APPENDIX A

ALTERNATIVE COMPONENTS: CATEGORIES AND MEASURES

NOTE: The list of measures is not intended to be inclusive. The reader should be aware these measures came out of a Formulation Workshop held to scope this Reconnaissance Study. If this project moves into feasibility, then additional scoping will occur and more measures will likely be generated for consideration.

Table A-1. Subbasin A—Columbia River Upstream of Priest Rapids Dam

Land and Water Purchase	
Measure 1	Purchase irrigation water – consider Columbia Basin project.
Other Non-Structural	
Measure 1	Buy flowage easement or fee at Bonners Ferry.
Measure 2	Improve operating efficiency by involving the Reservoir Control Center (RCC) in a brainstorming workshop and as a “reality check” for other alternatives being considered.
Levees	
Measure 1	Improve levees at Bonners Ferry (allows greater flexibility of operation at Libby).
Measure 2	Set back levees at Kootenay River (to reduce need for flood control storage at Libby).
Measure 3	Improve levees protecting Kalispell (to reduce need for flood control storage at Hungry Horse).
Measure 4	Modify levees on the Flathead River (to reduce need for flood control storage at Hungry Horse).
New Storage Dams	
Measure 1	Undertake structural modifications to add new storage to Canadian headwater projects.
Transfer Storage	
Measure 1	Have Libby and Hungry Horse swap storage.
Measure 2	Investigate all system storage measures.
Measure 3	Implement Lower Granite and John Day transfer storage measures.
Measure 4	Develop operational agreement to purchase additional Canadian storage.
Measure 5	Provide water from other storage projects in years when Hungry Horse is overdrafted at end of summer, which leads to no refill in subsequent years.
Measure 6	Through the International Joint Commission, have Duncan contribute greater share of Kootenay Lake lowering formula (increases likelihood of trapped storage and high flows in April through August).
Measure 7	Develop operational agreement to purchase additional Canadian storage.

Table A-1. Subbasin A—Columbia River Upstream of Priest Rapids Dam (Con't)

Alternative Storage Regulation	
Measure 1	Modify treaty storage to increase flood control.
Measure 2	Incorporate existing non-Federal dams in overall operational changes to provide additional spring freshet flows.
Measure 3	Develop new rule curves for flood control requirement in a low-water year (VARQ).
Measure 4	Request the Reservoir Control Center to balance requirements for fish, power, flood control during average to below-average flow years.
Improve Forecasts	
Measure 1	Re-evaluate SRDs (Storage Reservation Diagrams - modeling study) to improve forecasts.
Measure 2	Develop new and improved forecasts, especially for low-water years.
Measure 3	Use current technology to upgrade models used to forecast.
Measure 4	Add more sno-tel sites in the Upper Columbia Basin (Canada) to improve water supply forecasting.
Measure 5	In a low-water year, operate to the 70 percent exceedance to ensure more refill.
Measure 6	Allow more flexibility in flood control operations by seeking improvements in forecasting technology – data collection.
Measure 7	Re-evaluate flow control objectives bi-monthly or more frequently.
Measure 8	Re-evaluate simulation model for real-time flood forecasting (or even a custom model).
Measure 9	Consider operating at 70 percent exceedance level during low-water years.
Measure 10	Use multiple curves for different annual conditions – low-water year vs. high-water year.
Improve Operational Efficiency	
Measure 1	Reduce the target December 31 draft using early forecasts.
Measure 2	Include reservoir control system staff in the discussion process for any average to below-average flow years.
Measure 3	Draft to December 31 flood control targets to maximize fall chinook benefits.

Table A-2. Subbasin B — Snake River Upstream of Hells Canyon Dam

Land and Water Purchase	
Measure 1	Purchase irrigation water; consider Columbia Basin project.
Other Non-Structural	
Measure 1	Buy out flood easements in Idaho Falls, Burley, and Ontario.
Measure 2	Flood-proof Idaho Falls, Burley, and Ontario.
Levees	
Measure 1	Build levees in Idaho Falls, Burley, and Ontario.
New Storage Dams	
Measure 1	Provide new storage for fish, high flow storage in Galloway Reservoir, Twin Springs, Teton Dam.
Transfer Storage	
Measure 1	Investigate all system storage measures.
Alternative Storage Regulation	
Measure 1	Incorporate existing non-Federal dams in overall operational changes to provide additional spring freshet flows.
Measure 2	Develop new rule curves for Jackson, Palisades to Boise, remainder of Snake River System to Brownlee; reshape curves for more water in low-water years (like VARQ).
Improve Forecasts	
Measure 1	Allow more flexibility in flood control operation by seeking improvements in forecasting technology – data collection.
Measure 2	Develop new and improved forecasts, especially for low-water years.
Measure 3	Re-evaluate SRDs (Storage Reservation Diagrams - modeling study) to improve forecasts.
Measure 4	Re-evaluate flow control objectives bi-monthly or more frequently.
Measure 5	Re-evaluate simulation model for real-time flood forecasting (or even a custom model).
Measure 6	Consider operating at 70 percent exceedance level during low-water years.
Measure 7	Develop multiple curves for different annual conditions – low-water year vs. high-water year.
Improve Operational Efficiency	
Measure 1	Re-evaluate initial control flow calculation (triggers start of refill).
Other Structural	
Measure 1	Use variable basin outlet at Brownlee for temperature control.
Measure 2	Deepen Federal reservoirs (to add storage).
Measure 3	Provide alternate power sources to handle power emergencies without trading power for fish flows in power emergencies.

