File Copy

DOE/EIS-0163

# 1992 Columbia River Salmon Flow Measures Options Analysis (OA)/ Environmental Impact Statement (EIS)

Lead Agency:

Department of the Army
Walla Walla District
Corps of Engineers
Building 602
City-County Airport
Walla Walla, WA 99362-2965

For further information contact:

Greg Graham
Study Manager
Department of the Army
Walla Walla District, Corps of Engineers
Walla Walla, WA 99362-2965
(509) 522-6596

Comments must be received:

Within 15 days after publishing of the Notice of Availability of the OA/EIS in the Federal Register

Abstract:

Public comments are sought on this Final OA/EIS. The Corps of Engineers, with the Bonneville Power Administration and Bureau of Reclamation as cooperating agencies, analyzed four general alternatives to modify the flow of water in the lower Columbia-Snake River. The intent of these actions would be to help the juvenile and adult anadromous fish migrate past eight multi-purpose Federal dams. Themes for these alternatives are: (1) nc action, (2) drawing down lower Columbia-Snake River reservoirs, (3) augmenting river flow, and (4) combining drawdown and flow augmentation options. The preferred plan of action for 1992 consists of: (1) all 4 lower Snake River projects at MOP from April 1 to July 31, (2) Lower Granite/Little Goose drawdown test in March, (3) John Day at minimum irrigation pool (262.5') from May 1 through August 31, or until irrigation impacts are realized, (4) augment lower Snake River flow from Dworshak to meet target flow of 100 kcfs from April 15 to May 31, (5) augment lower Columbia River flow to meet target flow of 200 kcfs from May 1 to June 30, and (6) temperature control test on the lower Snake River at Dworshak in August, using releases from Dworshak.

ACOE/1-4-92/13:08/01634A

# ABSTRACT


In compliance with Federal and State regulations and authorities, the U.S. Army Corps of Engineers, in cooperation with the Bonneville Power Administration and the Bureau of Reclamation has prepared this Options Analysis/Environmental Impact Statement (OA/EIS) on the effects of operational changes at certain Federal multi-purpose water projects in the Columbia River Basin System. This OA/EIS considers several alternative water management actions that may be taken in 1992 at dam and reservoir projects along the lower Snake and Columbia rivers to improve juvenile and adult anadromous salmon migration conditions. This is partially in response to the December 20, 1991 listing of the Snake River sockeye salmon as endangered and the proposed listing of several other wild salmon stocks as endangered or threatened under the Endangered Species Act.

Options considered can be grouped into five general alternatives: (1) no action, (2) reservoir drawdown (including short-term tests), (3) flow augmentation, (4) combination of drawdown and flow augmentation, and (5) temperature control test. The action alternatives are designed to increase the velocity of the water, thereby presumably passing the young salmon downstream faster during the April to August migration.

A variety of drawdown proposals are offered for all or part of the April to August migration, ranging from drawing down the reservoirs to the minimum normal operating level to lowering the elevation of certain reservoirs to near the level of the overflow structure of the dam (spillway). The Corps has identified eight finite options that fall within these drawdown ranges and also meet operating considerations and flow velocity objectives. Six of the options apply to the lower Snake River projects, while two could be implemented at the lower Columbia River projects.

With flow augmentation, additional water would be released from storage reservoirs in the spring to increase the river flow during fish migration. Options considered vary with respect to the source of the water used to augment flows, the volume of storage to be released, and the timing of releases. Based on computer analyses of combinations of options that provide significant increases in flow velocities, three combinations have been identified as likely scenarios and are discussed in this OA/EIS.

The Snake River can be 4 to 5 degrees warmer than the Columbia River at the confluence in late August or early September, which may impede fall chinook migration and degrade fish health. A test release of cool water from Dworshak in August 1992 will be used to model projected effects of various release options.

The environmental impacts of the proposed actions considered in this OA/EIS include the effects of altering normal river operations on a number of resource areas. These areas are water quality, anadromous fish, resident fish, wildlife, soils, air quality, transportation, agriculture, power, recreation, aesthetics, cultural resources, socioeconomics, and dam safety.

The cooperating agencies have selected a preferred plan of action for 1992 that includes: (1) drafting all 4 lower Snake River projects to MOP from April 1 to July 31, (2) conducting a drawdown test of Lower Granite and Little Goose in March, (3) operating John Day Reservoir at 262.5 feet (the minimum pool at which irrigation pumps will function) from May 1 through August 31, or until irrigation impacts are realized, (4) augmenting the lower Snake River flow with 900 KAF or more from Dworshak and variable releases to meet a target flow of 100 kcfs at Lower Granite from April 15 through May 31, (5) augmenting the lower Columbia River flow up to 3 million acre feet or less to meet a target flow of 200 kcfs at The Dalles from May 1 through June 30, and (6) releasing up to 360 KAF from Dworshak in August to test temperature control options.

Comments on this OA/EIS can be sent to the Department of the Army, Walla Walla District, Corps of Engineers, Building 602, City-County Airport, Walla Walla, Washington 99362-2965. Public information meetings will be held in Lewiston, Idaho, and Pasco, Washington, January 28 and 29, respectively, to answer questions and provide more detail on the preferred plan.

1992 COLUMBIA RIVER SALMON FLOW MEASURES
OA/EIS

CONTENTS

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

# 1992 COLUMBIA RIVER SALMON FLOW MEASURES
# OA/EIS

## TABLES

TABLES (continued)

TABLES (continued)

TABLES (continued)

TABLES (continued)

## FIGURES

FIGURES (continued)

FIGURES (continued)

FIGURES (continued)

# Executive Summary

# EXECUTIVE SUMMARY

## 1.0 INTRODUCTION

This Options Analysis/Environmental Impact Statement (OA/EIS) identifies, presents effects of, and evaluates the potential options for changing in-stream flow levels in efforts to increase salmon populations in the lower Columbia and Snake rivers. The potential actions would be implemented during 1992 to benefit juvenile and adult salmon during migration through eight run-of-river reservoirs. The Corps of Engineers (Corps) prepared this document in cooperation with the Bonneville Power Administration and the Bureau of Reclamation. The U.S. Fish and Wildlife Service (FWS) is a participating agency.

The text and appendices of the document describe the characteristics of 10 Federal projects and one private water development project in the Columbia River drainage basin. Present and potential operation of these projects and their effects on the salmon that spawn and rear in the Columbia and Snake River System are presented. The life history, status, and response of Pacific salmon to current environmental conditions are described. The document concludes with an evaluation of the potential effects that could result from implementing proposed actions. The conclusions are based on evaluation of existing data, utilization of numerical models, and application of logical inference.

## 1.1 PURPOSE AND NEED

The purpose of implementing any of the alternatives considered in this document is to improve in-river migration conditions (flows and temperature) for juvenile and adult salmon in the lower Columbia and Snake rivers in 1992, or to conduct tests that will yield information needed to evaluate future improvements. These actions are part of an effort to improve the survival rate of declining stocks of Pacific salmon originating in the Snake River System.

## 1.2 LOCATION OF STUDY AREA

The Columbia River and its tributaries form the dominant water system in the Pacific Northwest. The geographic scope of this analysis is the Columbia River Basin from Bonneville Dam in Oregon and Washington upstream to the middle Snake River reservoirs in Idaho, and north along the mainstem to Mica Dam in British Columbia, Canada. Federal and non-Federal reservoir projects in the United States and Canada that influence flows past the eight Corps of Engineers run-of-river dams on the lower Columbia and Snake rivers are included (Figure ES-1).

## 1.3 SYSTEM DESCRIPTION

The Federal and non-Federal dams and reservoirs on the Columbia and Snake rivers are operated to meet multiple purposes including navigation, flood control, hydropower, recreation, irrigation, and fish and wildlife. Annual plans are established for operating storage and run-of-river projects to meet these needs with consideration of potential snowmelt, rainfall, and runoff conditions, and the needs of each purpose and use. Water use and control plans may be adjusted at projects for all purposes, including adjustments to provide water flows and elevations that might better meet the needs of anadromous fish.

An array of management practices and structures to protect juvenile and adult salmon migrating past the mainstem projects are continually being evaluated and upgraded. Each Corps run-of-river dam was constructed with an adult fish ladder system; some of these have been modified to improve fish utilization. Juvenile bypass systems were incorporated in Bonneville, John Day, Lower Monumental, and Little Goose during project construction; however, their effectiveness was limited. Field testing of prototype turbine screens and associated juvenile bypass systems was initiated at Ice Harbor in 1969. A full travelling screen and bypass system was built into Lower Granite in 1975, and subsequently added at Little Goose, McNary, John Day, and Bonneville. Similar systems to protect juvenile salmon will be operational at Lower Monumental by spring 1992, Ice Harbor in 1993, and The Dalles in 1998. These upstream and downstream passage systems have been developed in cooperation with regional fisheries agencies and tribes.

A juvenile fish transport program is in place to speed downstream migration. Also developed in coordination with regional fisheries agencies and

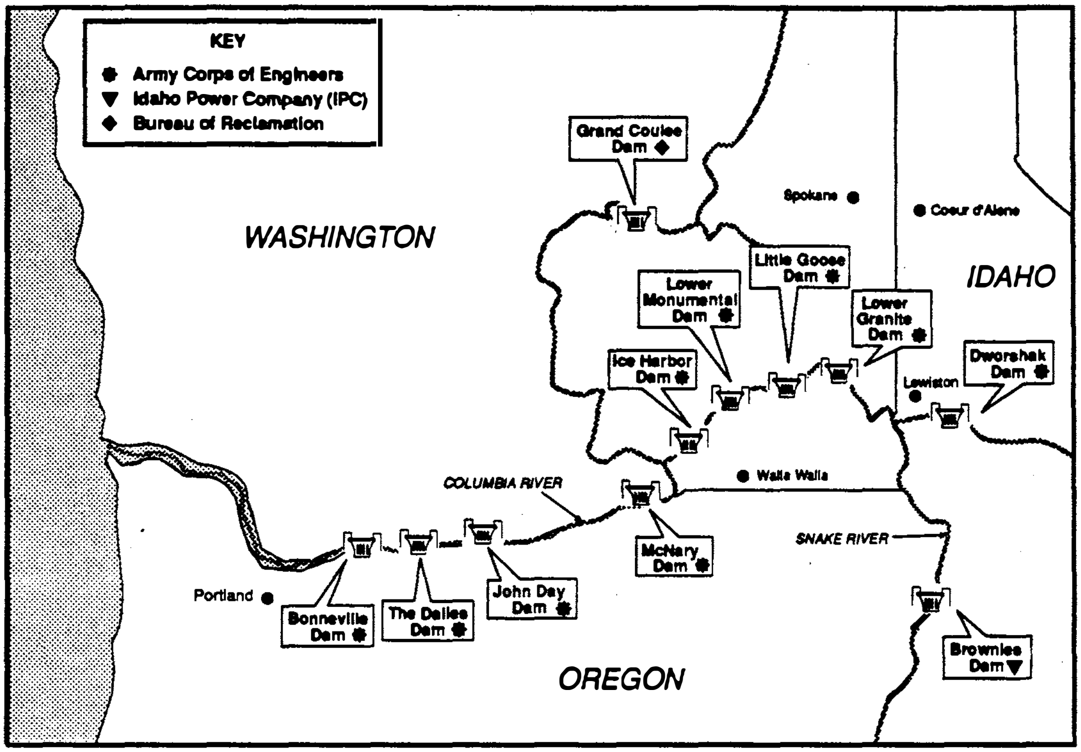



**Figure ES-1.** Study area.

tribes, the barge and truck collection and transportation facilities are installed at Lower Granite, Little Goose, and McNary dams. Currently, about 20 million juvenile salmon and steelhead are typically collected annually at these three projects and transported directly below Bonneville Dam. Additional collection and transportation facilities are being designed for Lower Monumental Dam.

An existing Water Budget also speeds the migration of juvenile salmon downstream between dams. The Water Budget provides additional flow from mid-April through mid-June using releases from upstream storage reservoirs. The volume and timing of this Water Budget is cooperatively managed with the regional fisheries agencies and tribes.

## 1.4 Problems, Opportunities, and Objectives Identified in Options Analysis

One of the most pressing environmental issues facing the Pacific Northwest today is the declining population of salmon that once thrived in the Columbia River Basin. In 1900, an estimated 8 to 16 million wild salmon and steelhead returned to the Columbia and Snake rivers to spawn. Recent records indicate that the runs are about 2.5 million (including known fish harvested in the ocean) of which about 0.5 million are wild fish. In 1990, 1.2 million salmon and steelhead and returned to the mouth of the Columbia River, excluding ocean harvest. About 0.3 million of these were wild fish (ODF&W and WDF, 1991). The remainder are hatchery-produced fish. Some Columbia River Basin salmon populations have declined to such an extent that their existence is threatened. In 1991, three stocks of Snake River salmon (sockeye, spring/summer chinook, and fall chinook) were proposed for endangered or threatened status under provisions of the Endangered Species Act (ESA). On November 20, 1991, the National Marine Fisheries Service declared the Snake River sockeye endangered effective December 20, 1991 pursuant to the Endangered Species Act.

Many factors have contributed to the declining populations including dams built by the Corps, other Federal agencies, and public and private utilities over many decades; loss of spawning and rearing habitat; reduced streamflows from water withdrawals; harvest levels; pollution in river and ocean environments; and various other stress factors from increased human use of environmental resources. Although many factors contribute, one factor known to affect the overall health of salmon stocks is river flow during juvenile migration.

Before dam construction, juvenile salmon experienced swift water conditions during their outmigration period. Based on the assumption that the rate of juvenile salmon travel is directly related to water velocity, it is possible that improving flow conditions in the Lower Snake and Lower Columbia rivers will increase survival of salmon in the Columbia River Basin. The increased water velocity, as measured by water particle travel time through the reservoirs, would presumably translate into reduced travel time for migrating smolts. It is believed that the quicker the fish pass through the system to the estuary, the less impact existing dams and reservoirs will have on salmon stocks. This is because a shorter travel time provides fewer opportunities for predation, residualism, and other physiological stresses. However, it must be stressed that the relationship between travel time and survivability is a general one, not a precise, quantitative expression. Thus, a 25 percent increase in water velocity might not correspondingly result in a 25 percent increase in survival because other factors (e.g., species, age, degree of smoltification, water quality, water temperatures, and availability of food) are also important survival factors for migrating juvenile salmonids.

Under current and historical conditions, the Snake River can be 4 to 5 degrees warmer than the Columbia River, at the confluence. This condition normally occurs in late August or early September. Historical data (Vigg and Watkins 1991) indicate that warm temperatures at the mouth of the Snake River may not have impeded Snake River fall chinook migration. However, during some recent years, high temperature at the mouth of the Snake River has been documented to impede upstream passage and cause salmon and steelhead mortalities. Reduction of temperature to 68°F at the mouth of the Snake River could enhance upstream migration.

The petitions by the Shoshone-Bannock Tribe on April 2, 1990, and by a group of conservation organizations on June 7, 1990, to list the Snake River salmon as endangered or threatened stimulated much regional concern. Accordingly, Senator Mark Hatfield of Oregon called for a regional assembly of organizations concerned with conserving these fish and managing the water. A task force, known as the Salmon Summit, was formed on June 30, 1990. This group was tasked with developing a comprehensive plan to assist in the survival of Columbia River Basin salmon and, in particular, the Snake River stocks. The Salmon Summit held their last meeting on March 4, 1991 and a 1991 action plan was drafted.

The Salmon Summit requested that the Corps of Engineers "undertake the processes necessary to design a study for Snake River reservoir drawdown during the operational year 1992 that would improve passage of migrants (juveniles) without impeding the upstream migrations (adults)." Subsequent agency discussions expanded the original scope of work to include all practical water management measures to improve salmon passage. This work, including all necessary National Environmental Policy Act analysis, was to be completed by March 1992. Accordingly, the Corps of Engineers, Walla Walla District, initiated this work on May 10, 1991 and anticipates implementing an action plan in time for the 1992 spring outmigration. The Bureau of Reclamation and Bonneville Power Administration are cooperating agencies, and the U.S. Fish and Wildlife Service is a participating agency.

The Salmon Summit identified two major physical objectives for the Corps and other reservoir-operating agencies to consider. The cooperating agencies adopted these objectives for this document: 1) for juvenile salmon, the objective is to reduce water particle travel time in 1992, and 2) for adult migration, the objective is to reduce water temperatures in the lower Snake River downstream to the confluence of the Snake and Columbia rivers during the warmest time of the summer (generally sometime between mid-August and September) in 1992.

## 1.5 SCOPE

This document presents an evaluation of alternatives for flow improvements that may be achieved by modifying the manner in which existing projects (dams and reservoirs) can be operated. The scope is limited to flow improvement measures that potentially could be implemented in 1992. Measures requiring major structural modifications at existing projects are not evaluated because they can not be implemented by 1992. The actions evaluated are temporary measures, for 1992 only, designed to test proposed methods by which water management agencies might be able to contribute to the survival of the salmon stocks that have been listed or proposed for listing under the Endangered Species Act. Actions for 1993 and beyond are being addressed by separate studies.

A large number of potential structural modifications to the run-of-river projects have been identified as possible measures to help improve fish passage conditions. Many of these potential measures have been identified by the Corps, based on operating experience with the projects. Others were proposed by various Salmon Summit participants or contributors to the scoping process for this OA/EIS.

Regional deliberations over the status and recovery of salmon stocks have also identified proposed measures that would not directly involve the Federal projects. Most of these concepts have been under consideration by fisheries managers for a decade or more, and many are being implemented through the Northwest Power Planning Council's (NPPC) Fish and Wildlife Program.

## 2.0 Actions and Alternative Plans Considered

Numerous alternatives were identified through a public scoping process and span a range of opportunities for increasing river velocities. The following five basic water management alternatives were identified:

1. Existing conditions (the no action alternative).
2. Improving flows by one or more drawdown measures, including test measures that would address potential future drawdowns.
3. Improving flows by augmenting existing releases from storage reservoirs.
4. Improving flows by a combination of drawdown and flow augmentation measures.
5. Storage releases to provide temperature improvements for adult migrants.

## 2.1 Existing Conditions (No Action)

Under this alternative for 1992, the reservoirs and dams on the lower Columbia and Snake rivers during salmon migration would be operated as they were from about 1985 to 1990. The Corps would use the Juvenile Fish Transportation Program as the primary method to move juvenile salmon downstream more rapidly from April through mid-July on the lower Snake and until mid-September on the lower Columbia. Mainstem reservoirs would operate within normal ranges. To enhance the movement of fish from dam to dam, river flow would be augmented by releases of stored water between April 15 and June 15 under the Water Budget. Water would be spilled over Lower Monumental, Ice Harbor, John Day, and The Dalles projects in the spring and summer to move fish past the dams instead of through the turbines as per the spill agreement. Juvenile and adult fish passage facilities at all eight run-of-river projects would continue to operate throughout the fish passage season. The Corps would continue to actively monitor the juvenile and adult migration at Corps dams. Monitoring migration generally involves counting fish moving through the fish ladders and the collection and bypass facilities and sampling the condition of juvenile fish collected. The Corps would also continue its research activities related to fish migration.

## 2.2 Reservoir Drawdown

This alternative addresses lowering the reservoir elevations at the lower Snake and Columbia reservoirs during all or part of the smolt migration. These lock, dam, and reservoir projects are operated as run-of-river projects within the integrated Columbia River Basin System. As such, under normal operations their surface elevations fluctuate on a daily and weekly basis within a relatively narrow range between the minimum and maximum operating pool levels. By controlling the spillway gates and flows through the powerhouse, reservoir levels can be maintained at virtually any elevation between spillway crest and maximum pool, generally a range of 30 to 50 feet or more. Based on operating considerations and flow velocity objectives, the Corps has identified nine finite options (in addition to existing conditions and including two different timing scenarios for two of the drawdown concepts) that represent the range of reservoir drawdown alternatives. Six of these options apply to the lower Snake River projects, while two could be implemented at the lower Columbia River projects. The basic specifications of each of these options are summarized below. A typical dam cross-section with reference elevations is provided as Figure ES-2.

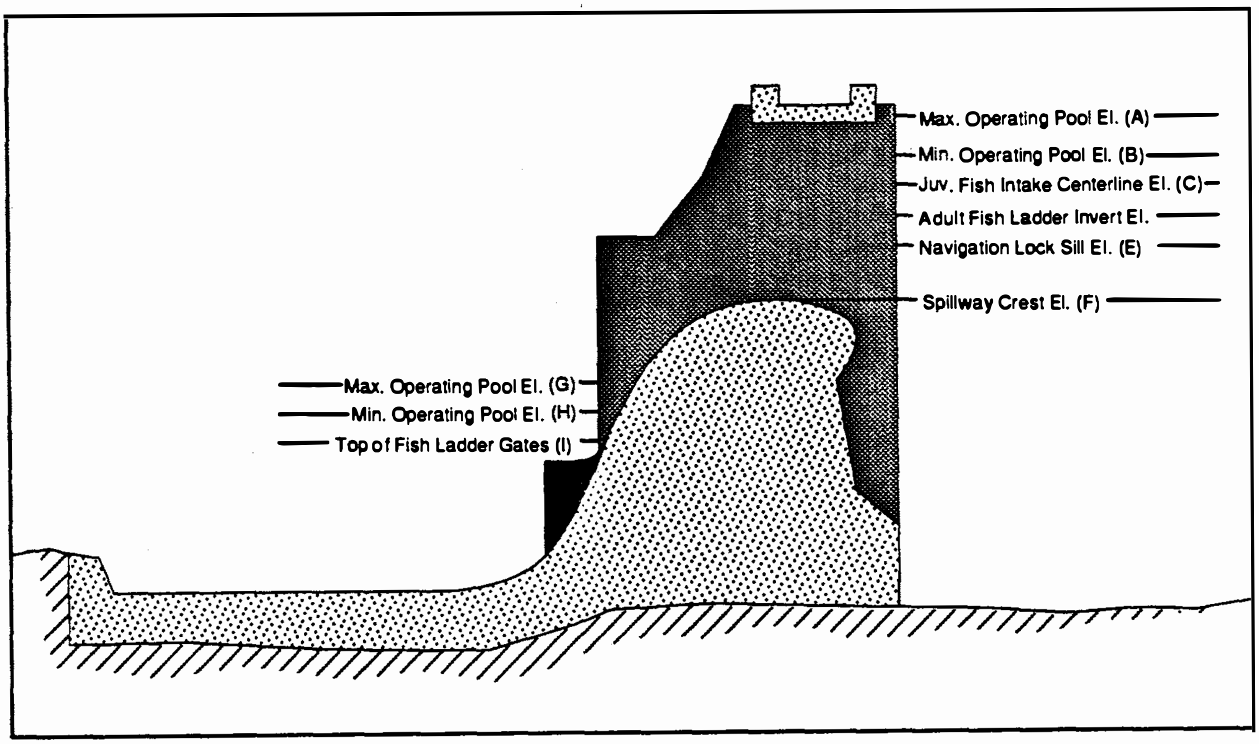



Figure ES-2. Summary of pertinent project data and operating limits.

### 2.2.1 Lower Snake River Projects

**Draft Lower Snake Projects to MOP.** Under this option, the Corps would operate the four lower Snake River projects (Lower Granite, Little Goose, Lower Monumental, and Ice Harbor) at minimum operating pool (MOP) from April 1 to July 31. Reservoir elevations would remain relatively static. Operation of the reservoirs at MOP would fall within the authorized operating limits as identified in the respective project water control manuals.

**Draft Lower Snake Projects to Near Spillway Crest.** This option would lower the four lower Snake River projects near spillway crest. Near spillway crest is defined as opening the spillway gates and allowing the pools to drop to free-flow elevations represents the lowest pool elevations that could be physically achieved without passing some of the flow through the turbines. It would also represent the lowest possible water particle travel time. Drawdown to near spillway crest could be maintained from April 15 through June 15, corresponding to the major portion of the downstream migration period for sockeye and spring and summer chinook. Alternatively, this drawdown could be maintained through August 15 to extend the velocity increases through the bulk of the fall chinook migration.

**Draft Lower Granite to 710 Feet, Remaining Projects to MOP.** Under this option, Lower Granite Reservoir would be drawn down to 710 feet from April 15 to June 15, and Ice Harbor, Little Goose, and Lower Monumental would be drawn down to MOP from April 1 to July 31. The 710-foot elevation was selected because this is the lowest reservoir level at which the Lower Granite adult fish ladder can operate. This option would theoretically allow continued upstream migration via fish ladders through the entire lower Snake River reach.

**Four-Week Test: Draft Lower Granite to Near Spillway Crest.** The objective of this option would be to conduct a 4-week test drawdown when it would not adversely affect adult or juvenile salmon migrations. Lower Granite Reservoir would be drafted to near spillway crest, and the other three Snake River projects would be operated at normal levels. Physical conditions at the projects would be carefully monitored, with primary focus on Lower Granite, to attempt to determine the level of physical effects likely to occur if major drawdowns were implemented in the future for longer periods at one or more lower Snake projects. Two specific periods of the year are under consideration for the timing of this test—July 15 to August 15, 1992 and February 1 to 28, 1993.

**Two-Reservoir Drawdown Test: Draft Lower Granite and Little Goose in March to Simulate Spillway Freeflow.** A new option added for the final OA/EIS would be to conduct a physical test, involving Lower Granite and Little Goose reservoirs, to gather data on reservoir drawdown to near spillway crest for potential use in developing long-term reservoir drawdown operations. The test objectives are to evaluate environmental and structural effects under reservoir drawdown conditions. The test would be conducted from March 1 to March 31 when few migrating fish are present, thus minimizing the risk of injury to fish. Depending on actual river flows, Lower Granite would be drafted to a minimum of 696 feet, while Little Goose would be drafted up to 15 feet below MOP.

### 2.2.2 Lower Columbia River Projects

**Draft Lower Columbia Projects to MOP.** This option would lower all four lower Columbia River projects (Bonneville, The Dalles, John Day, and McNary) to MOP from April 1 to August 31. Reservoir elevations would remain relatively static during this period. The change in elevation from average normal to MOP in each case would range from about 3.5 to 10 feet. MOP is the lowest reservoir level at which the projects were designed to operate.

**Hold McNary to 337 feet and John Day to 262.5 feet, Lower Bonneville and The Dalles to MOP.** Under this option, McNary and John Day would be operated at elevations somewhat above MOP, while Bonneville and The Dalles would be lowered to MOP. The higher elevations for McNary and John Day correspond to pool levels intended to avoid major disruptions to key water users.

## 2.3 Flow Augmentation

The principle of flow augmentation is the same as that for the Water Budget. Additional water would be discharged from the storage reservoirs during the spring migration to increase river flow. As with reservoir drawdown, a wide variety of options to increase Snake and Columbia river flows are considered in this OA/EIS. These options vary with respect to source of the water used to augment flows, the volume of storage to be released, and timing of releases.

### 2.3.1 Snake River

Ten specific flow augmentation options for the Snake River consist of a variety of modifications to existing Water Budget releases. In some cases, these would be combined with reservoirs being held to flood control rule curves and/or a shift of system flood control capacity from Dworshak and Brownlee to Grand Coulee. Volumes under consideration generally range from 600 thousand acre-feet (KAF) to 1,200 KAF from Dworshak, up to 200 KAF from Brownlee, and up to 300 KAF from multiple smaller sources above Brownlee. The most extreme case involves using the full storage available at Brownlee and Dworshak, if required, to meet a 140 kcfs flow target. The volumes cited for Brownlee refer to additional storage drafts above those included in the existing operation. The upper Snake volumes represent drafts from irrigation reservoirs upstream of Brownlee. Based upon an analysis of the 50-year flow conditions, guidelines have been established to ensure that both flood control objectives and Grand Coulee operating constraints would be maintained.

### 2.3.2 Columbia River

In addition to the supplemental water that might be added to the Snake River, Columbia River flows could be augmented by releases from Grand Coulee and Arrow. Potential Columbia River actions could involve two strategies: A measure to a augment spring flows (Target 200) and a measure to augment summer flows (non-treaty storage).

**Target 200.** Up to 6.4 MAF would be stored in Arrow and Grand Coulee if the January to July runoff forecast is 80 MAF or less and 3.4 MAF if the January to July runoff is 90 MAF or more and used to augment Columbia River flows in May and June. A mean monthly flow of 200 kcfs at The Dalles during May and June is expected from this augmentation.

The 3 MAF difference between the volumes to be stored (3.4 and 6.4 MAF) is the additional water to be stored over the existing water budget.

Three Target 200 options were considered, incorporating three of the Snake River flow augmentation options ranging from 600 KAF to 1,200 KAF from Dworshak and 50 to 200 KAF from Brownlee to meet target flows at Lower Granite.

**Non-Treaty Storage Releases.** In 1984, BPA and B.C. Hydro signed a 10-year agreement to coordinate the use of an additional portion of the water stored in the reservoir behind Mica Dam in southeastern British Columbia. Because this water storage was not covered in the Columbia River Treaty, the agreement is referred to as the "Non-Treaty Storage Agreement." A portion of this storage could be made available to augment Columbia River flows. For 1992, the cooperating agencies are considering releasing non-treaty storage in Mica Reservoir to augment Columbia River flows at The Dalles in July and August. The objective of this option would be to maintain somewhat higher flows after the peak of the snowmelt runoff to benefit upstream and downstream fall chinook migrations. Up to 1.1 MAF could be released from Mica in summer, which would increase average inflows at The Dalles by 10 kcfs.

## 2.4 COMBINATIONS OF DRAWDOWN AND AUGMENTATION

A program of flow improvement measures for 1992 will include a combination of reservoir drawdown and flow augmentation options. For purposes of discussion, three combinations of alternatives were evaluated: Combination Options X, Y, and Z. These combinations do not represent all possible combinations, nor is the preferred alternative exactly represented. The given combinations are discussed to illustrate how the various alternatives could be combined and the impacts displayed. All impacts resulting from individual alternatives have been outlined and further combinations will not present new information on impacts. The following three combination alternatives were identified as likely scenarios.

### 2.4.1 Combination Option X

- Release up to 600 KAF from Dworshak to meet a target flow of 85 kcfs at Lower Granite in May (flow augmentation Option A, existing condition).
- Flow augmentation from Grand Coulee and Arrow to meet 200 kcfs at The Dalles from April 15 to June 15 (Target 200).
- Operate the four lower Snake River projects at MOP from April 1 to July 31.
- Operate John Day at elevation 262.5, McNary at 337, and Bonneville and The Dalles at MOP from April 1 to August 31.

### 2.4.2 Combination Option Y

- Release up to 900 KAF from Dworshak, 150 KAF from Brownlee, and 100 KAF from above Brownlee to meet a target flow of 100 kcfs at Lower Granite in May (flow augmentation Option G).
- Flow augmentation from Grand Coulee and Arrow to meet 200 kcfs at The Dalles from April 15 to June 15 (Target 200).
- Operate the four lower Snake River projects at MOP from April 1 to July 31.
- Operate John Day at elevation 262.5, McNary at 337, and Bonneville and The Dalles at MOP from April 1 to August 31.

### 2.4.3 Combination Option Z

- Release up to 600 KAF from Dworshak to meet a target flow of 85 kcfs at Lower Granite in May (flow augmentation option A, existing condition).
- Flow augmentation from Grand Coulee and Arrow to meet 200 kcfs at The Dalles from April 15 to June 15 (Target 200).
- Operate Lower Monumental, Little Goose, and Ice Harbor at MOP from April 1 to July 31.
- Operate Lower Granite at elevation 710 from April 15 to June 15.
- Operate John Day at elevation 262.5, McNary at 337, and Bonneville and The Dalles at MOP from April 1 to August 31.

## 2.5 STORAGE RELEASES FOR TEMPERATURE CONTROL

Releases of large volumes of cool water from Dworshak in late summer have the potential to ameliorate the temperature conditions in the Snake River. A test release of cool water from Dworshak was made in August and September 1991. River and reservoir temperatures and velocities were measured, and data from the test were used to model the projected effects of various release scenarios. Another test release of Dworshak water is planned for 1992. This release would produce a draft of up to 20 feet at Dworshak in August, based on an assumed discharge of 10 kcfs for 20 days.

The final test protocol will be dependent upon 1992 conditions and will be coordinated with fish agencies and tribes.

## 2.6 MONITORING

Any option selected includes monitoring to observe, measure, and evaluate changes to key resources and concerns. An extensive and comprehensive monitoring program is being developed before implementation of 1992 flow improvement operations. The monitoring program will include biological, physical, water quality, and structural parameters, as well as navigation, recreation, irrigation, and cultural resources. Development of the detailed program is being coordinated with regional interests, including fish agencies and tribes.

## 3.0 EVALUATION

The cooperating agencies evaluated the various alternatives and options on two primary standards: 1) performance against the physical objectives for the proposed action, and 2) anticipated environmental effects. Numerical analyses were conducted to determine expected changes in water particle travel time and river temperatures resulting from individual or combined options. Existing inventory data on resources and their uses in the study area determined baseline environmental conditions; however, the schedule for the OA/EIS did not permit targeted characterization studies for this purpose. Expected changes from existing conditions were based on the key physical parameters for the options; specifically, the resulting water elevations and flows information associated with changing water levels, and cooperating agency staff observations based on many years of operating experience with the river system.

## 3.1 PERFORMANCE AGAINST PHYSICAL OBJECTIVES

The objective of the 1992 options for juvenile salmon is to reduce water particle travel time, or to provide test data that would be used to develop future measures to reduce travel time. The reservoir drawdown, flow augmentation, and combination alternatives were therefore evaluated against the calculated water particle travel time that would result in each case. Each case was evaluated from two perspectives. Absolute and percentage changes from existing travel times at different flow rates were calculated and used to evaluate the potential benefits to fish. Alternatives and options were also evaluated on the basis of the probability in any one year that a specific flow or water particle travel time objective could be met.

The physical objective for 1992 for adult migration was to reduce late summer water temperatures at the confluence of the Snake and Columbia rivers. Multiple options for temperature control releases have been evaluated against their ability to reduce temperatures at this location, particularly to a target level of 68°F.

### 3.1.1 Existing Conditions

Existing flow/travel time conditions for juvenile salmon migration in the Columbia-Snake River System are widely considered to be unsatisfactory in many years as indicated by the need for the proposed action. Water particle travel times vary with flow. Under existing conditions with the mainstem dams at normal operating levels, water particle travel times from the head of Lower Granite Reservoir to the Columbia River range from about 20 days at flows of 40 kcfs to 6 days at flows of 140 kcfs. Snake River flows at Lower Granite during the April 15 to June 15 peak outmigration are typically in the range of 80 to 100 kcfs. Flows have been considerably below these levels in several recent dry years. Water particle travel times on the Columbia River from the mouth of the Snake River to Bonneville Dam range from about 22 days at flows of 100 kcfs to 5 days at flows of 450 kcfs. Typical flows at The Dalles from April 15 to June 15 are in the range of 200 to 300 kcfs.

The Columbia Basin Fish and Wildlife Authority (CBFWA), an umbrella organization comprised of the regional fisheries and wildlife agencies and tribes, has proposed a program emphasizing enhanced river flows in the lower Columbia and Snake rivers to decrease fish migration time. The proposal recommended specific flow targets of 140 kcfs for the lower Snake River and 300 kcfs for the lower Columbia River from April 15 through June 15. These flows correspond to water particle travel times of 6.4 days and 8.7 days, respectively, for a combined total of 15.1 days. The probability of meeting these targets in any given year under existing conditions is about 17 percent for the lower Snake and 33 percent for the combined reach.

### 3.1.2 Reservoir Drawdown

Over the range of possible flow conditions, drawing the four lower Snake River reservoirs to MOP levels would reduce water particle travel time by 2 days at low flows to about 1/2 day at high flows. This absolute change would represent a relative improvement of at most about 7 percent, and 3 to 4 percent compared to typical operating.

In contrast, lowering the pools to near spillway crest would provide a 100 percent probability of meeting the target, based on simulations over a 50-year period of historical water conditions. This option would reduce water particle travel time in this reach by from 13 days at low flows to 3 or 4 days at high flows, representing reductions of about 50 percent over the range of flows.

Other drawdown options for the lower Snake River are intermediate between the above cases, involving deep drawdowns at Lower Granite while keeping the other three pools at normal or minimum levels. These options would yield water particle travel time changes ranging from about 7 to 10 days at low flows to 1/2 to 1 day at high flows. The relative decreases in water particle travel time would generally be about 15 to 20 percent for these cases.

The drawdown options for the lower Columbia River involve relatively modest changes in elevation from existing operations. Correspondingly, reductions in water particle travel time for this reach alone would be about 10 percent or less compared to the existing condition.

### 3.1.3 Flow Augmentation

The flow augmentation options were generally developed with the intention of meeting a specific target flow at Lower Granite or The Dalles. The targets for the Snake River options generally varied from 85 to 140 kcfs in flow for May. Long-term simulations indicate a 68 percent chance that flows will be 85 kcfs in May with existing conditions. The Snake River flow augmentation options would increase this probability to 74 to 98 percent. The probability of meeting a 100 kcfs target ranges from 44 percent with existing conditions to 96 percent, and is greater than 50 percent in most options. In contrast, the highest probability of meeting a 140 kcfs target is 46 percent, which could only be accomplished with an unrestricted draft from Brownlee and Dworshak.

A flow of 200 kcfs was the only target specified for lower Columbia River flow augmentation options. The annual probability of meeting this target ranged as high as 98 percent in May and 70 percent in June. These results reflect additional flow contributions from both the Snake and the upper Columbia rivers.

In terms of water particle travel time, the flow augmentation options would be capable of achieving modest reductions. The maximum reduction for the lower Snake River would be about 2 to 4 days with the unlimited draft option, representing a relative change of up to about 30 percent. Changes produced with the other options would generally be about one-half of this level or less. Options for the lower Columbia River could reduce water particle travel time by up to 2 to 3 days at low flows and 1 to 2 days at medium flows.

### 3.1.4 Combinations of Drawdown and Augmentation

Three specific combination options were evaluated in the OA/EIS. All three included some type of drawdown measure for the lower Snake and the lower Columbia and some level of flow augmentation from each river. The combined effects resulted in water particle travel times from Lewiston to Bonneville of approximately 19, 17, and 18 days, respectively. These times represent reductions of 1 to 3 days over existing conditions, or up to a 15 percent reduction.

Several additional conclusions can be drawn from the analysis of the respective components and combinations. The first is that drawing all eight run-of-river projects down from current pool elevations (midway between maximum and MOP) to MOP would reduce water particle travel time by only about 1 day. On the other hand, operating the four lower Snake projects at spillway free flow, in combination with the lower Columbia projects at MOP, would make it possible to achieve a travel time from Lewiston, Idaho to Bonneville, Washington of less than 15 days in all 50 simulated years without any additional flow augmentation measures.

Using the flow augmentation options alone, only the most extreme measure—unlimited storage drafts from Dworshak and Brownlee augmented with 300 KAF from the upper Snake (Option F)—approaches the CBFWA proposal. Option G, a draft of 900 KAF from Dworshak and 50 to 200 KAF from Brownlee, would reduce travel time by only about 1 day.

### 3.1.5 Storage Releases for Temperature Control

One alternative addresses the need to improve the temperature in the lower Snake River in late summer. Currently, temperatures in the Ice Harbor Pool reach levels up to 72°F or greater in late August to early September. High temperatures might create unfavorable environmental conditions for adult salmon. In August and September 1991, the Corps released water from Dworshak in an attempt to reduce Snake River water temperatures. Preliminary model results addressing the use of the cooler waters from Dworshak to cool the Snake River show some opportunity for temperature control at Ice Harbor. The data and results of these studies remain inconclusive, and additional field testing is proposed for 1992.

The preliminary model results indicate that releases on the order of 25 kcfs for 10 to 25 days would be needed to lower the temperature at Ice Harbor to 68° by September 1. Releasing this volume of water would result in drafts at Dworshak from 25 to 47 feet in August. Water model results indicated temperature could also be lowered to 70°F by late August with 10 kcfs flow from Dworshak for 20 days, which corresponds to the proposed action.

## 3.2 ENVIRONMENTAL EFFECTS OF ALTERNATIVES

The results of the environmental evaluation reflect expected impacts to an extensive and complex water resources system that is managed for a variety of uses, including fishery resources. As would be expected, some of the potential modifications to this system would produce substantial adverse impacts to existing users.

The following material is an abbreviated summary of those impacts, as presented in detail in Section 4.0 of the OA/EIS. The objective of this summary is to aggregate the details of the evaluation with respect to individual options and present broad conclusions that focus on the most significant environmental impact issues.

### 3.2.1 Existing Conditions (No Action Alternative)

The no action alternative is to continue to manage the Federal projects in the Columbia River System as was done during the operational years of 1984 through 1990. Water conditions and flows in the Snake River Subbasin might improve relative to recent dry years. If so, the Snake River salmon stocks might show an improvement, remain at their present levels, or continue to decline. This is because flow conditions, alone, might not be the dominant factor affecting stock survival and numbers.

### 3.2.2 Reservoir Drawdown

**Lower Snake River.** Drawing the lower Snake River projects down to MOP would result in minor and often offsetting impacts in most resource areas. Anadromous fish, for example, would likely benefit slightly from minor reductions in water particle travel time, but there would also be a minor reduction in rearing habitat for subyearling chinook. Similarly, spawning and rearing habitat for resident fish would be reduced somewhat, but spawning success might be increased by stabilized water surface elevations. The most significant impacts would be to power generation. Operation at relatively static levels near MOP would eliminate the opportunity to shape generation to match the variation in daily and weekly load demands, and could result in spilling of flows above turbine capacity at night. Capacity losses ranging from 550 to 1,400 MW during the MOP period would have an expected estimated cost of $11 million, while non-firm energy losses are estimated at an additional $9 to $13 million.

The two options for drafting the lower Snake River projects to near spillway crest would significantly reduce water particle travel time throughout this reach of the river. However, without prior modification of the projects, there would significant adverse impacts to reservoir aquatic habitat, navigation, irrigation, energy production, and recreation. Upstream passage for adult migrants would be blocked because fish ladders would no longer be operable. Because of these unacceptable impacts, without prior structural modification of the projects, drafting the lower Snake River projects to near spillway crest was eliminated from further consideration in the draft OA/EIS.

Three of the remaining Snake River drawdown options combine deep drawdowns at Lower Granite with MOP or normal operation at the other three projects. Environmental impacts from these options would be similar to those with all Snake River projects at run-of-river spillway crest, but would generally be localized to Lower Granite. Agricultural losses would not be associated with these options. The impact magnitude would be significantly less for several resource areas. Additional transportation costs from disruption of barge service would range from about $0.4 million to $0.9 million, because navigation would remain possible upstream through Little Goose Pool. The costs of lost peaking capacity, firm energy and non-firm energy would range from about $17 million to over $130 million for the lower Snake River System. Recreation effects would be measured by up to 158,000 recreation days of displaced use.

Two distinguishing characteristics among the options focused on Lower Granite should be noted. The option of operating Lower Granite at elevation 710 and the other three projects at MOP would theoretically maintain the possibility of upstream fish passage, thereby eliminating one of the major adverse impacts associated with drawdown to near spillway crest. Similarly, scheduling a test drawdown to near spillway crest at Lower Granite during winter 1993 would greatly reduce or eliminate adverse effects on anadromous and resident fish, recreation, and aesthetics compared to a summer drawdown.

Partially in response to public and agency review of the draft OA/EIS, a new reservoir test drawdown option has been investigated in the final OA/EIS. This test involves drafting Lower Granite to near spillway crest and drafting Little Goose by up to 20 feet, to simulate spillway free flow tailwater conditions, during March 1992. This option would avoid most of the potential adverse impacts to migrating adult and juvenile fish described above for other Snake River drawdown options, as few upstream or downstream migrants would be present. The 4-week duration of this test and its timing (in late winter) would work to minimize adverse impacts to navigation, irrigation and recreation. The primary environmental concern with this option is the potential for adverse impacts to fall chinook salmon, either though dewatering of spawning redds in the upper reaches of Little Goose Pool or dissolved gas supersaturation effects on alevins or fry.

**Lower Columbia River.** The differences between the two drawdown options for the Columbia River dams relate to whether John Day and McNary pools are lowered to MOP or are maintained at somewhat higher elevations; Bonneville and The Dalles pools would be lowered to MOP in either case. The elevation differences for John Day and McNary produce major differences in environmental effects between the options.

John Day and McNary projects encompass large areas of shallow water. Drawdown of these projects to MOP would result in dewatering much of this area. At John Day, for example, drawdown to MOP would expose over 10,000 acres of shallow-water habitat. One immediate effect would be the loss of the micro-invertebrates and aquatic plants established in these areas. The lower water levels and flat slopes could result in a change in the extent and diversity of the existing riparian vegetation, and elimination of the more sensitive species. These changes would result in immediate adverse impacts to resident fish, migrating and resting juvenile salmon, waterfowl, and terrestrial wildlife. Terrestrial impacts would be concentrated on wetland and riparian communities that have developed in the Umatilla and McNary National Wildlife Refuges.

Other resources that would be most affected by drawdown to MOP on the lower Columbia River would be agriculture, recreation, aesthetics, cultural resources, power, and municipal and industrial water uses. Impacts that are measurable in dollars would be greatest for agriculture. Lowering pools below irrigation intake levels would eliminate production from approximately 226,000 acres of irrigated land in 1992, with most of the acreage dependent on the John Day Pool. The net crop value that would be lost is estimated at $197 million. Power capacity losses would range from 1,500 to 2,400 MW. Including lost non-firm energy, power generation effects are estimated at $42 to 50 million in value. Lower water levels would impair or preclude the use of most of the boat ramps and swimming beaches at the four projects, resulting in significant shifts or declines in recreational use during most of the summer. Aesthetics would be degraded by exposure of large areas of reservoir bottom, again largely concentrated at John Day and McNary. Cultural resource sites are also most numerous at these two projects, and could be subject to increased exposure and damage.