Table A-3. Subbasin C—Clearwater River/Snake River, Upstream of Ice Harbor Dam

Transfer Storage	
Measure 1	Transfer storage between Dworshak and Grand Coulee or Brownlee.
Measure 2	Lower Granite Dam and John Day Dam emergency storage in lower water years.
Measure 3	Investigate all system storage measures.
Alternative Storage Regulation	
Measure 1	Develop new rule curve for Dworshak (like VARQ).
Improve Forecasts	
Measure 1	Allow more flexibility in flood control operation by seeking improvements in forecasting technology – data collection.
Measure 2	Develop new and improved forecasts, especially for low-water years.
Measure 3	Re-evaluate SRDs (Storage Reservation Diagrams - modeling study) to improve forecasts.
Measure 4	Re-evaluate flow control objectives bi-monthly or more frequently.
Measure 5	Re-evaluate simulation model for real-time flood forecasting (or even a custom model).
Measure 6	Consider operating at 70 percent exceedance level during low-water years.
Measure 7	Develop multiple curves for different annual conditions – low-water year vs. high-water years.
Improve Operational Efficiency	
Measure 1	Re-evaluate initial control flow calculation (triggers start of refill).
Other Structural	
Measure 1	Dredge the confluence for added storage at Federal reservoirs.
Measure 2	Increase the capacity (raising the dam, increasing the draft.).
Measure 3	Modify channels downstream of Dworshak Dam to meet summer flows by raising the dam (adds flow capacity).
Measure 4	Improve flow from Dworshak intake (to avoid total dissolved gas problem).
Measure 5	Modify channels downstream of Dworshak (increase flow capacity). Increase storage at Dworshak to meet summer flows by raising the dam.
Measure 6	Deepen Federal reservoirs (to add storage).
Measure 7	Improve flow from Dworshak intake to improve TDG constraint.
Measure 8	Provide alternate power sources to handle power emergencies without trading power for fish flows in power emergencies.
Channel Modification	
Measure 1	Remove in-channel dredge spoils (lower Columbia River) and existing pile dikes, increasing channel capacity.

Table A-4. Subbasin D—Lower Columbia River, Downstream of Upper End of McNary Pool

Levees	
Measure 1	Improve levees in (Lower Columbia) developed areas to allow for greater flows.
Measure 2	Remove some levees in the Lower Columbia that are associated with undeveloped areas to allow for restoration and some additional storage.
Measure 3	Increase levee monitoring during spring freshet flows along lower Columbia levees using PL 84-99.
Transfer Storage	
Measure 1	Investigate all system storage measures.
Alternative Storage Regulation	
Measure 1	Modify John Day or other lower Columbia dam to provide spring freshet flows in low-water years.
Improve Forecasts	
Measure 1	Allow more flexibility in flood control operation by seeking improvements in forecasting technology – data collection.
Measure 2	Develop new and improved forecasts, especially for low-water years.
Measure 3	Re-evaluate SRDs (Storage Reservation Diagrams - modeling study) to improve forecasts.
Measure 4	Re-evaluate flow control objectives bi-monthly or more frequently.
Measure 5	Re-evaluate simulation model for real-time flood forecasting (or even a custom model).
Measure 6	Consider operating at 70 percent exceedence level during low-water years.
Measure 7	Develop multiple curves for different annual conditions – low-water year vs. high-water year.
Improve Operational Efficiency	
Measure 1	Re-evaluate initial control flow calculation (triggers start of refill).
Other Structural	
Measure 1	Deepen Federal reservoirs (to add storage).
Measure 2	Increase lower Columbia dam(s) capacity to provide additional spring freshet flows (by dredging or raising or more turbines).
Measure 3	Provide alternate power sources to handle power emergencies without trading power for fish flows in power emergencies.