Drawdown of McNary to elevation 337, John Day to 262.5, and the others to MOP would result in much lesser impacts to most of these affected resources. One exception would be power generation, where the loss of operational flexibility would produce similar capacity and non-firm energy losses. Affected agricultural acreage would be reduced to 13,000 acres and the net value of lost production to $52 million. Without the large losses of shallow-water habitat, resident fish could benefit from enhanced spawning and rearing conditions due to more stable water levels. Municipal and industrial water supply intakes at McNary would continue to function as at present.

### 3.2.3 Flow Augmentation

The environmental consequences of the various flow augmentation options would generally be limited to the storage reservoirs. Storage releases to meet a target flow would most likely be varied to maintain that target flow until the allocated volume was exhausted. This would result in relatively stable flows and elevations at the run-of-river pools. Effects on wildlife, resident fish, plant communities, navigation, irrigation, recreation, and cultural resources at these projects would be limited to changes in velocity that would not be great.

Effects at the storage reservoirs (Dworshak, Brownlee, and Grand Coulee) would depend on the magnitude and timing of the elevation change (draft). These, in turn, are determined by the size of the release and the way in which operations are changed to accomplish the release. Options involving transfer of system flood control storage from Dworshak and Brownlee to Grand Coulee, for example, would generally maintain higher elevations at the former projects for the same volume of release.

The size and structure of the flow augmentation options result in a pattern of greatest changes in elevation from base conditions at Dworshak, lesser effects at Brownlee, and minor to minimal changes at Grand Coulee. One option, intended primarily to test how much stored water would be required to meet the CBFWA target flow of 140 kcfs, allowed unrestricted drafts of both Dworshak and Brownlee. Simulation model runs indicate that this option would draft Dworshak and Brownlee to the bottom of each pool in May of most years. Less significant or drastic options would result in much more modest elevation changes. These changes are summarized below by project:

**Dworshak.** Aside from the unrestricted draft, the options would produce two general levels of elevation changes. One group of options, generally fixed discharges of 1,200 KAF (double the existing water budget), would result in typical May elevations that are up to 50 feet lower than expected with existing operations. These options also have a much lower chance of refill by the end of July, indicating that the lower elevations could persist through the summer and from year to year. A second group of options, incorporating discharges of up to 600 to 1,200 KAF and various operational modifications, would typically result in May elevation differences of 10 to 12 feet or less. These options would not drastically affect refill probability, and in one case would actually result in a higher chance of refill.

**Brownlee.** Some options do not require operational changes at Brownlee. Major changes in elevations from existing conditions would only occur with the unrestricted draft option. In all other cases, elevation differences are confined to May, June, and July, and refill patterns are not greatly altered. Drafts made in May produce elevations about 20 feet lower than base conditions. Drafts divided between May and June would result in May elevation differences of less than 10 feet, but extend refill into August under some water conditions.

> Grand Coulee. Due in part to operational constraints incorporated in the analysis, the probability and significance of elevation changes at Grand Coulee are not large. Flood control shifts from Dworshak or Brownlee would be possible in about 1 in 3 years of simulated water conditions. Differences in elevation were generally 5 feet or less in the few simulated cases where changes would occur, and none of the options would have a significant effect on the probability of refill in July.

The effects of these elevation differences would primarily apply to resident fisheries, recreation, aesthetics, and power production. The unrestricted draft option would significantly affect spawning, feeding and survival of resident fish, particularly at Brownlee. Other options with significant elevation differences would raise concerns over reduced production of food sources and transfer of fish downstream through entrainment.

Effects on recreation and aesthetics at Dworshak could range from severe to minor. The unrestricted draft option would virtually eliminate use at most recreation sites on the reservoir in a typical water year. This would result in displacement of an estimated 268,000 recreation days, or more than 75 percent of the existing use level. However, recreation impacts would be much less drastic with other options. Two options with relatively small elevation changes would displace visitation of 2,000 recreation days or less. Access for recreation at Brownlee in May and June would not be significantly reduced except with an unrestricted draft, so minimal changes in visitation would be expected with the other options. The size and probability of elevation changes at Grand Coulee are such that no visitation changes were projected.

Flow augmentation options for the Snake River would result in firm energy losses ranging from 40 average MW with the preferred plan to 450 to 500 average MW with unrestricted drafts. The associated value of these losses would range from $12 million to $146 million. Despite gains in non-firm energy production, total power costs would range from about $9 million to over $130 million. The Target 200 options for the Columbia River would result in power costs ranging from $20 million to $75 million.

### 3.2.4 Combinations of Drawdown and Augmentation

The effects of the three combination options evaluated amount to the additive impacts of the various components. Two of the combination options incorporate drawdown of all four Snake River projects to MOP, without any unresolvable adverse impacts to anadromous fish or other resources. One option would include drawdown of Lower Granite to elevation 710 feet, requiring 100 percent of the flow to be passed over the spillway. This much spill could limit upstream passage by disorienting adult salmon, and would result in elevated dissolved gas levels.

With respect to the Lower Columbia River, all three combination options incorporate the higher elevations for John Day and McNary. Consequently, the major adverse impacts to multiple resources that would be associated with operating all four lower Columbia projects at MOP would generally be avoided.

Two of the combination options include the existing level of flow augmentation for the Snake River, while the third involves additional storage releases that would likely lead to only minor elevation changes at Dworshak and Brownlee. All three combination options also include the Target 200 flow strategy for the Columbia River, which would have minimal effect on Grand Coulee elevations. The environmental impact contribution from the flow augmentation components of these options should therefore be minor.

### 3.2.5 Storage Releases for Temperature Control

Releasing cool water from Dworshak to attempt to reduce temperatures downstream in the Snake River would raise several potential issues concerning anadromous and resident fish in the river, and resident fish and recreation at Dworshak. Aside from providing needed test data, the proposed August release of cool water from Dworshak would have a measurable positive effect on temperature at Lower Granite, and to a lesser extent downstream. This would potentially enhance upstream migration success of some early fall chinook and steelhead. Growth rates (temporarily) for a portion of the steelhead at the Dworshak hatchery would be reduced. In general, resident fish would not be affected, although access to some of the smaller kokanee-spawning streams could be eliminated. Use of some elevation-sensitive recreational facilities at Dworshak would be curtailed or eliminated during a peak-use month, resulting in potential displacement of 9,000 recreation days. Recreationists continuing to use the reservoir would experience loss of aesthetic quality from a drawdown of up to 20 feet.

## 3.3 Cost-Effectiveness

The financial costs of implementing any of the flow measures have not been fully defined. Because the alternatives involve changes in reservoir operation, the cost of designing and implementing the revised operation would be modest. Some changes in operation have structural implications only because existing facilities such as embankments might not be adequately protected; again, these costs would not be substantial. Finally, the cost of implementing the monitoring program will not be determined until the alternatives have received further evaluation. It is not anticipated that the direct financial costs to implement any alternative would affect final plan selection.

Apart from the budgetary costs to the cooperating agencies of implementing any of the 1992 options, these options would have various cost impacts on uses of river resources. The primary resources for which these costs can feasibly be measured are navigation, irrigation, recreation, and power generation. The costs of the drawdown and flow augmentation options with respect to these resources were used to conduct a cost-effectiveness analysis, resulting in estimates of the total relative costs required to achieve a unit of change in the physical objective of reduced water particle travel time.

The reduction in water particle travel time (expressed in days) achieved by each option was weighted by the percentage of the juvenile fish run passing during the implementation period to determine the effective reduction in water particle travel time. The costs analyzed included direct net implementation costs and (primarily) foregone benefits in terms of reduced output of project benefits compared to current conditions. Only short-term costs impacts were estimated, as the analysis covers options for 1992 only, and average water conditions were used as the basis for estimating both costs and water particle travel time changes. Total direct costs by option were divided by the reduced weighted water particle travel time to arrive at a measure of the cost per day of reduced weighted water particle travel time.

This cost-effectiveness measure is not applicable to the three Snake River drawdown options that are purely physical tests, as these tests would be conducted outside of active juvenile migration periods and would not provide reduced water particle travel time benefits. Among the remaining four options in this category, drafting the four lower Snake River reservoirs to MOP from April 1 to July 31 would be most cost-effective, costing approximately $34 to $40 million per day of reduced water particle travel time. Drafting Lower Granite to elevation 710 or all four projects to near spillway crests (which could not be implemented before the projects were significantly modified) would have costs ranging from $52 to $82 million per day of reduced water particle travel time.

Drawdown options for the lower Columbia River also differ significantly in cost-effectiveness. Estimated costs per day of reduced water particle travel time are $116 to $120 million for all four projects at MOP and $60 to $65 million with John Day at 262.5, McNary at 337 and Bonneville and The Dalles at MOP. Drafting only John Day to 262.5 would achieve most of the obtainable benefits while avoiding many of the potential costs; this option would cost $24 to $28 million per day of reduced water particle travel time.

Depending upon actual (versus estimated) power costs, it appears that the Target 200 strategy may be the most cost-effective of the flow augmentation options. The estimated power costs for this option range from $20 to $75 million, resulting in costs per day of reduced water particle travel time ranging from $12 to $46 million. The estimated cost-effectiveness measures for the Snake River flow augmentation options are relatively close in magnitude. The low estimates of cost per day of reduced water particle travel time range from $22 to $73 million (excluding Option I, which is minimal change from existing operations and minimal benefit), while the high estimates range from $24 to $79 million.

## 3.4 Public Acceptability

The cooperating agencies evaluated the public acceptability of potential 1992 flow measures on the basis of two public input processes. Most directly, the public scoping process for the 1992 OA/EIS and the public review of the draft document provided substantial input on the views held by various public interests with respect to proposed river management actions. Scoping and review comments from the public indicated considerable support for a test drawdown of two reservoirs on the lower Snake River during a non-migratory period, and for the concept of augmenting river flows to improve fish passage conditions. Public comments also indicate a widely held view that near-spillway drawdowns of all four lower Snake River projects cannot reasonably be implemented in 1992, as there would not be time to undertake structural modifications needed to avoid adverse impacts to fish and other resources. Finally, the comments received during the OA/EIS process expressed nearly unanimous support for taking action to assist recovery of wild salmon stocks, although there was considerable difference of opinion on the nature and degree of recovery measures.

The Northwest Power Planning Council's (NPPC) process to amend the regional Fish and Wildlife Program also provided a gauge of the public acceptability of various actions under consideration. During the latter part of 1991, the NPPC considered a number of possible program amendments on mainstem survival, harvest, production, and other measures to protect salmon and steelhead. Many of these measures are identical or similar to potential actions evaluated by the cooperating parties in the OA/EIS. The measures considered by the NPPC were proposed by fish and wildlife agencies, Indian tribes, and other interested parties within the region through an open nominating process. The NPPC solicited and received extensive written comment on the proposals from the public, and held meetings at multiple locations. The final amendments on these measures adopted by the NPPC on December 11, 1991 constitutes a regionally accepted set of salmon and steelhead recovery measures. The cooperating agencies can accordingly consider the acceptability of measures included in both the NPPC program and the 1992 OA/EIS.

## 3.5 UNRESOLVED ISSUES

The analyses presented in the OA/EIS point to a number of unresolved issues related to the environmental impacts of the options or their performance against the physical objectives. Brief summaries of key unresolved issues are provided below. A number of these issues are based on the state of existing information and knowledge on key topics. The cooperating agencies recognize that precise and definitive information is not available for some very important aspects of fish passage or other system uses. In such cases, the agencies have relied upon the best information that is available, and have attempted to develop the most logical and supportable interpretations of that information.

### 3.5.1 Flow/Travel Time/Survival Relationship

The OA/EIS presents a lengthy discussion of the relationships among flow, water particle travel time, smolt travel time, and smolt survival. As indicated above, it is generally believed that quicker downstream passage will benefit salmon stocks, but the relationship between travel time and survivability is a general one and not a quantitative expression. Therefore, it is not possible to reliably predict a specific change in juvenile fish survival that will result from a given change in water particle travel time. Moreover, the migration research that supports the general travel time/survival relationship applies only to selected stocks of fish; it does not address sockeye, and presents conflicting or contradictory results for fall chinook.

It should also be noted that there are a legitimate differences of opinion within the scientific community as to the applicability of the travel time/survival relationship over the entire range of flows or velocities. These differences are based on varying approaches to statistical analysis of migration data. The result is that some scientists believe that Snake River flows of 140 kcfs (or equivalent water particle travel times) are needed to provide survival benefits, while others predict little benefit from increasing flows beyond the range of 85 to 100 kcfs.

### 3.5.2 Dissolved Gas Levels and Effects

One of the most significant adverse effects of some of the reservoir drawdown options could be increased levels of dissolved gas supersaturation from increased spilling. Existing water quality models do not allow specific calculation of the gas levels that could occur under these circumstances, as there is no operating experience with mainstem reservoir levels below MOP with which to develop model inputs. In the absence of analytical model results, the cooperating agencies have attempted to estimate potential increases in dissolved gas concentrations based on past experience relative to spill episodes. These results indicate that drawdown options causing major spill could produce gas levels shown to be lethal to fish over extended river reaches. Correspondingly, there is a significant probability that these options could result in increased net mortality within the system and negate any benefits that might accrue from reduced water particle travel time. While this consequence is uncertain, the possibility of major losses of fish must be weighed carefully in evaluating options.

### 3.5.3 Ability to Monitor Benefits

One of the intended values from implementing flow improvements is to develop monitoring data under new or test operating conditions that will increase knowledge of fish passage and other functions of the system. A monitoring program tailored to specific actions will be included as part of the selected plan. While this program will provide valuable information, it will not be able to provide answers to all of the outstanding unresolved issues. The cooperating agencies note that many commentors in scoping requested "absolute biological proof" that proposed measures would provide measurable benefits to salmon before implementing any flow improvements. This standard does not exist within the available research information and cannot be met with the proposed monitoring program. There will always be potential confounding factors that will introduce uncertainty to monitoring results. Further, the ultimate impact of various measures intended to improve fish passage cannot be known or speculated upon until adult fish returns over a period of years have been evaluated.

### 3.5.4 Long-Term Solutions

One of the most common issues raised in scoping for the OA/EIS was the need for long-term solutions to the fish passage situation and declining salmon stocks. The cooperating agencies share this desire, and are working toward long-term actions through other processes. The long-term solution will be based on the information gained in 1992 from monitoring and evaluation programs and the results of related but separate actions. The principal actions being conducted by Federal agencies whose results will contribute to a long-term solution are:

1) Interim Operational Actions (e.g., the 1992 Flow Options EIS and ongoing operational evaluations);

2) The recovery plan to be developed by NMFS for Snake River salmon;

3) Ongoing and scheduled NPPC Fish and Wildlife Program research and management studies;

4) The System Operation Review (SOR) EIS (SOR is scheduled for completion in the first quarter of 1994); and

5) Structural Modification and System Improvement Studies.

Until a long-term solution for Snake River salmon has been identified and implemented, it is likely that the Columbia River System will be operated on an interim operational basis. Improvements and changes to the plan will be incremental and based on the results of the evaluations completed in the previous year.

The actions to be implemented after 1992 will be guided by the recommendations developed in the recovery plan for Snake River salmon. At the same time, the information and results developed by interim actions and by ongoing research under the NPPC Fish and Wildlife Program will be used to assess the recovery plan recommendations.

SOR will provide the "big picture" view of how the system can be operated to meet multiple purpose needs, including anadromous fish. The SOR will lead to agency decisions on a new Pacific Northwest Coordination Agreement and will also provide analytical support to long-term drawdown evaluations such as biological benefits and system impacts. It will incorporate, where appropriate, the results of interim operational actions, the recovery plan for Snake River salmon, and ongoing NPPC fish and wildlife research studies. In turn, the results of SOR will be used to develop and refine interim operational action plans and contribute to assessments of recommendations of the recovery plan.

Finally, the structural modification and system improvement studies will provide information and recommendations on structural alternatives and improvements to project facilities. This information will be incorporated into SOR, subsequent detailed implementation studies, and interim action plans as it becomes available. This information will also be used to assess the recommendations of the recovery plan for Snake River salmon. The cooperating agencies and appropriate parties will be conducting evaluations of these measures on a continuing basis during the foreseeable future.

Since development of a long-term solution will be based on information to be generated in the short term, interim operations between 1992 and development of a long-term solution may require additional analysis of impacts and supplemental environmental compliance.

## 4.0 PLAN SELECTION AND IMPLEMENTATION

A preferred plan for 1992 was selected following public and agency review of the draft document, based on the following general criteria:

- Ability to implement the plan in 1992
- Cost effectiveness
- Performance against physical objectives
- Acceptability of the environmental impacts
- Public acceptability

Key aspects of the selection and implementation process are summarized below.

The physical objectives regarding juvenile and adult migrants became the starting point for the evaluation procedures established for this document. Individual options were screened to determine whether they satisfied (to some degree) one or more of the physical objectives. Those that did not meet this test were discarded from further consideration. The next step was to screen remaining measures into categories of implementability. Category one options can be physically implemented by March 1992 and can be implemented within existing authorities. The remaining category is a deferred status for consideration in subsequent years.

Options determined to be implementable by March 1992 and within existing authorities were then evaluated on whether the option will (1) have significant effects on fish and wildlife; (2) provide information beneficial to future fish activities and will not foreclose future flow alternatives; (3) present unreasonable safety hazards to the physical structures or to the operation of the projects; (4) maintain the water quality of the Columbia River Basin; and (5) address project operations in a manner which recognizes a balance of the uses served by the Columbia River Basin while providing biological benefits to fish. These options are presented for review by the public in this document.

Cost effectiveness and acceptability have served as a major considerations in the plan selection process. The cost-effectiveness criteria, in terms of relative costs to achieve a decrease in water particle travel time and water temperature goals, were used to rank the alternatives. Acceptability of these alternatives by State and local entities and the public were considered for each of the alternatives.

Finally, from this process an alternative which most closely meets regionally established objectives with acceptable costs, minimal environmental damage, and public acceptability was selected for the 1992 juvenile fish action plan. The alternative selected for implementation in 1992 might require adjustment depending on hydrologic conditions. To identify what adjustment might be required, the forecasts of selected plan will be evaluated against low and high forecasts of basin runoff volumes.

## 4.1 INITIAL SCREENING OF ALTERNATIVES

All measures to some degree satisfy the objective of reducing travel time for migrating salmon. Thus, to satisfy Step 1 of the screening criteria, measures must be implementable in 1992. To evaluate implementability in 1992, three questions were asked:

1. Will the measure negatively affect fish?
2. Will the measure present unreasonable safety hazards to physical structures or the operation of the projects?
3. Will the measure foreclose future actions (i.e., result in irreversible effects)?

If the answer to any of these questions was yes, the measure was determined to be non-implementable in 1992.

Although producing the greatest reduction in water particle travel time, the options that have all lower Snake River projects at near spillway were determined not to be implementable in 1992. This condition would have significant negative impacts to salmon stocks. Adult passage facilities would be inoperable and could not be modified in time for the 1992 upstream migration. Thus, all adult passage from Ice Harbor Dam on upstream would be eliminated. Also, increased spill would cause a significant increase in dissolved gas levels (135 to 150 percent). These levels are considered lethal to fish. Finally, this option presents an unreasonable safety hazard to the projects. Without adequate tailwater elevations, unacceptable scour and severe erosion could occur at the downstream toe of each project. Project modifications to accommodate upstream fish passage and structural protection would require extensive hydraulic modeling before effective designs could be completed. Implementation could, therefore, be sometime after 1992.

Flow augmentation alternatives that include water volumes greater than 100 KAF from the upper Snake River System (above Brownlee) are also not implementable in 1992. Negotiations for this water are very complex and cannot be completed in time for the water to be available in spring 1992.

## 4.2 Public Involvement

There are a large number of highly controversial issues associated with some of the actions evaluated; consequently, public input was sought before a plan was selected for 1992. Among other things, the National Environmental Policy Act (NEPA) requires that the views of interested members of the public be sought and incorporated into the final plan. The process of soliciting the concerns and interests of the public began with the issuance in May 1991 of the Notice of Intent to proceed with the project and to conduct an environmental analysis. Public scoping was conducted in June to define the issues to be addressed in the draft OA/EIS. The draft OA/EIS was sent to a total of 1,500 people. Following its release, a 50-day public comment period took place during which written and verbal comments on the alternatives were sought. Six workshops/public meetings were held to solicit comments. The cooperating agencies received written or verbal comments from a total of 207 commentors. This final OA/EIS reflects the cooperating agencies' responses to public comments.

In addition, the public participation required in the NEPA process satisfies the requirements of Section 310(b) and Section 415(b) of the Water Resources Development Act of 1990. Section 310(b) requires public participation in changes to reservoir operation criteria. Section 415(b) requires public notification (hearings) of actions associated with drawdown of Dworshak Reservoir.

## 4.3 Comparison of Alternatives for 1992

Seven reservoir drawdown options and seven flow augmentation alternatives have potential for implementation in 1992. Additionally, three combination measures have been analyzed. These combinations do not represent all possible combinations. They are discussed to illustrate how various alternatives can be combined and the impacts displayed. Following public review of the draft OA/EIS, a slightly different combination is presented in the final document. However, all impacts resulting from individual alternatives have been outlined and further combinations will not present new information on impacts. The discussion in Section 3 of this summary presents a comparison of these alternatives.

## 4.4 Plan Selection Conclusions

Based on performance against the five plan selection criteria, summary conclusions from the evaluation of the options are presented below.

### 4.4.1 Snake River Drawdown

#### 4.4.1.1 Lower Granite to Elevation 710 with the Remaining Projects to MOP

The drawdown of Lower Granite Reservoir to elevation 710 would result in many significant environmental impacts. These include:

- Possible increases in the dissolved gas (atmospheric) levels to the lethal stage; and

- Adult fish passage problems associated with spilling 100 percent of the flow at Lower Granite and creating an extremely turbulent condition in the tailrace area that would disorient adult salmon and prevent them from entering the fish ladder entrances.

In addition, this alternative received no support based on comments received during the Draft OA/EIS public review. As a result, this alternative was eliminated from further consideration.

#### 4.4.1.2 Drawdown to MOP

The drawdown of all four projects to MOP appears to be cost-effective. Whereas the benefits to water particle travel time are not considered to be significant, the economic and environmental effects are also very small. The major impact is to power, resulting in a loss to some peaking capacity. This alternative was implemented in 1991 without significant incident. It also has been incorporated within the NPPC Fish and Wildlife Management Program, and based upon comments received on the Draft OA/EIS, this alternative has public support. This option is recommended for implementation for 1992.

### 4.4.2 Columbia River Drawdown

#### 4.4.2.1 Drawdown to MOP

Drawdown of the four lower Columbia River projects to MOP was eliminated from further consideration primarily due to a lack of cost-effectiveness. With this alternative, the economic impacts within the John Day and McNary reservoirs were very high, primarily due to the loss of irrigation.

#### 4.4.2.2 Drawdown of John Day to 262.5, McNary to 337, and Bonneville and The Dalles to MOP

Although this alternative appeared to be cost-effective, the benefits to water particle travel time were very low, particularly within Bonneville, The Dalles, and McNary reservoirs. The maximum combined reduction in water particle travel time for these reservoirs was approximately one-half of one day. This small reduction in water particle travel time is considered to be negligible when taking into account the level of detail used in the evaluations and the combined water particle travel time of the existing reservoir system. Therefore, even the relatively minor impacts associated with these drawdowns is unwarranted.

Drawdown of John Day Reservoir to 262.5 was implemented in 1991. The reservoir was raised when needed to mitigate for impacts to irrigation. This action resulted in no significant impacts for 1991 and can be implemented again in 1992. This drawdown will provide a reduction in water particle travel time, ranging from 1/2 to 2 days depending on the flow conditions. This alternative is supported by the public and has been included as part of the NPPC's Fish and Wildlife Management Program. This option is recommended for implementation for 1992.

### 4.4.3 Snake River Flow Augmentation

A number of flow augmentation options evaluated for the Snake River appear to be cost-effective. However, due to limitations of modeling using monthly averages and a constant allocation of water budget versus the actual daily operation and shapeable water budget, the cost-effectiveness analysis was unable to distinguish much difference between each specific augmentation option.

Storage from Brownlee has been eliminated from further consideration and will not be recommended for implementation in 1992. Although use of Brownlee storage would be beneficial for flow augmentation purposes, the cooperating agencies do not have any authority to control Brownlee operation for fish passage.

The preferred option for 1992 is one which follows the NPPC plan if the April Lower Granite runoff forecast is less than 16 MAF and Option J if the forecast is 16 MAF or greater. This provided a balance of improving water particle travel time (compared with the Base Case) and impacts to Dworshak, primarily associated with the probability of refill. Each plan by itself was strong in certain areas and weak in others. The NPPC plan provides more flow augmentation than Option J in the low runoff years (forecast runoff of 16 MAF or less). However, in mid-range runoff forecasts, Option J provides more water budget than the NPPC plan and a better probability of refill in years when the 100 kcfs target flow at Lower Granite can be provided without a large contribution from Dworshak. Based on early forecasts for 1992 runoff, preliminary estimates of refill probability at Dworshak for the preferred plan is 77 percent. This option incorporates a substantial portion of the NPPC Fish and Wildlife Plan and is recommended for implementation in 1992.

### 4.4.4 Columbia River Flow Augmentation

The time frame for completing this OA/EIS was very short. Therefore, the scope of study was limited. One of the limits was the number of storage reservoirs on the Columbia River that could be included for evaluation. For example, Libby and Hungry Horse (large storage reservoirs in Montana) were excluded. As a result, the amount of flow augmentation on the Columbia River was also limited. Due to the limited scope, Target 200 was the only flow proposal evaluated in this OA/EIS. Studies addressing actions for 1993 and beyond will evaluate additional flow augmentation proposals on the Columbia River.

The evaluations indicated that the Target 200 proposal is cost-effective and has acceptable environmental effects. This proposal has the same effects as the proposal identified in the NPPC amended program. Therefore, it is considered to be the same and have regional acceptance and is recommended for implementation in 1992.

### 4.4.5 Temperature Control for Adults

The temperature control studies, both field and computer model, conducted in 1991 are still considered to be preliminary because the data and results remain inconclusive. The limited cool water releases from Dworshak in 1991 resulted in lower river temperatures within Lower Granite and Little Goose reservoirs. Results from the COLTEMP model indicated that large volumes (1 MAF) of cool water would be required to meet the temperature objectives at the mouth of the Snake River. This would lower Dworshak Reservoir approximately 50 feet, resulting in substantial negative environmental impacts. In addition, there is a lack of information available concerning the biological benefits (timing of releases and target temperature) to implement a 50-foot drawdown.

Additional field tests are recommended in 1992. This test will further evaluate the effectiveness of cool water releases on improving migration conditions. The information collected from this test will also be used to verify the COLTEMP model projections. The NPPC supports this action and has included this action in their amendment plan.

### 4.4.6 Physical Test Drawdown

The objective of this alternative is to collect data, to be used in the development of long-term studies associated with drawdown proposals on the lower Snake River. Although the test is not considered to be a biological test, information obtained will assist in making long-term decisions regarding means to improve migration conditions. Since the objective is not to increase water particle travel time, cost-effectiveness is not a criteria.

#### 4.4.6.1 Lower Granite to Near Spillway

This alternative could be implemented or July 15, 1992 or February 1993. The July 15 test was determined to impact adult and juvenile salmon migration, although this period is not considered to be a peak migration season. As a result the National Marine Fisheries Service did not support this period, and it was eliminated. The February 1993 test was not heavily supported by the region. Regional interests wanted a test in 1992; therefore, the February test was eliminated from further consideration.

#### 4.4.6.2 Two-Reservoir Drawdown Test: Lower Granite and Little Goose

The two-reservoir drawdown test has strong regional support. This is evident based upon comments received to the draft OA/EIS and the fact that it has been included in the NPPC Fish and Wildlife plan. By performing the test in 1992, the information can be used in long-term drawdown studies identified in the NPPC Fish and Wildlife plan. By drawing down two sequential reservoirs, the tailwater conditions at Lower Granite Dam will be similar to four reservoir drawdown conditions. This test will also provide some information that is unattainable through three-dimensional laboratory models (i.e., turbine operation, gas saturation levels, etc.). The data collected will also validate ongoing modeling efforts and projections.

## 4.5 PREFERRED PLAN OF ACTION FOR 1992

The cooperating agencies did not elect to identify a preferred alternative for 1992 river operations in the draft OA/EIS. Because of the complexity of the issues and potential options, the agencies wanted to obtain public review of the various options and their effects before selecting a preferred plan. By deferring selection of a preferred plan to the final OA/EIS, the cooperating agencies were able to more efficiently coordinate plan selection and evaluation with the NPPC planning process.

As a result of the analysis presented in the draft OA/EIS, public review of the document, and further analysis in response to review comments, the cooperating agencies have selected a set of options comprising the preferred alternative for 1992. The preferred alternative includes the following measures discussed previously in Sections 3.2.2 through 3.2.5:

- Drafting all four lower Snake River projects to MOP from April 1 to July 31.
- Conducting a two-reservoir drawdown test at Lower Granite and Little Goose reservoirs on the lower Snake River in March.
- John Day Pool would be drafted to near elevation 262.5 starting on May 1 and ending on May 31. This elevation will be maintained for as long as possible without impacting irrigators located on the reservoir. The pool will be raised accordingly to assure that irrigators are not affected.
- Lower Snake River flow augmentation of 900 KAF or more from Dworshak, based on total basin forecast (April-July) of 16 MAF (or less) at Lower Granite. This volume of water is in addition to any minimum flow release requirements at Dworshak when run-off forecasts are above 16 MAF. The above volume will be provided with the following conditions:

  1) When natural flows at Lower Granite Dam exceed 100 kcfs, the volume of water from Dworshak will be reduced.

  2) Additional water from Dworshak (above 900 KAF) will be released when refill probability is in excess of 70 percent.

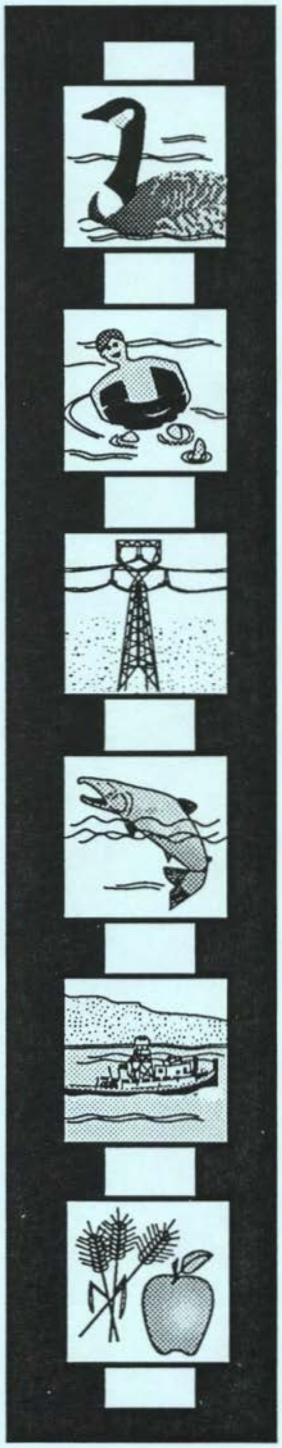
  Dworshak will be operated to MRCs and flood control shift to Grand Coulee would occur when the forecast April to July inflow to Dworshak is less than 2.6 MAF.

- Lower Columbia River flow augmentation of up to 6.4 MAF if January through July runoff is 80 MAF or less and 3.4 MAF if runoff is 90 MAF or more during the months of May and June. Mean monthly flows of about 200 kcfs at The Dalles are expected.
- Field studies will be conducted in August 1992 to test the effectiveness of cool water releases from Dworshak Dam to reduce water temperatures in the lower Snake River to benefit adult fall chinook. If Dworshak is full or nearly full by the end of July, draft the reservoir up to 20 feet in August as needed for the temperature control evaluation. This could results in Dworshak releases of up to 360 KAF. In September, beginning immediately after Labor Day, release up to 200,000 acre-feet of additional cool water from Dworshak reservoir, as needed for the temperature control evaluations. If Dworshak reservoir is not full, use of Dworshak for temperature control will be addressed in the July meeting of the Fish Operations Executive Committee.

The environmental effects of these individual components of the preferred alternative are discussed in detail in Section 4. The collective effects and the basis for selecting this plan are addressed in Section 5.

# 1.0

# Introduction



1992 COLUMBIA RIVER SALMON FLOW MEASURES
OA/EIS

## CONTENTS



## FIGURES

# 1.0 INTRODUCTION

On April 5, 1991, the National Marine Fisheries Service (NMFS) proposed that the Snake River sockeye salmon be listed as an endangered species under the Federal Endangered Species Act (ESA) (56 FR 14055). On June 7, 1991, the NMFS announced the proposed listing of the Snake River spring, summer, and fall chinook salmon as threatened species (56 FR 29542; 56 FR 29547). On November 20, 1991, the NMFS declared the Snake River sockeye salmon endangered effective December 20, 1991.

These actions are the culmination to date of a historical decline in wild salmon stocks in the Snake-Columbia River System. The NMFS has until April 1992 to make a final decision on whether to list these salmon stocks as endangered or threatened.

Both natural and human-caused factors have contributed to the endangered status of these wild salmon stocks. This Options Analysis/Environmental Impact Statement (OA/EIS) addresses only one human-caused factor—modification of natural river flow by eight Federal run-of-river dams and reservoirs in the Columbia River Basin.

## 1.1 PURPOSE AND NEED

The system of dams and reservoirs constructed along the lower Snake and Columbia rivers have provided many benefits—power, commercial navigation, irrigation, water quality, recreation, and fish and wildlife—to the region. However, the projects also have lowered the rate at which the water flows through the river system. This slower flow rate might increase the time it takes juvenile salmon to migrate from their freshwater spawning grounds to the saltwater of the Pacific Ocean. Some believe the longer migration time may affect salmon survival by increasing their chances of being eaten by predators. It may also interfere with the natural physical changes required for them to adapt from freshwater to saltwater, thus, reducing their instinct to migrate and decreasing their survival.

The purpose of this OA/EIS is to evaluate the impacts and benefits of several alternatives to the way certain dams and reservoirs in the Snake-Columbia River System are currently operated. Some of the proposed changes in the operation of the dams are designed to increase the flow of the Snake-Columbia rivers during the 1992 outmigration period to decrease the travel time for young salmon to migrate to the ocean. It is thought that this, in turn, would increase salmon survival rates. Other proposed actions are intended as tests that would provide data to be used in developing long-term structural and operational modifications. The study also examines the effect of river flows and temperatures on adult salmon migration.

As the title indicates, the document deviates somewhat from the traditional EIS in that it also serves as a U.S. Army Corps of Engineers (Corps) planning document. The Options Analysis focuses on how well the alternatives meet the physical objectives established for this study (decreasing water particle travel time for juveniles and reducing water temperature for adults), and their cost-effectiveness, implementability, and acceptability by public and private interests. The evaluation led to the selection of a plan to improve fish passage down the lower Snake-Columbia rivers for the 1992 season and obtain data for use in other long-term studies.

## 1.2 BACKGROUND

The Shoshone-Bannock Indian Tribe of Idaho on April 2, 1990, petitioned the NMFS to list the Snake River sockeye salmon under the ESA. On June 7, 1990, a group of conservation organizations filed separate petitions with the NMFS to list the Snake River spring, summer, and fall chinook salmon and the lower Columbia River coho salmon under the ESA. In response, Senator Mark Hatfield of Oregon convened a regional assembly of organizations and interests concerned with the plight of the Snake-Columbia River salmon. These interests included public agencies responsible for water management, power production and marketing, and fisheries management; representatives of affected states and potentially affected economic interests; and members of the public concerned with conservation of the Pacific Northwest salmon. This group, known as the "Salmon Summit," held its first formal meeting on June 30, 1990. The mission of the Salmon Summit was to produce a salmon management plan in response to the petitions to list the five salmon stocks under the ESA. The plan was to include actions related to salmon harvest, production, habitat, and water management.

Although the Salmon Summit reached no consensus on a long-term plan of action, it did agree on a plan for 1991. This plan included an evaluation of expanding the volume of the Water Budget (an amount of water released from certain reservoirs in the spring to increase river flows to aid migrating juvenile salmon [see Section 3]), drawing down (releasing water to lower the reservoir) certain reservoirs along the lower Snake and Columbia rivers to minimum normal operating levels to increase river flow (velocity) and extending the length of time the Corps operates its program to transport juvenile salmon downstream to the ocean by barge or truck. These regional actions contributed to the decision by NMFS not to invoke an emergency listing for sockeye salmon.

The Salmon Summit also requested that the Corps "undertake the processes necessary to design a study for Snake River reservoir drawdown during operation year 1992 that would improve the passage of migrants (juveniles) without impeding the upstream migration (adults)." Subsequent agency discussions expanded the original request to include all practical water management measures to improve salmon passage, for both juveniles and adults, through the eight Federal dams on the lower Columbia and Snake rivers. Alternatives for test drawdowns and river temperature control were also included.

## 1.3 SCOPE

This document evaluates alternatives to improve salmon passage through the Corps' four lower Columbia River and four lower Snake River reservoirs during the 1992 operating year. Options identified are system operational changes in the management of river flows and changes to specific project operations. Actions evaluated are those that water management agencies might implement to contribute to the survival of the salmon proposed for listing. System changes requiring significant new construction or structural facility modifications are outside of the scope and intent of this document.

The geographic scope of this analysis is the Columbia River Basin from Bonneville Dam in Oregon upstream to the upper Snake River reservoirs in Idaho, and north to Mica Dam in British Columbia, Canada. Included in this analysis are run-of-river and storage reservoirs (see Glossary) on the Columbia and Snake rivers. Storage projects include Federal and non-Federal dams in the United States and Canada, which influence flows past the Corps' eight run-of-river dams on the lower Columbia and lower Snake rivers (Figure 1.3-1).

This OA/EIS presents five basic alternatives for improving the flow of the lower Snake and Columbia rivers to benefit salmon in 1992.

1. No action (conditions similar to those during 1985 to 1990).
2. Improve flows, or provide test data needed for future actions by drawing down the four lower Snake and four lower Columbia River projects (9 different options).
3. Improve flows through flow augmentation from storage projects (15 different options).
4. Improve flows by a combination of drawdown and flow augmentation options.
5. Storage releases for control of river temperature in late summer.

Because of the urgent need to protect the Snake-Columbia River salmon, this document was prepared in an extremely short timeframe, restricting the development of new data or information. Therefore, the analysis presented is based on existing available information. Data on fish survivability, relationship of improved fish passage to increased fish returns, and the effect of reduced migration times on actual fish run recovery are not available. In the absence of empirical relationships based on hard data, relationships based on logical inferences have been used. For example, water particle travel time (the time it takes a unit of water to move from one point downstream to another) has been used in place of actual juvenile fish travel time. In all cases, consistent data have been presented for each action; thus, alternatives can be compared on an equal basis.

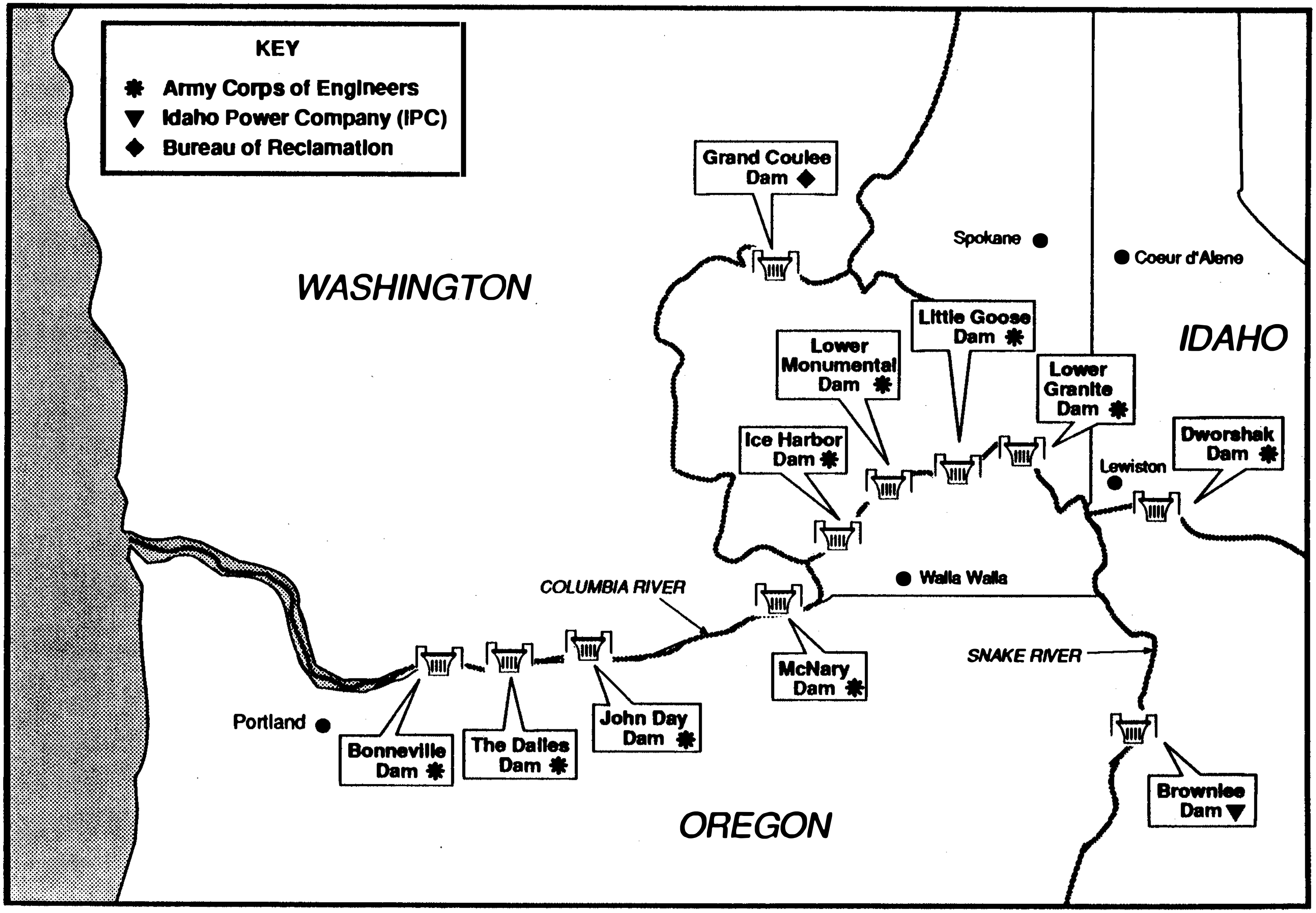



Figure 1.3-1. Study area.

Finally, the decision process and selection criteria used to select a plan of action in the final OA/EIS is presented. A preferred plan was not identified in the draft OA/EIS. A large number of highly controversial issues are associated with some of the actions evaluated; consequently, public input was sought before a plan was selected for 1992.

This document satisfies the requirements of the National Environmental Policy Act (NEPA). NEPA requires that (1) a range of alternatives for achieving the project's goal be put forth, (2) an analysis of the environmental impacts of each alternative be conducted, (3) measures to mitigate adverse impacts be discussed, and finally (4) the views of interested members of the public be sought and incorporated into the final plan. The OA/EIS accomplished the first three objectives. The process of achieving the final objective—soliciting the concerns and interests of the public—began with the issuance in May 1991 of the Notice of Intent to proceed with the project and to conduct an environmental analysis. Public scoping was conducted in June to define the issues to be addressed in the draft OA/EIS. After the draft OA/EIS was published, a 50-day public comment period took place during which written and verbal comments on the alternatives were obtained.

As the lead agency, the Corps expects to complete all necessary NEPA analysis by March 1992. The Corps is preparing this document in cooperation with the Bureau of Reclamation (BoR) and the Bonneville Power Administration (BPA), because these agencies have a major role in water management decisions within the Columbia River Basin. The BoR is responsible for identifying impacts to Grand Coulee Dam which it built and manages. The BPA is responsible for evaluating impacts to hydropower and non-Federal projects. Following selection of an action plan for 1992, the Corps, in cooperation with regional interests, will develop a specific approach to implement the action plan in 1992.

The results of this 1992 plan will be factored into other studies currently underway aimed at finding long-term solutions to the problem of the survival of the Pacific Northwest salmon. A more comprehensive review of the multiple uses of the Columbia River System, including fisheries, will be undertaken through the System Operation Review (SOR) being conducted by the Corps, BoR, and BPA. The Northwest Power Planning Council (NPPC), created by the U.S. Congress to develop and oversee the Columbia River Basin Fish and Wildlife Program, is developing a comprehensive, long-term recovery plan for salmon and steelhead stocks. And, finally, the Corps is conducting the Columbia River Salmon Mitigation Analysis (CRSMA), which will include an evaluation of a variety of possible long-term measures, primarily structural, to increase the salmon runs. These studies and this OA/EIS will be integrated to provide short- and long-term solutions to meet the needs of both people and natural resources, protecting the resources while maintaining the benefits created by the dams.

One of the most common issues raised in scoping for the OA/EIS was the need for long-term solutions to the fish passage situation and declining salmon stocks. The cooperating agencies share this desire, and are working toward long-term actions through other processes. The long-term solution will be based on the information gained in 1992 from monitoring and evaluation programs and the results of related but separate actions. The five principal actions being conducted by Federal agencies whose results will contribute to a long-term solution are:

1) Interim Operational Actions (e.g., the 1992 Flow Options EIS and ongoing operational evaluations);

2) The recovery plan to be developed by NMFS for Snake River salmon;

3) Ongoing and scheduled NPPC Fish and Wildlife Program research and management studies;

4) The SOR EIS (SOR is scheduled for completion in the first quarter of 1994); and

5) Structural Modification and System Improvement Studies.

Until a long-term solution for Snake River salmon has been identified and implemented, it is likely that the Columbia River System will be operated on an interim operational basis. Improvements and changes to the plan will be incremental and based on the results of the evaluations completed in the previous year.

The actions to be implemented after 1992 will be guided by the recommendations developed in the recovery plan for Snake River salmon. At the same time, the information and results developed by interim actions and by ongoing research under the NPPC Fish and Wildlife Program will be used assess the recovery plan recommendations.

SOR will provide the "big picture" view of how the system can be operated to meet multiple purpose needs, including anadromous fish. The SOR will lead to agency decisions on a new Pacific Northwest Coordination Agreement and will also provide analytical support to long-term drawdown evaluations such as biological benefits and system impacts. It will incorporate, where appropriate, the results of interim operational actions, the recovery plan for Snake River salmon, and ongoing NPPC fish and wildlife research studies. In turn, the results of SOR will be used to develop and refine interim operational action plans and contribute to assessments of recommendations of the recovery plan.

Finally, the Structural Modification and System Improvement Studies will provide information and recommendations on structural alternatives and improvements to project facilities. This information will be incorporated into SOR and interim action plans as it becomes available. This information will also be used to assess the recommendations of the recovery plan for Snake River salmon. The cooperating agencies and appropriate parties will be conducting evaluations of these measures over the next several years.

Since development of a long-term solution will be based on information to be generated in the next few years, interim operations between 1992 and development of a long-term solution may require additional analysis of impacts and supplemental environmental compliance.

## 1.4 LIFE HISTORY OF PACIFIC SALMON

An understanding of the unique characteristics of the life cycle of the Pacific salmon helps to explain why the river flows and hydropower dams along the Snake-Columbia rivers play such a critical role in salmon survival. Salmon are anadromous fish; that is, they spawn in freshwater, rear in freshwater rivers, migrate downstream to the estuary, enter the ocean, grow to maturity in the ocean, and return to freshwater to reproduce and die. This movement from freshwater to saltwater historically followed the natural flow patterns of their spawning and rearing waters before human development altered that flow pattern. Most species spawn in late fall when flows are at their lowest or are rising, increasing the chance that eggs are always covered with water. The eggs typically hatch in December or January. The hatchlings (called alevins) live for a month or more on nutrients stored in their yolk sac. Once the sac is absorbed, the young fish (called fry) must find and capture food to survive. Fortunately, hatchlings typically develop into fry during the spring thaw (March or April) when the first hatch of aquatic insects occurs, providing a ready source of food. As the waters and temperatures become warmer, and more and different kinds of invertebrate food sources become available, the fry grow rapidly. Depending on the species and stock, fry will spend as little as a month to over a year in the stream of their birth. Sometime during the first or second spring of life, the fry begin a biochemical change called smoltification that triggers the migration urge. Smoltification is the change that adapts the body from a freshwater to a saltwater environment. The young salmon (smolts) move down the river tributaries, migrating mainly during spring and summer when natural water flows would normally be at their highest. Smolts are moved along by the flow of the river, and must reach the ocean before the physiological capability of surviving in saltwater ceases.

The ocean provides the larger and more abundant food resources required for salmon to grow to maturity (6 to 60 pounds). These fish may spend as little as a year or as much as 5 years in the ocean before they become sexually mature and begin their return to freshwater. This requires that they undergo physiological changes to return to freshwater. Most return to the same stream where they were hatched. It is believed that they do this by being able to distinguish minute differences in the chemical composition of the water of different streams. In order to make this trip, they need bypass facilities (fish ladders) to get up and around the dams on the rivers and back to their spawning grounds. Here they spawn and die, producing a new generation in the same waters that gave them life.

This complex life cycle, with its near miraculous journey, as well as their significant commercial value, make the Pacific salmon highly vulnerable to the actions of modern human activity. Changes in water quality caused by agricultural, municipal, industrial and mining actions; overharvest; diversion of spring and summer runoff for irrigation; riparian habitat loss due to logging; uncontrolled grazing; and direct and indirect effects of dams (blockage to upstream spawning grounds and modification of downstream waters) all have contributed to the decline of Pacific salmon.

## 1.5 STATUS OF PACIFIC SALMON

The population decline of adult fish returning from the ocean to their freshwater spawning grounds paralleled the development of dams, irrigation diversion, livestock grazing, mining, municipal and industrial development, and over-fishing of the salmon and steelhead runs. Before these developments in the Columbia Basin, up to 16 million wild salmon and steelhead returned to the Columbia and Snake rivers to spawn in streams where they were born (Chapman, 1986; CBFWA, 1991b). By 1938 when Bonneville Dam was completed, this number had fallen to 5 to 6 million, mainly as a result of over-fishing and the effects of upstream activities that blocked spawning access or degraded habitat. Today, the total run is typically about 2.5 million, including known fish harvested in the ocean. About 0.5 million of these are wild fish. In 1990, 1.2 million salmon and steelhead entered the Columbia River (excluding ocean harvest), about 0.3 million of these were wild fish (ODF&W and WDF, 1991).

The loss of Pacific salmon habitat is dramatically illustrated in Figures 1.5-1 and 1.5-2 (NPPC database). Figure 1.5-1 illustrates the extent of the spawning and rearing habitat of salmon and steelhead within the Columbia River Drainage Basin in the United States before 1900. Figure 1.5-2 illustrates the present extent of the spawning and rearing habitat of salmon and steelhead within the same area.

It is apparent that much of the historical range has been lost. For example, the areas above Chief Joseph and the Hells Canyon Complex are now inaccessible to salmon and steelhead. The loss of additional habitat is the result of several factors (e.g., water diversion projects, loss of suitable riparian habitat, etc). The single largest area of remaining spawning and rearing habitat for wild salmon and steelhead in the system is in the Snake River System (including the Salmon River Basin) upstream of Lower Granite and downstream of the Hells Canyon Complex. To reach this spawning ground, fish must pass through the eight run-of-river reservoirs and dams examined in this OA/EIS.

## 1.6 ISSUES OF CONCERN

Several major key issues are at the heart of the development of any plan to improve salmon survival by altering river flows.

### 1.6.1 Flow-Survival Relationship

The relationship between improved flow conditions and increased survival of salmon in the Snake-Columbia rivers is based upon the assumption that the rate of travel of juvenile salmon is related to water velocity. The increased water velocity results in reduced water particle travel time through the lower Columbia-Snake river reservoirs that presumably translates into reduced travel time for migrating smolts. The quicker the fish can pass, the more will survive. A shorter travel time provides fewer opportunities for predation, residualism, and other physiological stresses.

Substantial uncertainty exists in the scientific community over the exact limits or conditions of the flow-survival relationship. There is general agreement that a positive relationship between flow and survival exists. All agree that there are limits to this relationship, but the degree of those limits remains uncertain. This relationship becomes more controversial with flows higher than 85,000 cubic feet per second (85 kcfs) on the Snake River and 220 kcfs on the Columbia River. For purposes of this study, it was concluded that the relationship is a general one and should not be considered a precise quantitative expression. Thus, other factors (e.g., species, age, smoltification, gas

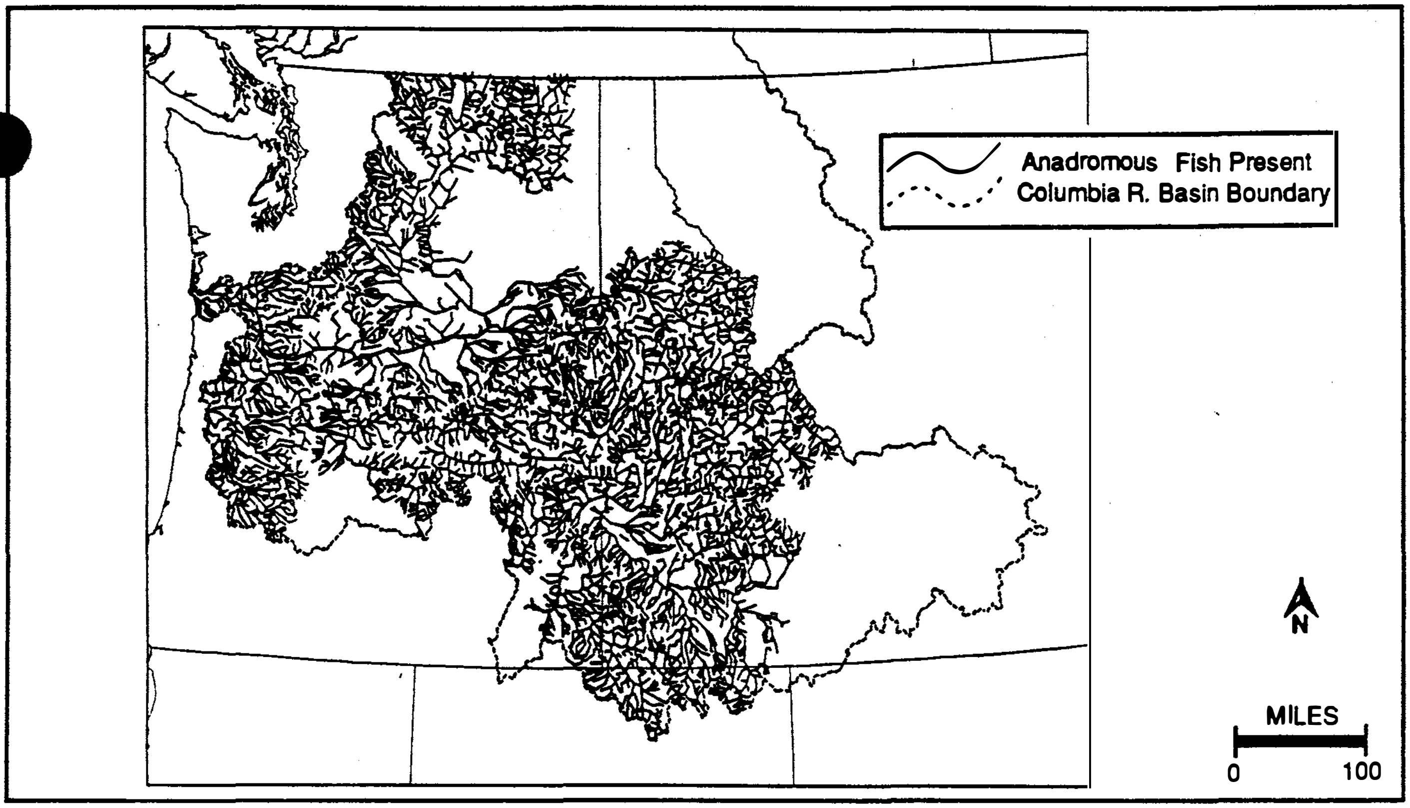



**Figure 1.5-1.** Historic distribution of anadromous fish in the Columbia River Basin (U.S. portion) (Source: BPA).

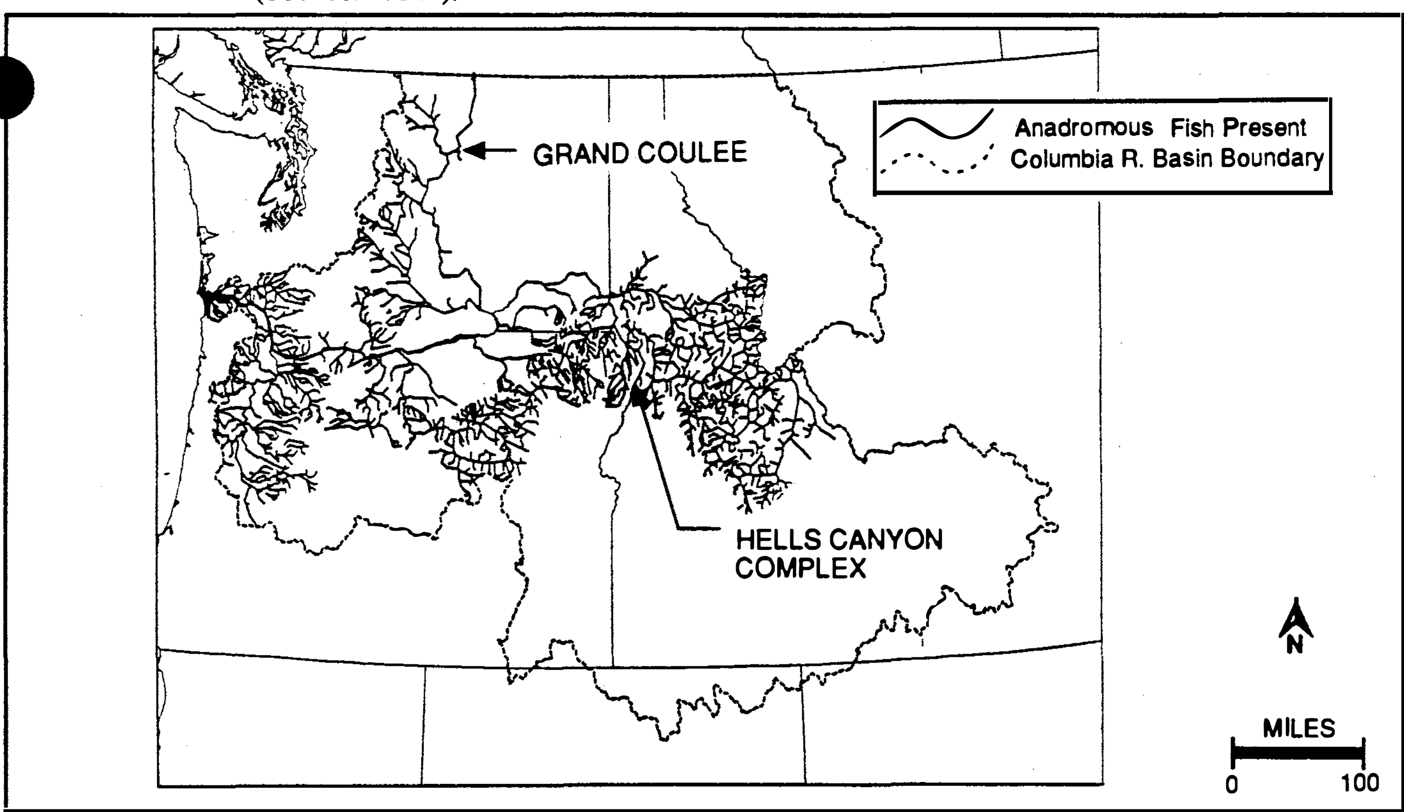



**Figure 1.5-2.** Present distribution of anadromous fish in the Columbia River Basin (U.S. portion) (Source: BPA).

supersaturation, water temperature, water turbidity, availability of food [see Section 4.2]) must also be considered when assessing the survival of migrating salmon.

### 1.6.2 Impacts to Other Users

The public scoping meetings demonstrated that the potential impacts of project drawdowns are of direct interest to many users. Impacts to navigation, power, irrigation, and recreation are expected. These impacts are discussed in detail in Section 4.

### 1.6.3 Impacts to Other Species

A concern is that the altered flow regimes, or the drawdown of storage reservoirs to augment river flows, will affect resident fish, wildlife, and wetland and riparian plant communities. These effects are discussed in Section 4. The manner in which these tradeoffs will be made is of concern to a number of interests and will be addressed in considering mitigative actions.

### 1.6.4 Wild Versus Hatchery Stocks

The desire to improve survival of the Snake River stocks of salmon encompasses preserving genetic diversity. Debate has been ongoing over the benefits of hatchery versus wild stocks. This debate is beyond the scope of this document and will not be considered further.

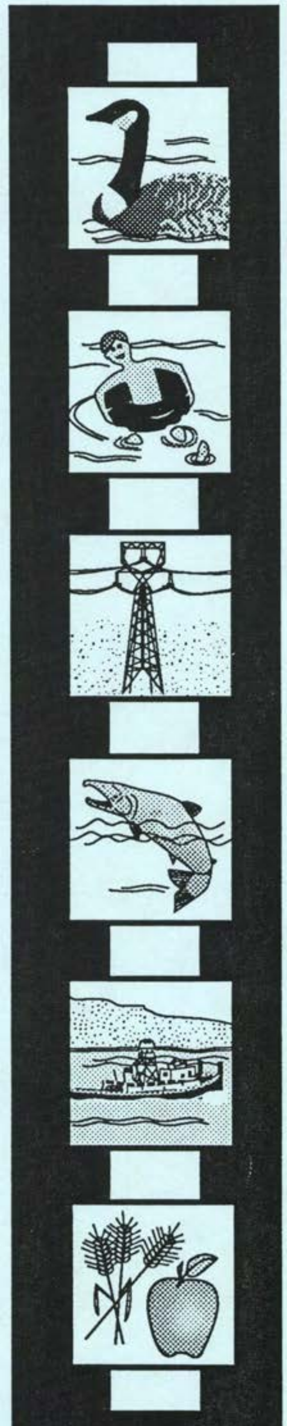
## 1.7 AUTHORITY

Each Federal project in the Columbia River Basin was constructed and is operated and maintained under specific Federal authorization and under compliance with general authorities applicable to the project. Within these authorities, the Corps and BoR make decisions on how to operate the projects to meet or balance authorized uses. This document discusses factors that the managing agencies may apply to the alternatives to reach a decision on project operations for 1992. For example, they would consider if the alternative would (1) not have significant negative effects on fish and wildlife; (2) provide information beneficial to future fish migration seasons, and not foreclose future flow alternatives; (3) not present unreasonable safety hazards to the physical structures or to the operation of the projects; (4) maintain the water quality of the Columbia River Basin; and (5) address project operations in a manner which recognizes a balance of the uses served by the Columbia River Basin and provides biological benefits to fish. Any proposed operation for 1992 will be expected to improve salmon migration and will be designed to provide information that may contribute to further fish survival and subsequent decisions on future operations.

In addition, the public participation required in the NEPA process satisfies the requirements of Section 310(b) and Section 415(b) of the Water Resources Development Act of 1990. Section 310(b) requires public participation in changes to reservoir operation criteria. Section 415(b) requires public notification (hearings) of actions associated with drawdown of Dworshak Reservoir.

# 2.0

# Description of Existing Environment



1992 COLUMBIA RIVER SALMON FLOW MEASURES
OA/EIS

CONTENTS

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

## TABLES

## FIGURES

FIGURES (continued)

# 2.0 DESCRIPTION OF EXISTING ENVIRONMENT

This section provides information about the existing environment of the portion of the Columbia River Basin System that might be affected by the action alternatives described in Section 3. It includes a summary description of the basin and the affected projects and their relationship to the overall system. This is followed by discussions of physical, biological, cultural, economic, and social environments. The purpose of this section is to provide the resource baseline information against which to measure the anticipated impacts from the river management alternatives considered in this document.

## 2.1 COLUMBIA RIVER BASIN

The Columbia River and associated tributaries comprise one of the principal economic and environmental resources in the Pacific Northwest. The river originates in the Rocky Mountains of British Columbia, Canada, and flows south to be joined by two major tributaries, the Kootenai and Pend Oreille rivers, near the U.S.-Canadian border (Figure 2.1-1). Another important tributary, the Snake River, originates in the region of Yellowstone National Park in Wyoming and joins the Columbia River 330 miles upstream from the mouth. From there the river flows westward past the city of Portland to the Pacific Ocean. The total drainage area of the basin is 259,000 square miles, and the annual runoff is 173 million acre-feet. About 40 percent of the total area lies in the Snake River drainage; however, this relatively arid region contributes only about 18 percent of the total flow during drought years. The greatest contribution of the river's runoff (almost 60 percent in dry years) comes from the Canadian portion of the drainage, which represents only 14 percent of the total drainage area.

The Columbia River Basin is primarily a snow-fed regime in which snow accumulates in the mountains during the winter (November through March), then melts to produce runoff during the spring and summer. A broad-crested flood peak usually occurs in early June, and thereafter the river recedes during the late summer and fall. Summary hydrographs of streamflow for the mainstem Columbia River at The Dalles and for the Snake River at Lower Granite Reservoir (Figures 2.1-2 and 2.1-3) show this general hydrologic pattern.

Tributaries to the Columbia River that lie near the west coast, such as the Willamette River that flows through Portland, are dominated by winter rains. These result in high streamflow of short duration throughout the winter and lower flow in the summer.

Since the 1930s, the basin has been developed by the construction of dams to capitalize on the hydroelectric potential of the rivers, provide inland navigation on the lower Columbia and lower Snake river reaches, and achieve improved flood control for areas that have been subject to flooding in the past. Some 77 Federal and non-Federal projects have been constructed, making the basin one of the most highly developed in the world. The total storage capacity of the system is approximately 40 million acre-feet.

Table 2.1-1 lists the mean annual runoff of the Columbia and Snake rivers in cubic feet per second (cfs), with the equivalent inches of runoff, for selected basin areas during a 40-year period, July 1928 through June 1968. Mean annual runoff for the Columbia River at The Dalles was 129 million acre-feet; at its mouth it was 173 million acre-feet, adjusted for irrigation depletions.

## 2.2 AFFECTED PROJECTS AND PROGRAMS

Most juvenile salmon originating from the Snake River Basin must make their way past eight dam and reservoir projects on the lower mainstem Snake and Columbia rivers before reaching the Pacific Ocean. The actions considered in this OA/EIS are operational changes that could be implemented at 10 Federal projects and 1 private project in 1992, including the 8 mainstem dams and 3 upstream storage reservoirs. These 11 projects are Lower Granite, Little Goose, Lower Monumental, and Ice Harbor on the lower Snake River; McNary, John Day, The Dalles, and Bonneville on the lower Columbia River; Dworshak on the North Fork Clearwater River; Grand Coulee on the middle Columbia; and Brownlee on the middle Snake River (Figure 2.1-1). Brownlee is a Federally licensed facility owned and operated by the Idaho Power Company (IPC). The other 10 projects are Federal projects, of which Grand Coulee is

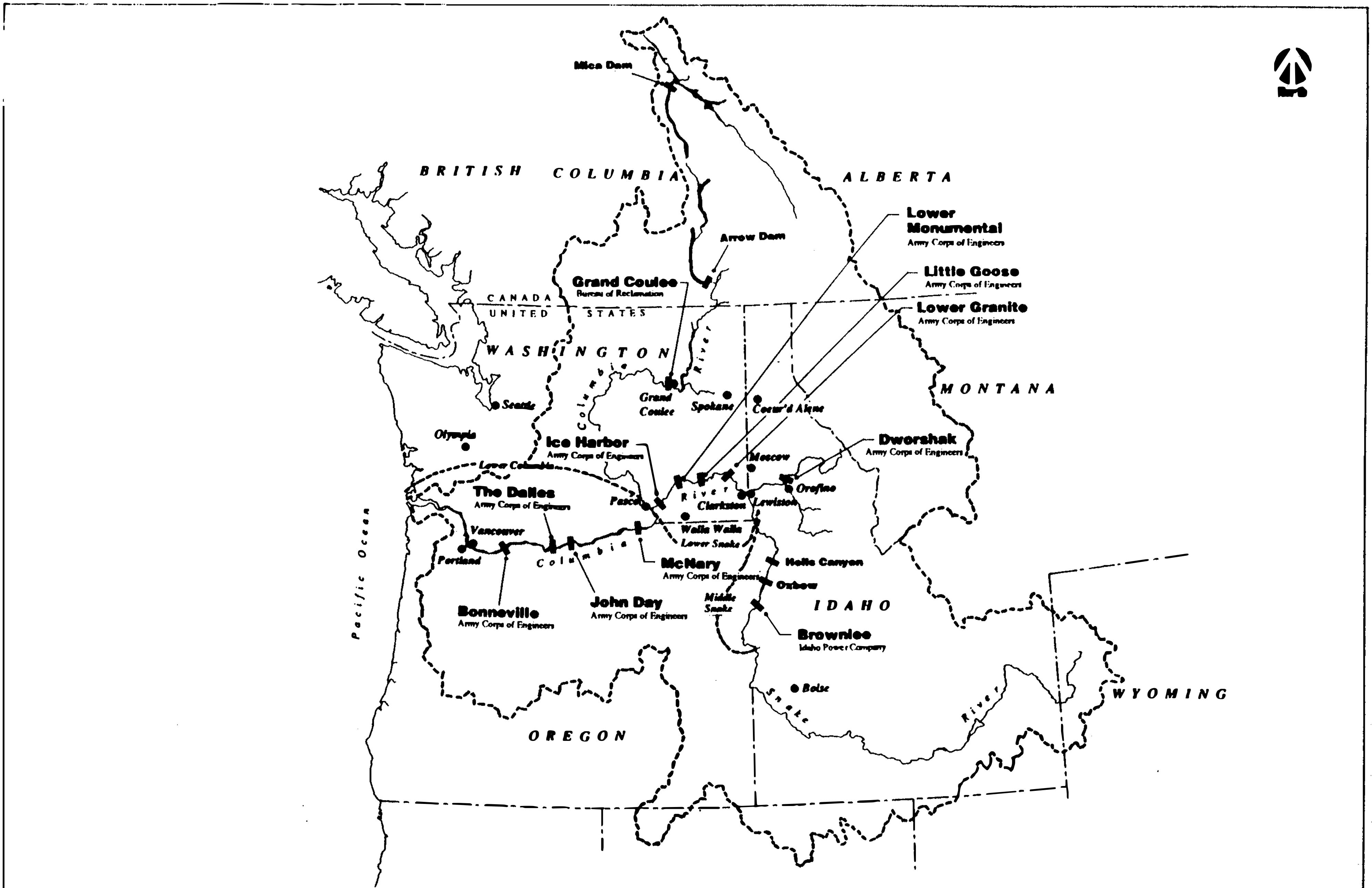



Figure 2.1-1. 1992 Columbia River Flow Measures EIS study area map (Source: Corps, 1991a).

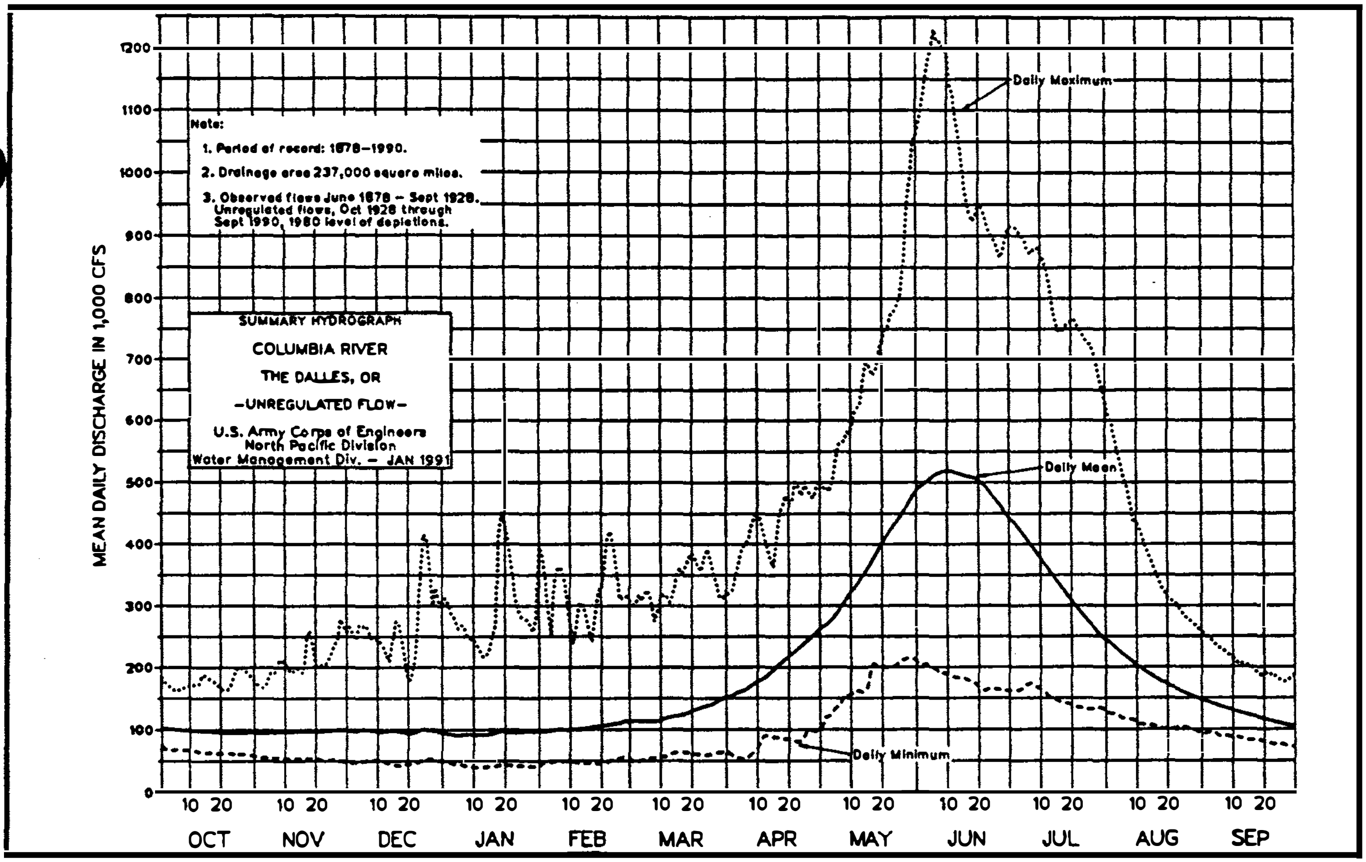



**Figure 2.1-2.** Summary hydrograph of the Columbia River at The Dalles, Oregon.

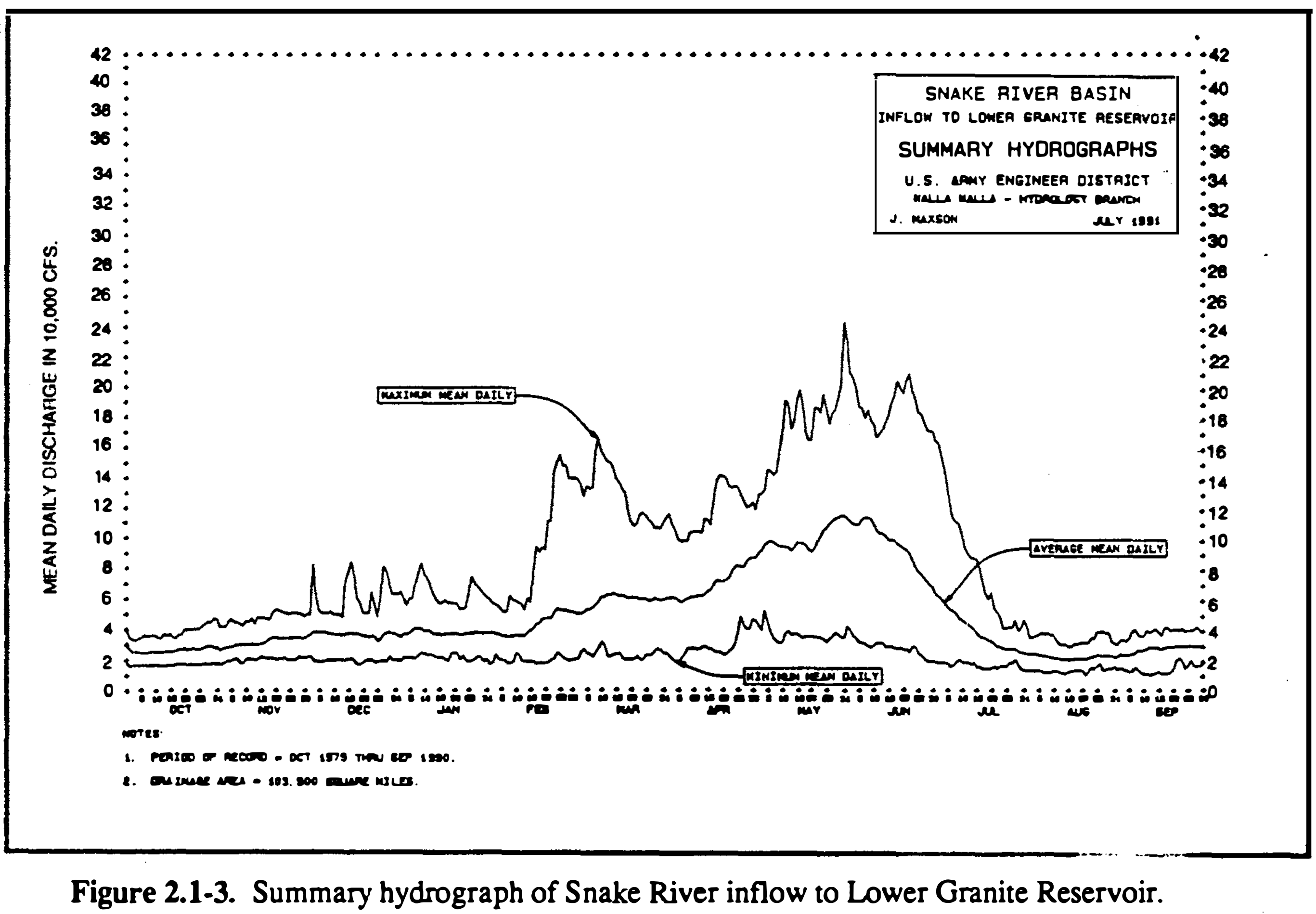



**Figure 2.1-3.** Summary hydrograph of Snake River inflow to Lower Granite Reservoir.

**Table 2.1-1.** Columbia and Snake river drainage characteristics.[a]

| Drainage Area Location | Drainage Area (Sq. Mi.) | Mean Annual Runoff: Mean Flow (cfs) | Mean Annual Runoff: Volume Acre-Feet (1,000s) | Mean Annual Runoff: Equivalent Precipitation (Inches) |
|---|---|---|---|---|
| Columbia River at Grand Coulee Dam | 74,100 | 107,700 | 77,970 | 19.7 |
| Snake River at Brownlee Dam | 72,500 | 16,530 | 11,970 | 3.1 |
| Salmon River at Whitebird (Freedom D.S.) | 13,320 | 10,650 | 7,710 | 10.9 |
| Clearwater River at Spalding (Lenore D.S.) | 8,300 | 14,110 | 10,220 | 23.0 |
| Snake River at Ice Harbor Dam | 109,000 | 47,680 | 34,520 | 6.0 |
| Columbia River at The Dalles Dam | 237,000 | 177,900 | 128,900 | 10.2 |
| Columbia River at the mouth | 259,000 | 238,800 | 172,890 | 12.5 |

Source: Corps, North Pacific Division.

a/ Runoff figures based on July 1928 through June 1968.

operated by the BoR, and the rest are operated by the Corps (Table 2.2-1).

### 2.2.1 Characteristics of Affected Projects

The Federal projects on the Snake and Columbia rivers are multi-purpose projects that provide many public benefits in many different areas. Project facilities include dams and reservoirs; hydroelectric powerplants and high-voltage transmission lines; navigation channels and locks; irrigation diversions and pumps; juvenile and adult fish passage facilities; parks and recreational facilities; lands dedicated to project operations; and areas set aside as wildlife habitat. The 11 projects fall into two major categories: storage and run-of-river projects (Figure 2.2-1). Dworshak, Brownlee, and Grand Coulee are storage facilities, and the remainder are run-of-river facilities.

#### 2.2.1.1 Storage Projects

The main purpose of storage reservoirs is to adjust the natural flow patterns of a river to closely conform to water uses. Storage dams in the Columbia River Basin store the spring and summer runoff water until it is needed. Hydropower operations typically require concentrated releases of stored water from late fall through early spring to generate electricity. Flood control requirements usually require releases in late fall and/or before the spring runoff to make flood storage space available. These two uses of storage are the primary reasons for drawdown, although releases may be made for other uses at individual projects.

These releases of water from storage projects result in a wide range of reservoir elevations during a year's operation. For example, Dworshak can operate over a range of 155 feet; Grand Coulee can operate over a range of 82 feet. Active storage

Table 2.2-1. Characteristics of projects.

| Project | Type of Project | Location (State, River, River Mile) | Project Ownership | Reservoir Name | Reservoir Capacity (normal operating range, acre feet) | Reservoir Elevation Normal Operating Range (msl) | Reservoir Length (miles) |
|---|---|---|---|---|---|---|---|
| Grand Coulee | Storage | WA, Columbia, 596.6 | BoR | Lake Roosevelt | 5,185,000 | 1,208-1,290 | 151 |
| Brownlee | Storage | ID, Snake, 285 | IPC | Brownlee | 980,000 | 1,976-2,077 | 60 |
| Dworshak | Storage | ID, N. Fork Clearwater, 1.9 | Corps | Dworshak | 2,016,000 | 1,445-1,600 | 53.6 |
| Lower Granite | Run-of-River | WA, Snake, 107.5 | Corps | Lower Granite Lake | 49,000 | 733-738 | 43.9 |
| Little Goose | Run-of-River | WA, Snake, 70.3 | Corps | Lake Bryan | 49,000 | 633-638 | 37.2 |
| Lower Monumental | Run-of-River | WA, Snake, 41.6 | Corps | Lake Herbert G. West | 20,000 | 537-540 | 28.7 |
| Ice Harbor | Run-of-River | WA, Snake, 9.7 | Corps | Sacajawea | 25,000 | 437-440 | 31.9 |
| McNary | Run-of-River | WA/OR,Columbia, 292 | Corps | Lake Wallula | 185,000 | 335-340 | 61.6 |
| John Day | Run-of-River [a/] | WA/OR, Columbia, 215.6 | Corps | Lake Umatilla | 500,000 | 255-268 (7/1-10/1)<br>260-265 (11/1-6/1) | 76.4 |
| The Dalles | Run-of-River | WA/OR, Columbia, 191.5 | Corps | Lake Celilo | 53,000 | 155-160 | 24 |
| Bonneville | Run-of-River | WA/OR, Columbia, 146.1 | Corps | Lake Bonneville | 100,000 | 71.5-76.5 | 45.0 |

acoe191

a/ John Day is technically a storage project, because it provides some flood control storage, but is presented as a run-of-river project due to common characteristics with other mainstem projects.

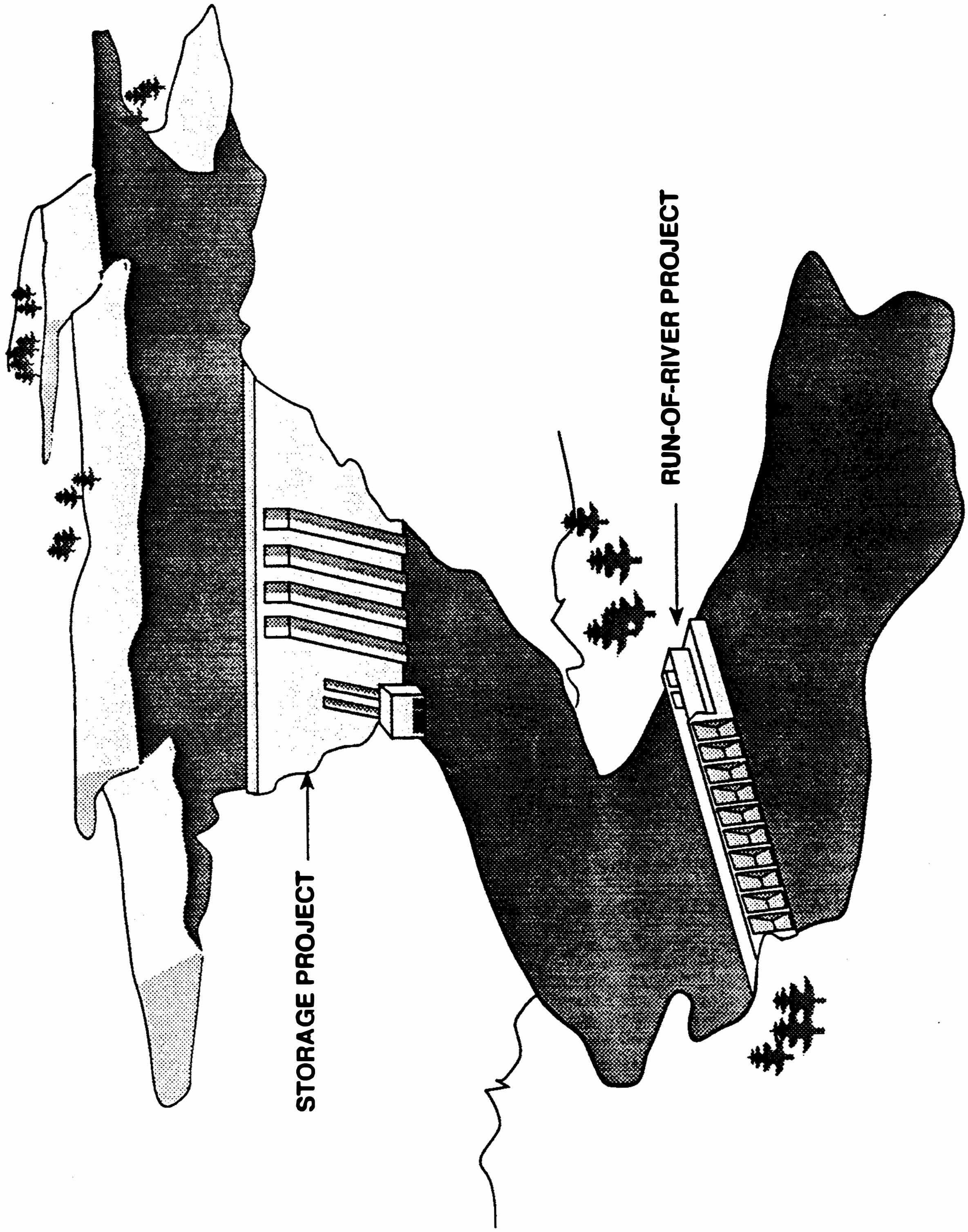



**Figure 2.2-1.** Storage and run-of-river projects.

capacity of these 3 projects ranges from 980,000 acre-feet at Brownlee to 5,185,000 acre-feet at Grand Coulee.

### 2.2.1.2 Run-of-River Projects

The eight run-of-river projects on the lower Snake and Columbia rivers were constructed to serve two major purposes: (1) to provide adequate water depth for navigation over rapids and other obstacles, and (2) to provide for power generation. With the exception of John Day, these projects do not have enough storage to permit seasonal regulation of streamflows. However, each has several feet of daily/weekly storage (pondage), which is used for hourly regulation of powerhouse discharges to follow the daily and weekly load patterns (Appendix A). John Day has, in addition, a limited amount of seasonal flood control storage space.

Table 2.2-1 lists the normal operating ranges and usable storage volumes for each project. While it is physically possible to draft these reservoirs well below the normal minimum pool levels, the projects were not designed to operate in that range. Some of the project facilities, such the navigation locks, fish ladders, and juvenile bypass facilities, would no longer function and railroad and highway fills and other embankments would not be protected against wave action.

## 2.2.2 Project Purposes and Uses

With the exception of Brownlee, which is owned and operated by IPC, each project was constructed under specific Federal authorizing legislation identifying the major intended uses for each project. IPC is responsible for operating Brownlee in a manner that best serves multiple uses. Most of the other projects were specifically authorized for power production, flood control, navigation, or irrigation. The abundance of water and the predictability of its use allows a project to support other purposes as well, but only after its authorized uses are met (Table 2.2-2). Generic Congressional authorization allows for such uses as water quality, fish and wildlife, recreation, and municipal and industrial water supply. While the authorizing legislation stipulated intended use, it seldom contained explicit provisions for operating the individual projects or for their coordinated operation within the total system. The Corps and BoR are responsible for deciding how to operate their projects based on principles of multiple-use operation, their agency charters, operating experience, and public concerns. The major uses of the projects are summarized below. Figure 2.2-2 on page 2-9 shows the water levels required to accommodate some of these uses. Table 2.2-3 on page 2-10 gives specific elevation per project for each item noted in Figure 2.2-2.

### 2.2.2.1 Power Generation

Falling water provides the energy to turn power-generating turbines at the dams. Hydropower supplies approximately 75 percent of the electricity in the Pacific Northwest (BPA et al., 1991). When in surplus, it is also an export product for the region. The remainder of the region's electricity comes from thermal resources, mainly nuclear and coal-fired plants.

Power production on the Columbia River System involves three primary objectives that system managers try to meet, within a variety of system constraints:

- Meeting the region's firm energy commitments
- Optimizing future energy production through refill
- Maximizing non-firm energy production to keep regional power rates as low as possible

**Firm Power.** Firm power contracts are long-term commitments that carry a guarantee to meet some or all of a customer's load requirements over a defined period. These contracts are based on an estimate of the firm energy load-carrying capability (FELCC) of the system. FELCC can be defined as the energy produced by the hydroelectric system if the four critical water years (1928 to 1932, the four lowest consecutive years of runoff in the 50-year period used for power planning) were to reoccur. The Northwest's publicly owned utilities have first claim on power produced by the Federal Columbia River System projects. BPA has long-term firm power sale contracts with over 120 utilities, including municipalities, public utility districts, and rural cooperatives. The agency also sells firm power directly to some of the region's large industries, including aluminum smelters. IPC is not a member of the Pacific Northwest Coordination Agreement and does not integrate its actions.

Table 2.2-2. Project uses.

| Project | Authorized Uses |
|---|---|
| Grand Coulee | power generation, flood control, irrigation, and other beneficial uses |
| Brownlee[a/] | power generation, navigation, recreation, fish/wildlife, irrigation, and flood control |
| Dworshak | power generation, flood control, navigation, recreation, and fish/wildlife |
| Lower Granite[b/] | power generation, navigation, recreation, fish/wildlife, irrigation, and water quality |
| Little Goose[b/] | power generation, navigation, recreation, fish/wildlife, and irrigation |
| Lower Monumental[b/] | power generation, navigation, recreation, fish/wildlife, and irrigation |
| Ice Harbor | power generation, navigation, recreation, fish/wildlife, and irrigation |
| McNary[b/] | power generation, navigation, recreation, fish/wildlife, and irrigation |
| John Day | power generation, navigation, flood control, recreation, fish/wildlife, and irrigation |
| The Dalles[b/] | power generation, navigation, recreation, fish/wildlife, and irrigation |
| Bonneville | power generation, navigation, fishery, and recreation |

Sources: Corps, 1989a, 1988a-d, 1986a, 1968, 1962, 1961a.

a/ Authorized uses per IPC license from Federal Power Commission (now Federal Energy Regulatory Commission).

b/ Other project purpose is water quality.

**Refill.** As plans are formulated to draft reservoirs to meet firm power needs, provide flood control, and generate as much non-firm energy as possible, other continuing needs for reservoir water must be considered. Enough water must be retained in storage to provide flows necessary for spring fish migration and to ensure a high likelihood of reservoir refill by summer to fulfill recreational needs, and provide water for next year's power generation.

**Non-firm Power.** Non-firm generation is power in excess of that needed to meet firm power requirements. In most water years, stream flows are high enough to produce at least some non-firm generation. This is particularly true after January 1, when initial runoff forecasts make it possible to estimate how much water will be available from snowpack runoff. In an average year, non-firm generation may add 25 percent or more to the hydro system's generating output. Non-firm power is generally sold with no guarantee of continuous availability and with the ability to terminate delivery on very short notice. Non-firm energy is purchased from BPA by Northwest utilities, California utilities, and some large industries that contract directly with BPA for power. Customers in the Northwest have priority to purchase non-firm power.

Storage reservoirs are the key to matching the region's plentiful water resources with electricity use patterns. Energy, in the form of water, is held in reservoirs when natural streamflows exceed power generation requirements. Water is released for generation when it is needed to produce electricity.

### 2.2.2.2 Flood Control

The primary flood control season in the Columbia River System is May through July. Rain-induced

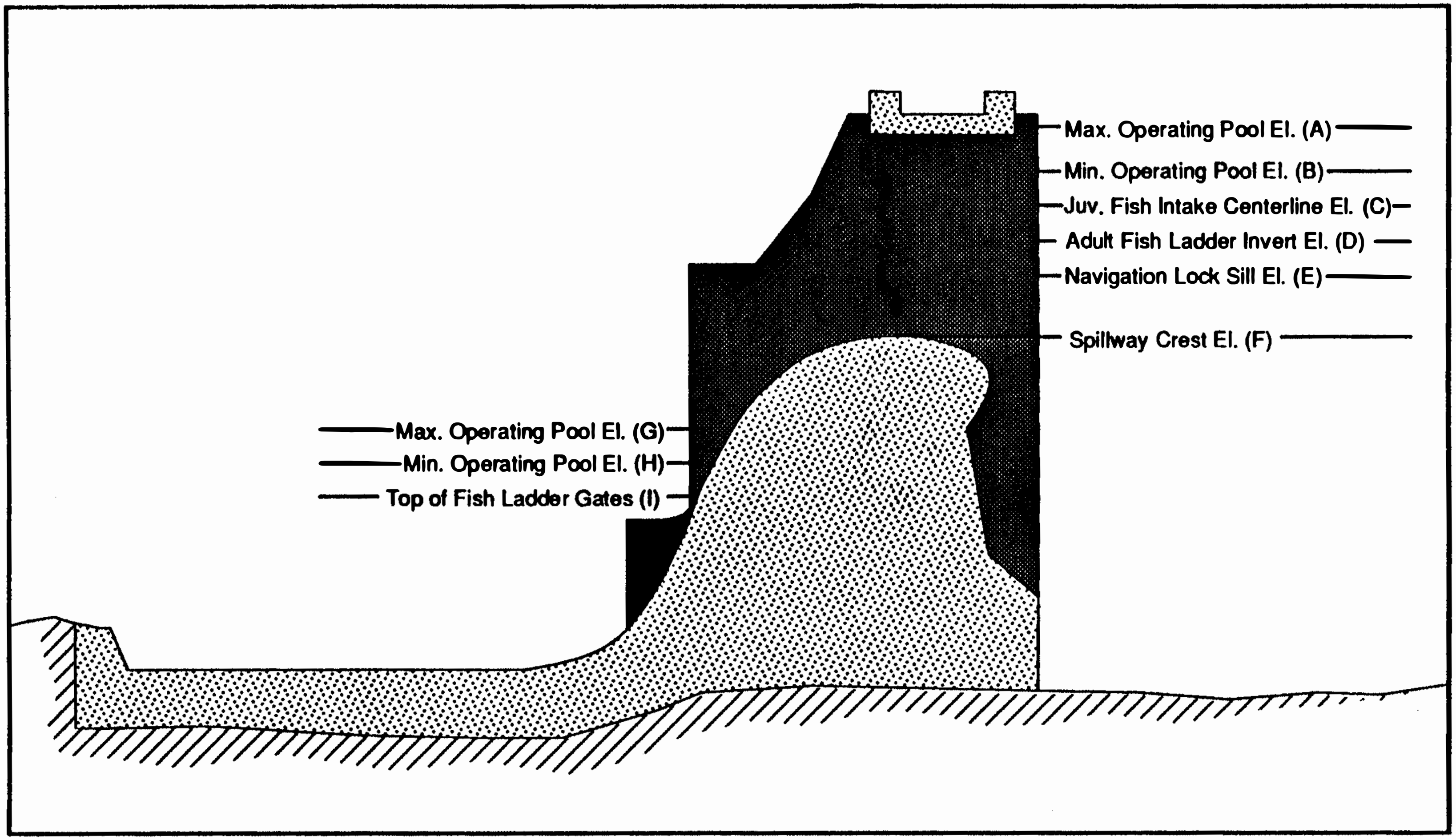



**Figure 2.2-2.** Summary of pertinent project data and operating limits.

**Table 2.2-3.** Summary of pertinent project data and operating limits (fmsl).

| Project | Upstream: Maximum Operating Pool Elevation A | Upstream: Minimum Operating Pool Elevation B | Upstream: Downstream Juvenile Fish Intake Center Line C | Upstream: Adult Fish Ladder Exit Invert Elevation D | Upstream: Navigation Lock Sill Upstream Elevation E | Upstream: Spillway Crest Elevation F | Downstream: Maximum Operating Pool Elevation G | Downstream: Minimum Operating Pool Elevation H | Downstream: Top of Adult Fish Ladder Gates I |
|---|---|---|---|---|---|---|---|---|---|
| Columbia River | | | | | | | | | |
| Bonneville | 76.5 | 70.0 | 65.5 | 63.0 | 40.0 | 24.0 | 27.0 | 10.0 | 2.0[a/] |
| The Dalles | 160.0 | 155.0 | 151.0[b/] | 147.0 | 140.0 | 121.0 | 85.0 | 75.0 | 67.0 |
| John Day | 268.0 | 257.0 | 250.4 | 250.5 | 242.0 | 210.0 | 166.0 | 157.0 | 154.0 |
| McNary | 340.0 | 335.0[c/] | 330.0 | 330.0 | 320.0 | 291.0 | 269.0 | 264.0 | 252.0 |
| Snake River | | | | | | | | | |
| Ice Harbor | 440.0 | 437.0[c/] | 431.5[b/] | 431.0 | 422.0 | 391.0 | 346.0 | 340.0 | 332.0 |
| Lower Monumental | 540.0 | 537.0[c/] | **[d/] | 530.5 | 521.0 | 483.0 | 442.0 | 439.0 | 431.0 |
| Little Goose | 638.0 | 633.0[c/] | 628.9 | 627.0 | 618.0 | 581.0 | 541.0 | 538.0 | 530.0 |
| Lower Granite | 738.0 | 733.0[c/] | 729.0 | 727.0 | 718.0 | 681.0 | 638.0 | 633.0 | 625.0 |

a/ Fish ladder floor elevation; no minimum tailwater requirement for fish ladder operation.

b/ Top of sluiceway.

c/ Minimum forebay elevation used for design of existing fish passage facilities which corresponds to current minimum operating pool (MOP).

d/ No downstream fish bypass facilities.

floods also occur in the winter in the southern and western parts of the drainage. No significant flooding of the Columbia River below Bonneville Dam has occurred since completion of the Federal projects. Because the ability to forecast the source of most flooding (snowmelt) in the study area has improved over time, the amount of flood control storage can be determined several months in advance. Consequently, flood control storage space in Columbia River reservoirs is maintained only during those months with high flood risk, and the amount of space needed can be predicted by the amount of runoff expected. This situation makes it possible to use the reservoir space to store water for other uses (e.g., hydropower, irrigation, recreation, and fish flows), when there is reduced flood risk, and for joint purposes during the flood season.

### 2.2.2.3 Navigation

The Columbia-Snake Inland Waterway from the Pacific Ocean to Lewiston, Idaho consists of two segments. The first is the 40-foot-deep, open-river channel for ocean-going vessels that extends 106 miles from the ocean to Portland, Oregon and Vancouver, Washington. The second is the shallow-draft barge channel that extends 359 miles from Vancouver to Lewiston.

Navigation between Bonneville Dam and Lewiston is possible because each dam has a system of locks, and the projects maintain sufficient water at minimum operating pool (MOP) to pass vessels in the authorized 14-foot channel depth. This navigation channel connects the agricultural interior basin with the deep-water ports on the lower Columbia River.

### 2.2.2.4 Irrigation

Irrigation is an authorized use at nine of the affected projects (Table 2.2-2). Grand Coulee, operated by the BoR, is the only one of the affected projects where irrigation diversion facilities are integral to the dam and related structures. Irrigation water is withdrawn from the other projects by pumping stations at the reservoir margins. None of the projects have storage allocated to irrigation. The major irrigation consideration at these projects is to ensure that pool elevations are high enough to permit the pumps to operate. The irrigation season generally extends from about April through September, but can continue into October or November.

### 2.2.2.5 Fish

A variety of fish facilities and programs have been developed at the affected projects. Adult fish passage facilities were built into all eight of the mainstem Columbia and Snake River dams. In the early 1950s, the Corps began an intensive program, in cooperation with regional fish agencies and other experts, to improve adult fish passage and develop methods of safe juvenile fish passage at each of the mainstem dams. These research efforts led to the development of submersible traveling screens to divert juvenile fish away from turbine intakes and into special conduits for subsequent bypass around the dam or collection for transport downstream by truck and barge. Five of the projects currently have these systems, including Lower Granite, Little Goose, McNary, Bonneville, and John Day, and a system at Lower Monumental will be completed by 1992. Ice Harbor and The Dalles currently use sluiceways and will have bypass systems installed by 1993 and 1998, respectively.

In addition to physical facilities, other measures that change the way the river is operated have been implemented to protect fish and wildlife. One such measure is the Water Budget, in which water is discharged from storage projects to increase spring flows for juvenile fish passage in the Snake and Columbia rivers. In another action taken in 1989, NPPC amended their program to incorporate terms of a recently signed regional Long-Term Spill Agreement (LTSA). The amendments called for passing a specific amount of water over the spillways of four Corps projects—Lower Monumental, Ice Harbor, John Day, and The Dalles—in the spring and summer (summer only at John Day), providing non-turbine passage for juvenile fish at these projects. This replaced previous Corps spill programs in effect since 1977, which used nightly hydro-acoustic monitoring at Lower Monumental and John Day to initiate spill if fish at the powerhouse exceeded threshold numbers.

Rivers and reservoirs are also home to fish that do not migrate to the sea. These fish, such as trout and bass, are referred to as resident fish. System operators monitor water levels to protect the shallow spawning habitat of resident fish in the reservoirs as much as possible. State fish and wildlife agencies manage the resident fisheries in these reservoirs for the benefit of the public.

#### 2.2.2.6 Wildlife

Although the focus of most mitigation and enhancement actions of Federal projects in the Columbia River System has been on fish, wildlife protection is also a consideration. Much of the land within and adjacent to Federal project boundaries is designated and managed as wildlife habitat. Several national wildlife refuges are located on project lands, and a large number of other parcels are operated as habitat management units (HMUs). Wildlife considerations also affect project operations and water management. For example, more than 20,000 acres at Dworshak have been designated for present and future wildlife management. In addition, special operating requirements are put into effect at certain projects in the early spring, when geese are selecting their nesting sites, to keep geese away from areas that may later be inundated with water.

#### 2.2.2.7 Recreation

Recreational facilities are provided at all of the affected projects (Table 2.2-2). Recreation is a specifically authorized project purpose in a few cases. More commonly, recreational use and development is generally authorized under legislation such as the Federal Water Project Recreation Act of 1964. Facilities are provided by the project operators or a variety of Federal, State, local, and tribal agencies. Key activities include fishing, swimming, waterskiing, picnicking, camping, hunting, boating, windsurfing, and sightseeing. Use of the reservoirs occurs mostly from late spring through early fall. Normal operation of the projects for flood control, power generation, and other purposes sometimes conflicts with optimum conditions for recreational use. Where compatible with other project purposes, the projects are operated to maintain recreation benefits.

#### 2.2.2.8 Water Supply and Water Quality

The projects supply water to some cities and industries by diversion or pumping, but these diversions are small. Water quality in the Columbia River System is generally good, but pesticide runoff in areas of heavy agricultural use jeopardizes wildlife populations. Municipal and industrial discharges also degrade water quality in some reaches. In the tributaries, streamflows from reservoir projects must be adequate to maintain water quality requirements for aquatic life, municipal or industrial use, and water recreation. Minimum outflows are specified for each project based on downstream requirements. With the exception of dissolved gases, the projects generally have little effect on water quality.

### 2.2.3 Project Operation (Prior to 1991)

The Corps, BoR, and BPA play key roles in direct operation of the integrated and coordinated Columbia-Snake River System. The Corps operates nine of the projects considered in this OA/EIS (except Grand Coulee and Brownlee). It is responsible for flood control at all major reservoirs in the Columbia River Basin. The Corps also maintains navigation channels to accommodate barges and other river traffic. BoR is responsible for Federally financed water development and irrigation programs. BoR built and operates Grand Coulee Dam. BPA markets and distributes the power generated at the Federal projects on the Columbia-Snake rivers. BPA sells power from the dams and other generating plants to public and private utilities, and it builds and operates transmission lines that deliver the electricity. The Corps and BoR develop operating requirements for their projects and, within these limits, BPA schedules and dispatches power.

Operation of all major dams and reservoirs in the Columbia River System, except for Brownlee, is coordinated to maximize the power benefits provided by storage, within the constraints placed on the system. The Pacific Northwest Coordination Agreement, a complex contract for planned operation among the Federal project operators and power generating utilities of the Pacific Northwest, deals with the power aspects of the coordination. It calls for annual planning, which first must accommodate all the authorized purposes of the Columbia River System projects. All parties to the agreement coordinate to meet the overall system requirements.

Historically, the dominant functions of the reservoir system have been navigation, power generation, and flood control. Recently added functions include maintaining high flows in certain seasons to help the juvenile salmon and steelhead migrate downstream, and ensuring higher lake levels for resident fish and summer recreation.

Reservoirs are operated according to guidelines called rule curves. The curves are used to operate individual reservoirs, as well as the total coordinated reservoir system. Rule curves specify reservoir water levels that are desirable for each month and provide guidance in meeting project purposes. Each project operator develops a plan to meet the rule curve at the start of each operating year. Plans are updated as the year progresses and as more information on snowpack and streamflow becomes available.

Before each new operating year begins in August, an operating plan is developed from the critical period water sequence that is based on water conditions that occurred from September 1928 through February 1932. Once the basic operating guidelines are set, actual operation of the system over the year is based on meeting several related but sometimes conflicting objectives:

- Provide adequate flood storage space for controlling spring runoff,
- Maintain an acceptable probability that reservoirs will refill to provide water for next year's operation,
- Provide flows to aid downstream migration of juvenile fish, and
- Maximize power generation, within the requirements imposed by other objectives.

Many variables cause short-term operational adjustments. For example, sometimes more rain causes higher flows in the fall. This water can be used to produce non-firm energy, or the water can be left in storage for future use if storage space is available. In a poor snowpack year, it may be necessary to draft reservoirs to levels jeopardizing their refill to get enough power to meet firm energy demand in the region or to meet other obligations. Once every 4 years or so, runoff is so low that reservoirs in the system fail to refill. When this occurs, optional power sales cease and power generation is limited to meeting firm power requirements.

General operation of the system can be divided into three seasons:

- **August through December** is the fixed drawdown period, when storage reservoirs are operated according to predetermined rule curves because forecasts of the runoff from the snowpack are not available until January.
- **January through March** represents the variable drawdown period, when operation of the reservoirs is guided by the runoff forecasts. Reservoirs are drafted to provide flood control space and to meet power needs. They are also drafted to make non-firm energy sales. But enough water must be kept in storage to provide fish flows necessary for spring fish migration and to reasonably ensure reservoir refill by summer.
- From **April through July,** the reservoirs store spring runoff. Also during this time, water is released to help juvenile salmon and steelhead migrate to the ocean. Operations for flood control and power sales continue as needed.

### 2.2.4 Activities Related to Fish

An extensive array of fishery programs has been developed at the projects. Many of these programs have evolved over time as project operators have sought to meet specific needs. Passage of the Northwest Electrical Power Planning and Conservation Act of 1980 significantly expanded these programs. The Act created the NPPC and led to its Fish and Wildlife Program, which greatly increased the funding available for programs to protect, mitigate, and enhance fish and wildlife.

#### 2.2.4.1 Juvenile Bypass Program

Migrating juvenile salmonids originating above Lower Granite must pass the eight mainstem dams to reach the ocean. Unless bypass facilities are provided, downstream migrants can pass over the spillway or through the powerhouse at each dam. Reduced spring flows in the lower Snake and Columbia rivers have led to less water released over the spillways, resulting in the passage of more juveniles through the powerhouse turbines. Rapid changes in pressure are the primary cause of mortality when juveniles pass down through the turbines. The impact of the turbine blades and the shearing action of water in the turbine can also cause injury and death. In addition, juvenile salmon and steelhead may be stunned and disoriented after passing through the turbines, making them more susceptible to predation (Corps, 1991a).

All eight lower Columbia and Snake River dams have been equipped with some type of bypass system for downstream migrants. Five of the projects have been equipped with facilities to divert juvenile anadromous fish away from the turbine intakes and through a bypass system to the tailrace, where they are collected for transport or released back into the river (Figure 2.2-3). The systems at Lower Granite, Little Goose, and McNary dams are used to collect fish for the transport program. The bypass systems at Bonneville and John Day dams discharge fish back to the river below the projects. A new bypass system is currently being constructed at Lower Monumental Dam. This system will be operational in 1992. Bypass facilities for Ice Harbor and The Dalles are being designed and should be operational in 1994 and 1998, respectively. These two projects currently use sluiceways to bypass juvenile fish.

The bypass systems use submersible traveling screens to deflect juvenile fish out of turbine intakes into a gatewell slot. From the gatewell slots, juvenile fish pass through orifices into a collection gallery inside of the dam. The collection galleries run the length of the powerhouses, then transition to either pipelines or open flumes that carry juvenile fish to release sites below the projects or to transportation facilities. At projects with transportation facilities, fish pass through separators to remove juvenile fish from adult salmonid fallbacks or larger resident fish. From the separators, juvenile fish pass through a sampling and distribution system and are routed into raceways. Here they are held for transportation or passed directly onto a barge for transportation. Juvenile fish are generally held in raceways for less than 2 days (from the time they are collected to when they are transported).

Ice and trash sluiceways are currently operated for passing fish at The Dalles and Ice Harbor. These sluiceways are concrete channels along the upstream faces of the dams and are separated from the reservoirs by a series of gates. The system was designed so that the gates could be lowered to skim floating ice or debris from the reservoir behind the dam. The sluiceways work in a similar fashion to attract surface-oriented juvenile salmonids. Juvenile fish are attracted into the sluiceways where they pass through the channel to the tailraces below the dams.

### 2.2.4.2 Transport

NMFS and the Corps, in cooperation with the fish agencies and tribes, developed the Juvenile Fish Transportation Program. The program was instituted as an emergency measure because of adverse water conditions during the mid-1970s, but it was continued because research showed that it was an effective way to bypass juveniles around the dams. At the collector dams (Lower Granite, Little Goose, and McNary), screens in the turbine intakes guide the fish to collection systems, gather the smolts, and move them to holding facilities. At appropriate intervals, the fish are loaded onto barges or trucks where they are transported downstream. Barges constantly circulate river water, so the smolts can imprint on the chemical composition of the water and, thus, locate their home stream when they return. The barges also dissipate high dissolved gas levels in the river, improving survival.

There has been considerable debate within the region as to whether the transportation program is an acceptable way to enhance survival of downstream migrating fish. The program under the control of NMFS began as an experimental method for improving survival in 1975 through the use of trucks. In 1976, the fishery agencies approved mass hauling of up to 50 percent of the total outmigrants of spring and summer chinook salmon from Little Goose and Lower Granite dams (Chapman et al., 1991). In 1977, barges were added for transport. In 1981, the transport program was taken over by the Corps, but NMFS retained an advisory role. Other agencies are involved through the Fisheries Transport Oversight Team.

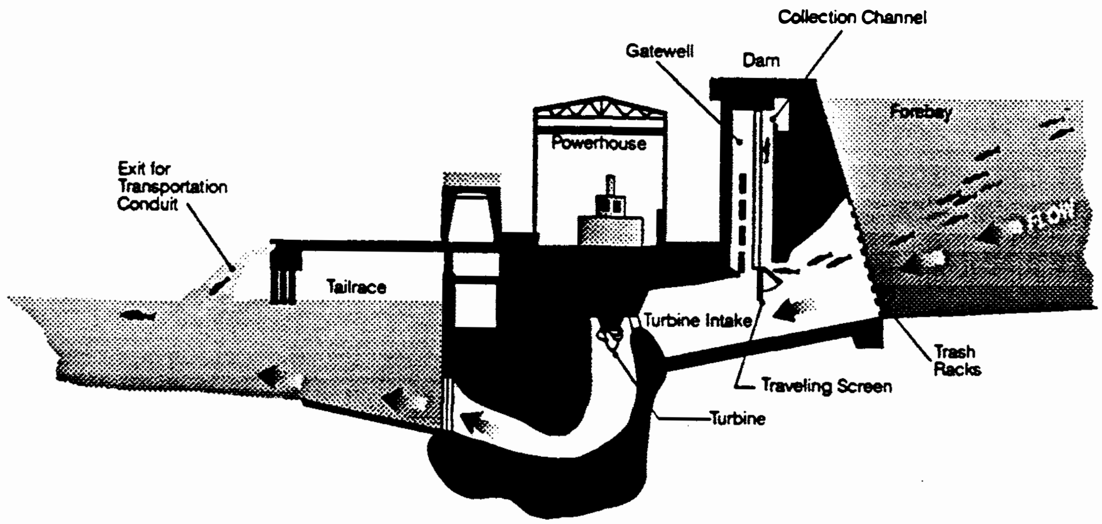



**Figure 2.2-3.** Juvenile bypass facilities.

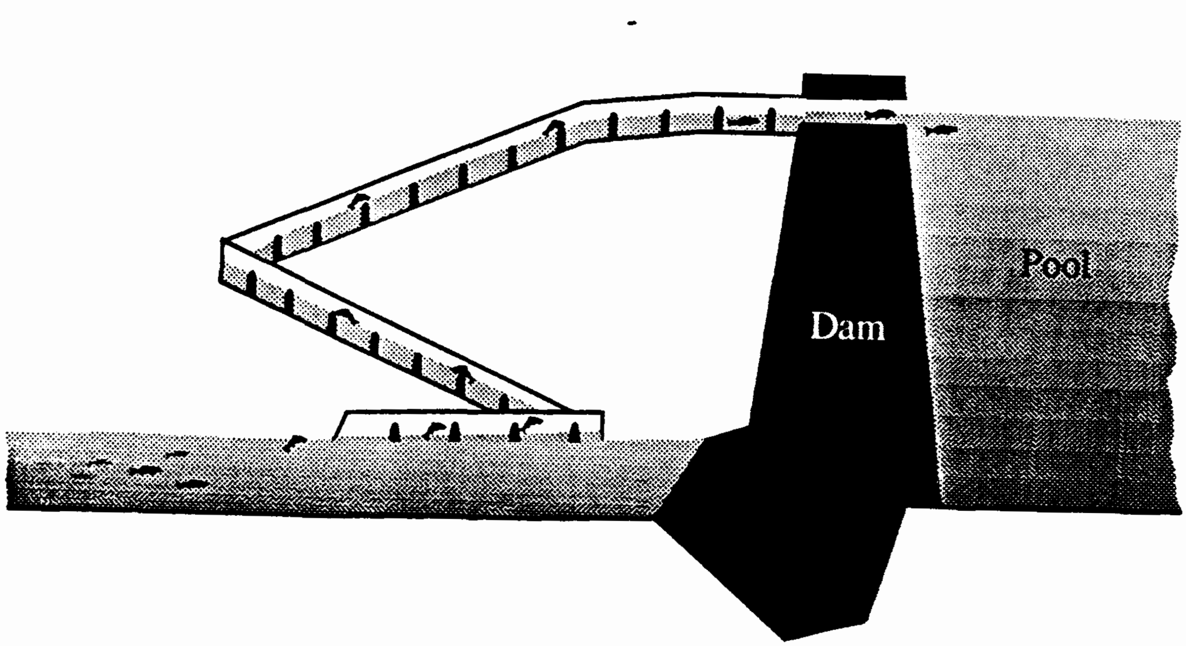



**Figure 2.2-4.** Adult fish ladder.

Tests have been conducted over the course of transportation activities to determine the relative survival of transported compared to non-transported fish. In the past, these tests have indicated mixed but mostly positive results. Of 28 tests conducted, only 13 indicated significant changes in survival. Of these, 12 were positive and one (a truck test) was negative for transported versus non-transported fish. In another 10 tests, improved survival was measurably positive but not statistically significant (Chapman et al., 1991). Many factors have been improved in collection, handling, and transport since some of these studies were conducted. The latest results indicated a positive transport benefit ratio for spring/summer chinook salmon and steelhead from the Snake River (Matthews et al., 1990).

In spite of the mostly positive results, concern remains over the benefits of transporting fish. A main concern is that survival of transported fish, while often higher than in-river migrants, is not as high as expected although several known mortality factors in the river are avoided. Possible causes for lower survival include straying of fish, stress from transport, stress from crowding with different size fish, and increased disease transmission. The level of effect, if any, of each of these concerns has not been accurately determined. In some cases, another cause of lower-than-expected survival could be that many of the fish might suffer mortality independent of dam passage, such as from disease, that might not adversely affect fish survival until after they pass Bonneville Dam. The fisheries agencies' policy concerning transport is to "spread the risk." They believe that the transport benefit ratio for spring and summer chinook is less than it should be, and that fish might have an equal or better chance of survival by migrating down the river without being transported during good flow years; they do, however, recognize significant transport benefits in low flow years.

On the average, up to 20 million young salmon are transported each year. The typical travel time for transported fish is about 2 days, which is much quicker than in-river travel time. The transport program generally has operated from April through mid-July on the lower Snake River and through mid-September on the lower Columbia River. Trucks are used to transport the smaller numbers of smolts collected during the early and final stages of the transport program.

Historically, survival per project without transportation on the Snake River and some Columbia River projects has been a maximum of about 85 percent per project and often much lower, including reservoir and dam passage mortality (Sims et al., 1983). With turbine screening, reduced gas supersaturation effects, and improved bypass facilities, this survival rate under the best condition would probably be higher, although in average or low flow years survival could still be lower. The absolute survival of fish that pass all eight dams from Lower Granite to Bonneville cannot be predicted accurately at this time. However, one estimate could use higher than measured values as an indication of what might occur under relatively good passage, flow, and predation conditions in this system. A relatively high estimate of survival could be 90 to 95 percent survival per project for fish not transported. For fish originating above Lower Granite Dam, passing all eight dams (based on these two per project survivals) would result in a survival rate of 43 to 66 percent survival to below Bonneville Pool.

Currently, survival for in-river migrants is lower than this in most years, possibly 20 to 25 percent overall. Typically, about 98 percent of transported fish survive from collection at the dam to release below Bonneville Dam. This suggests that survival for transported fish should be much higher (1.5 to 5 times higher) than fish not transported. Tests of survival of transported fish versus non-transported suggests that the differences are in the lower range of these values which is to be expected since research is only permitted in good flow years (when survival of in-river fish is also expected to be the best). Transport benefit ratios (i.e., relative survival) of marked fish released below Little Goose Dam to those collected at Lower Granite Dam and transported below Bonneville Dam for yearling chinook and steelhead average, respectively, 1.6 and 2.0 times higher than the non-transported control fish (Matthews et al., 1990). It should be noted that the control group released below Little Goose Dam traverses through only six projects and reservoirs (as opposed to seven), and therefore the benefit of transport is underestimated. The most recent transport benefit ratios were obtained from a very good flow year, and would therefore be expected to be in the lower range. The NMFS has concluded that transport is beneficial to chinook and steelhead under all flow conditions (Matthews et al., 1991).

### 2.2.4.3 Adult Passage

Fish ladders, which are fish passage facilities for adult upstream migrants, have been constructed at all eight run-of-river projects (Figure 2.2-4 on page 2-15). Each run-of-river project has from one to three ladders that generally operate from March 1 through December 31.

Bonneville, The Dalles, John Day, McNary, Ice Harbor, and Lower Monumental dams have two fish ladders each, one next to the powerhouse and one on the other side of the dam next to the spillway. Little Goose and Lower Granite dams each have one fish ladder next to the powerhouse. Adult fish enter a ladder through either a collection system that runs along the entire front of the powerhouse, or through a small collection system at the bottom of the spillway fish ladder. Specific flow conditions near the ladder and at its entrances are needed to attract the adults into these systems. Once inside a collection system, adult fish swim upstream to the base of the fish ladder where they migrate up the ladder and exit into the reservoir above the dam.

Water for operating the fish ladder comes through the fish ladder exit. At most projects, additional water can be added part way down the ladder to maintain the correct amount of water for fish migration. More water is added to the fish collection systems through systems which spread the flow over the floors of the ladder entrances and along the collection systems. This additional water provides sufficient flow for attracting adult fish into the fishway entrances. The attraction water is provided by pumps, small turbines, or gravity flow from the reservoirs behind the dam, depending on the design of an individual system. Each fish ladder contains a fish counting station where adult fish pass an underwater viewing window, allowing them to be observed and identified by species.

Additionally, some fish pass upstream through the locks at each of the eight dams in the Columbia and Snake rivers. The proportion using these locks is probably a small portion of the total runs of fish passing up the Columbia and Snake rivers.

### 2.2.4.4 Spill

In 1989, fisheries agencies, Indian tribes, BPA, and others signed a LTSA that established a plan for spilling water to protect juvenile salmon and steelhead during their spring migration. The spill agreement provides that a specific amount of water be passed over the spillways of four projects—Lower Monumental, Ice Harbor, John Day, and The Dalles—in the spring to protect young fish. Juveniles are in the water spilled, passing them over the spillways instead of through the turbines. The spill agreement was adopted by the NPPC as a temporary measure for 10 years or until permanent fish bypass facilities could be installed at these dams. The Corps has agreed to consider implementing the spill provisions annually and has done so in 1989, 1990, and 1991.

The spill implementation principles adopted by the Corps provide for specific spill rates by season, as long as the spill does not adversely affect non-power uses. Average seasonal spill rates range from 5 percent of total flow at The Dalles in summer to 70 percent at Lower Monumental in spring and summer. The spill plan for 1991 is summarized in Appendix A.

### 2.2.4.5 Water Budget

Spring flows are augmented to levels above those required for authorized project functions when conditions must be improved for the outmigration of juvenile fish. This is accomplished within the Water Budget program, a feature of the NPPC Fish and Wildlife Program. Each winter the Corps develops a Coordinated Plan of Operations (CPO) to implement the Water Budget, in consultation with fisheries agencies, tribes, power interests, and other interested parties. The CPO is submitted to NPPC in late March, with implementation from April 15 to June 15. Releases from storage reservoirs are made after considering requests from the Fish Passage Center in Portland, Oregon, representing the fisheries agencies and tribes. The increased flow is presumed to help flush fish downriver and reduce their exposure to predators and other hazards in reservoirs.

Up to 4.64 million acre-feet (MAF) of water can be released each spring. The total Water Budget volume includes up to 1.19 MAF on the lower Snake River, and up to 3.45 MAF on the middle and lower Columbia River. The amount and timing of Water Budget releases are determined annually.

The Water Budget is used to achieve target flows at specific points along the river. Currently, Priest Rapids Dam on the Columbia River and Lower Granite Dam on the Snake River are the monitoring points. Because neither Priest Rapids nor Lower Granite has significant storage under normal operations, flows for the Water Budget must come from natural flows and releases from upstream storage projects such as Grand Coulee, Dworshak, and Brownlee. On the Snake River, most spring flows are dependent on natural runoff. As a result, release cannot be achieved in low runoff years, even with large releases from storage reservoirs.

#### 2.2.4.6 Research and Monitoring

Many agencies and organizations are involved in a variety of fishery research and monitoring programs related to Columbia-Snake River salmon and steelhead. These efforts encompass the dams and fish passage facilities, hatcheries associated with the projects, the reservoirs, and tributary streams. The Corps actively monitors juvenile and adult migration at Corps dams, conducts or sponsors ongoing research on anadromous fish, and participates in the research programs of other organizations. The Corps also operates 17 stations along the river system that monitor dissolved gas levels, which can be harmful to fish. BPA sponsors a wide variety of fish research and enhancement programs related to reservoir mortality, hatcheries, disease, spawning habitat, and numerical modeling of system fish survival. The Fish Passage Center monitors each year's juvenile outmigration, primarily through the Smolt Monitoring Program and by receiving system operations, fish passage, and power generation data from the Corps and BPA. State fish and wildlife agencies from Idaho, Oregon, and Washington and Indian tribes are active participants in research efforts. Most of the funding for research and monitoring comes from either BPA or the Corps.

### 2.2.5 River Management Actions in 1991

As a result of the Salmon Summit, the governors of Idaho, Montana, Washington, and Oregon agreed to a river management plan in 1991. This plan was used to supplement the Water Budget with additional releases of stored water during the spring juvenile fish migration period. It consisted of the following actions:

- The Corps, with the support of the State of Idaho, released an additional 615 thousand acre-feet (KAF) of outflow from Dworshak during the spring.
- In addition to the 615 KAF from Dworshak, the Corps provided water made available by transferring system flood control requirements at Dworshak to Grand Coulee. This flood control transfer yielded an additional 400 KAF from Dworshak. This water was released between April 24 and May 4.
- IPC released 150 KAF from Brownlee between May 5 and May 15.
- BPA arranged the release of an additional 100 KAF from Brownlee, which was subsequently replaced by releases from reservoirs above Brownlee.
- BPA, agencies, and tribes expanded a program to harvest northern squawfish, the primary predator on juvenile salmonids. This program was to include all eight lower Snake and Columbia river projects in 1991, as well as the river below Bonneville.
- The BoR, as well as other interested parties, initiated water conservation demonstration projects with Idaho, Washington, and Oregon.
- A cooperative effort was initiated between dam operators and fish agencies to improve adult passage by monitoring operations and providing recommendations for improvements.

## 2.3 WATER QUALITY

This section describes the existing water quality conditions of the affected environment. Significant human-caused changes have occurred to some water quality parameters over the past century in the Clearwater, lower Snake, and lower/middle Columbia River systems. These changes range from a shift in temperature characteristics to introduction of nutrients and exotic radionuclides (Idaho Department of Health and Welfare, 1982; Pruter and Alverson, 1972; Vigg and Watkins, 1991). Because of the distinctive nature of their general water quality, each of these river systems is discussed separately following the discussion of water quality criteria. The primary emphasis is on the key water quality parameters of dissolved gas and temperature, although other parameters are briefly addressed.

### 2.3.1 Water Quality Criteria and Standards

The U.S. Environmental Protection Agency (EPA) and States of Idaho, Oregon, and Washington have established surface water criteria or standards applicable to the Columbia River Basin. This discussion focuses on the State standards because they are the same as or more stringent than the Federal criteria, and are legally enforceable. The codes, rules, and regulations for these State standards are voluminous, so only selected highlights of the standards are presented in this document. The reader is referred to the Idaho Department of Health and Welfare, the Oregon Department of Environmental Quality, and the Washington Department of Ecology for copies of the respective standards for each State. All three States have established a policy of antidegradation and beneficial uses for their surface waters, which precludes the discharge or introduction of any toxic or hazardous materials (e.g., the EPA's 126 priority pollutants) or deleterious contaminants.

Idaho's beneficial uses are domestic and agricultural water supply, cold-water and warm-water biota, salmonid spawning, primary and secondary contact recreation, and special resource water. All except warm-water biota have been designated as beneficial for the Brownlee, Oxbow, Hells Canyon, and Dworshak reservoirs, North Fork of the Clearwater River, and the Snake River downstream of Brownlee (BNA, 1991).

In a four-level water quality classification system that ranges from AA (Extraordinary) to C (Fair), the State of Washington has classified the Columbia River from Grand Coulee Dam downstream to the Pacific Ocean and the Snake River as Class A (excellent). Beneficial uses are water supply (domestic, industrial, agricultural); stock watering; fish and shellfish rearing, spawning, and harvesting; wildlife habitat; recreation (primary contact); and commerce and navigation (BNA, 1991).

Oregon defines various portions of the Columbia and Snake rivers as beneficial for public and private domestic supply, industrial water supply, irrigation, livestock watering, anadromous fish passage, salmonid fish rearing, salmonid fish spawning, resident fish and aquatic life, wildlife and hunting, fishing, boating, water contact recreation, aesthetic quality, hydropower, and commercial navigation and transport (BNA, 1991).

All three States have established numerical standards for many water quality parameters, including those for total dissolved gas and temperature. A total dissolved gas standard of 110 percent saturation at ambient atmospheric pressure is the maximum level for acceptable total dissolved gas set by the three States (BNA, 1991).

Each State has different thermal criteria. Idaho specifies the criteria in relation to specific use categories. The most restrictive use criterion is for salmonid spawning, with maximum water temperatures set at 55°F (13°C) with daily averages no greater than 48.2°F (9°C). Oregon allows no water temperature increases in the Columbia River, outside of an assigned mixing zone, when the stream water temperature is at or above 68°F (20°C). When the river is 67.5°F (19.7°C) or less, the Oregon standard dictates that no more than a 0.5°F (0.28°C) increase is allowed due to a single-source discharge. No more than a 2°F (1.1°C) increase is allowed by all sources when the stream is 66°F (19°C) or less. In Washington, no increase over 68°F (20°C) due to human activity is allowed. In addition, no increase over 0.3°C (0.54°F) is allowed from Priest Rapids Dam (river mile, RM 309) to Grand Coulee Dam (RM 595) when the stream is naturally over 68°F (20°C). In the lower Columbia River and Snake River above the Clearwater River (RM 139.3), no increase over 0.3°C (0.54°F) caused by human activity can occur from a single source, or no increases over 1.1°C (2°F) from all activities when the stream is over 68°F (20°C). In the Snake River below the Clearwater River, the 1.1°C (2°F) restriction is dropped in favor of no temperature increase exceeding $t = 34/(T+9)$°C where $t$ = change in temperature and $T$ = background temperature.

Idaho and Washington specify that turbidity shall neither exceed 5 nephelometric turbidity units (NTU) over background levels when the background level is 50 NTU or less nor have more than a 10 percent increase when background is more than 5 NTU. Oregon simply specifies the 10 percent increase criterion (BNA, 1991).

Dissolved oxygen standards vary for each State. Idaho has specific criteria below existing dams. From June 15 to October 15, these criteria are set at 6.0 milligrams per liter (mg/l; 30-day mean), 4.7 mg/l (7-day mean minimum), 3.5 mg/l (instantaneous minimum), and 6 mg/l or 90 percent of saturation (whichever is greater) for salmonid spawning uses. Oregon specifies 90 percent of saturation for portions of the Columbia mainstem, and Washington specifies 8 mg/l for Class A waters (BNA, 1991).

Fecal coliform and pH standards vary among States, use classifications, and river system reaches. Typically, pH is restricted to levels between 6.5 and 8.5 pH units. Fecal coliforms must be less than 100 organisms/100 ml.

## 2.3.2 Lower/Middle Snake River Water Quality

Within the study area the water quality of the Snake River varies depending upon the location. River reaches from Brownlee Reservoir to the confluence of the Salmon River depend upon the water quality of the middle Snake River. Generally, the middle Snake River receives poor ratings because of human-caused and natural conditions. Downstream of the confluence with the Salmon River, and especially below the confluence of the Clearwater River, the lower Snake River water quality is somewhat improved because it mixes with water from two other systems. Water quality from Dworshak Reservoir, on the North Fork of the Clearwater River, is controlled (dissolved gas levels and temperature) to meet requirements of Dworshak National Fish Hatchery.

### 2.3.2.1 Dissolved Gas Saturation

Dissolved gas supersaturation in the Snake River is caused when water passes over a dam's spillway. The spilling water carries trapped atmospheric air deep into the waters of the plunge pool or "stilling basin" where increased hydrostatic pressure dissolves the air into the water. At depth, this dissolved gas is "supersaturated" in relation to conditions at the surface. When brought to the surface, the gas will either come out of solution and equilibrate with atmospheric conditions or form bubbles. If these bubbles form within the tissue of aquatic organisms, they might injure or kill the organism. Since the dams have slowed the velocity, lessened the turbulence, and shortened the free-flow sections of the Snake River, the river is not able to equilibrate the excess dissolved air between the dams, and the supersaturation condition can persist for extended distances. This is especially true during periods of high flow and continuous spillage.

The spill over the dams in the lower/middle Snake River has increased gas supersaturation, although pre-dam conditions might have also experienced supersaturation. Levels in the lower Snake River are influenced by flow from the Clearwater River (including releases from Dworshak) as well as the middle Snake River, and typically range from 105 to 110 percent saturation in the Lower Granite forebay during the spring in high flow years. Levels successively increase downstream through the Little Goose, Lower Monumental, Ice Harbor, and McNary forebays when all projects are spilling. Installation of spillway deflectors at Lower Granite, Little Goose, and Lower Monumental dams has reduced the levels of dissolved gas supersaturation associated with spillway discharges. However, maximum supersaturation ranging from 110 to 140 percent has been observed for extended periods during high flow events. Thus, State standards are exceeded during certain periods of the year, when high spilling occurs.

### 2.3.2.2 Water Temperature

Water storage capacity at the four lower Snake River reservoirs is very limited and retention time is approximately 8 to 20 days. Therefore, thermal stratification (vertical temperature gradients decreasing from top to bottom) is rare, but during some low flow years, it may occur for short periods and range up to 7°F (3.9°C). In general, however, the maximum difference is about 4°F (2.2°C). Temperatures are generally lower during the spring of a high flow year, but they increase in July or August.

Vigg and Watkins (1991) have further characterized temperature in the Snake River as follows:

> Mean water temperature in the lower Snake during 1985-89 was above 70°F (21°C) from 17 July to 19 August; considerable annual variation occurred with temperatures exceeding 70°F (21°C) from 10 July to 14 September in individual years (Figure 2.3-1). Based on an

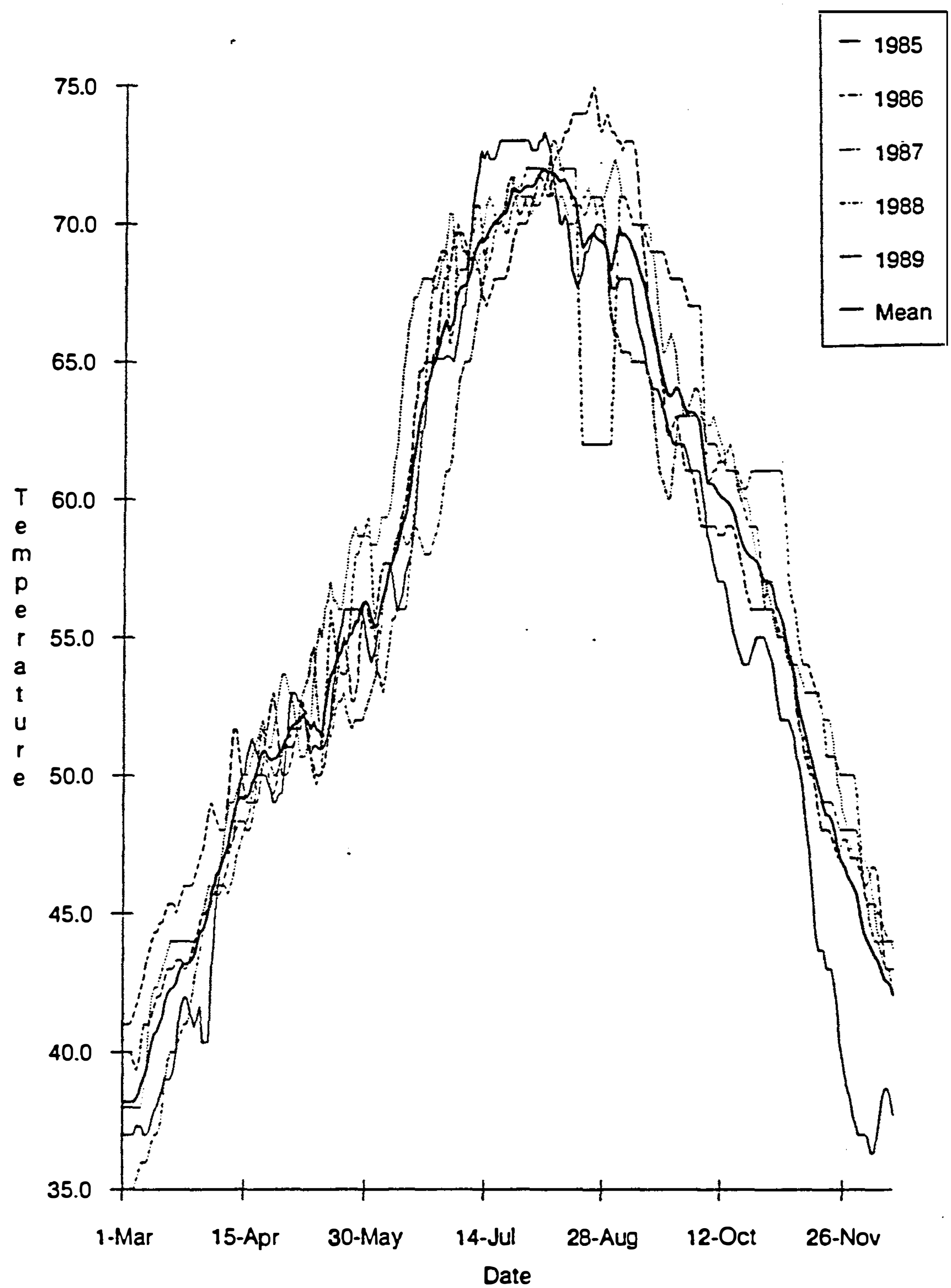



**Figure 2.3-1.** Annual variation in water temperature (F) at Lower Granite Dam, 1985 to 1989.

analysis of 1938 to 1966 USGS data, the effect of the hydropower system and other anthropomorphic (human-caused) changes on temperature in the Columbia River became apparent in the mid-1950s; the major effect has been shifting temperature maximums so that warmer temperatures occur later in the year (EPA and NMFS, 1971; Crawford et al., 1976). The most significant changes have been above the confluence of the Snake and Columbia rivers. Pre-dam (1955 to 1958) water temperatures were high >72°F (22°C) in the lower Snake River during mid-July to late August (Figure 2.3-2; FWPCA, 1967). Other human-caused watershed disruptions (e.g., defoliation and water diversion) probably elevated maximum temperatures over historic levels in the Snake River Basin (for example, irrigation-associated influences increased river temperature 6°F (3.3°C) to 7°F (3.9°C) between Parker and Kiona in the Yakima River (FWPCA, 1967).

The U.S. Geological Survey (USGS) maintains a temperature station (Anatone) on the lower Snake River 1.2 miles downstream of the Grand Ronde confluence. The most recent data from this station are presented in Appendix B.

### 2.3.2.3 Other Water Quality Parameters

Water quality conditions for other parameters in the lower and middle Snake River have been summarized as follows (Idaho Department of Health and Welfare, 1982):

> The Snake River trend stations have historically recorded escalating concentrations of bacteria, nutrients, and suspended sediment as the river flows from Marsing to Weiser. A current comparison of water quality between Marsing and Weiser cannot be determined due to insufficient data at Marsing; however, the Snake [River] at the Weiser station continues to reflect consistently high nutrients and sediment. Bacterial densities exceed criteria for primary contact recreation (May-September) at Weiser. Subsequent decreases in bacteria and suspended sediment are observed below Hells Canyon Dam, after the river has passed through Brownlee, Oxbow, and Hells Canyon Reservoirs. Nutrients continue to be of concern below the dam accompanied by occasional low dissolved oxygen levels. Toxaphene residues, in concentrations associated with reduced growth and reproductive failure, have been detected in fish taken from the Snake River at Weiser and Hells Canyon Dam. Overall water quality in the Snake River drainage remains unchanged and in poor condition with the exception of slight improvements in bacteria at Weiser. Below Hells Canyon Dam, water quality remains in fair condition and unchanged from past records. The slight improvement in metal toxicity is believed to be due to hydrologic factors.

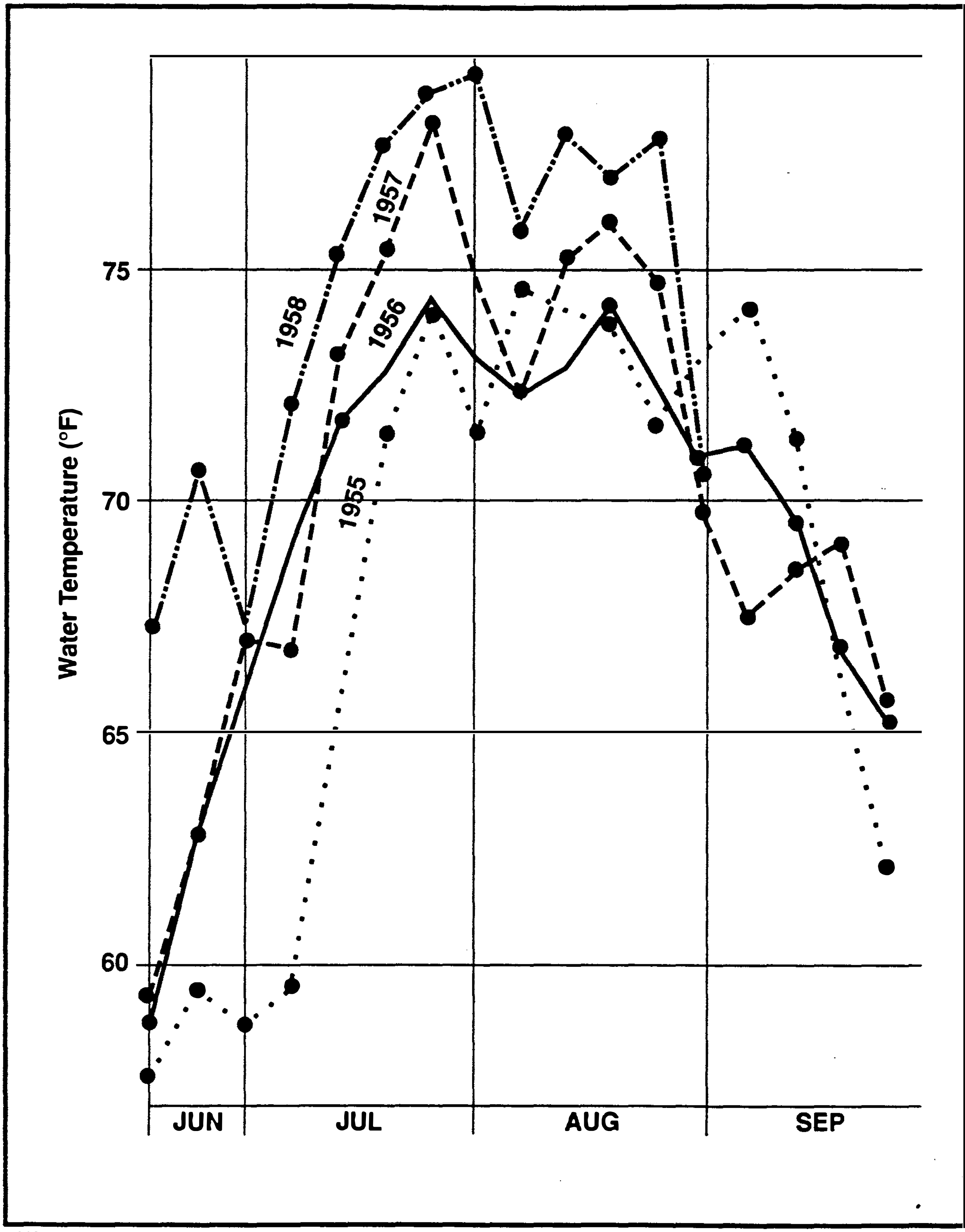
The report also states that non-point source inputs from irrigation returns and grazing areas are the principal pollution problems in the reservoir complex. The EPA has classified the middle Snake River as having marginal water quality (receiving moderate or intermittent pollution) (BPA, 1985).

Water quality data near the confluence of the Snake and Columbia rivers are collected by the USGS at Burbank, Washington. Data for the most recent year are presented in Appendix A, Table A-5. These values are consistent with the above description.

In summary, the waters of the lower and middle Snake River are degraded; the waters are high in nutrients, dissolved solids, and bacteria that result in high productivity. Water temperatures are somewhat elevated and depleted of dissolved oxygen in certain areas. Although not well documented, it is likely that organic residuals associated with pesticide and herbicide applications are also present. All of these observations are consistent with the quality of irrigation return water, which constitutes a high percentage of the middle Snake River flow.

## 2.3.3 Lower/Middle Columbia River Water Quality

The entire Columbia River Basin encompasses a 259,000-square-mile area. There is no authoritative description of overall water quality conditions in the basin, in part, because the basin is shared by two nations and six States. Each State has unique water quality standards, management programs, and monitoring programs. Technical specialists and the general public have identified the need to develop a




ACOE138

Figure 2.3-2. Snake River at Sacajawea. Water temperatures (6-day average, 1955 to 1958) (Source: FWPRA, 1967).

comprehensive water quality information base to understand the water resources of the Columbia River Basin. To address this need, the Washington and Oregon State legislatures established the Bi-State Lower Columbia River Water Quality Program in 1990 to characterize water quality conditions in the lower 146 miles of the Columbia River. Results from this program were unavailable at the time this OA/EIS was prepared. Sufficient information from other sources was available to address the two parameters of greatest concern relative to the proposed action: dissolved gas saturation and water temperature.

### 2.3.3.1 Dissolved Gas Saturation

The factors affecting dissolved gas saturation in the Columbia River are similar to those described in Section 2.3.2 for the lower Snake River. When spilling is minimal (September through March), the saturation level is near normal (100 percent). However, dissolved gas concentrations might increase to as much as 140 percent during heavy spill from April through August.

Dissolved gas supersaturation associated with Corps dams in the Columbia-Snake River System has generally exceeded the States' maximum acceptable standard of 110 percent saturation. One problem is the release of water over the spillways, much of which is provided for fish passage. However, water entering the Corps impoundments from Canada or the upper Snake River might already be supersaturated with dissolved gas, especially nitrogen.

The Corps has made major efforts to reduce gas supersaturation in the Columbia River System. One approach has been to develop structural components called "flip lips" that were installed in the mid-1970s at the base of some Corps' spillways (e.g., Bonneville and Lower Monumental dams). A detailed description of flip lips is provided in Appendix C. These flip lips were designed to reduce the plunge of water into the pools below the dams, and consequently, avoid the hydrostatic pressure that forces the atmospheric gases into solution (Figure 2.3-3). Neither spill control (e.g., reservoir regulation and releases through turbines to minimize spill) nor flip lips have been completely effective in reducing dissolved gas to safe levels.

Dissolved gas concentrations in the Columbia River System have been monitored by the Corps' North Pacific Division since 1968. A Dissolved Gas Monitoring Program became an integral part of the daily reservoir regulation activities during 1979. In 1984, the number of dissolved gas monitoring stations was increased from 5 to 15 sites. These sites range from near Grand Coulee Dam (RM 597) to downstream of Bonneville Dam (RM 145). The concentration of dissolved gas is measured at each major area of concern during the late spring and summer when significant spill is expected in the system. Spills from the dams are then adjusted by shifting the power loads to other dams in the system to minimize spill and gas supersaturation.

### 2.3.3.2 Water Temperature

The physical characteristics associated with water temperature have major effects on the distribution of water in reservoirs because of the variable density of different temperatures. The temperature of water within a reservoir depends upon the volume and temperature of the entering water, the volume and temperature of the already impounded water, the surface area, weather conditions, the shape of the bottom of the reservoir, the location of the outlets for water withdrawal, and the rate of withdrawal.

Reservoir regulation (i.e., how a reservoir is refilled) also plays a major role in how solar radiation and atmospheric temperature affect the thermal characteristics of each type of reservoir. The thermal characteristics of the large storage projects are very different from those of the run-of-river projects. The deep storage projects have water retention times of several months, are thermally stratified, and have complex hydrodynamic thermal mixing characteristics. The relatively shallow run-of-river reservoirs have short retention times of only a few days, and have more uniform water temperatures from the surface to the bottom.

Lower Columbia River water temperatures vary seasonally and have a recorded range from 31°F (-0.5°C) to 75°F (24°C). Winter temperatures (December to March) range from 32°F (0°C) to 48°F (9°C), and from March and June, water temperatures rise to about 58°F (14°C). By August, the river usually warms to its annual maximum average of 68°F (20°C).

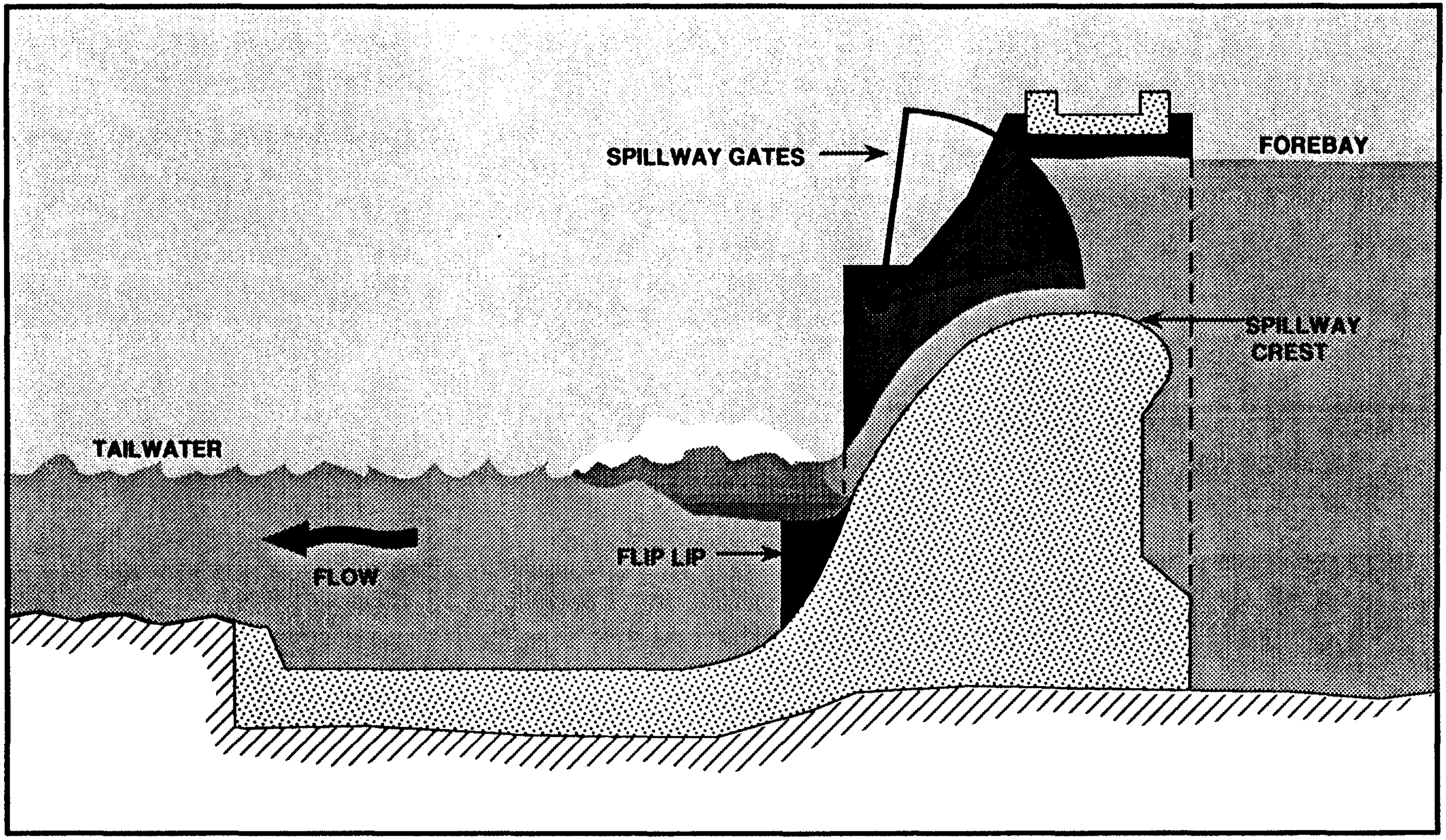



**Figure 2.3-3.** Spillway deflector (flip lip), Lower Granite Dam spillway.

#### 2.3.3.3 Other Water Quality Parameters

The most recent USGS State Water Resources Data Reports provide information on other water quality parameters (Appendix B). The existing water quality of the lower Columbia River can be described as good. Concentrations of dissolved oxygen are relatively high, ranging from approximately 70 to 135 percent saturation, with a mean saturation of 105 percent. Based on previous studies, the pH value generally ranges from 6.4 to 8.5 pH units (Corps, 1977). Fecal coliform bacteria, expressed as Most Probable Number (MPN), have recently ranged from <1 to 120 colonies per 100 ml. Typically, MPN values have been under 40 colonies per 100 ml (Appendix A).

Suspended sediment loads depend on the volume of water, flow velocity, and the slope of the riverbed. The primary sources of river sediment are the erosion of stream banks, farm land, forest lands, and the drainage from urban centers. The resulting suspended material is continuously moved downstream and redeposited in areas where the water velocity decreases. Suspended solids in the Columbia River rarely exceed 1,000 parts per million (ppm), and the annual suspended sediment load averages about 15,000,000 cubic yards for the entire river. Approximately 98 percent of dredged Columbia River bed sediments below Bonneville Dam is clean, fine sand. The remaining material is typically organic matter that might come from log rafts, wood debris, fish and waterfowl carcasses, aquatic vegetation, domestic and industrial waste, discharges, agricultural runoff, and other miscellaneous materials. At present, these organic materials have little, if any, effect on water quality because they are usually diluted by the large flows of the Columbia River. Stringent water quality standards and regulations have greatly restricted the release of potentially harmful substances into the river (Corps, 1977) (see Appendix B). Junge and Oakley (1966) and Bottom and Jones (1990) have noted that mainstem and estuarine turbidity have dramatically decreased since construction of the mainstem dams.

### 2.3.4 Clearwater River Water Quality

Data for the Clearwater River System are limited, although studies are being conducted that may provide useful information. A major human-induced effect on the Clearwater System is Dworshak Reservoir. This storage reservoir is deep (600 feet in the forebay) and narrow; consequently, the lake thermally stratifies consistently every year with a thermocline at approximately 40 to 50 feet. Deep water (below 40 to 50 feet) temperatures remain consistent throughout the year at about 39°F (4°C) to 41°F (5°C). Retention time in the reservoir is about 1 year. The reservoir has been characterized as oligotrophic (i.e., low in productivity and nutrient limited).

Dissolved oxygen concentrations at Dworshak Reservoir are expected to be similar to those experienced at the Columbia River System dams discussed above. The USGS station at Spalding, Idaho, a national stream quality accounting network station, provides data on other water quality parameters. Data from the most recent available year are presented in Appendix B. These data are consistent with the oligotrophic characterization of the reservoir and indicate exceptional water quality that is low in dissolved solids and devoid of inorganic contaminants.

## 2.4 ANADROMOUS FISH

### 2.4.1 Background

Several species and races of anadromous fish inhabit the Columbia River and pass over all or some of the mainstem hydroelectric dams during their life. These fishes include spring, summer, and fall chinook (*Oncorhynchus tshawytscha*), sockeye (*O. nerka*), coho (*O. kisutch*), chum (*O. keta*), and pink salmon (*O. gorbuscha*); steelhead trout (*O. mykiss*); sea-run cutthroat trout (*O. clarkii*); shad (*Alosa sapidissima*); sturgeon (*Acipenser transmontanus*); and lamprey (*Entosphuenus tridentatus*).

The spring, summer, and fall races of chinook salmon enter and migrate through the Columbia River at different times of the year. They also spawn at different times and places and differ in age of juvenile migration, run strength, and whether stocks are hatchery or wild.

#### 2.4.1.1 Spring Chinook Salmon

Adult spring-run chinook begin entering the Columbia River in February. By July, most have passed by the Corps projects on the lower Columbia and Snake rivers (Figure 2.4-1). Most chinook migrate from early April through mid-June and spawn in tributaries far upstream above the influence of the projects. On the trip to the ocean, juvenile spring chinook outmigrate as yearlings from about March through June. The majority pass the mainstem dams in April and May (Figure 2.4-2), rear in the ocean, and return to the river after 2 years. A significant number spend 3 years in the ocean, some remain 4 or 5 years, and a few return after 1 year as "jacks," early maturing fish (CBFWA, 1991b).

The Snake River spring and summer chinook stocks are proposed for listing as a threatened species and as an evolutionary significant unit under the ESA. Spring and summer chinook migrate above all eight Corps projects to spawn in small streams at high elevations (Matthews and Waples, 1991). There are five major spawning and rearing basins for these stocks: three large river basins (Clearwater, Grande Ronde, and Salmon) and two smaller basins (Tucannon and Imnaha).

The spawning timing and habitat of the Snake River spring race is typically earlier and higher in the watershed than the summer race. But, because their migration times can overlap, they might occupy the same region of a river during a spawning period; therefore, gene flow between these races cannot be ruled out. For this reason, they could not be classed as different stocks for proposed ESA listing by the NMFS (Matthews and Waples, 1991). However, because genetic separation is not the only consideration, the final ruling on whether to separate the two stocks under the ESA has not been made.

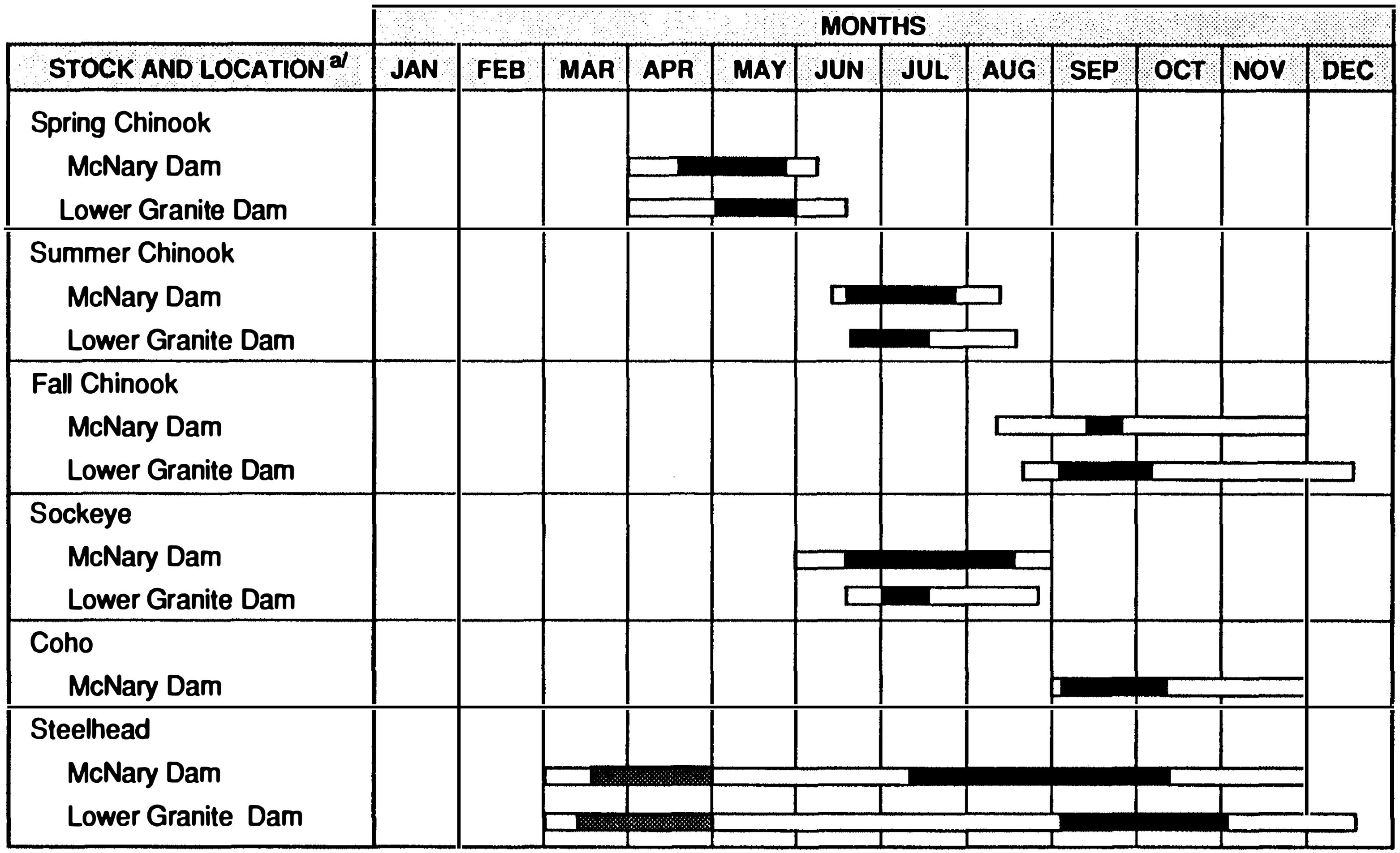
### 2.4.1.2 Summer Chinook Salmon

Adult summer chinook begin entering the Columbia River in May and pass the mainstem dams by September (Figure 2.4-1). The majority pass from mid-June through mid-August. Summer chinook generally spawn and rear in tributaries upstream of the influence of the projects, although some of the upper Columbia River subyearlings rear in the lower Columbia region. Juvenile summer chinook outmigrate from the Snake River as yearlings primarily from March through June; the majority pass by the dams in April and May (Figure 2.4-2). Upper Columbia River smolts outmigrate from May to September, with the majority passing the dams in June, July, and early August. Most adults spend 2 or 3 years in the ocean before returning (CBFWA, 1991b). Like the spring chinook, the spawning regions for the summer chinook are found in the Snake River tributaries.

### 2.4.1.3 Fall Chinook Salmon

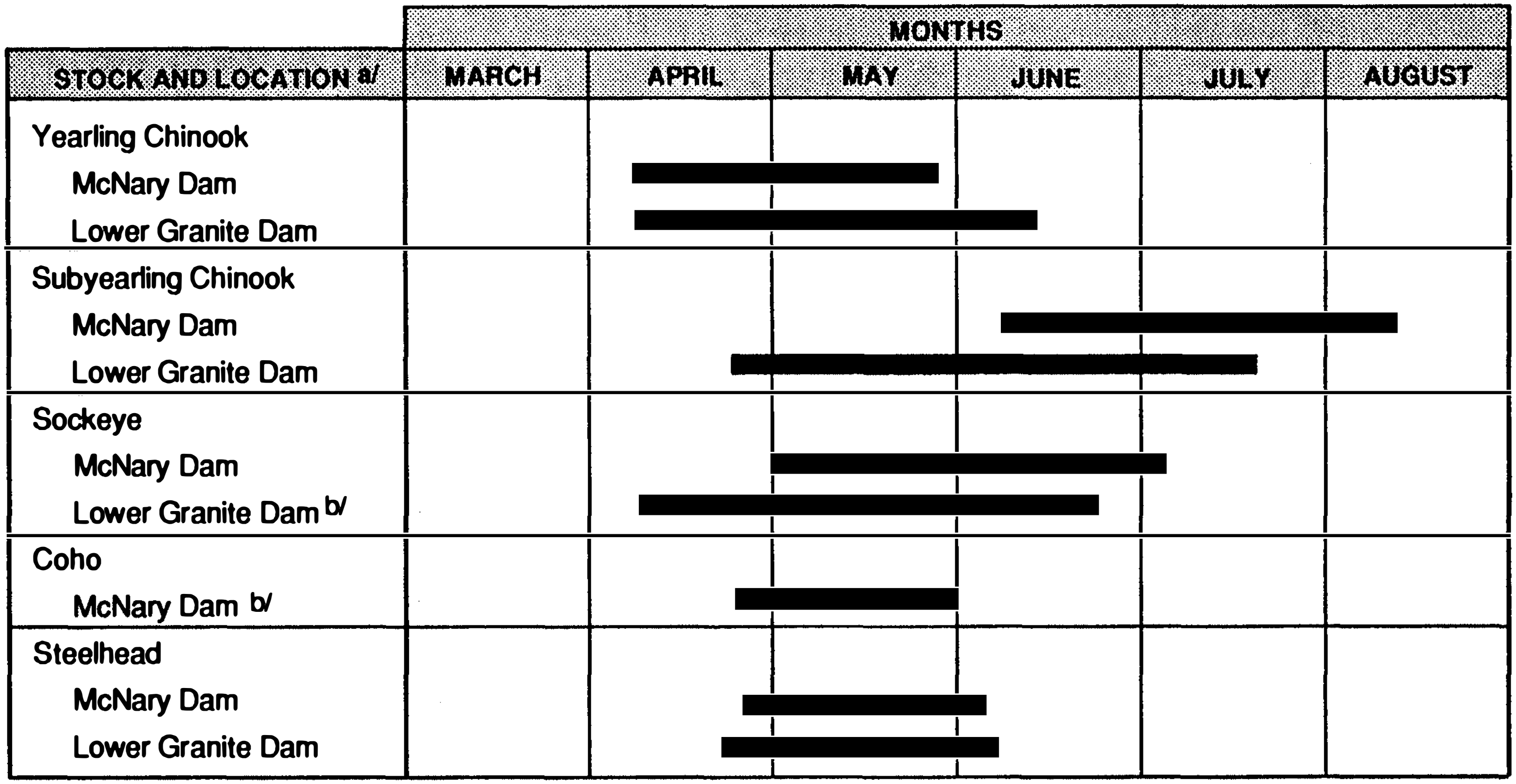
Adult fall-run chinook begin entering the Columbia River in July and pass the mainstem dams by the end of November (Figure 2.4-1). The majority of fall Chinook pass from mid-August to November. There are two basic races of fall chinook—tules and upriver brights. The tules are an early spawning (September), lower river variety of fall chinook. Tules returning to areas above Bonneville Dam are primarily hatchery fish, because there is very little natural spawning above the dam. Most natural spawning occurs in the tributaries of the Bonneville Pool. Some of the wild-spawned tule fry rear in the shallow water of the reservoir until they migrate in the spring. Lower river, hatchery, and wild tules migrate down the Columbia River from June through October, and the majority pass by the dams in July and August (Figure 2.4-2).

Upriver brights are a late-spawning (November through January) upriver variety comprised of both hatchery and wild fish. Wild fish in the mainstem river, primarily below Priest Rapids Dam, rear in the shallow water of the rapids downstream, including the four lower Columbia River reservoirs. Upriver brights outmigrate during the same approximate period as tules. Some upriver brights rear during the outmigration in the lower Columbia and Snake River reservoirs, particularly in Lake Umatilla above John Day Dam. The current spawning range of the proposed threatened Snake River stock is limited to approximately 103 miles of the mainstem Snake River—from Hells Canyon Dam to the Lower Granite pool and the lower reaches of the Imnaha, Grande Ronde, Clearwater, and Tucannon rivers. Some deepwater spawning may be available below the tailraces of the lower Snake River dams (Waples et al., 1991a). Fall chinook that rear in the Snake River typically outmigrate before mid-July because the warm temperatures in late summer are not suitable for chinook. Tule stocks typically rear in the ocean for 2 to 3 years; upriver brights rear in the ocean for 3 to 4 years (CBFWA, 1991b).




a/ Migration period range and peak annual counts shown as darker central region, shaded area indicates small secondary peak.

**Figure 2.4-1.** Adult salmonid main upstream migration periods.




a/ Range of 10% and 90% passage for 1986 to 1990 except where indicated (source: the Corps).
b/ Range of 10% and 90% passage for 1989 and 1990 (source: Koski et al., 1990; Ceballos et al., 1991)

**Figure 2.4-2.** Peak periods of downstream migration of salmonid smolts.

### 2.4.1.4 Sockeye Salmon

Adult sockeye salmon begin entering the Columbia River in April and continue to pass by the dams through October (Corps, 1991b). The majority of adult passage occurs from June through early August (Figure 2.4-1). Sockeye spawn and rear in systems with lakes, primarily on the upper Columbia River System in the Wenatchee and Okanogan rivers, with some remnant runs in the Snake River System (CBFWA, 1991b). Sockeye typically spawn in September and October; spawning peaks in mid-September. Most sockeye rear in lakes for over 1 year and migrate downstream in the spring (May and June) of their second year (Figure 2.4-2). Most Columbia River sockeye spend 2 years in the ocean before returning to the river (CBFWA, 1991b). All sockeye in the Columbia River System are natural stocks because no hatchery operation currently occurs.

The Snake River System sockeye, listed as an endangered species on November 20, 1991 by the NMFS, is currently limited to Redfish Lake in the Stanley Basin in Idaho, 900 miles from the ocean (Waples et al., 1991a). These fish typically arrive from mid-July through August at Redfish Lake to spawn in beaches during October (Chapman et al., 1990). Juveniles rear in this lake 1 to 2 years before migrating from April through mid-May. In recent years, the majority have passed Lower Granite Dam by mid-June (Chapman et al., 1990).

### 2.4.1.5 Steelhead Trout

Adult steelhead enter the Columbia River as winter and summer races year-round. The winter race is restricted to regions from the Bonneville Pool downstream.

The summer races occur in most areas but are the only run in the upriver areas. The upriver summer steelhead are divided into two groups: Group A and Group B. Group A fish are present in all upriver basins while the Group B fish are only produced in the Clearwater and Salmon rivers of the Snake River drainage (CBFWA, 1991b). A number of Group B steelhead hold over and migrate in the following year. The summer race enters the river beginning in February and passage at the mainstem dams continues through December. Group A summer steelhead mainly enter the river from June to early August while Group B fish enter the river from late August into October (CBFWA, 1991b). The upstream migration for the winter race begins in November and continues through March. The majority of summer steelhead passage occurs from mid-June through October (Figure 2.4-1). Steelhead spawn and rear in tributaries above the influence of the mainstem projects. Juvenile steelhead outmigrate as yearlings primarily from March through June, with the majority passing in April and May (Figure 2.4-2). Many summer steelhead overwinter in the mainstem reservoirs, including tributaries of the Bonneville Pool, and pass the projects in the early spring. Most adults spend 2 years in the ocean before returning to their spawning ground; some return after 1 year, and a small portion returns even later.

### 2.4.1.6 American Shad

Adult shad, the only member of the herring family found in the fresh waters of the Pacific Coast, begin entering the Columbia River in April and continue to pass the mainstem dams through August. The majority of upstream passage occurs from mid-May at Bonneville Dam through July. Shad spawn in the open water of the mainstem reservoirs during July and early August, and their spawning peaks from July 20 to August 5 (Wydoski and Whitney, 1979). Extensive rearing takes place in productive shallow-water zones of the reservoir until the juveniles are ready to migrate. When juvenile shad are 4 inches long, they outmigrate as subyearlings primarily from October through December, with the majority passing the dams in late October and early November. Adult shad spend 3 to 4 years at sea before returning to the home stream to spawn (Wydoski and Whitney, 1979).

### 2.4.1.7 Sturgeon

The white sturgeon, a member of ancient groups of fish without true bone, is the largest anadromous fish in the Western Pacific, reaching a size up to 1,800 pounds (Wydoski and Whitney, 1979). Although this fish is anadromous, few currently migrate above Bonneville Dam (Corps, 1991b). However, many subpopulations exist in the individual reservoir pools of the Columbia and Snake rivers, completing their life cycle without migrating to the Pacific Ocean. The anadromous stocks may be present in the lower river year-round. Spawning typically occurs from May into

July (Wydoski and Whitney, 1979). High concentrations of eggs are found within a few miles below Bonneville Dam suggesting spawning in this region (Nigro, 1990). Eggs develop into larvae that settle to the bottom. The young-of-year fish are often found in deep-water areas below Bonneville Dam and in the lower Columbia River reservoirs, often in sandy regions (Nigro, 1990). Although sturgeon are primarily a bottom-feeding fish consuming crustaceans, clams, and insects (Nigro, 1990), they often consume quantities of fish (Wydoski and Whitney, 1979). Sturgeon mature in 9 to 16 years and may live to be over 80 years old (Wydoski and Whitney, 1979).

#### 2.4.1.8 Lamprey

The Pacific lamprey is a member of the group of fish without bones and resembles an eel. As adults, during the saltwater phase of their life history, lamprey behave as parasites on other fish. The adult Pacific lamprey begins upstream migration in the Columbia River in April and continues through August. The majority of upstream passage occurs from May at Bonneville Dam through mid-July. Lamprey spawn typically in June and July in the sandy bottoms in the upper ends of pools of small tributary streams, including streams feeding the mainstem reservoirs (Wydoski and Whitney, 1979). The juveniles (ammocoetes) emerge and drift downstream to burrow in the mud in low-velocity reaches of small tributary streams. After residing in the mud for 5 to 6 years, juvenile lamprey outmigrate to the sea primarily from April through mid-July, with the majority passing the dams in May and June.

### 2.4.2 Hatcheries

Over 80 hatcheries producing salmon and steelhead are located on the Columbia-Snake River System. However, only those hatcheries that could be directly affected by potential operational changes are addressed.

Eight hatcheries and three satellite stations are located within the project area. The Bonneville Hatchery rears upriver bright and tule fall chinook. About 1 mile above Bonneville Dam on the Oregon side of the river is Cascade Hatchery that rears primarily coho. Further upstream is Oxbow Hatchery located east of the town of Cascade Locks. This is a small facility used to start chinook and coho stock for other facilities. Herman Creek, just upstream of Oxbow Hatchery, and Wahkeena Pond are satellite facilities associated with this hatchery. Two other hatcheries are located on the Bonneville Pool. The Little White Salmon Hatchery at the mouth of Little White Salmon River rears both fall and spring chinook. Tule chinook is the primary stock reared at the Spring Creek National Fish Hatchery.

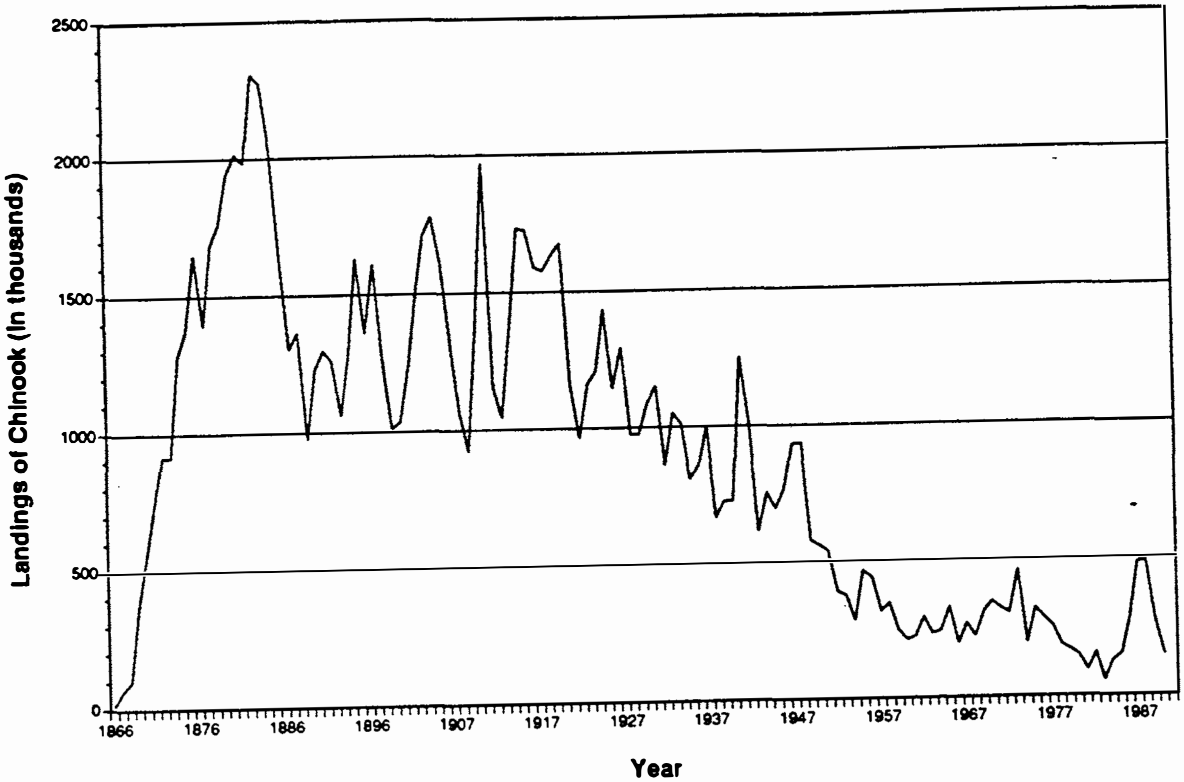
Irrigon Hatchery in Oregon is on the John Day Pool at RM 279. This facility rears spring and fall chinook and steelhead. All fish are released off site, and no facilities are available for adult entry because adults are transferred from other facilities. Umatilla Hatchery, currently under construction just below Irrigon Hatchery, will operate the same as Irrigon Hatchery.

Lyons Ferry Hatchery, located on the north shore of the Lower Monumental Pool just below the mouth of the Palouse River, is the only facility on the Snake River that rears fall chinook salmon. It also rears steelhead. Spring chinook are reared here but are not collected or released directly from this facility. The hatchery's brood stock are collected from Ice Harbor Dam and from direct adult returns to the hatchery.

The Dworshak National Fish Hatchery (NFH) is located on the north fork of the Clearwater River and raises steelhead and spring chinook. The Clearwater Fish Hatchery, across the river from Dworshak NFH, will raise the same stocks when construction is complete.

### 2.4.3 Run Status and Trends

Prior to development of the region by non-natives, the annual runs to the Columbia River were estimated to be 8 to 16 million fish. Recent records indicate that the runs are about 2.5 million (including known fish harvested in the ocean) of which about 0.5 million are wild fish. In 1990, 1.2 million salmon and steelhead actually entered the Columbia River, excluding ocean harvest. About 0.3 million of these were wild fish (ODF&W and WDF, 1991). Columbia River harvest of chinook and sockeye beginning in 1886 is presented in Figure 2.4-3 to indicate the historical run changes of these stocks. Prior to about 1940 or possibly later, most of the Columbia River stocks were harvested in the river, so the numbers are a good



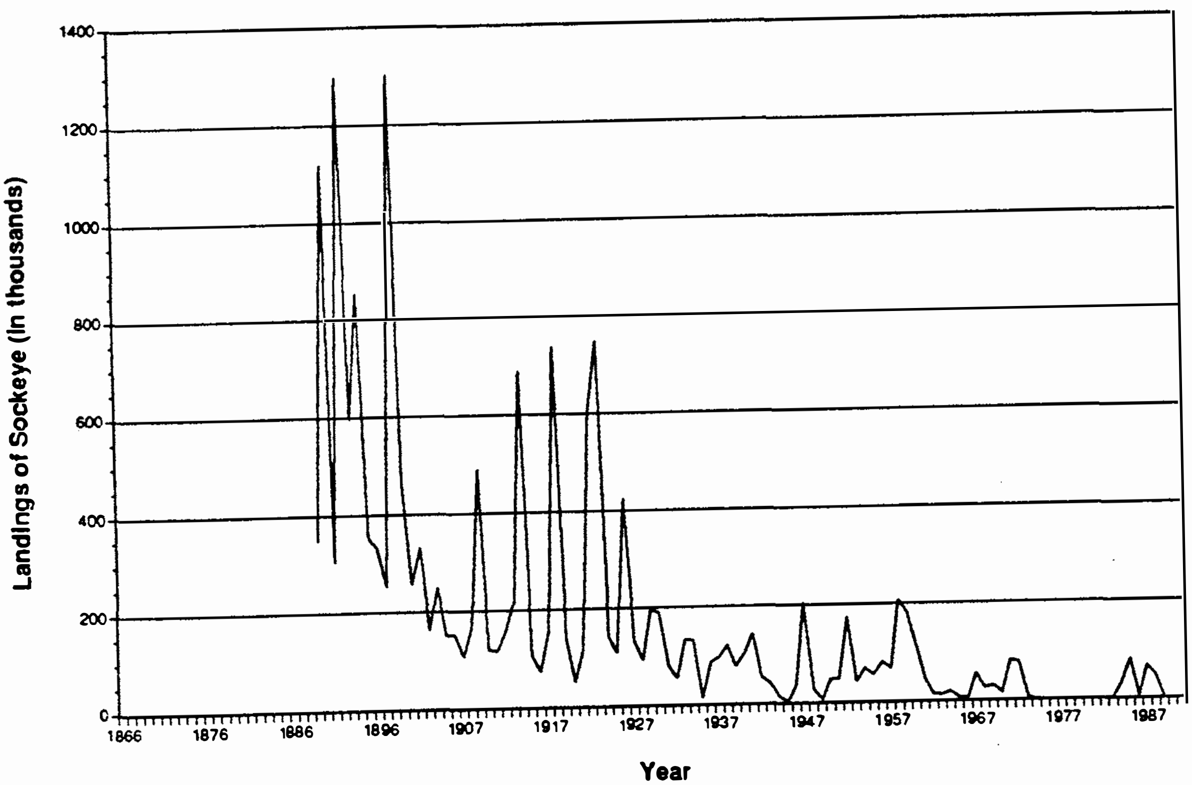




Figure 2.4-3. Total commercial landings (thousands of fish) of chinook and sockeye salmon in the Columbia River, 1866 to 1990 (Sources: NPPC, 1986; ODF&W and WDR, 1991).

indication of run trends during this period. Significant decreases in these two stocks occurred prior to 1900; then again, after about 1920, abundance gradually decreased through 1940. Later reductions occurred in the stocks, but harvest in the Columbia River is not a reliable indicator of total runs because harvest in the ocean and further upriver may have become important. Yet, counts of salmonid over Bonneville Dam have not changed markedly since the dam was built. However, runs decreased substantially from historical levels by 1940 for both chinook and sockeye.

Recent trends in stocks of the Columbia and Snake rivers show similar patterns. Recent counts at Bonneville and McNary dams indicate that upriver spring chinook stocks (total hatchery and wild), reached lows in the early 1980s to mid-1980s, but rebounded in subsequent years. However, they declined in 1989 followed by a slight increase in 1990 (PFMC, 1991). Wild stocks have followed a similar trend. Hatchery stocks below Bonneville Dam have remained healthy, and in 1990 had the largest in-river run since before 1971 (PFMC, 1991).

The low estimate of total chinook produced from the Snake River Basin prior to 1850, based on habitat, was 1.4 million fish. Other estimating methods suggest the run could have been twice this size based on other estimates. By the mid-1900s historical abundance of spring and summer chinook from the Snake River had been reduced by 95 percent. In the last 30 to 40 years, abundance has been decreased another tenfold so that current populations of wild fish are only 0.5 percent of historical levels (Matthews and Waples, 1991).

The Snake River wild chinook population, as indicated by the number of spawning redds for summer and spring chinook combined, declined from 13,000 redds in 1957 to 620 redds in 1980 (Figure 2.4-4). The number of redds increased gradually through 1988 to 3,395 but declined again to 1,008 in 1989 and 1,224 in 1990 (Matthews and Waples, 1991).

Bonneville Dam counts indicated upriver summer chinook rebounded slightly from low numbers in the early 1980s to a slight peak in 1987 and have been declining since that time (PFMC, 1991). About 65 percent of these fish are wild stock (CBFWA, 1991b), so trends indicate declines in wild runs. Snake River stocks, in contrast, showed an increase in escapement in 1990 over record low numbers in 1989 (PFMC, 1991). The escapement information from Matthews and Waples (1991) indicated actual escapement to the spawning ground of both spring and summer chinook (Figure 2.4-4) (see spring chinook above). Hatchery stocks have shown a slight depression in recent years.

The upriver bright wild fall chinook stock, the major wild fall stock above McNary Dam, has declined from record numbers in 1987, but this species remains more abundant than in most years since 1971 (PFMC, 1991). Hatchery stocks from this region have followed a similar trend. Hatchery stocks (below Bonneville Dam) remain healthy, following a trend similar to upriver fish, except that 1990 showed a sharp decline in total river run (PFMC, 1991). Hatchery stocks between McNary and Bonneville dams remain healthy but also had a sharp decline in 1990 (PFMC, 1991).

The historical runs of fall chinook for the Snake River are not known but were probably a large part of the total chinook runs. Abundance decreased early in the century by the construction of Swan Falls Dam in 1910 that blocked 150 miles of spawning habitat. By 1958 another 165 miles of spawning habitat was lost with the construction of Brownlee Dam. Other dams, including Hells Canyon (completed in 1967), excluded access to prime upstream spawning areas. The lower four Snake River projects also reduced spawning area. Estimated average escapement went from 72,000 fish in 1938 to 1949 to 29,000 fish during the 1950s (Waples et al., 1991a). By 1964 to 1968 average counts over Ice Harbor Dam were 13,000 fish. Through 1980 all fish in the basin were of wild origin. The Snake River wild fall chinook gradually declined from these levels to about 1,000 in the mid-1970s. Escapement ranged from 200 to 400 fish from 1983 to 1989, with a sharp decline to only 78 fish in 1990 (Figure 2.4-4) (Waples et al., 1991a). The trend for Lyons Ferry Hatchery stock, the only active fall chinook hatchery on the Snake River, has been a decreasing return (Waples et al., 1991a). Waples et al. (1991a) noted that increasing numbers of stray fall chinook from the Umatilla River (up to 30 percent of all fall chinook in the Snake River) could have a negative effect on the genetic integrity and possibly the viability of the wild Snake River fall chinook stock.

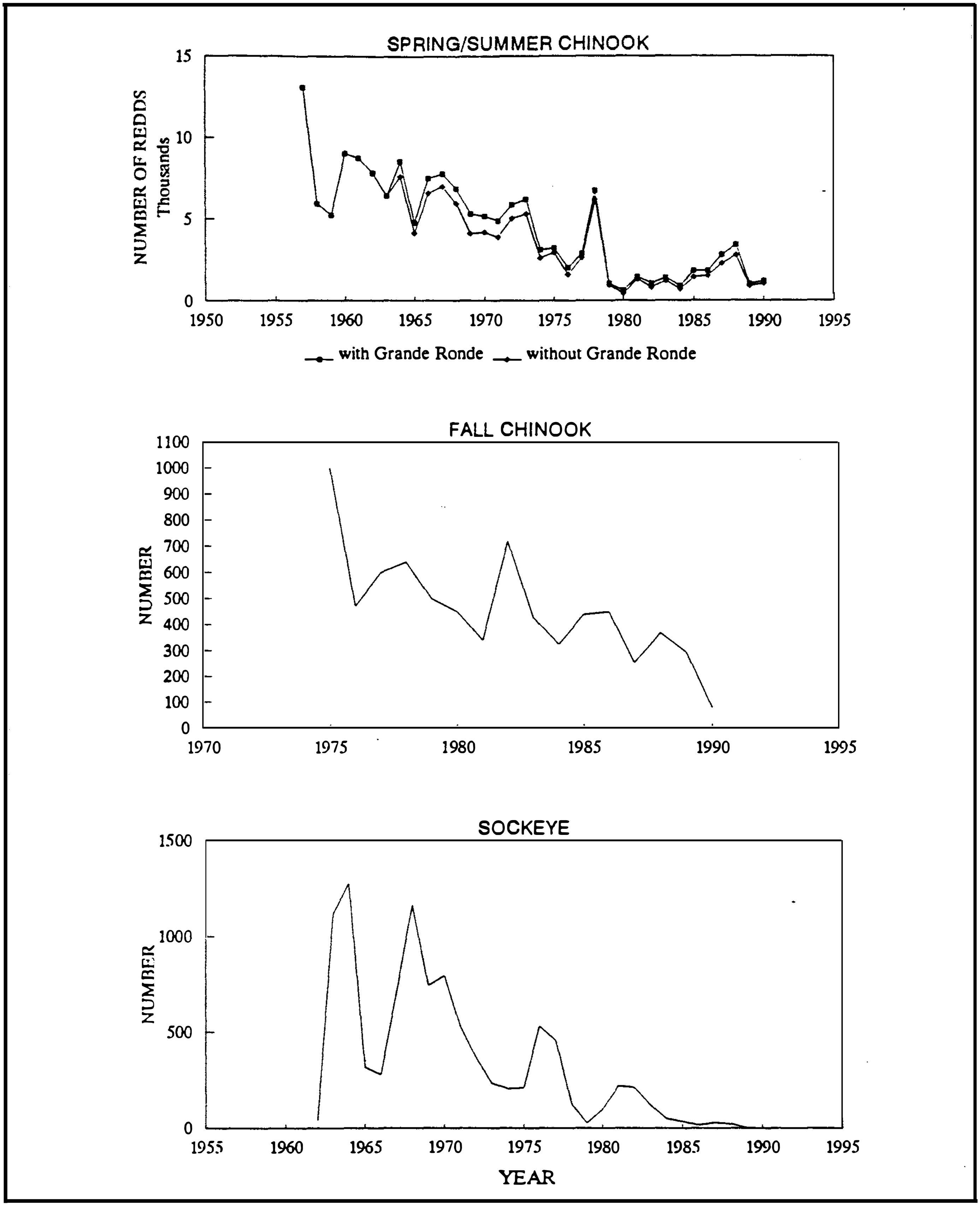



Figure 2.4-4. Number of Snake River wild spawning spring/summer chinook (redds), wild fall chinook above Lower Granite Dam, and sockeye passing Ice Harbor (before 1975) and Lower Granite Dam (after 1974) (Sources: Waples et al., 1991a; Matthews and Waples, 1991; and Corps, 1991b).

Based on counts from Priest Rapids Dam, upper Columbia River wild stocks of sockeye salmon, excluding the Snake River, have remained healthy but are continuing to decline, since large runs of 1984 and 1985 (Chapman et al., 1990). The historical run size of sockeye from the Snake River was estimated to be about 150,000 fish (NPPC, 1986). Much of the original rearing habitat is no longer accessible. Current estimates of potential for escapement to the remaining Stanley Basin lakes is about 6,000 (CBFWA, 1991b). Redfish Lake is the only one of the five lakes in this basin that currently is accessible to sockeye. This lake has an estimated potential to produce 1,500 spawning adults (Chapman et al., 1990). The returns of sockeye destined for Redfish Lake have been less than 1,000 fish since 1970, and less than 100 since 1981 (Chapman et al., 1990). Based on counts past Ice Harbor, escapement averaged less than 20 fish from 1985 to 1988. Only two fish returned in 1989, and none in 1990 (Figure 2.4-4). However, to date in 1991, eight sockeye have passed Lower Granite Dam and four have returned to Redfish Lake.

The numbers of other anadromous stocks on the Columbia River show varying trends. Coho on the Columbia River, which are nearly all of hatchery origin, have declined significantly since a record return to the river in 1986. Runs are now well below the 10-year, in-river average. Coho destined above Bonneville Dam have followed the same declining trend (PFMC, 1991). Wild steelhead have been depressed in recent years, although hatchery stocks remain stable (Table 2.4-1). Shad populations have shown sharp increases in abundance with some of the highest numbers recorded over Bonneville Dam (nearly 3 million in 1990) in the last 10 years (Corps, 1990a). Pacific lamprey populations are declining. The status of white sturgeon in the lower Columbia is being investigated (Nigro, 1990).

## 2.4.4 Factors Affecting Run Status

As summarized by the NPPC (1986), the decrease in salmon and steelhead has been an ongoing trend that began with the arrival of white settlers (in the mid-1800s) to the Pacific Northwest.

The earliest identified negative human impact was fishing. Early harvest focused on chinook; when the chinook harvest declined after 1884, emphasis shifted to steelhead and sockeye (1890 to 1900), followed by chum and coho (1920s). By 1945, all species had declined significantly.

Other impacts closely followed fishing. By 1900, mining had become important in areas of Oregon, Washington and Idaho. By 1925, there were major increases in land devoted to agriculture, and there were also major advances in irrigation and logging as well. By 1941, large hydropower projects (Rock Island, Bonneville and Grand Coulee dams) had been built. The period 1940 to 1965 saw major increases in logging and water storage for a variety of purposes including hydropower generation and irrigation.

A brief review of the apparent influence of these and other factors on the sizes of the runs follows.

### 2.4.4.1 Harvest History

Methods of capturing fish on the Columbia River have changed dramatically. Historically, the Indians captured fish with methods ranging from gaffs to nets. The Indians constricted fish migration routes for major harvest; they harvested large numbers of salmon and steelhead at Celilo Falls above The Dalles Dam. They fished from shore or platforms using dip nets (long-handled nets). This region was inundated in 1957, so Indian fishing changed from dip nets to set gill nets (anchored nets that catch fish by the gills) (NPPC, 1986). The region of the Columbia River between Bonneville Dam and McNary Dam is still commercially fished exclusively by Natives in this manner. Prior to 1939, Kettle Falls above Grand Coulee Dam was another major Indian fishing area where Indians used baskets and spears to harvest fish.

Commercial fishing in the lower Columbia River has relied on various methods to harvest fish over the years. As harvests increased and concern for the runs became more apparent, many types of fishing gear were banned. Banned harvest methods

Table 2.4-1. Recent salmon and steelhead (including jacks) passage at selected Corps projects.

| | Project | | |
|---|---|---|---|
| Species | Bonneville | McNary | Lower Granite/ Ice Harbor[a] |
| **Spring Chinook** | | | |
| 1971-80 | 118,801 | 48,143 | 32,208 |
| 1981-85 | 67,956 | 36,611 | 17,216 |
| 1986-90 | 100,621 | 53,621 | 28,664 |
| 1990 | 96,252 | 44,499 | 20,730 |
| **Summer Chinook** | | | |
| 1971-80 | 50,399 | 34,266 | 11,369 |
| 1981-85 | 27,076 | 18,228 | 4,972 |
| 1986-90 | 33,254 | 24,346 | 6,505 |
| 1990 | 28,021 | 22,248 | 5,794 |
| **Fall Chinook** | | | |
| 1971-80 | 209,027 | 62,838 | 4,282 |
| 1981-85 | 233,189 | 95,471 | 3,959 |
| 1986-90 | 340,026 | 161,335 | 6,277 |
| 1990 | 216,717 | 80,692 | 5,317 |
| **Steelhead** | | | |
| 1971-80 | 142,555 | 109,795 | 38,057 |
| 1981-85 | 238,979 | 117,211 | 83,338 |
| 1986-90 | 286,574 | 151,917 | 96,229 |
| 1990 | 183,027 | 95,061 | 56,859 |
| **Coho** | | | |
| 1971-80 | 50,832 | 12,693 | 749 |
| 1981-85 | 41,172 | 3,817 | 26 |
| 1986-90 | 52,467 | 1,888 | 0 |
| 1990 | 24,852 | 2,056 | 0 |
| **Sockeye** | | | |
| 1971-80 | 57,818 | 39,769 | 299 |
| 1981-85 | 105,136 | 47,597 | 127 |
| 1986-90 | 69,259 | 51,235 | 14 |
| 1990 | 49,581 | 46,145 | 0 |

Source: Corps, 1991b.

a/ For chinook, Ice Harbor counts were used for all years. For all other stocks, Ice Harbor counts were used for 1971 through 1974, and Lower Granite counts were used for all other years.

include gaffs and spears, purse seine (a large net used to surround fish, either from boat or shore), whip seine (similar to purse seine), drag seine, set nets (anchored gill nets), traps (contains guides leading fish to trap), and fish wheels (large wheels with scoops placed near shore that turned with the current, scooping up migrating adult fish). Currently, the only commercial gear used on the lower Columbia River is drift gill nets (gill nets that drift with the current).

Around 1912, ocean commercial harvest began off the mouth of the Columbia River. Fishermen in small boats trolled baited hooks or lures. Later, larger boats were built that permitted harvesting in the salmon feeding areas farther offshore. Currently, this method still harvests substantial numbers of Columbia River stocks from Alaska to California. Sport fish harvest did not become a factor in the harvesting of Columbia River stocks until after World War II (NPPC, 1986). Sport harvest has varied by region, basin, and stock, with good early records not available. Spring chinook harvest in the lower mainstem Columbia was high in 1961 to 1974 but has decreased considerably since that time. Steelhead harvest in this region was also high in the 1960s but has declined substantially since that time. Lower river tributary harvest by sport fishing has been variable with some sport fishing showing increases since the 1950s while others have not. In Idaho, Snake River sport harvest of chinook was high in the 1950s but has declined substantially since then. In many years since 1965 harvests of some stocks have been closed. Steelhead harvest, decreasing from high levels in 1960 to record low levels in 1976, increased to high levels again by the early 1980s.

After an initial sharp decline around 1890, harvest of chinook salmon in the Columbia River remained fairly constant to about 1920, then it gradually decreased from 1920 to 1966 (Fulton, 1968). Much of this decline can be attributed to other sources of mortality (e.g., dams, logging, mining, and agriculture), but not overharvest. A decreasing trend of Columbia River commercial harvest is apparent for both chinook and sockeye from the late 1800s to the present (Figure 2.4-3). These figures do not account for all harvest of Columbia River stocks, particularly after the middle of the 19th century.

Ocean troll harvest of chinook salmon began to compete with river harvest in 1912 (NPPC, 1986). In the 1970s, more than 60 percent of the total chinook salmon run harvest was in the ocean, with the greatest portion of fish harvested off Alaska and British Columbia. Typically, less than 10 percent of the total chinook run was harvested in rivers during this period (NPPC, 1986). The 1985 U.S.-Canada salmon treaty has reduced harvest of U.S. fish in Canadian and Alaskan waters.

Recent tag data indicate that ocean harvest of spring and summer Snake River chinook stocks is probably less than 5 percent of the total run (Chapman et al., 1991). In-river harvest of all Columbia-Snake upriver spring and summer chinook is 10 to 13 percent. The harvest rate of Snake River fall chinook is much higher, possibly 75 percent of the total run, with ocean harvest accounting for about 35 percent (Chapman et al., 1991). Sockeye harvest in the Columbia River before 1950 was up to 86 percent of the total run, declining to less than 60 percent during most years from 1950 to 1969 (Chapman et al., 1990). The harvest rate between 1974 and 1983 averaged less than 2 percent, despite levels averaging 37 percent of the run from 1985 to 1988. The proportion of Snake River stocks in these harvest rates is unknown.

### 2.4.4.2 Dam Development

Dam development in the Columbia River Basin began in the 1800s. Mainstem dam development began with Rock Island Dam on the Columbia River in 1933 and continued through 1975 with the completion of Lower Granite Dam on the Snake River. Most of the dams were constructed from the 1950s through the 1970s. Fourteen mainstem Columbia River and 13 mainstem Snake River dams were constructed in areas critical to the upstream and downstream migration of anadromous fish stocks. Including tributary areas, 136 dams have been built for hydroelectric and other purposes in the Columbia drainage (NPPC, 1986).

Dam construction has had varied effects on anadromous fish stocks. Dams without upstream fish passage facilities completely block access to spawning and rearing habitat for returning adults. Even where fish ladders or other upstream passage facilities are provided, returning adults may encounter delays from increased water temperatures, water quality degradation, adverse flow conditions, and other factors associated with the dams. Dams and reservoirs also have had a significant effect on juvenile fish by impeding their downstream migration and elevating risk factors, such as predation and disease, in the downstream journey.

About 31 percent of all anadromous fish habitat (stream miles) that existed in predevelopment times has been blocked by dams (NPPC, 1986). Major habitat loss due to blockage by dams has occurred in nearly all major drainages of the Snake River System (Table 2.4-2). The loss in this system equals 46 percent of the predevelopment habitat. More than two-thirds of this loss occurred in areas above Hells Canyon Dam. Additionally, many miles of stream that are still accessible to fish have been converted from free-flowing water to slackwater reservoir conditions; accessible reservoirs account for 362 miles on the mainstem Columbia River and 137 miles on the Snake River. These areas generally no longer supply spawning habitat for anadromous stocks, due to inundation of former spawning beds, although juvenile rearing is possible.

In addition to the construction effects, the operation of these dams has had other negative effects on anadromous fish stocks. The effects have varied by project, changed over time with the application of different engineering solutions, and have affected juvenile and adult fish in different ways.

Juvenile salmon and steelhead migrating downstream can pass each dam they encounter in several different ways. One way is to travel over the spillway, although this avenue is only open if water is being spilled. Alternatively, fish can travel with the river flow toward the powerhouse. Fish screens and/or sluiceways are either installed or will be installed at all the run-of-river dams. These systems either collect or divert a portion of the downstream migrants away from the turbines. Collection systems are installed at the same dams to divert fish from the powerhouse and either bypass them back to the river downstream of the dam or route them to holding facilities for later transport by barge or truck. Some fish at these dams are not guided and pass through the turbines. At dams without screens or collection facilities, the only downstream passages are over the spillway or through the turbines or sluiceways (see Section 2.2.4).

Each passage has distinctive fish mortality risks. Overall, the key negative factors that have attributed to loss of juvenile fish include the following:

- turbine mortality,
- spillway mortality,
- delayed migration,
- increased predation,
- gas supersaturation, and
- temperature effects on rearing and migration.

Juvenile fish passing through turbines can be killed or injured by turbine blades or by hydraulic pressure and shear. Estimates of turbine mortality vary from one study to another and from one location to another in the Columbia-Snake River System. Specific estimates range from about 2 to 32 percent per project (the higher value includes unusual tailwater predator mortality) (Ledgerwood et al., 1990; Weber, 1954; Long et al., 1968). The most accepted level is about 15 percent (NPPC, 1989), which includes direct and indirect mortality.

Spillway direct mortality is estimated to be 2 percent per project (NPPC, 1986). Non-fatal injuries during spillway transit, such as descaling, leave juveniles vulnerable to disease. Stunned or disabled fish exiting spillways are more susceptible to predation than unstunned or uninjured fish. Actual direct and indirect mortality from passing over spillways could be much higher than 2 percent.

Migration delay and the resulting reduced survival of juvenile fish have been attributed to slower velocity and increased water retention time in the reservoirs (see Section 4.2). It is generally accepted that a variety of factors increase mortality of juvenile migrants at extreme low flows. These factors include residualism (smolted fish reverting to freshwater physiology and remaining in the reservoir); predation; stress; increased fish disease; and poor condition and improper timing of arrival at the estuary, which is dependent on the level of

Table 2.4-2. Salmon and steelhead habitat lost in the Snake River and tributaries and remaining habitat presently available by major drainage.[a]

| Major Drainage | Miles of Lost Habitat | Miles of Habitat[b] Presently Available |
|---|---|---|
| Mainstem Snake and minor tributaries | 440 | 175 |
| Tucannon | 0 | 55 |
| Clearwater | 627 | 1,248 |
| Grande Ronde | 0 | 647 |
| Salmon | 88 | 1,834 |
| Imnaha | 0 | 223 |
| Powder | 200 | 0 |
| Burnt | 140 | 0 |
| Weiser | 256 | 0 |
| Payette | 470 | 0 |
| Boise | 520 | 0 |
| Owyhee | 485 | 0 |
| Malheur | 205 | 0 |
| Total | 3,431 | 4,182 |

Source: NPPC, 1986.

a/ This report applies to salmon, but it is probably generally applicable to steelhead also.
b/ Current available habitat greatly underseeded with chinook stocks (Strategies for Recovery of Snake River Salmon, State of Idaho, 1991, 31 pages).

smoltification (CBFWA, 1991a; Giorgi, 1991). The effects of reduced water travel time on fish survival during higher flows is less clear (Giorgi, 1991; Kindley, 1991), although there is a statistically significant relationship between flow and fish travel time (Berggren and Filardo, 1991).

Increased gas saturation has been found to cause significant mortalities of juvenile and adult fish; Weitkamp and Katz (1980) summarized much of the literature about the effect of gas supersaturation on fish, including those in the Columbia River (see also Section 2.1). Studies found that juveniles near the surface of the water suffer high mortality when gas saturation is greater than 120 to 125 percent.

Weitkamp and Katz (1980) also cited studies that indicated an estimated 6 to 60 percent of adult salmon and steelhead were killed in the middle Columbia River from gas supersaturation from 1965 to 1970. Gas bubble disease was observed in juveniles at Columbia River dams during several years in this period. It was estimated that, prior to the installation of two dams on the Snake River, smolt mortality was 5 percent; after installation, mortality was 70 percent. Most of this loss, although unproven as to source, was attributed to increased gas supersaturation resulting from the dams (Rulifson and Abel, 1971). Since this time problems have been corrected and most mortalities are believed to have been eliminated (Ebel, 1979).

Increased water temperatures reduce juvenile rearing in some reservoirs. Preferred temperature for chinook, for example, is 54°F (12°C) to 57°F (14°C) (Brett, 1952). Even though they can survive higher temperatures, they tend to avoid temperatures above 59°F (15°C) (Brett, 1952). In some years, temperatures reach levels by early July that are not tolerable for salmonids. For example, in the Snake River reservoirs after early July, temperatures reach 62°F (17°C) to 72°F (22°C) (Chapman et al., 1991). Bell (1986) reports an optimum rearing temperature of 45 to 58°F (7 to 14°C) and an upper lethal limit of 77°F (25°C).

Adult salmon and steelhead have been blocked from migrating during some years because of elevated temperatures. The optimum temperature range for chinook migration is 49 to 58°F (9 to 14°C), while suitable temperatures are 38 to 68°F (3 to 20°C) (Bell, 1986). Adult salmon migration can be blocked at temperatures over 70°F (21°C) (EPA, 1971). In the Snake River, high temperatures over 70°F (21 °C) in 1967 and 1968 in late summer impeded migration of some summer chinook and steelhead. Some dead fish, whose deaths were possibly caused by these temperatures, were found in the Columbia River downstream from the mouth of the Snake River (Vigg and Watkins, 1991). Before lower Snake River dam construction, measured temperatures in the Snake River were higher than those recently recorded at least through August (Vigg and Watkins, 1991).

Adult migration can be directly and indirectly impeded at dams, resulting in assumed mortalities. Returning adults could have difficulty locating the entrances to fish ladders and spend excess time milling about below dams. This causes the fish to use more energy, depleting stored energy reserves, and potentially causing premature death. High water temperatures, particularly in the Snake River, have been found to delay upstream migration (see above). The higher water temperatures are thought to be a result of the increased time that water is retained in the reservoirs, although this has not been proven. Increased mortality per dam has been generally considered to be between 5 and 10 percent (NPPC, 1989). More recent information indicates it is more likely 3 to 4 percent (personal communication, Ted Bjornn, Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho, Moscow, Idaho, October 1991), with increasing levels of mortality occurring during high-flow years (Gibson et al., 1979). Some mortality is caused in passage independent of flow, as was documented at John Day Dam where mortality was estimated to be 20 percent independent of flow (Gibson et al., 1979).

Several project-related structural and operational measures have been implemented to reduce these adverse effects on fish. Many of these measures designed to improve juvenile fish survival include:

- fish screens and juvenile bypass and/or transport,
- designated fish spill,
- designated fish flows,
- flip lips to reduce dissolved gasses,
- improved fish ladders,
- predator removal, and
- controlled peaking.

Fish screens have been installed at five mainstem dams (will be six in 1992, seven by 1994, and eight by 1998) to divert migrating juveniles from the turbines. Screens pass diverted fish back to the river at Bonneville and John Day dams. At Lower Granite, Little Goose, and McNary dams, fish can be diverted, gathered, and transported by truck or barge to below Bonneville Dam for release to avoid the various sources of mortality on the downstream trip. Some fish at these dams are bypassed back to the river to meet the fish agency management strategy of "spreading the risk." The percent of fish screened and/or transported varies by species, time of year, and project; more than 50 percent of yearling chinook and steelhead and less than 50 percent of subyearling chinook and sockeye are transported. For example, in 1985, 51 percent of spring chinook and 74 percent of steelhead were transported. (See Section 4.2 for details at individual dams).

Designated water spilled for fish and storage releases have been adopted as part of the Columbia Basin Fish and Wildlife Program as part of their "spread the risk" strategy. Controlled spills divert fish from turbines in designated periods, typically during the peak downstream migration periods. Water Budget storage releases increase water velocity through the reservoirs and help flush fish over spillways.

Spill deflectors, called flip lips, have been installed on most major dams on the Snake and Columbia rivers to reduce supersaturated dissolved gas levels that, in the past, have been recorded during high-spill periods (see Section 2.3 for description). Levels above those considered safe (less than 110 percent) still occur annually on the Columbia and Snake rivers, but current levels are less than conditions recorded prior to installation of the flip lips.

### 2.4.4.3 Agriculture

Over 12 percent of the Columbia Basin is farmland. Most of the farm acreage is in central Washington and southern Idaho. Farm acreage in the basin increased gradually until 1960 and then leveled off. Irrigated farmland has increased from 0.5 million acres before 1900 to 7.6 million acres by 1980 (NPPC, 1986). Total irrigated land in the Snake River Basin has followed a similar pattern, increasing from about 2 million acres in 1930 to 4.5 million acres in 1980 (NPPC, 1986).

More than half of the Columbia Basin is suitable for livestock grazing. Records since 1945 indicate that public land grazing peaked in the 1950s, but fell in the early 1980s by about 10 percent in Washington and Oregon and about 25 percent in Idaho from those peak levels (NPPC, 1986). Nevertheless, grazing acreage and intensity remain high.

The adverse effects of agriculture are many: loss of streamside vegetation, increased temperature, increased erosion adding silt to spawning beds, reduced flow in rearing areas, impedance to fish migration, addition of toxicants and nutrients to streams, and loss of fish in unscreened irrigation diversions. Unscreened diversions are one of the major problems. While most irrigation intakes have been screened, many screens are not functional; they wash out of the river, catching fish that stick to the moving screens (NPPC, 1986). Many of these problems have been reduced, but not eliminated.

Grazing is one of the major factors affecting the quality of stream habitat in Idaho. About 80 percent of anadromous fish habitat in the Snake River drainage lies in areas managed by federal agencies, and much of this land is open to grazing (Chapman et al., 1991). Stream habitat, and its ability to produce salmonids, deteriorates in regions that are grazed. Stream bank erosion reduces pool habitat, loss of streamside vegetation allows streams to warm, and increased sediment in the water reduces egg survival.

### 2.4.4.4 Logging

Logging was probably the first non-native industry to develop in the Columbia River System (NPPC, 1986). Early logging was typically restricted to lowland areas, resulting in little disturbance from sedimentation that can be detrimental to streams. From about 1880 to 1920, streams were often used to transport cut logs. Occasionally, dams were constructed and then breached to sluice logs. This resulted in extensive streambed scouring, primarily in the lower reaches of the Columbia tributaries. Logging increased sharply during and after World War II. Logging in the Snake River drainage increased most dramatically in the early 1960s, from lows of 1- to 30-million board feet per year to over 600-million board feet per year, and remained high through the 1980s (NPPC, 1986).

Logging has significant adverse effects on fish habitat. The major effects are increased sedimentation, reduced egg survival, loss of streamside cover, increased stream temperatures, and reduced instream habitat. Significant adverse effects on fish habitat and/or production in Snake River tributaries have been documented since the advent of increased logging activities in the 1960s (Chapman et al., 1991).

### 2.4.4.5 Mining

Mining was one of the earlier industries to develop in the Northwest. By the late 1800s, some of the major mining areas were in Snake River anadromous fish habitat (NPPC, 1986). Gold and silver mining were more extensive in Idaho than in Washington and Oregon. Mining methods included both underground mining and dredging or sluicing of riverine (placer) deposits. Some of the heaviest in-stream mining occurred in Snake River tributaries, destroying large areas of aquatic and riparian habitat. Other impacts from mining included acid mine leaching and heavy sediment deposition. Most of the damage from mining occurred in the first half of this century, although some degraded habitat still exists in Idaho tributaries such as the South Fork Clearwater, Bear Valley, and Crooked River (NPPC, 1986).

### 2.4.4.6 Hatcheries, Disease, and Genetics

Currently, a large portion of total salmon and steelhead trout runs to the Columbia River System originate from a hatchery. Therefore, factors affecting the success of hatchery fish greatly influence total runs to the river. Several problems occur with hatchery fish compared to wild stocks. Generally, hatchery stocks have poorer smolt-to-adult survival rates than do wild stocks. Survival from a given hatchery also tends to decline over time. For example, the Pacific Salmon Commission (PSC, 1990) has kept records on the relative survival of 32 stocks of chinook salmon (all but 2 hatchery origin) from Alaska, British Columbia, Washington, and Oregon. They found that 17 stocks (55 percent) had a long-term decreasing trend in survival, independent of fishing mortality, while only 5 stocks (16 percent) showed an increasing trend. Trends for the other stocks were either indeterminant (1 stock) or based on insufficient data (9 stocks). This included stocks from areas above the dams on the Columbia River and from other areas not affected by the dams.

Another hatchery problem that might have serious consequences on fish survival is the incidence and severity of disease. One of the most severe problems of fish in the Columbia River is bacterial kidney disease (BKD). The bacterium that causes this disease can be transmitted from parents to their eggs. BKD most seriously affects spring chinook smolts. Warren (1989) and Pascho and Elliott (1991) indicated that prevalence of the disease in smolts in Snake River Federal hatcheries ranged from 15 percent to 100 percent. Juveniles reared from adults with low indicators of the disease survived from release to return to the hatchery at a rate three times higher than predicted, while adults with high levels of indicators of the disease survived at 70 percent of the predicted rate. Raymond (1988) believed the lack of improvement in survival of hatchery spring chinook from the Snake River in the 1980s was caused by BKD mortalities after smolts reached the ocean. This disease theoretically could be passed on to wild fish. Its incidence in the wild currently may be high (Pascho and Elliott, 1989; Elliott and Pascho, 1991). Recent progress has reduced the level of BKD in hatchery fish in Washington State Department of Fisheries hatcheries through inoculation with erythromycin (Michak et al., 1990). However, Pascho and Elliott (1989, 1991) indicated that up to 100 percent of the spring/summer chinook leaving the mid-Columbia and Snake rivers tested positive for BKD.

Hatchery fish that spawn in the wild may reduce the viability of the stocks. Chilcote et al. (1986) found that natural-spawning hatchery steelhead in the Kalama River produced smolts with a survival rate only 28 percent of that of wild fish. The extent of wild spawning by hatchery stocks in the basin is variable. It may be large in some areas with large hatchery runs ultimately reducing the viability and production of wild fish. In the Snake River, although large outplanting of hatchery fish to streams has occurred, wild spawning of hatchery releases of spring and summer chinook is apparently low (Matthews and Waples, 1991). However, recent (since 1983) stray hatchery fall chinook from the lower river may be entering the spawning areas of wild fall chinook in significant numbers, and hatchery fish from earlier activities (1983 or earlier) in the basin could have been spawning in the wild (Waples et al., 1991a).

#### 2.4.4.7 Other Effects

Several other factors, as yet poorly quantified, also could be having significant effects on salmon and steelhead production in the Columbia-Snake River System. These effects include increased marine mammal predation, shad competition, and high-seas drift net harvest.

Populations of marine mammals have been increasing since the Marine Mammals Protection Act of 1972. Many of these mammals feed on salmonids. Recent records indicate that the harbor seal population has increased around the Columbia River mouth. The highest historical incidence (19.2 percent) of injuries from seal bites on spring and summer chinook were recorded in 1990 (Chapman et al., 1991). The level and proportion of this impact on salmonid populations are not clear because salmon typically make up a small portion of seals' diets.

Shad were introduced to the Columbia River from east coast stocks in the 1880s. Since fish counts began at Bonneville Dam in 1938, numbers have increased dramatically from less than 10,000 to over one million fish annually in the 1980s. The highest number on record was counted in 1990 at 3 million fish (Corps, 1990a). The direct and indirect effects of the shad population on salmonid stocks are not well understood. However, there is a possibility of predation by shad adults on salmonid smolts. Adult shad migration may cause stress to adult salmon at ladders because of their higher numbers. Finally, competition between shad and salmonid juveniles for food resources in the estuary and possibly the ocean environment affects salmon survival (Chapman et al., 1991).

The exact effect of high-seas drift net fishing on Columbia River stocks is not known. Results from observers on Japanese drift net fishing vessels suggest that the effects are probably small because less than 10,000 salmon and steelhead were reported captured in one fishing season (International North Pacific Fisheries Commission, 1991). However, recent undercover operations have indicated that thousands of metric tons of salmonids have been captured from illegal drift net operations that are not monitored by observers. The magnitude of this activity on salmonid populations remains unquantified.

## 2.5 RESIDENT FISH AND AQUATIC ECOLOGY

### 2.5.1 General Conditions

Fish species in the reservoirs of the lower Snake and Columbia rivers include a mixture of native riverine and introduced species that typically are associated with lake-like or lacustrine conditions (Bennett et al., 1983; Bennett and Shrier, 1986; Hjort et al., 1981; Mullan et al., 1986). Dominant native species include northern squawfish, redside shiners, mountain whitefish, chiselmouth, bridgelip sucker, and largescale sucker. The most common game species include walleye, bluegill, smallmouth bass, largemouth bass, white crappie, black crappie, American shad, carp, channel catfish, and yellow perch.

Cold-water resident species (such as trout and mountain whitefish) that were once common in the Columbia and Snake rivers have declined since the construction of the dams. Species composition has changed due to the blockage of spawning migrations and modification of habitats (Mullan et al., 1986). The prey base also has changed since the construction of the dams, shifting from dominance of benthic organisms to dominance of pelagic phytoplankton. This shift in prey organisms might also have contributed to the decline of cold-water resident species (Sherwood et al., 1990).

Resident fish in the reservoirs occupy numerous habitats and often use separate habitats for different life history stages (Bennett et al., 1983; Bennett and Shrier, 1986; Hjort et al., 1981; Bennett et al., 1991). Each reservoir has three general zones which are characterized by different habitats (Hjort et al., 1981). The first zone is the forebay area, which is typically lacustrine in nature. At the upper end of the reservoir is a second zone that tends to be shallower and have significant flow velocities. In between these two zones is a transition area that changes in the upstream end from riverine to more lake like in the downstream direction. Each zone can include several habitat types; however, most can be characterized as either backwater (including sloughs and embayments) or open-water habitats (Hjort et al., 1981; Bennett et al., 1983; LaBolle, 1984).

Backwaters and embayments generally provide slightly warmer habitat, finer substrate, and submergent and emergent vegetation. Backwater areas are used for spawning by bass, black crappie, white crappie, bluegill, pumpkinseed, yellow perch, and carp (Bennett et al., 1983; Bennett and Shrier, 1986; Hjort et al., 1981; Bennett et al., 1991; Zimmerman and Rusmussen, 1981). Fish normally spawn in shallow water less than 6.5 feet deep. Spawning and incubation times vary between species; however, most of these backwater species spawn from May through mid-July (Figure 2.5-1).

Shad, cyprinids, suckers, walleye, sandroller, white sturgeon, and possibly redside shiner spawn in open water. Prickly sculpin spawn in both open water and backwater, based upon the distribution of prolarvae (Hjort et al., 1981). The greatest abundance of larvae are generally found in the backwaters and nearshore areas. Only yellow perch and prickly sculpin larvae are commonly found in open-water areas.

Most of the native species spawn in flowing waters at the headwaters of the reservoirs or in tributary streams. Some species, however, also spawn in the reservoirs. For instance, northern squawfish will spawn either in flowing water or along gravel beaches in reservoirs (Wydoski and Whitney, 1979).

Juvenile fish are found in abundance in backwater and open-water areas where flowing water is found. The two habitats are occupied by distinctly different

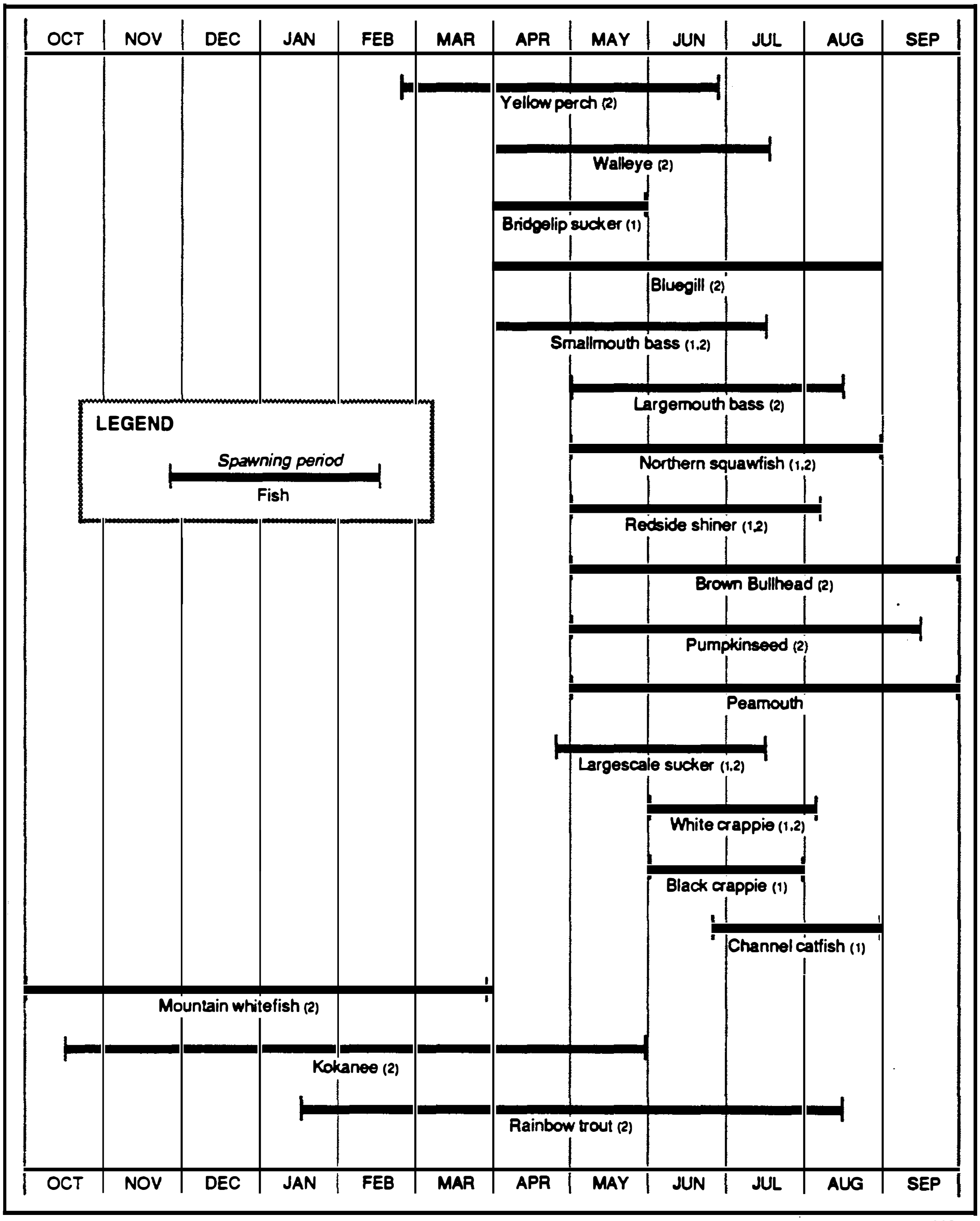



**Figure 2.5-1.** Spawning and incubation chronology of fish species.
Sources: Bennett et al., 1983; Stober et al.,1979.

fish species. Introduced species, which are primarily lacustrine fishes, are more common in the backwater areas while native riverine species are most common in the flowing water regions (Hjort et al., 1981; Bennett et al., 1983; Bennett and Shrier, 1986; Mullan et al., 1986). Juvenile shad are widely distributed in reservoirs, which may be related to the dispersion of their semi-pelagic (not attached, semi-buoyant) eggs (Hjort et al., 1981).

Adult distribution is generally similar to spawning and juvenile distribution but can change depending upon feeding strategy. Adults may occur throughout the habitats and move seasonally or daily to different areas (Bennett et al., 1983; Bennett and Shrier, 1986; Hjort et al., 1981). Although adults will use various habitats, lacustrine species are generally abundant in shallow, slower velocity backwater areas and native riverine species occur abundantly in areas with flowing water (Bennett et al., 1983).

In general, the backwater areas have the greatest abundance of fish in all life stages. Deep habitats support fewer fish. The majority of the species found in deeper waters are non-game suckers (*Catostomidae*) and Minnows (*Cyprinidae*). White sturgeon (*Acipenser transmontanus*) are also found in deeper waters. Mid-depth habitats support a community higher in species diversity and abundance than deep habitat, but generally lower in abundance than shallow habitat (Bennett et al., 1991).

In many reservoir systems, fish abundance in shallow waters has been shown to correlate with the presence of aquatic or submerged vegetation. However, the results of studies conducted in Little Goose Reservoir by Bennett et al. (1983) did not indicate a strong correlation between fish abundance and aquatic vegetation.

The use of backwater areas by numerous species may be at least partially related to the availability of prey. Zooplankton are generally sparse in the Columbia River except in sloughs and backwaters (Mullan et al., 1986; Stober et al., 1979). High concentrations of zooplankton in the backwater areas attract smaller prey species that feed upon these organisms. In turn, high concentrations of prey fishes attract larger predator fish species. Therefore, higher concentrations of zooplankton in backwater areas may affect the habitat selection of several species.

Zooplankton abundance is also related to water retention time in the reservoirs. During spring floods, large influxes of nutrients enter the reservoirs. Long water retention times (i.e., 3 to 4 months) enable primary and secondary producers to use these nutrients over a relatively long period of time. Shorter retention times reduce the time the spring influx of nutrients is present in a reservoir, and, therefore, limits the potential productivity of the reservoir (Beckman et al., 1985; Peone et al., 1990).

Benthic organisms can also contribute significantly to the diets of many reservoir fish species (Bennett et al., 1983). Benthic production is usually minimal in shallow-water areas because water level fluctuations expose the organisms. As a result, benthic organisms are usually depleted in littoral zones where water levels fluctuate (Mullan et al., 1986).

### 2.5.2 Lower Snake River Reservoirs

Reservoirs in the lower Snake River are typically warm in summer and either do not stratify or only stratify weakly. They have a relatively long (roughly 15 to 25 years) history of sedimentation; therefore, finer substrates prevail. The fine substrates, warmer temperatures, and associated lower dissolved oxygen levels tend to favor warm- and cool-water species (Bennett et al., 1983).

Approximately 25 to 30 species of resident fishes are known to inhabit the lower Snake River reservoirs (Table 1, Appendix B). About half of these are introduced species. Native fishes include sturgeon (*Acipenseridae*), trout and salmon (*Salmonidae*), minnows (*Cyprinidae*), suckers (*Catostomidae*), and sculpins (*Cottidae*). The largest family representation of introduced fishes is from the sunfish (*Centrarchidae*) family. Seven members have been introduced including largemouth bass, smallmouth bass, pumpkinseed, bluegill, black crappie, white crappie, and warmouth. Numerous catfish species (*Ictaluridae*) are also common in the Snake River reservoirs. They include channel catfish, flathead catfish, brown bullhead, yellow bullhead, and tadpole madtom. Most of these fishes have been introduced for sporting purposes.

There is little difference in the species composition of the four lower Snake River reservoirs. Species found in higher abundance in all reservoirs include suckers (bridgelip and largescale), northern squawfish, smallmouth bass, chiselmouth, and redside shiners (Bennett et al., 1983; Bennett and Shrier, 1986; Bennett et al., 1988). Species such as crappies, sunfish, and largemouth bass are highly abundant in backwaters of all reservoirs. Other species are equally abundant in some reservoirs (Appendix D; Bennett et al., 1983). Minor variations in species composition are related to variations in the availability of backwater habitats and flowing waters in the various reservoirs.

Little Goose and Lower Monumental reservoirs have a greater number of backwater areas than the Lower Granite and Ice Harbor reservoirs (Bennett et al., 1983). The confluences of two major tributaries (Palouse and Tucannon rivers) with the Snake River provide additional backwater habitat in Lower Monumental. Therefore, these reservoirs tend to support larger numbers of species that are dependent upon these shallow-water habitats during some part of their life histories. Channel catfish and carp are more abundant in Lower Monumental and Ice Harbor reservoirs. Their abundance in these reservoirs is believed to be related to the availability of suitable habitat (waters with little current, often soft substrates with emergent and submergent aquatic vegetation). Yellow perch are also more abundant in reservoirs with aquatic vegetation. Smallmouth bass, pumpkinseed, and white crappie are more abundant in upriver reservoirs (Bennett et al., 1983).

Native species (including white sturgeon, chiselmouth, northern squawfish, and redside shiners) primarily inhabit areas along the main river channel and are most abundant in flowing water (Bennett et al., 1983). The confluence of two major tributaries (Palouse and Tucannon rivers) provides access to flowing water for native species in Lower Monumental. The confluence of the Clearwater and Snake rivers provides important flowing water habitat in Lower Granite. The native species primarily spawn in the tributaries; however, headwaters of reservoirs serve a similar function. For example, in Lower Granite Reservoir, northern squawfish migrate upstream to the lotic (flowing water) conditions in the Snake and Clearwater rivers. In other reservoirs without major tributaries (such as Little Goose), fish migrate to the tailwater of the next dam upstream for spawning and possibly feeding benefits. Although no data were found to compare relative abundance of native species in the four reservoirs, the availability of flowing water habitat in Lower Granite and Lower Monumental would provide better habitat for native species than Little Goose and Ice Harbor.

Most of the dominant sport fishes (*Centrachidae*) in the lower Snake River reservoirs require high-quality, shallow-water (6.5 feet or less) habitats for spawning and rearing (Bennett et al., 1983; Bennett and Shrier, 1986). In addition to the requirement of shallow-water habitat, that habitat must also remain inundated throughout the incubation period to ensure good egg survival. Fluctuations in water surface elevation can, therefore, have potentially large effects on spawning success, particularly in April through July when most shallow-water species spawn. Bennett et al. (1983), however, found that current project operations appear to have little effect on recruitment into the sport fishery.

### 2.5.3 Lower Columbia River Reservoirs

The species composition of the lower Columbia River reservoirs is very similar to that of the lower Snake River reservoirs. Dominant species in the lower Columbia River include largemouth bass, smallmouth bass, walleye, squawfish, crappie, and suckers (Appendix D). Most of these species have been introduced into the system. Native species in the reservoirs include northern squawfish, redside shiner, various species of sucker, mountain whitefish, and sand roller. The warm waters and slow flows in the reservoirs tend to favor the production of the introduced warm-water species.

The four lower Columbia River reservoirs (McNary, John Day, The Dalles, and Bonneville) vary in the amount of open-water and backwater habitat they contain. In general, Bonneville and The Dalles contain fewer backwater areas than John Day and McNary. Because backwater areas are generally more productive for resident species, John Day and McNary are probably the most productive of the four reservoirs.

Studies conducted in John Day Reservoir indicate that spawning success in any year for a given species depends upon water surface elevation as well as other factors (Hjort et al., 1981). Low water surface elevation can reduce the available habitat, and fluctuating elevations can expose eggs during incubation. Most fish in the lower Columbia River reservoirs spawn from June to mid-July.

### 2.5.4 Brownlee Reservoir

Brownlee Reservoir has elevated water temperatures, thermal stratification, high primary productivity, and seasonal nutrient cycling patterns (BPA, 1985). Nutrient inputs from upstream irrigation returns and sewage outfalls are high and contribute to the high productivity levels in the reservoir. Oxygen content of the waters below the thermocline frequently approaches zero in summer. Furthermore, decomposition of organic matter contributes to nutrient cycling and oxygen depletion.

The reservoir primarily supports a warm-water fishery. Smallmouth bass, channel catfish, and black crappie populations are the dominant game species (Rohrer, 1984; Table 3, Appendix B). The reservoir is particularly noted for its smallmouth bass and channel catfish fisheries (BPA, 1985). Carp and sucker, which are typically productive in warm, highly vegetated waters, are also very common. Studies have indicated that production of game fish in the reservoir might be limited by availability of forage species (Bennett and Dunsmoor, 1986; Rohrer, 1984).

Many of the species in the reservoir are bottom spawners and therefore may be affected by variations in water surface elevations. Smallmouth bass, which typically spawn at elevations of 1 to 15 feet may be particularly sensitive to variations in water surface elevation. Smallmouth bass spawn in May and June, and spawning varies somewhat with water temperatures. Spawning habitat in Brownlee Reservoir has not been identified, but it is most likely confined to tributary inflow areas, gravel ledges in the littoral zone, edges of islands, or anywhere where there is suitable, relatively silt-free gravel. Spring spawning normally coincides with near-peak reservoir levels when shallow gravel areas are most likely to be inundated. Other spring spawners may be equally affected by the drawdowns.

### 2.5.5 Dworshak Reservoir

Dworshak Reservoir is a deep, oligotrophic storage reservoir with a steep-sided shoreline (Falter, 1982). The reservoir stratifies during the summer, providing warm-water habitat in the surface layer and cold water at depth (Falter, 1982). Dissolved oxygen is typically sufficient to support fish production. Most phytoplankton and zooplankton production occurs in the epilimnion, which generally extends over the upper 40 feet of the reservoir (Corps, undated). The reservoir has drawdowns of up to 155 feet (Maiolie, 1988) in the fall and winter, and is subsequently refilled in spring and early summer (Corps, undated). Because of the extensive variation in water surface elevation and continued wave action, aquatic macrophytes are virtually non-existent along the shorelines and benthic production is low (Corps, undated).

Primary sport species present in the reservoir include kokanee, rainbow trout, smallmouth bass, largemouth bass, bull trout, cutthroat trout, brook trout, mountain whitefish, and brown bullhead (Maiolie, 1988; Appendix D). Because of the steep shorelines, little shallow-water habitat is available to support natural reproduction of smallmouth bass (Corps, undated). Maximum spawning habitat exists at full pool. Trout and kokanee spawn in the fall primarily in the tributaries to the reservoir (Maiolie, 1988). It is presumed that mountain whitefish also spawn in the streams or in the Clearwater River upstream of the reservoir. Kokanee mortality rates in the reservoir appear to be unusually high. Mortality of young fish is estimated near 80 percent (personal communication, Melo Maiolie, Idaho Department of Fish and Game, Coeur d'Alene, Idaho, August 23, 1991). Entrainment of fish may be partially responsible for this mortality. An unknown but possibly substantial number may be entrained through the penstocks during power generation. The magnitude of entrainment or the exact relationship between drawdown and kokanee entrainment is unknown, although the perception is that the greater the drawdown, the greater the entrainment. Initial investigations suggest that large numbers of kokanee are entrained with releases greater than 8,000 cfs (personal communication, Melo Maiolie, Idaho Department of Fish and Game, Coeur d'Alene, Idaho, August 23, 1991). The temperatures of the Clearwater River below

Dworshak Dam are colder than the river, and the species composition of the river reflects this difference. The primary resident species in the Clearwater River include redside shiners, rainbow trout, suckers, and mountain whitefish. Northern squawfish, smallmouth bass, kokanee, dace, and sculpins are also present in low numbers.

### 2.5.6 Lake Roosevelt

Walleye, yellow perch, and largescale sucker are the most abundant species in Lake Roosevelt (Appendix D). The primary species targeted by sports fishers, in order of importance, include rainbow trout, walleye, kokanee, smallmouth bass, and yellow perch.

The walleye is an exotic species, introduced into Lake Roosevelt during the 1940s or 1950s, that has thrived in the reservoir. Walleye spawn in the Spokane Arm of the lake in April and May (Peone et al., 1990). The young fish are typically found in littoral areas associated with woody debris and adults are most common near the mouths of embayments and tributaries (Peone et al., 1990). Spawning success of walleye in the reservoir appears to be unaffected by current variations in water surface elevation. In fact, walleye spawn during a rise in water surface elevation in the spring that corresponds to some extent to the refilling of the pool in May and June. It is generally believed that the lack of forage, rather than spawning habitat, currently limits walleye production (Peone et al., 1990). Walleye appear to have a competitive advantage over the native northern squawfish in that the walleye numbers have steadily increased while populations of northern squawfish have decreased.

Kokanee are landlocked sockeye salmon. The original kokanee population in this reservoir probably came from a portion of a sockeye run that was prevented from migrating to the ocean after Grand Coulee Dam was constructed. This population may have originally spawned in Arrow Lakes, as did the sockeye runs before them. Closure of Arrow Lakes reduced the amount of spawning habitat available to them. The population has also been severely affected by flood control and hydropower drawdowns in the spring, following the closure of Arrow Lakes and the completion of the third powerhouse at Grand Coulee Dam. Recently, two hatcheries were constructed to replenish the periodically depleted kokanee population in Lake Roosevelt.

The rainbow trout fishery is also a supplemented fishery. In addition to the production from the hatchery managed by the Confederated Tribes of the Colville Reservation and other State and Federal hatcheries, rainbow trout naturally reproduce in some of the tributaries to the reservoir.

Although not strictly a "put and take" fishery, numerous net pens located throughout the reservoir are used to raise rainbow trout to catchable size; then they are released into the reservoir from May through June (Peone et al., 1990). Most of these fish are caught within 14 months of the time they are released (Peone et al., 1990). Large drawdowns in the spring sometimes affect the net pen operations by forcing operators to move their net pens often. Protected areas for some of the net pens are not available at lower pool elevations. In previous years, some operators have released their fish early (April instead of May or June) in response to extreme drawdowns.

Yellow perch and smallmouth bass spawn in spring, primarily from late April through mid-May (Peone et al., 1990). These species also spawn primarily in shallow-water areas.

Annual spring drawdowns affect phytoplankton and zooplankton production in the reservoir because of decreases in water retention time and subsequent reductions in the availability of nutrients (Beckman et al., 1985). Zooplankton densities and biomass are generally high when water retention time in the reservoir is high and vice versa. Water retention time of about 30 to 35 days appeared to be of critical importance to provide sufficient forage for kokanee, rainbow trout, and other young-of-year fish (Peone et al., 1990).

## 2.6 TERRESTRIAL ECOLOGY

### 2.6.1 Habitat

The Columbia and Snake rivers delineate transitional zones between several physiographic provinces in Washington and Oregon, including the Willamette Valley; South, West, and High Cascades; and Columbia River Basin (Franklin and Dyrness, 1973). Consequently, plant communities throughout the project area are extremely diverse. The Columbia River represents a sea-level transition from marine to continental climate that is separated by major mountain barriers. Plant associations east and west of the Pacific Crest have therefore adapted to regional and local differences in edaphic conditions, moisture regimes, and fire histories. West of the Pacific Crest, the Columbia River passes through the mesophytic Douglas-fir (*Pseudotsuga menziesii*)/western hemlock (*Tsuga heterophylla*) association (Franklin and Dyrness, 1973). Just east of Hood River, the xerophytic Douglas-fir/Oregon white oak (*Quercus garryana*) association predominates.

Northward from Richland, Washington, the Columbia River passes through four major vegetation zones, including the following: (1) shrub-steppe [with sagebrush (*Artemisia* sp.)], (2) steppe (lacking sagebrush), (3) Ponderosa pine (*Pinus ponderosa*), and (4) a broad zone supporting Douglas-fir and grand fir (*Abies grandis*) (Franklin and Dyrness, 1973; Payne et al., 1975).

The Snake River and associated tributaries (including the Clearwater River) in eastern Washington and Idaho pass through the xerophytic shrub-steppe, Ponderosa pine, and Idaho white pine (*Pinus monticola*) series (Franklin and Dyrness, 1973; Daubenmire and Daubenmire, 1984). The white pine belt consists of mixed stands of white pine, grand fir, Douglas-fir, Engelmann spruce (*Picea engelmannii*), and western red cedar (*Thuja plicata*). Both the Columbia and Snake rivers are major migration and dispersal corridors for plants and wildlife and have a high degree of endemism (Franklin and Dyrness, 1973).

The project reservoirs have influenced the extent and distribution of numerous plant and wildlife communities that have existed within the river corridor for many years. Local plant communities have established under normal pool fluctuations and periodic drought. Specifically, riparian, wetland, and shallow-water habitats on the lower Columbia and Snake rivers have established under normal, daily pool fluctuations of 3 to 5 feet. Similarly, plant communities along the storage reservoirs (Brownlee, Dworshak, and Grand Coulee) established under extensive drawdowns of up to 50 feet during the growing season. The following discussion is limited primarily to the major plant and wildlife associations within the project pools, including shallow-water, riparian, wetland, embayment, and designated managed habitats.

### 2.6.1.1 Shallow Water

Shallow-water habitat exists primarily along the shoreline of the lower Columbia and Snake rivers and around islands within the various project pools. Extensive shallow-water habitat exists at John Day and McNary pools and is considered to be relatively limited in other mainstem pools and storage reservoirs. Shallow-water beds in these areas typically support aquatic plants that provide a valuable food source for waterfowl. Precise location, extent, and composition of aquatic beds within shallow-water areas is largely unknown throughout the project area. In general, however, aquatic beds are most prevalent in shallow-water areas where sand and silt deposits have accumulated.

### 2.6.1.2 Riparian

Riparian habitat along the lower Columbia River is limited primarily to riparian shrub, riparian hardwood, and riparian herb types (Table 2.6-1). Collectively, the four projects on the lower Columbia River include approximately 5,600 acres of riparian vegetation that occur mainly in the backwaters. Riparian vegetation is most abundant along the McNary Pool and least abundant along The Dalles Pool (Table 2.6-1). The relatively short pool and juxtaposition of highways and railroads has limited establishment of extensive riparian areas at The Dalles Pool. The McNary Pool is an extremely diverse area consisting of numerous islands, shallow-water and backwater areas, riparian forests, and wetlands. Riparian hardwoods in this area are some of the largest in the region. In general, riparian hardwoods associated with the lower Columbia River projects are characterized by (in order of abundance) Russian olive (*Elaeagnus angustifolia*), willows (*Salix* spp.), black

Table 2.6-1. Wetland and riparian areas associated with project reservoirs along the Columbia, Snake, and Clearwater rivers in Washington, Oregon, and Idaho

| | Riparian Type | Acres | Wetland Type | Acres | Embayment, Ponds, and Associated Tributaries (Acres) | HMUs (Acres) |
|---|---|---|---|---|---|---|
| **Lower Columbia River, WA/OR** | | | | | | |
| Bonneville | Shrub-riparian hardwood | 1,089 | Emergent | 15 | 933 | -- |
| | Total | 1,089 | | | | |
| The Dalles | Riparian shrub | 299 | Emergent | 52 | 284 | -- |
| | Other | 78 | | | | |
| | Total | 377 | | | | |
| John Day | Riparian shrub | 867 | Emergent | 419 | 2,464 | -- |
| | Riparian hardwood | 361 | | | | |
| | Total | 1,228 | | | | |
| McNary | Riparian hardwood | 1,349 | Emergent | 1,010 | 21 | 4,547 |
| | Riparian shrub | 611 | | | | |
| | Riparian herb | 948 | | | | |
| | Total | 2,908 | | | | |
| **Lower Snake River, WA** | | | | | | |
| Ice Harbor | Scrub-shrub | 50 | Emergent | 15 | -- | 404 |
| | Forest scrub | 98 | | | | |
| | Total | 148 | | | | |
| Lower Monumental | Scrub-shrub | 126 | Emergent | 87 | -- | 144 |
| | Forest shrub | 84 | | | | |
| | Total | 210 | | | | |
| Little Goose | Scrub-shrub | 123 | Emergent | 9 | -- | — |
| | Forest-shrub | 131 | | | | |
| | Total | 254 | | | | |

ACOE.5/8-91/01474A

Table 2.6-1. Wetland and riparian areas associated with project reservoirs along the Columbia, Snake, and Clearwater rivers in Washington, Oregon, and Idaho (Continued).

| | Riparian Type | Acres | Wetland Type | Acres | Embayment, Ponds, and Associated Tributaries (Acres) | HMUs (Acres) |
|---|---|---|---|---|---|---|
| Lower Granite | Scrub-shrub | 102 | Emergent | 4 | -- | 26 |
| | Forest-shrub | 183 | | | | |
| | Total | 285 | | | | |
| **Clearwater River, ID** | | | | | | |
| Dworshak | a/ | 2,255 | Deciduous scrub-shrub | 725 | -- | — |

Source: Sather-Blair et al., 1991

a/ No classification given.

cottonwood (*Populus trichocarpa*), red alder (*Alnus rubra*), and white alder (*A. rhombiflora*). Riparian shrubs include willows, young hardwoods, and false indigo (*Amorpha* sp.). Riparian herbs include a mixture of various forbs and grasses that occupy sand, mud, and gravel bars in the pool areas. A more complete listing of plant species characteristic of the study area is available in Asherin and Claar (1976), and Tabor (1976).

Several factors have contributed to the lack of extensive riparian areas along the lower Snake River. The steep shorelines associated with project reservoirs is primarily responsible for limiting development of riparian communities in the project area. Furthermore, extensive grazing (Lewke and Buss, 1977), the expansion of railroads, and the gradual inundation of the river bottom by dams have also limited riparian vegetation to narrow vegetation corridors and backwater areas. These particular changes have reduced the extent of many of the woody plant communities such as cottonwood, willow, and white alder that once characterized the riparian zone. The woody plant community that remains in this area is more drought-resistant and is composed of black locust, Russian olive, and various hybrid cherries (*Prunus* sp.) (Asherin and Claar, 1976).

Along the lower Snake River, the project reservoirs are characterized by scrub-shrub, forest scrub, and forest-shrub riparian communities (Table 2.6-1). Collectively, the four lower Snake River reservoirs are bordered by approximately 900 acres of riparian vegetation. Riparian areas range from 148 acres at Ice Harbor to 285 acres at Lower Granite. In general, riparian hardwood forests on the lower Snake River are dominated primarily by Russian olive but also include black cottonwood, black locust, hackberry (*Celtis reticulata*), and white alder. Scrub-shrub includes coyote willow (*S. argophylla*), other willows, and false indigo. Herbaceous plants in this area include dotted smartweed (*Polygonum punctatum*), cocklebur (*Xanthium* sp.), thistle (*Carduus* sp.), and mustard (*Brassica* sp.). A few large sand bars and islands occur along the river that also support plant communities typically dominated by licorice-root (*Glycyrrhiza lepidota*), cocklebur, and willows. One of these islands, New York Island, is an important nesting area for Canada geese (*Branta canadensis*) (Lewke and Buss, 1977). A more detailed list of plants is available for the study area (Asherin and Claar, 1976; Tabor, 1976; Lewke and Buss, 1977).

Although information on riparian vegetation at Lake Roosevelt was unavailable for this OA/EIS, this reservoir lacks extensive riparian communities (Payne et al., 1975). The southern portion of Lake Roosevelt is within the shrub-steppe region of eastern Washington (Franklin and Dyrness, 1973) and is therefore subject to periodic drought. Consequently, extensive reservoir drawdown often occurs in winter and spring. This situation has resulted in plants being perched well above the water table during the early spring (Payne et al., 1975). In the upper reaches of the lake, moisture is more abundant and established plants are not as subject to extended drought. However, most riparian habitat at the lake is associated with small streams and springs (Payne et al., 1975). Riparian vegetation has established in areas of silt accumulation that are subject to only infrequent flooding. Associated riparian species in these areas include cottonwood, birch (*Betula sp.*), red alder, white alder, red-osier dogwood (*Cornus stolonifera*), and alder buckthorn (*Rhamnus alnifolia*).

Dworshak Reservoir, along the Clearwater River, is bordered by approximately 2,250 acres of riparian vegetation (Table 2.6-1). The primary riparian association along the reservoir includes red alder/maidenhair fern (*Adiantum* sp.) (Asherin and Orme, 1978). Coyote willow, black cottonwood, and serviceberry also occur in this area. Less common species include western red cedar, paper birch (*B. papyrifera*), western larch (*Larix* sp.), and Douglas-fir. The understory shrub layer is noticeably undeveloped and consists primarily of mock orange (*Philadelphus lewisii*) and mallow ninebark (*Physocarpus malvaceus*); this vegetation type is considered unique and rare along the reservoir (Asherin and Orme, 1978).

Riparian vegetation along Brownlee Reservoir was quantified by percentage of shoreline vegetation for specific segments of the reservoir (BPA, 1985). At the upper end of the reservoir, willow comprises 12.6 percent of the shoreline vegetation. This vegetation type is dominated by peach-leaf willow (*S. amygdaloides*), coyote willow, and red willow (*S. lasiandra*). It grows between the high- and low-water lines and is flooded annually. Creeping wildrye (*Elymus triticoides*) is the dominant species on islands at the upper end of the reservoir. A limited distribution of cattail (*Typha* sp.) and cottonwood occur around shallow bays in the upper reservoir.

Vegetation in the many small, side canyons along Brownlee Reservoir varies considerably depending on slope, aspect, and length of time water is present. If water is flowing during the entire year, white alder dominates several different associations. In narrow, steep canyons, a dense tree and shrub association with a poorly developed herbaceous layer occurs. Black cottonwood is occasionally interspersed with alder. Wider, gentler canyons have more diverse plant associations and are characterized primarily by an equal mix of alder and cottonwood.

In addition to riparian communities along Brownlee Reservoir, at least five upland grass/forb and six upland shrub/grass or brush/grass vegetation types occur along the river (BPA, 1985). Small patches of conifers occur in several locations along the river, and rocky cliffs, talus slopes, and sand dunes abut the project reservoirs. This variety of habitats close to water at relatively low elevation results in many types of wildlife along this portion of the Snake River.

### 2.6.1.3 Wetlands

Wetlands associated with the project reservoirs along the lower Columbia River are characterized by the emergent variety (Table 2.6-1). These wetlands generally occur where drainage from adjoining slopes is interrupted by railroad or highway embankments, or agricultural activities. In general, wetland vegetation consists primarily of rushes, sedges, and cattails. Collectively, the four project reservoirs on the lower Columbia River are bordered by approximately 1,500 acres of emergent wetlands. Wetlands are most abundant at McNary and least abundant at Bonneville (Table 2.6-1). Extensive wetlands occur at the McNary Pool along the upper end near the confluence of the Walla Walla and Snake rivers and at the confluence of the Yakima and Columbia rivers.

Wetlands along the lower Snake River pools are also characterized by emergents (Table 2.6-1). These wetlands are limited to approximately 116 acres, and range from 4 acres at Lower Granite to 87 acres at Lower Monumental. Cattails and bulrush (*Scirpus* sp.) are the predominant wetland plants at these reservoirs.

Lake Roosevelt lacks extensive wetland areas. Wetlands dominated by canary reedgrass (*Calamagrostis sp.*) are limited, but occur primarily in the northern portion of the reservoir where moisture is more abundant (Payne et al., 1975).

Wetland vegetation in the vicinity of the Dworshak Pool consists of approximately 72.5 acres of the deciduous scrub-shrub type (Table 2.6-1). Wetland habitat associated with Brownlee Reservoir is limited to shallow bay areas at the upper end of the reservoir and is characterized by sparse amounts of cattails (BPA, 1985). Detailed plant lists are available for each of these reservoirs (Asherin and Orme, 1978; BPA, 1985).

### 2.6.1.4 Embayments, Ponds, and Associated Tributaries

Embayments are bodies of water separated from the main channel, usually by highway or railroad causeways, and are typically connected to the main channel by culverts or side channels. Embayments, ponds, and associated tributaries provide backwater habitat that support the majority of emergent wetland and riparian communities at each of the lower Columbia River reservoirs (Table 2.6-1). Individual embayments range from less than 5 acres to 548 acres. Collectively, the four lower Columbia River projects contain approximately 3,700 acres of embayments and associated habitats. Backwater areas are most abundant at John Day and least abundant at McNary. Although site-specific information on this habitat type was lacking for the other project areas, the lower Snake River projects collectively contain about 328 acres of backwater habitats.

### 2.6.1.5 Designated Managed Habitat

Several areas designated for habitat management occur along the lower Columbia and Snake rivers. Three designated sites (no acreages given) occur along John Day and The Dalles pools and are managed by the Oregon Department of Fish and Wildlife. Five additional areas totaling over 4,500 acres occur on the McNary Pool (Table 2.6-1) and are managed by the Corps as HMUs (Sather-Blair et al., 1991) HMUs are lands designated to be managed primarily for wildlife habitat. These areas provide essential habitat for numerous plants and wildlife of the lower Columbia-Snake River System and have been developed or have established naturally under prolonged periods of normal reservoir operating conditions. The 500-acre McNary Wildlife Nature Area is located just downstream of McNary Dam, and the 3,600-acre McNary National Wildlife Refuge (NWR) is managed by the U.S. Fish and Wildlife Service (FWS) near the confluence of the Snake and Columbia rivers. Approximately 760 acres of irrigated HMUs are associated with the four lower Snake River projects (Table 2.6-1) (Sather-Blair et al., 1991). Irrigated HMUs receive surface water from the project reservoirs and are dependent on high pressure irrigation systems for continued vegetative growth. These HMUs have been planted extensively with trees and shrubs, food plots, and herbaceous forage species as an intensive management technique to replace riparian areas lost when the dams were constructed.

Approximately 760 acres of irrigated lands are associated with the intensively managed HMUs on the four lower Snake River projects (Table 2.6-1) (Sather-Blair et al., 1991). The largest HMU is located at Ice Harbor Dam. HMUs at each of the project dams have been planted extensively with trees and shrubs along reservoir shorelines and with herbaceous plants to establish feeding areas for various wildlife.

### 2.6.2 Wildlife

The project reservoirs provide food, water, and cover for numerous wildlife species and are especially important east of the Pacific Crest where moisture is extremely limited. Although detailed information about the distribution and abundance of various wildlife species in the project areas is limited, riparian areas and wetlands associated with the project reservoirs on the Columbia, Snake, and Clearwater rivers provide essential habitat for 42 reptile and amphibian species, 263 bird species, and 81 mammal species (Payne et al., 1975; Tabor, 1976; Lewke and Buss, 1977; Asherin and Orme, 1978). Wildlife in these areas are typically concentrated in pockets of natural and developed habitat along the reservoirs. Wildlife that typically use riparian and wetland areas associated with the project areas can be divided into seven main groups: waterfowl, raptors, upland game birds, aquatic furbearers, big game, other wildlife groups, and threatened and endangered species (Asherin and Claar, 1976; Tabor, 1976; Asherin and Orme, 1978). Each group is discussed below.

#### 2.6.2.1 Waterfowl

Wintering waterfowl are probably the most abundant wildlife resource on the Columbia and Snake rivers. Resident, breeding waterfowl numbers are generally low except for Canada geese (*Branta canadensis*), which occur throughout the projects, and various duck species concentrated in and around the Umatilla NWR.

Apparently, because of the lack of agricultural lands in the Columbia River Gorge, the Bonneville Pool supports fewer (approximately 2,500 to 3,000) wintering waterfowl than either The Dalles or John Day. Wintering concentrations of diving ducks, primarily scaup (*Aythya* sp.), are distributed throughout the pool. Adjacent lakes, marshes, and backwaters are important foraging and loafing areas for wintering waterfowl at the Bonneville Pool. In addition to wintering concentrations, up to 168 goose nests were located in 1991, primarily along reservoir islands at the Bonneville Pool. Wells Island at Hood River supported 74 nests in 1991.

Waterfowl use in The Dalles Pool is primarily associated with reservoir islands used extensively by nesting Canada geese and wintering ducks and geese. In 1991, 117 goose nests were recorded in this area. The majority of goose nesting in the pool occurs on Brown's, Little Miller, and Rufus islands. Most geese with broods feed along park lawns, grass-forb communities adjacent to the river, embayments, and backwater areas.

The John Day Pool and Umatilla NWR support one of the most significant wintering concentrations of waterfowl, particularly Canada geese and mallards (*Anas platyrhynchos*), in Oregon and Washington. At present, a peak population of 600,000 ducks, primarily mallards, and 100,000 geese inhabit this area in early December. Most of these birds winter in the vicinity of the Umatilla NWR. Wintering waterfowl in this area strongly depend on agricultural crops (field corn and winter wheat) grown in the region. For example, a single acre of corn can generally support up to 10 mallards wintering in the Columbia Basin (Anonymous, 1983). The Columbia River and its islands also provide protected and relatively undisturbed loafing, resting, and roosting habitat for wintering waterfowl.

In 1991, 323 goose nests were located along the John Day Pool. In addition, more than 14 species of ducks, with an annual production of 2,000 to 2,500 young, typically nest in this pool. The majority of waterfowl nests occur on islands in the Umatilla NWR, although McCredie and Three Mile islands also support substantial goose numbers. McCredie and Three Mile islands are near shore and, therefore, are susceptible to the formation of land bridges. Most of the remaining reservoir islands are farther offshore and protected from mammalian predation.

Brood-rearing areas in the John Day Pool primarily occur along sloughs and backwater areas near the Umatilla NWR (Asherin and Claar, 1976). Gently sloping shorelines with grass-forb communities are typically used as foraging areas by geese inhabiting these areas.

McNary Pool supports a large population of nesting Canada geese. The 25-plus islands, together with the McNary NWR and HMUs, produced up to 675 goslings and provided habitat for nesting ducks, primarily mallards, in 1991. Most goose nesting in 1991 at McNary Pool occurred on seven islands, with the greatest numbers of successful goose nests (73) occurring on Badger Island. Canada goose nesting on the lower Snake River occurs primarily on reservoir islands and along cliffs. Of the four project areas on the lower Snake River, Little Goose supports the highest goose-nesting densities; 90 nests producing 448 goslings were reported in 1991. The remaining projects supported the following nesting goose densities in 1991: Lower Granite, 34 nests, 88 goslings; Lower Monumental, 5 nests, 20 goslings; and Ice Harbor, 3 nests, 12 goslings.

Overall density of wintering ducks is considered low at Grand Coulee primarily because of colder winter conditions and lack of adequate food supplies. Some goose nesting has been reported in the vicinity of Northport on reservoir islands mainly between the Spokane River and Northport (Payne et al., 1975). In general, however, nesting concentrations are considered low primarily because of the lack of extensive riparian and wetland habitat at this pool and extensive reservoir drawdown during the waterfowl nesting season.

Dworshak Reservoir along the Clearwater River does not provide nesting habitat for waterfowl. A lack of nesting islands and few vegetated shoreline areas are probably responsible for the absence of waterfowl nesting in the area.

Approximately 30 species of waterfowl have been reported using the Snake River in the vicinity of Brownlee Dam (Asherin and Claar, 1976). Of these, six species are known to nest, or are suspected of nesting, near the dam. These species include Canada goose, mallard, northern pintail (*A. acuta*), American widgeon (*A. americana*), green-winged teal (*A. crecca*), and common merganser (*Mergus merganser*). Canada geese are the most numerous waterfowl species nesting in this area; most geese nest above Brownlee Dam. Up to 200 pairs of geese, representing 20 to 25 percent of the entire goose-nesting population on the Snake River from Walter's Ferry to Farewell Bend, have been reported nesting on islands in the Brownlee Pool (BPA, 1985). In 1975, 741 goslings were produced from 151 nests located on islands in the Brownlee Pool. Annual production in the reservoir ranged from 186 to 320 goslings during 1975 to 1983 (BPA, 1985). Three major nesting islands totaling 13 acres occur within the pool area when the pool is at elevation 2,065 feet. These islands are considerably larger during reservoir drawdown. Additional pairs of geese also nest along the banks and cliffs of the reservoir. Major brooding areas along Brownlee Reservoir are located in pasture lands and alfalfa fields in the vicinity of nesting islands. Agricultural land in the Farewell Bend/Olds Ferry and Porter Flat areas is also heavily used by goose broods.

As many as 7,678 ducks (mostly mallards and common mergansers) and geese have been recorded wintering on the Snake River in the vicinity of Brownlee Reservoir (Asherin and Claar, 1976). Of these, approximately 900 goldeneye (*Bucephala* spp.) have been observed wintering along the middle and upper reach of the Snake River including the Brownlee Pool (Tabor, 1976).

## 2.6.2.2 Raptors

Riparian forests and wetlands along the Snake, Columbia, and Clearwater rivers provide perching and nesting opportunities, and concentrated prey (e.g., small mammals and songbirds) for up to 24 raptor species (Tabor, 1976; Asherin and Claar, 1976; Asherin and Orme, 1978). Of these, only the osprey (*Pandion haliaetus*), northern harrier (*Circus cyaneus*), and bald eagle (*Haliaeetus leucocephalus*) are directly associated with riparian or wetland areas in the reservoirs. The bald eagle is discussed in Section 2.6.2.7 below.

On the lower Columbia River, osprey nesting is confined principally to the Bonneville Pool area where substantial forested habitat occurs adjacent to the river. Approximately 10 to 12 osprey nest sites are found along the Oregon and Washington shores of Bonneville Pool. Additional osprey nest sites are known to occur within the Columbia River Gorge, at Lake Roosevelt (Payne et al., 1975), and Dworshak Reservoir (Asherin and Orme, 1978). Most osprey nesting associated with the project occurs along the reservoir shoreline and near shallow bays or inlets.

The presence of raptors other than the osprey and bald eagle in riparian zones is influenced primarily by special habitat features that sometimes occur in association with the project reservoirs (Payne et al., 1975). In general, cliffs and large trees along river banks typically support diverse raptor populations. The project reservoirs along the lower and upper Columbia River and along the lower Snake River provide cliff areas in proximity to the river that may provide potential nest and roost sites for golden eagles (*Aquila chrysaetos*) and prairie falcons (*Falco mexicanus*) (Payne et al., 1975; Asherin and Claar, 1976; Tabor, 1976). Large trees along the lower Columbia River near the Umatilla NWR provide important nest sites for Swainson's hawk (*Buteo swainsoni*), red-tailed hawk (*B. jamaicensis*), great horned owl (*Bubo virginianus*), and northern pygmy owl (*Glaucidium gnoma*) (Payne et al., 1975; Asherin and Orme, 1978). Moreover, large cottonwoods and dense stands of Russian olive provide nesting habitat for up to eight species of raptors along the lower Columbia and Snake rivers (Tabor, 1976). Other raptors, including American kestrel (*F. sparverius*), common barn-owl (*Tyto alba*), western screech owl (*Otus kennicottii*), long-eared owl (*Asio otus*), short-eared owl (*A. flammeus*), and northern saw-whet owl (*Aegolius acadicus*), rely heavily on riparian trees and coniferous forests adjacent to Dworshak and Brownlee reservoirs for nesting and foraging (Asherin and Orme, 1978).

### 2.6.2.3 Upland Game Birds

Riparian and wetland areas associated with the project reservoirs provide habitat for at least 12 species of upland game birds (Tabor, 1976; Asherin and Orme, 1978). Although most of these birds are generally associated with upland areas, they also use riparian areas for water, food, shade, and nest cover. Riparian vegetation in these areas provides nesting cover and winter food sources for wild turkey (*Meleagris gallopavo*), ruffed grouse (*Bonasa umbellus*), and ring-necked pheasant (*Phasianus colchicus*). Although information on distribution of these species is incomplete for the project areas, wild turkeys can be found in riparian stands near Bonneville and Grand Coulee. Turkeys are also present in low numbers on the Snake River HMUs during the winter and spring (Tabor, 1976). Ruffed grouse occur in riparian habitat primarily at the lower end of the Bonneville Pool (Tabor, 1976). Grouse use riparian areas for water and brood-rearing. Ring-necked pheasants are strongly associated with riparian and agricultural areas along the Columbia and Snake rivers and are particularly abundant at the John Day Pool and the HMUs along the Snake River during breeding and wintering (Lewke and Buss, 1977). Mourning doves (*Zenaida macroura*) are found throughout the study area and use riparian vegetation for nesting and roosting where upland forests are sparse (Tabor, 1976). Chukars (*Alectoris chukar*) are common in suitable habitat east of The Dalles, and locally abundant along the Snake River upstream from Central Ferry. Chukars are very rare along Dworshak Reservoir. Chukars are dependent on the rivers, backwaters, embayments, seeps, and springs for water sources, especially during the fall. However, they are apparently less dependent on the riparian zone in wetter years and often move to much higher altitudes as green forage becomes available (McKern, 1976). Periodic drought also seems to affect reproductive success of chukars (McKern, 1976). Chukars are particularly abundant east of The Dalles and from Central Ferry upstream along the Snake River (McKern, 1976, Asherin and Orme, 1978). Common snipe (*Gallinago gallinago*) are most common in tidal zones and are locally abundant where appropriate habitats are available upstream. Snipe occur inland through Lake Roosevelt and McNary, Lower

Monumental, and Lower Granite reservoirs (McKern, 1976).

#### 2.6.2.4 Aquatic Furbearers

Aquatic furbearers occur in each of the project reservoirs and include muskrat (*Ondatra zibethicus*), beaver (*Castor canadensis*), river otter (*Lutra canadensis*), and mink (*Mustela vison*). In general, this group is dependent on riverine areas, embayments, ponds, tributaries, and riparian forests for den sites and foraging areas. The presence of a water barrier around den sites provides essential protection from predators and is especially important when young are present in the early spring and summer.

Beaver distribution within the project reservoirs is strongly associated with the presence of cottonwood and protected areas such as embayments, inlets, ponds, and sloughs (Asherin and Claar, 1976). Muskrats are particularly abundant in embayments and sloughs where aquatic plants are also abundant. Mink and river otter use the project reservoirs, ponds, sloughs, and backwater areas for foraging and denning. Both the mink and river otter use riprap areas along the banks of the lower Snake River as den sites (Sather-Blair et al., 1991).

#### 2.6.2.5 Big Game

Black-tailed deer (*Odocoileus hemionus*) (west of the Pacific Crest) and mule deer (east of the Pacific Crest) are the most common big game inhabiting the project area (Tabor, 1976). In general, densities of black-tailed deer and mule deer associated with Bonneville and The Dalles pools are considered low, especially along the Oregon shoreline, where deer habitat has been highly fragmented by Interstate 84 and the expansion of the railroad system (Tabor, 1976). Mule deer occur in habitats adjacent to John Day Pool and along the lower Snake River reservoirs (Asherin and Claar, 1976; Tabor, 1976). Along McNary Pool and the lower Snake River reservoirs, mule deer are found in increasing numbers upstream, reaching peak numbers on Lower Granite Pool and the upper half of Little Goose Pool. White-tailed deer are locally abundant in the vicinity of the Tucannon River-Snake River confluence and at the Wallula HMU. Habitat important to mule deer at John Day includes bitterbrush (*Purshia tridentata*), tributaries, riparian, and wetland areas. Additional big game occurring in the lower Columbia River include elk (*Cervus canadensis*) and white-tailed deer (*O. virginianus*). Both species occur in low numbers along tributaries associated with the John Day and McNary pools.

Big game along Lake Roosevelt, in order of abundance, include black bears, mule deer, white-tailed deer, and elk (Payne et al., 1975). Big game, primarily deer, at Lake Roosevelt use a variety of upland and riparian areas year-round. Riparian shrub and cottonwood provide important summer range for big game at this reservoir. In addition, deer forage along extensive mudflats that have been colonized by annual forbs and grasses following spring drawdown (Payne et al., 1975). Elk, however, seem to avoid riparian areas at this reservoir (Payne et al., 1975).

Both Dworshak and Brownlee reservoirs are important wintering areas for deer and elk. Big game at these reservoirs use a variety of habitats in addition to exposed mudflats that have been seeded naturally by annual forbs during spring drawdown (Asherin and Orme, 1978).

#### 2.6.2.6 Other Wildlife

The project reservoirs provide essential habitat for numerous reptiles, amphibians, small mammals, bats, colonial nesting birds, shorebirds, and songbirds (Asherin and Claar, 1976; Tabor, 1976; Asherin and Orme, 1978). Up to 65 (50 percent) of 129 vertebrate species occurring along the Snake River Canyon in Washington are dependent on tree-shrub riparian habitat associated with the project reservoirs (Lewke and Buss, 1977). In general, riparian and wetland areas support higher population densities and species numbers than dryland shrub-steppe, talus, cliff, and/or grassland habitat, which are also prevalent along the project reservoirs. Habitats associated with the river generally support trees or dense grass-forb cover that provide more structurally complex areas and more abundant forage resources than adjacent uplands.

Shallow-water areas, embayments, shorelines, riparian areas, and wetlands associated with the project reservoirs provide important foraging and nesting habitat for shorebirds and colonial birds. Nine great blue heron (*Ardea herodias*) rookeries, ranging in size from 3 to 555 nesting pairs, and 3 nesting colonies (10 to 30 pairs) of black-crowned night herons (*Nycticorax nycticorax*), forage and nest along the main channel and backwater areas of the Columbia River (Tabor, 1976). An additional heron rookery, consisting of three to five nesting great blue herons, occurs just below Lake Roosevelt (Payne et al., 1975). Other species, including California gulls (*Larus atricilla*), ring-billed gulls (*L. delawarensis*), Forester's terns (*Sterna forsteri*), Caspian terns (*S. caspia*), and double-crested cormorants (*Phalacrocorax auritus*) nest in large concentrations on the lower Columbia River, particularly on Crescent and Foundation Islands along the McNary Pool. Pied-billed grebes (*Podilymbus podiceps*) and rail species use many of the backwater areas throughout the project area. Killdeer (*Charadrius vociferus*) and spotted sandpiper (*Actitis macularia*) nest and forage just upslope from the high pool line and along the shoreline throughout the project area. In addition, over 1,000 white pelicans (*Pelecanus erythrorhynchos*) typically occur along the lower Columbia River from Bordman, Oregon to Vernita Bridge. Locally, white pelicans are common during the summer in embayments, shallow-water ponds, and potholes associated with the John Day and McNary pools.

A number of insectivorous species that inhabit riparian and wetland areas are present in substantial numbers throughout the project area. These insectivorous species include various woodpeckers, warblers, flycatchers, bats, common nighthawks (*Chordeiles minor*), and small mammals.

### 2.6.2.7 Threatened and Endangered Species

The bald eagle and peregrine falcon (*Falco peregrinus*) were identified by the FWS as Federally listed threatened or endangered species potentially occurring in the project area. Detailed information on these species is provided in the Biological Assessment (Appendix E).

The peregrine falcon may forage in wetlands and riparian areas associated with the project reservoirs. However, peregrine falcons are known to use only the project area on the lower Columbia River. One pair nests approximately 5 miles downstream of Bonneville Pool; four pairs nest between Bonneville and The Dalles pools; and one pair nests immediately above The Dalles (personal communication, K. McAllister, Washington Department of Wildlife (WDW), January 3, 1992, Corps, unpublished). In addition, a seventh pair of peregrines is suspected to be nesting at the John Day Pool (Corps, unpublished). Peregrine falcons may occasionally use portions of the project area during migration as well. Sporadic sightings of migrating peregrines have been reported throughout eastern Washington; however, most peregrine falcons are sighted in coastal areas (personal communication, K. McAllister, WDW, July 24, 1991). Wintering areas most commonly used by peregrines in Washington also occur along the coast in intertidal mudflats and estuaries of the Skagit Flats, Gray's Harbor, and Willapa Bay near the mouth of the Columbia River (Pacific Coast American Peregrine Falcon Recovery Team, 1982).

Currently, six to seven bald eagle nesting territories are associated with reservoirs in the project area, specifically on Bonneville and Lake Roosevelt (personal communication, K. McAllister and D. Anderson, WDW, July 18, 1991). One bald eagle nest site is located on the lower Columbia River, in Washington, immediately above Bonneville Dam and five to six bald eagle nest territories are located on the shoreline of Lake Roosevelt (personal communication, K. McAllister, WDW, July 18, 1991). No bald eagle nest sites have been reported on either the lower Snake or Clearwater rivers (personal communication, K. McAllister, WDW, July 18, 1991; personal communication, G. Stevens, Idaho National Heritage Program (IDHP), July 18, 1991).

In addition to nesting populations, the project reservoirs support relatively high concentrations of wintering bald eagles. Results of Washington mid-winter bald eagle surveys indicate that in 1990 approximately 150 to 200 eagles wintered on Lake Roosevelt, 40 on Umatilla NWR and 15 elsewhere on the lower Columbia River, and 10 on the lower Snake River (personal communication, R. Taylor, WDW, July 23, 1991; Isaacs, 1991). In Idaho, from 1980 to 1991, wintering eagles ranged from 4 to 29 birds on Dworshak Reservoir, and in 1990, approximately 150 eagles were reported wintering on Brownlee Reservoir (personal communication, G. Stevens, INHP, July 18, 1991; K. Steenhof, Bureau of Land Management, Boise District, July 18, 1991).

The Heritage Programs of Washington, Oregon, and Idaho were contacted to obtain information on state-listed and candidate plants and wildlife that potentially occur in the vicinity of the project reservoirs. Information on listed-species for the project reservoirs was based on records obtained from established search areas specific to each state's Heritage Program. The INHP limited the search area to within 6 miles of the project reservoirs for highly mobile species such as the gray wolf (*Canis lupus*) (personal communication, G. Stephens, Data Manager, INHP, 25 July 1991). The gray wolf was listed on the state list provided by the Heritage Program; however, wolves typically forage over extensive areas including numerous habitat types. Therefore, at this time, no determination has been made on whether a Biological Assessment is necessary for this species. The occurrences of remaining species in Idaho are within roughly 1 mile of the reservoirs. Both the Oregon Natural Heritage Program (ONHP) and Washington Natural Heritage Program (WNHP) limited the search area to within roughly 2 miles of the reservoirs (personal communication, T. Weber, Data Manager, ONHP, 30 July 1991; K. McAllister, Data Manager, WNHP, 25 July 1991).

The list of occurrences provided by the heritage programs was further refined to include only wildlife that use wetlands and riparian areas as primary habitat for feeding or breeding as defined by Brown (1985) and Thomas (1987). Habitat information on state-listed plant species was obtained from Hitchcock and Cronquist (1973) and discussions with local heritage botanists.

The project reservoirs along the Columbia, Snake, and Clearwater rivers in Washington, Oregon, and Idaho provide essential habitat for numerous state-listed and candidate species (Appendix F). Listed species potentially associated with project wetlands and riparian areas include numerous plants, insects, herpetofauna, birds, and mammals. Like the numerous plants and wildlife species associated with project area wetlands and riparian areas, listed species have also become established under normal reservoir operating conditions that have been in place for several decades.

## 2.7 GEOLOGY AND SOILS

The lower Columbia River drains much of the northwestern interior of the United States and some of southern British Columbia. The general physiography of the region is shown in Figure 2.7-1. The physiographic provinces within the area of consideration include the Okanogan-Selkirk Highlands, the Columbia Basalt Plain; the South Cascade Range, the Willamette Lowland, the Rocky Mountains, and the Blue Mountains (Figure 2.7-1; Baker et al., 1987; Galster et al., 1989). The Columbia River originates in Canada and flows south through the Okanogan-Selkirk Highlands. Then, the river flows across the Columbia Basalt Plain where it is joined by the Snake River. From this confluence the Columbia River flows west, exiting the Columbia Basalt Plain; then it flows between the South Cascade Range, the Willamette Lowland, and finally, through the Coast Ranges. The lower Snake River flows north along the eastern margin of the Blue Mountains, then turns west as it flows through the Columbia Basalt Plain. The Snake River also receives water from several tributaries, including the Clearwater River, that drain the Rocky Mountains. Along much of the Columbia Basalt Plain and the Blue Mountains, these two rivers flow within canyons that are several hundred to over 2,000 feet deep.

The Okanogan-Selkirk Highlands consist primarily of granitic and metamorphic rocks with sedimentary rock. The bedrock geology of the Columbia Basalt Plain consists primarily of thick successions of basaltic lavas. Numerous basaltic formations are distinguished within these lavas, and they are generally known as the Columbia River Basalt Group (CRBG) (Galster and Sager, 1989). The original extrusion of these basalts blocked rivers and impounded lakes. Therefore, several areas have fluvial and lacustrine sedimentary rocks intercalcated between the basalt flows. The South Cascade Range consists of older volcanic and granitic rocks with a series of superimposed Quaternary volcanoes. The Blue Mountains have a core of volcanic and sedimentary rocks. To the north, these core rocks are covered by the CRBG, which in turn has been upwarped slightly by the Blue Mountains. To the east, the Snake River flows along the flank of the Blue Mountains where the CRBG does not obscure the underlying rocks.

Before entering the Blue Mountains, the Snake River flows through a bedrock sequence of fine-grain lake and marine sediments that are susceptible to landsliding (BPA, 1985). The Clearwater River, in the vicinity of Dworshak

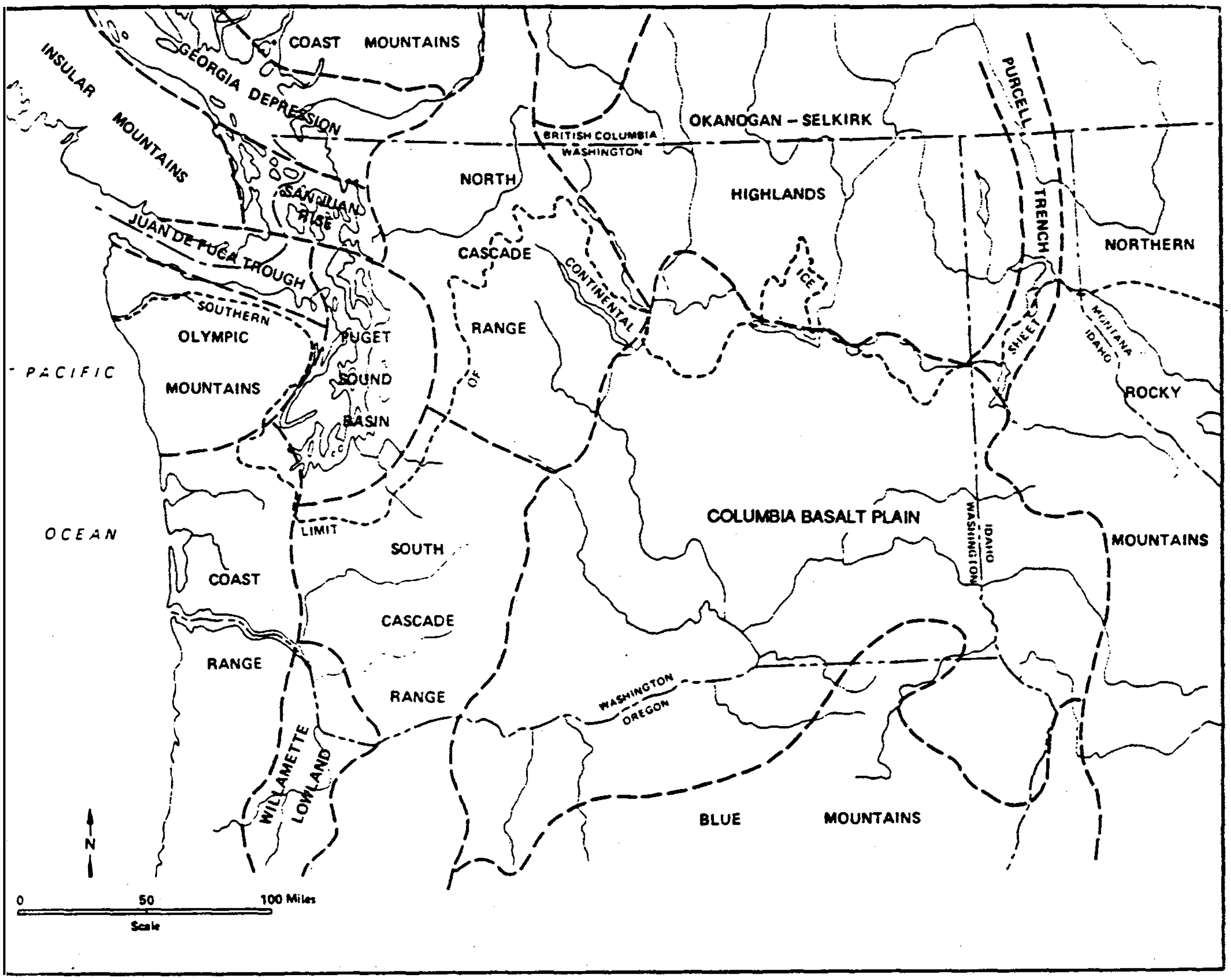



**Figure 2.7-1.** Physiographic provinces (Source: Galster et al., 1989).

Reservoir, flows through metamorphic and igneous rocks within the Rocky Mountain physiographic province (Corps, 1975).

During the Quaternary period, repeated advances of the Lake Pend Oreille lobe of the Cordilleran ice sheet dammed the Clark Fork River and impounded glacial Lake Missoula. This lake released catastrophic floods numerous times during the late Pleistocene, scouring much of the surface of the Columbia Basalt Plain. In the vicinity of Grand Coulee Dam, another glacier lobe dammed the Columbia River creating glacial Lake Columbia (Hansen, 1989). The glacial Lake Missoula floods entered and overtopped this lake. A similar flood emerged from pluvial Lake Bonneville (now Great Salt Lake) and flowed down the Snake River (Malde, 1968).

These floods eroded the river valleys and produced large deposits of river sediments (Baker et al., 1987). These river deposits occur as scattered terraces along the river valleys. The flood erosion also produced steep slopes that have undergone some retreat, producing steep, coarse-grain talus slopes along the bedrock cliffs. Post-glacial river incision has reworked some of the older river deposits producing lower elevation and younger alluvial terraces that are scattered along the rivers. Since impoundment, some smaller rivers have deposited alluvial fans where they enter the reservoirs; others are completely drowned, forming small embayments. All the Pleistocene and contemporary river and alluvial fan deposits consist of gravels and sands with minor amounts of silt and clay.

During the Pleistocene glaciation, sea level was several hundred feet lower than it is today. The lower Columbia River eroded a deep canyon to reach the lower sea level and this erosion created oversteepened slopes in the lower valley. These slopes have failed, producing large landslides. Rising of the sea level at the end of the glaciation drowned the Columbia River, causing sediment deposition and creating numerous islands along its lower channel.

During the Pleistocene and into the post-glacial period, winds eroded exposed fine-grain sediments. These silt-size sediments, known as loess, have been deposited over large areas. These deposits are most common on the upland surfaces of the Columbia Basalt Plain in a region known as the Palouse (Busacca et al., 1985). These materials occur only to a minor extent around the perimeter of the region's reservoirs. At Ice Harbor Dam, there is a large wind-derived sand deposit (Miklancic, 1989a), and small areas of sand dunes exist along some reservoirs.

Sedimentation within the reservoirs is dominated by river influx and wave-eroded materials. The heavier sediments, gravels and sands, can no longer be transported beyond the length of each reservoir. Lighter sediments, silts and clays, move through spillways, fishways, and powerhouses. River erosion is concentrated within a narrow band between high- and low-pool levels along the upper reservoir shorelines.

Landslides of various types occur along the reservoir shorelines. These landslides are generally within the surficial sediments, especially those that are somewhat poorly drained because of an admixture of finer grain sediment. Some landslides involve the CRBG and its interbedded river and lake deposits (Sagar, 1989a, 1989b, 1989c). Some of the larger landslides are currently immobile while others still move at slow rates (Sagar, 1989a). The Grand Coulee area has had an especially large number of landslides (Hansen, 1989).

## 2.8 AIR QUALITY

This discussion of the air quality in the existing environment focuses on factors that could be influenced by the proposed flow measures. The air quality of the Columbia River System study area varies widely because it is influenced by local air pollution sources, local meteorology, and local topography. In general, the area is relatively arid in the summer, and disturbance of surface silt and sand can generate high localized particulate matter concentrations.

### 2.8.1 Fugitive Dust

The study area experiences dry summer conditions and receives the bulk of precipitation from October through April (Ruffner and Bair, 1979). For this reason, high dust conditions are expected during late summer and early fall. EPA has addressed the issue of rural fugitive dust on several occasions (52 CR 24716). While rural areas may experience locally elevated concentrations of fugitive dust, the study area is largely designated as attaining air quality standards. The exception is the area near Wallula, Washington, which has been designated by the Washington Department of Ecology and the EPA as not being likely to meet standards for particulate matter smaller than 10 microns (PM-10) (56 FR 11101).

### 2.8.2 Odors

As flows vary in the rivers and reservoirs, newly exposed sediments can generate objectionable odors as organic materials decay. Odors in nature are subjective and localized. There are no national standards for odors, and EPA has chosen not to set allowable limits because no human health hazard has been identified with ambient concentrations of commonly occurring odorous substances. However, many states have nuisance related rules designed to protect the enjoyment of property. For example, the rules of the Washington Department of Ecology (WAC 173-400-040) state that "(a)ny person who shall cause or allow the generation of any odor from any source which may unreasonably interfere with any other property owner's use and enjoyment of his property must use recognized good practice and procedures to reduce these odors to a reasonable minimum."

### 2.8.3 Chemical Emissions

Because the system produces enormous electric generation, any potential loss of generation could ultimately be replaced by nuclear plants or by burning additional fuels in thermal powerplants in the region. Several large coal-fired powerplants serve the region, including stations near Centralia, Washington and Boardman, Oregon. There are nuclear powerplants on the Columbia River in Oregon and Washington. Each plant is licensed so that operation of the plants at maximum capacity will not cause any ambient air quality standard to be exceeded. No area immediately influenced by emissions from these plants is designated by pollution control agencies to exceed air quality standards. For this reason, the existing air quality near the thermal plants is acceptable based on standards to protect human health and welfare. These standards are applicable to powerplant emissions for sulfur dioxide, nitrogen dioxide, carbon monoxide, particulate matter, lead, and hydrocarbons, which can lead to ozone formation.

## 2.9 TRANSPORTATION

The Columbia River has historically been a major transportation corridor. As the only nearly sea-level passage through the Cascades, it provided a key linkage to the ocean from the eastern interior portions of the Northwest for both natives and settlers. Today, the Columbia River and the Snake River directly provide water transportation while the adjacent river valley is used as a land transportation corridor.

### 2.9.1 Navigation

The Columbia-Snake Inland Waterway is a 465-mile-long water highway formed by the eight mainstem dams on the lower Columbia and Snake rivers. The waterway provides navigation access from Lewiston, Idaho to the Pacific Ocean. It serves commodity shipments from a large tributary area in the Northwest and from as far away as South Dakota (Corps, 1989b). Specific elements include navigation channels and locks, port facilities, and shipping operations.

#### 2.9.1.1 Navigation Channels

The Federal barge navigation channel begins at the Columbia River entrance and extends inland to Lewiston, Idaho on the Snake River. The existing authorized navigation system provides for a 40-foot-deep by 600-foot-wide channel from the Columbia Bar (CRM 3.0) to Vancouver, Washington (CRM 105.6) on the Columbia River (Corps, 1986a). Upstream from Vancouver, the authorized channel is 27 feet deep by 300 feet wide to The Dalles, Oregon. However, the channel is only maintained to 17 feet. The authorized channel from The Dalles to Lewiston is 14 feet deep by 250 feet wide.

Maintaining these depths can require both dredging and water management actions at the dams. Contacts with barge industry representatives indicate that sites on both the Snake and Columbia rivers have recurring siltation problems, necessitating periodic dredging in order to maintain 14-foot-deep channels. The most prominent problem areas include Schultz Bar on the Little Goose Pool (recently dredged), the Snake-Clearwater River confluence, and the area just downstream of the Ice Harbor locks. Rocks and other submerged obstacles can present navigational problems at other sites at lower water depths. Barge operators have also experienced difficulties in lock transits during high currents.

**Navigation Locks.** The navigation locks on the mainstem dams provide hydraulic lifts of up to approximately 100 feet in elevation. In addition to the overall lift, the operating range of a navigation lock is determined by the depth of the sills at the upstream and downstream ends of the lock. The existing Bonneville lock has a downstream sill depth of 23 feet at minimum tailwater elevations, but the new lock will have a minimum downstream sill depth of 19 feet after the current improvement project that should be completed by 1993. The existing Bonneville lock upstream sill depth is 30 feet at MOP elevation of 70 feet, but the new lock will have a minimum depth of 19 feet. The remaining lower Columbia and Snake River dams have upstream and downstream sill depths of 15 feet.

### 2.9.1.2 Port Facilities

A detailed inventory of port facilities on the Columbia-Snake River reservoirs is provided in Appendix G. The distribution of port terminals by type and pool is summarized in Table 2.9-1.

The number of port facilities on all eight reservoirs totals 54, including 34 on the lower Columbia River and 20 on the lower Snake River. The geographic distribution of port facilities reflects the concentration of shipping activity near Lewiston on the Lower Granite Pool and Pasco on the McNary Pool. Grain terminals are the most common facilities, accounting for nearly half of all terminals within the study area. Minimum water depths alongside these facilities range from 10 to 40 feet for active facilities (Corps, 1986).

Port facilities at Clarkston and Lewiston have histories of siltation problems. These problems are caused by the hydraulic conditions created where the Snake River enters the Clearwater arm of the pool formed by Lower Granite Dam. River water slows as it enters the pool, dropping large amounts of sediment. Maintaining water depth has been most critical on the south side of the river at Clarkston and to a lesser extent at Lewiston. Facilities on the north bank downstream of the Clearwater-Snake confluence have reported few problems.

On the McNary Pool, eddies and other conditions cause marginal water depths at some facilities, especially downstream of Clover Island. These depths historically have been a problem for Harvest States and other elevators in the Tri-Cities area. Other facilities with marginal water conditions at present include the Cargill and Connell facilities at Burbank, the Boise Cascade facility at Wallula, and the Umatilla elevators.

### 2.9.1.3 Shipping Operations

The barge industry operating in the Columbia-Snake River System includes the following six firms: Bernert Barge Lines, Brix Maritime, Brusco Tug & Barge, James River Corporation/Western Transportation, Shaver Transportation, and Tidewater Barge Lines. Approximately 40 towboats and 175 barges operate in the upper river according to the American Waterway Operators. Brix and Tidewater are particularly active in the Snake River. Typical operations involve a tow, ranging from one to five barges towed by a single towboat. Freight revenue from Snake River accounts represents approximately 60 percent of total annual Columbia-Snake River revenues for one major barge company. Corresponding data for other firms were not divulged.

The Columbia-Snake Inland Waterway through McNary to the Lower Granite Pool handled a cumulative total of nearly 6.7 million tons in 1990. This included cargo originating in the Lower Granite, Little Goose, Lower Monumental, Ice Harbor, and McNary reservoirs. Cargo flows on these pools increased steadily as project completion proceeded upstream. Since 1980, cumulative cargo volumes have ranged from approximately 5 to 8 million tons per year (see Appendix F). Tonnage using at least a portion of the Snake River segment, as measured by the figures for Ice Harbor, averaged about 3.8 million tons per year from 1980 through 1990.

Downstream tonnage in 1990 was more than four times the volume of upstream tonnage. This volume difference is primarily because of the large movements of grain bound for export terminals below Bonneville. Grain shippers are the primary users of barge transportation in the shallow draft areas of the Columbia-Snake River System. Most frequently, one barge of general cargo or wood chips is moved in a tow with two or more grain

Table 2.9-1. Number and type of port facilities by pool, lower Columbia and Snake rivers.

| | Number of Terminals by Primary Use | | | | | | |
|---|---|---|---|---|---|---|---|
| Pool | Grain | Petroleum Products | Chemical/ Fertilizer | Wood Products | Heavy Lift/ Container General | Other | Total |
| Bonneville | 2 | | | 2 | | | 4 |
| The Dalles | 1 | | | | | | 1 |
| John Day | 4 | | | 2 | 1 | | 7 |
| McNary | 7 | 3 | 3 | 1 | 4 | 4 | 22 |
| Ice Harbor | 2 | | | | | | 2 |
| Lower Monumental | 1 | | | | | | 1 |
| Little Goose | 5 | | | | | | 5 |
| Lower Granite | 4 | — | — | 5 | 3 | — | 12 |
| TOTAL | 26 | 3 | 3 | 10 | 8 | 4 | 54 |

Source: Corps, 1986a.

barges. Without the large grain movements, it is likely that either rates for transporting other cargos would be substantially higher or barge service would not be available at all.

The majority of the tonnage moving downriver originates at the Lower Granite Pool, which accounts for 38 percent of the total downbound tonnage. Respective shares for the McNary and Little Goose pools are 28 percent and 22 percent of downbound tonnage. Relatively little tonnage originates at the Ice Harbor (9 percent) and Lower Monumental (3 percent) pools. Downriver cargos include grain, primarily wheat and barley; wood products, such as pulp and paper exports from the Potlatch Company in Lewiston; and vegetable products, primarily peas and lentils. These cargo groups typically represent 98 percent of total annual downriver cargo.

McNary is the most important upbound cargo destination on this section of the river, accounting for 1.2 million tons (primarily petroleum products) or 89 percent of total upbound tonnage. Lower Granite accounted for the remaining 11 percent.

Improvements in vessel loading at lower Columbia River ports below Bonneville have led to an increasing number of vessels drawing more than 35 feet of water. A total of 484 vessels was reported to have exceeded this level over a recent 18-month period (Ogden Beeman and Associates, 1990). These vessels all need a 40-foot-deep channel at a minimum. Approximately 60 percent of these vessels carried grain. The increasing traffic of deeper draft ships has led to concerns about maintaining navigation access in this reach, because even slight modification to existing water depths could cause access difficulties at the Port of Portland and possibly other facilities.

### 2.9.1.4 Upper River Navigation

While the authorized and maintained inland navigation channel ends at the head of the McNary and Lower Granite pools, river reaches and reservoirs above these pools are used for various types of navigation. The most common type of upstream navigation is for recreation. Many types of motorized and non-motorized pleasure craft are used by private boaters on the mid-Columbia reservoirs, the Snake and Clearwater rivers above Lower Granite and Dworshak reservoirs, and the three reservoirs (Brownlee, Oxbow, and Hells Canyon) of the Hells Canyon Complex. Commercial tour, guiding and transportation services also exist in some locations, particularly on the Hells Canyon reach of the Snake River upstream from Lewiston, Idaho. An open-river channel with a minimum depth of 3 feet extends for 90 miles on the Snake River above Lewiston (Corps, 1984).

Another specific commercial use of affected project waters for navigation is transporting logs at Dworshak. Logs from harvest operations in the North Fork Clearwater River drainage above the reservoir are hauled to staging areas at various points along the reservoir and are rafted to log dumps near the dam. The logs are collected at the dumps and transferred to trucks for hauling to mills. Using the reservoir for a portion of the trip can save significant trucking distances over low-speed roads. Log transportation on the reservoir is not possible during periods of significant drawdown.

The status of the log dump sites is summarized in Table 2.9-2. The Robinson Creek and Breakfast Creek dump sites have never been used by Potlatch. Use of the Milk Creek dump site is limited by its elevation and the configuration of the reservoir bottom at this location. The other three sites are used regularly.

The recent history of log handling on Dworshak Reservoir is as follows:

| | |
|---|---|
| 1988 | 25 million board-feet of logs |
| 1989 | 14 million board-feet of logs |
| 1990 | 22 million board-feet of logs |
| 1991 | expect 20 million board-feet of logs at the Little North Fork dump site |

The average for this period is 20 million board-feet per year.

## 2.9.2 Railroads

Based on origin-destination relationships for commodities shipped on the Columbia-Snake Inland Waterway, the area potentially affected by the proposed flow measures includes primarily the grain growing areas of Washington, Oregon, Idaho, and Montana. These areas are served by the Burlington Northern Railroad (BNRR), the Union Pacific Railroad (UPRR), and several shortline operations. Among the latter, the Camas Prairie Railroad serves Idaho and Washington, and the Montana Rail Link serves Idaho and Montana.

In Washington, the BNRR and UPRR have an agreement to jointly manage the mainline track from Seattle to Portland. From Vancouver, Washington, the BNRR line runs along the northern side of the Columbia River through the Tri-Cities to Spokane. It continues north to Sandpoint, Idaho, then runs southeast to Missoula, Montana and on into the Midwest. The BNRR has crossings into Oregon at Portland, Wishram, and Wallula. The UPRR runs along the southern side of the Columbia River from Portland to Hinkle, Oregon, then runs south to Boise and on into the Midwest. Both the BNRR and the UPRR provide extensive trackage in all four states.

The Camas Prairie Railroad is a joint venture operated cooperatively by the BNRR and UPRR. Camas Prairie tracks connect Revling and Kamiah in Idaho through Lewiston to Riparia on Lower Monumental Reservoir in Washington. Montana Rail Link provides service from Sandpoint, Idaho to Garrison, Montana.

Rail line abandonment has occurred extensively in the Northwest, particularly in Washington and Idaho. Since 1976, Idaho has had abandonment of 542 miles of track, accounting for 20.6 percent of the 2,631 miles in existence at that time (Henry, 1991). Washington lost 1,557 miles of track during the same period. A number of other rail segments have been placed in Category 1 status with the Interstate Commerce Commission, which makes them a candidate for abandonment within 3 years. Much of the abandoned track served the grain-producing areas of these two states.

Most notably, the Palouse region of Washington and Idaho has been affected by abandonment. A recent study indicated that 285 miles (35 percent) of the original 825 miles of rail in the Palouse area had been abandoned by 1987 (Idaho Transportation Department [ITD] and Washington State Department of Transportation [WSDOT], 1987).

Table 2.9-2. Dworshak log dump characteristics.

| Log Dump Site | Constructed by | Maintained by | Elev. At Lower End of Ramp | Location |
|---|---|---|---|---|
| Little Meadow Creek | Potlatch | Potlatch | 1,580 | Left Bank RM 37.3 |
| Robinson Creek | Corps | Nobody | 1,565 | Right Bank RM 39.3 |
| Breakfast Creek | Corps | Nobody | 1,570 | Little North Fork at Breakfast Cr. |
| Benton Creek | Corps | Potlatch | 1,570 | Left Bank RM 43.5 |
| Little North Fork | Potlatch | Potlatch | 1,570 | Little North Fork, Right Bank |
| Milk Creek | USFS | USFS | 1,590 | Right Bank RM 52.2 |

Current abandonments include a section of BNRR line to Moscow, Idaho, and a section of two UPRR lines in Whitman County, Washington (approved for abandonment in October 29, 1990). A section of the Camas Prairie Railroad from Lewiston to Grangeville is threatened. The main reason for abandoning rail lines in Whitman County was competition from barge transportation on the Snake River. These railroad abandonments have taken away options for shippers in certain areas to switch easily to rail.

### 2.9.3 Highways

The highway network serving the study area includes interstate, Federal, State, and county highways. With respect to the proposed actions, the primary interest centers upon routes that could be affected by potential diversion of commodities from barge transportation. These highways are categorized in Table 2.9-3 as primary and secondary facilities; alternative routes north of the lower Snake River pools are also identified.

Based upon preliminary review of the existing highway network serving the study area, the majority of the links in the network are currently serving low traffic volumes. Excluding Interstate 84 and some portions of U.S. Route 395 with 4 travel lanes, the majority of the remaining primary and secondary highways have 2 travel lanes. These highways generally serve rural areas with few large population concentrations.

## 2.10 AGRICULTURE

### 2.10.1 Study Area Overview

The study area for agriculture was defined to include 15 counties adjacent to the affected projects. Of these counties, 8 are in Washington, 5 are in Oregon, and 2 are in Idaho (Table 2.10-1). The latest Census of Agriculture reports that about 2.9 million acres of cropland were harvested in the study area in 1987 (USDA, 1987a, 1987b, 1987c). Approximately 720,900 acres (about 25 percent) of the total harvested cropland were irrigated (Table 2.10-1). An estimated 380,000 acres (about 53 percent) of the irrigated cropland is irrigated with water drawn from the eight lower Columbia and Snake River pools and Brownlee Reservoir. Overall, approximately 13 percent of the harvested cropland in the study area counties was irrigated from these pools.

According to the Census, the predominant irrigated crop in most counties in the study area is hay, and wheat is the second most irrigated crop. The statistics vary widely by county, however. In Benton County, Washington, for example, 29 percent of the irrigated cropland was devoted to corn, 22 percent to orchards, and 22 percent to potatoes; only 27 percent was devoted to hay and wheat combined.

### 2.10.2 Irrigation from Affected Pools

Although the Census of Agriculture provides the most comprehensive picture of agricultural patterns in each county, the countywide statistics are not

Table 2.9-3. Key study area highways.

| Highway | Segment/Location |
|---|---|
| **Primary Highways** | |
| Interstate 84 | U.S. 97 (Biggs) to Pendleton |
| Interstate 82 | I 84 to U.S. 395 (Pasco) |
| U.S. 395/730 | I 84 to U.S. 12 |
| U.S. 12 | U.S. 395 (Pasco, WA) through Lewis County, ID |
| U.S. 95 | Lewis and Adams Counties, ID |
| OR 11 | I 84 to WA state line |
| WA 14 | U.S. 97 (Maryhill) to I 82 (Plymouth) |
| WA 124 | U.S. 12 (near Pasco) to U.S. 12 (Waitsburg) |
| WA 125 | WA 125 to OR state line |
| WA 193 | U.S. 12 to Port of Wilma |
| **Secondary Highways** | |
| U.S. 395 | U.S. 12 (Pasco) to WA 260 (near Mesa) |
| WA 260 | U.S. 395 to WA 261 |
| WA 261 | WA 260 to US 12 |
| WA 127 | U.S. 12 to Central Ferry |
| WA 129 | U.S. 12 to OR state line |
| WA 397 (proposed) | US 395 to Finley Industrial Park |
| **Alternative Routes North from Snake River** | |
| U.S. 195 | U.S. 12 to WA 26 |
| WA 26 | U.S. 195 to U.S. 395 |
| WA 260 | WA 261 to WA 26 |
| WA 263 (proposed) | WA 260 (Kahlotus) to Windust |

necessarily representative of those who draw irrigation water from particular sources. The cropping patterns of those drawing water from the Columbia and Snake River pools may not follow the countywide trend because the farms are located at lower elevations and are suitable for a different array of crops.

Because of the limitations associated with relying on Census of Agriculture data to depict the agricultural characteristics of Columbia and Snake River irrigators, the Corps contacted local irrigators to determine the size and characteristics of their farming operations. The irrigators were interviewed by telephone, and were asked a series of questions concerning the characteristics of their pumps, the crops grown on their irrigated acreage, and their perception of their options if the pools were drawn below the point where their pumping stations operate.

Not all irrigators on the affected pools were contacted because there is no complete, up-to-date list of those who draw water from the pools. The list of those contacted was drawn from information provided by the State agencies responsible for granting water withdrawal rights, from the Corps list of those holding permits for pumping stations, and from industry groups such as the Columbia/Snake Irrigators Association and the Eastern Oregon Irrigators Association. The State agency and the Corps records do not reflect changes in ownership since the water right was acquired or the pumping station was permitted. Also, they do not indicate if the owner of the water right or pumping permit leases all or part of the water to other irrigators. Over 80 interviews were conducted, of which 65 provided information used in this characterization of irrigated agriculture, and served as the basis for estimating impacts on agriculture. The interviews not included here were eliminated for two reasons. First, some of those

Table 2.10-1. Selected crops grown on irrigated land, 1987.

| | Total Harvested Cropland | Irrigated Land: Total | Irrigated Land: Harvested Cropland | Irrigated Land: Pasture and Other | Selected Crops: Wheat | Barley | Hay | Corn | Vegetables | Orchards | Oats | Edible Dry Beans | Irish Potatoes | Sugar Beets |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Washington** | | | | | | | | | | | | | | |
| Asotin | 40,644 | 459 | 352 | 107 | NA | NA | 240 | 0 | 21 | 73 | NA | NA | NA | NA |
| Benton | 238,490 | 112,366 | 104,259 | 8,107 | 15,323 | 1,033 | 12,922 | 30,053 | 2,544 | 23,035 | NA | NA | 22,700 | NA |
| Columbia | 111,538 | 2,198 | 1,843 | 355 | 288 | NA | 1,220 | 0 | NA | NA | NA | NA | NA | NA |
| Franklin | 284,324 | 193,960 | 186,300 | 7,660 | 32,506 | 2,980 | 57,588 | 14,742 | 21,284 | 11,365 | NA | NA | 30,000 | NA |
| Garfield | 116,854 | 1,914 | NA | NA | NA | NA | 920 | 0 | 0 | 17 | NA | NA | NA | NA |
| Klickitat | 101,543 | 23,744 | 18,311 | 5,433 | 4,057 | 597 | 6,347 | 300 | 1,288 | 2,351 | NA | NA | 1,200 | NA |
| Walla Walla | 298,896 | 75,333 | 69,281 | 6,052 | 13,348 | 2,095 | 9,072 | 6,736 | 8,171 | 2,656 | NA | NA | 8,000 | NA |
| Whitman | 727,024 | 9,971 | 8,479 | 1,492 | 1,173 | 1,853 | 2,359 | 0 | 3 | 110 | NA | NA | NA | NA |
| Washington Subtotal | 1,919,313 | 419,945 | 388,825 | 29,206 | 66,695 | 8,558 | 90,668 | 51,831 | 33,311 | 39,607 | NA | NA | 61,900 | NA |
| **Oregon** | | | | | | | | | | | | | | |
| Baker | 73,102 | 108,930 | 67,532 | 41,398 | 3,998 | 3,425 | 59,812 | NA | NA | 33 | 109 | NA | 260 | NA |
| Gilliam | 114,210 | 6,281 | 5,675 | 606 | 1,294 | 294 | 2,940 | NA | NA | NA | 0 | NA | NA | NA |
| Morrow | 201,171 | 75,255 | 71,470 | 3,785 | 19,920 | 1,312 | 23,534 | NA | NA | 1,725 | NA | NA | 17,600 | NA |
| Umatilla | 372,197 | 111,657 | 93,211 | 18,446 | 24,890 | 3,194 | 27,728 | NA | 8,687 | 4,603 | 211 | NA | 12,800 | NA |
| Wasco | 90,685 | 25,195 | 20,781 | 4,414 | 4,891 | 515 | 8,014 | NA | 7 | 7,102 | 0 | NA | NA | NA |
| Oregon Subtotal | 851,365 | 327,318 | 258,669 | 68,649 | 54,993 | 8,740 | 122,028 | NA | 8,694 | 13,463 | 320 | NA | 30,660 | NA |
| **Idaho** | | | | | | | | | | | | | | |
| Payette | 42,363 | 49,638 | 40,733 | 8,905 | 4,158 | 2,560 | 11,875 | NA | NA | NA | NA | 1,487 | 591 | 4,507 |
| Washington | 53,929 | 38,026 | 32,636 | 5,390 | 7,255 | 2,818 | 14,675 | NA | NA | NA | NA | 318 | 359 | 2,460 |
| Idaho Subtotal | 96,292 | 87,664 | 73,369 | 14,295 | 11,413 | 5,378 | 26,550 | NA | NA | NA | NA | 1,805 | 950 | 6,967 |
| Study Area Total | 2,866,970 | 834,927 | 720,863 | 112,150 | 133,101 | 22,676 | 239,246 | 51,831 | 42,005 | 53,070 | 320 | 1,805 | 93,510 | 6,967 |

Total Reported Acres = 644,531 Total Unreported Acres = 76,332

Source: 1987 Census of Agriculture; Geog. Area Series, Parts 12, 37, 47; Chapter 2, Tables 7 and 15.
Note: Total irrigated land equals sum of harvested cropland and pasture and other. Sum of selected crops does not equal harvested cropland; some crops are unreported.
NA = Not available

interviewed used irrigation water to irrigate lawns or golf courses, to assist in fish and wildlife habitat management, or for other nonagricultural purposes. That information was provided to other members of the OA/EIS team for use in their evaluation of impacts on other resources, such as wildlife habitat. Second, some interviewed irrigators draw water from the Snake River upstream of Brownlee Reservoir, and it was determined that none would be affected by any alternative under consideration in this OA/EIS. The focus of this analysis is therefore on the 65 successful interviews with agricultural irrigators who draw water from the Bonneville, Dalles, John Day, McNary, and Ice Harbor pools and Brownlee Reservoir. No agricultural irrigators were found who draw water from the Lower Monumental, Little Goose, or Lower Granite pools. Those interviewed control 255,512 acres of irrigated land, or about 71 percent of the approximately 360,000 acres irrigated with water from the study projects, and the sample is believed to be representative of most irrigators.

Table 2.10-2 summarizes the interview results. Fifty-seven irrigators, representing over 249,027 irrigated acres, draw water from the John Day, McNary, and Ice Harbor pools. The other pools account for significantly less irrigated land but are also represented by the interviews.

The chief crops include potatoes, corn, vegetable row crops, wheat, and alfalfa hay. Of the major crops, the land devoted to fruit, potatoes, and other vegetables is most valuable. Irrigated acreage in fruit and vegetable crops produces crops valued at $1,500 to $3,000 per acre per year, while acreage in wheat, hay, and field corn is valued at about $400 to $500 per acre per year (WASS, 1990).

Except in The Dalles Pool, most irrigators use fixed pumps; that is, the pumps are fixed in the pool at a certain elevation and work only within a limited range. Most are fixed at or near MOP for the reservoir. Many pumps are accompanied by boosters that assist in lifting the water from the reservoir surface to the cropland. As shown on Table 2.10-2, the lift can vary from a modest 2 feet to over 700 feet. The amount of lift is a key determinant in the power required by irrigators to maintain their operations. Irrigators stated that power usage costs ranged from $3 to $120 per acre per year, with an average of $75 per acre per year.

According to Idaho and Oregon water rights information, there are approximately 1,400 acres of irrigated land along Brownlee Reservoir (BPA, 1985). The low total acreage reflects the poor local topography conditions, which make much of the adjacent area unsuitable for large-scale cultivated agriculture. There are 12 irrigation withdrawals downstream of Brownlee Dam and 17 irrigation withdrawals upstream. The total amount of water diverted is 36.3 cfs. Typical pumping plant elevations are 2,034 feet. The Corps located and successfully interviewed operators of only three farms, representing 324 acres, who would be potentially affected by any of the alternatives.

Lake Roosevelt is the irrigation water source for the vast Columbia Basin Project. Water is pumped from 270 to 360 feet from the reservoir into a feeder canal to Banks Lake, where it is distributed by canal to irrigators. The Columbia Basin Project currently irrigates over 500,000 acres from Banks Lake through the main canal and other features. Irrigation requires approximately 2.3 to 2.7 MAF of water annually and in 1988 produced crops valued at over $430,000,000. The diversion of 2.3 MAF is slightly over 2 percent of the average total annual flow of the Columbia River at Grand Coulee Dam.

Crops grown with irrigation water from the lower Columbia and Snake River pools are sold to diverse markets throughout the country. Some crops, such as apples, are sold fresh nationwide. At the other end of the spectrum, 85 percent of the potato crop is sold for local processing into frozen french fries before being shipped to consumer markets. In addition to providing water for irrigation, irrigation return flows provide for recreation and fish and wildlife values within the basin before approximately 35 percent of the initial diversion returns to the Columbia River.

## 2.11 ELECTRIC POWER

The Columbia-Snake River System has been heavily developed for hydroelectric power generation. The Federal Columbia River Power System (FCRPS), the integrated system of 30 Federal hydroelectric projects in the Columbia River Basin operated by the Corps and BoR, has a total installed generating capacity of approximately 21,700 megawatts (MW) (Corps, 1984). Actions to modify flows on the Snake and Columbia rivers

Table 2.10-2. Characteristics of irrigated farms.

| Pool[1/] | State | Number of Interviews[2/] | Number of Acres Irrigated | Primary Corps | Characteristics of Pumps | | |
|---|---|---|---|---|---|---|---|
| | | | | | Elev (ft) | Lift (ft) | Type |
| Bonneville | WA, OR | 2 | 6,035 | Vegetables, fruit trees | 73 | 10-150 | Fixed |
| The Dalles | WA | 3 | 126 | Vegetables | 72-155 | NA | Floating |
| John Day | WA | 10 | 65,640 | Potatoes, corn, other vegetables, wine grapes, fruit trees, other | 257-265 | 10-600 | Fixed |
| | OR | 17 | 90,368 | Potatoes, corn, alfalfa hay, wheat, wine grapes, other | 257-266 | 2-400 | Fixed |
| McNary | WA | 11 | 37,131 | Potatoes, corn, alfalfa hay, apples, other | 335-337 | 80-650 | Fixed |
| | OR | 5 | 15,822 | Potatoes, onions, wheat, corn, alfalfa hay, other | 335-337 | 580-700+ | Fixed |
| Ice Harbor | WA | 14 | 40,066 | Potatoes, corn, apples and other fruit, wheat, other | 437 | 100-575 | Fixed |
| Brownlee | ID | 3 | 324 | Vegetables, wheat, alfalfa hay, other | NA | NA | NA |
| TOTAL | | 65 | 255,512 | | | | |

1/ Listed pools include those with at least one interviewed agricultural irrigator who could be affected by one or more alternatives. Other pools excluded either because no agricultural irrigators would be affected or no agricultural irrigators were found.

2/ Interviewed agricultural irrigators on the listed pools include the following. Some irrigators have more than one operation, and were interviewed separately for each operation.

AgriNorthwest
Alford Farm
Barbee Orchard
Braat Farm
Broetje Orchards
Burbank Ranch
Carlson Farm
Carr Farms
Charlie Cox Farms
Cheran Orchards
Circle C
100 Circle Ranch
Columbia Improvement District
Dickey Farms
Eastern Oregon Farming
Flat Top Ranch
GLB Farms, Inc.
Grandview Farms
Gunkle Orchards
H2O Farm
Harris Farm
Hawman Farms
Hillside Partnership
Ice Harbor Farms
Imada Farm
Kennewick Public Hospital District
T&J Kosmos Farms
Kundt Farm
LeGrow Water Co.
Makamura Farm
Mehlenbacher Farms
Mercer Ranch
Middleton Farms
Mikami Brothers
Milliman Farms
North Dalles Irrigation District
Perkins Farm
Port of Morrow
Potato Growers of WA
PTL Farms
Rogers Farm, Inc.
Royale Columbia Farms
Sandpiper Farms
Snake River Vineyards
Stimson Lane Ranch
Strebin Farms
Sullivan Farm
Sun Heaven Farms
T&R Farms
Taggarus Farms
Takahashi Farm
Trafton Farm
U.S. Fish and Wildlife Service
Van Tassell Farm
WA State Dept. of Natural Resources
Watts Brothers Farms
Western Extension Irrigation District
Western Empire
Worden Farms

Source: Corps interviews with irrigators, July-August, 1991.

would have implications throughout the FCRPS as well as for other hydroelectric facilities owned by public and private utilities.

### 2.11.1 Existing Hydroelectric Facilities

All 11 dams at which the proposed flow measures might be undertaken have hydroelectric facilities. The 10 Corps and BoR projects are part of the FCRPS, while Brownlee is owned and operated as part of the IPC electric system. These projects collectively have a total of 126 individual generating units with a total installed capacity of 17,904 MW (Table 2.11-1). The combined capacity of the 10 Federal projects represents about three-quarters of the overall capacity of the FCRPS. Including Brownlee, the total 11-project capacity is equivalent to about 45 percent of all hydroelectric resources in the Columbia River Basin. By project, installed capacity ranges from 460 MW at Dworshak to 6,494 MW at Grand Coulee.

The hydraulic capacity of a project can be a significant variable in planning and evaluating flow-related actions. The maximum water volume that can be routed through the powerhouses of the affected projects ranges from 10.5 kcfs at Dworshak to 375 kcfs at The Dalles. Hydraulic capacity is at least two times the average annual streamflow at each project, allowing generating operations to provide additional power during high flow periods.

### 2.11.2 Operations and Generation Levels

Power generating operations follow a variety of cyclic patterns. Because hydro projects can increase or decrease their generation rapidly, they are usually operated to follow the peaks in power demand. Output levels generally vary significantly on a daily basis, with generation much higher during daylight hours than at night. On a weekly basis, power loads and generation tend to be considerably higher on weekdays than on weekends. The mainstem dams, in particular, often follow these daily and weekly cycles, causing reservoir levels to fluctuate frequently within the normal operating range.

In most of the Northwest, seasonal variation in power demand reflects a pattern of peak loads in the winter and lowest loads in the spring and summer. Output from both storage projects and run-of-river projects, therefore, tends to be highest during the winter, as described in Section 2.2. Brownlee is an exception to this pattern because irrigation pumping demands produce the highest loads on the IPC system during summer (BPA, 1985). Annual streamflow patterns also influence generation patterns. During years of relatively high runoff, hydro plants are often operated at high levels in the spring to take advantage of the surplus water to generate non-firm or secondary energy. This has particularly been the case under system management for the Water Budget, as power planners have generally tried to maximize hydro output and keep thermal plants inactive during the Water Budget period to avoid spilling water that would otherwise not be used for power production.

## 2.12 RECREATION

The rivers, reservoirs, and adjacent land areas included in the scope of this OA/EIS are regionally important recreational resources. Although a wide variety of activities occur at project recreational sites, the OA/EIS concentrates on recreational resources that are water oriented and affected by project operations. The affected projects offer numerous opportunities for water-based recreational activities including boating, swimming, fishing, water skiing, and wind surfing. Many boat ramps, beaches, marinas and other facilities have been developed to support these activities. Land-based activities such as camping and picnicking are also popular and often occur at facilities oriented to the reservoirs.

### 2.12.1 Facilities and Activities

Project recreational sites vary greatly in terms of size, type of facilities, level of development, features, management, use, and accessibility (Table 2.12-1 on page 2-73, Appendix H). Virtually all sites provide for recreation that is either dependent on water or enhanced by the proximity of water.

Table 2.11-1. Hydro project characteristics.

| Project | No. Units | Generation Capacity (MW) | Hydraulic Capacity (kcfs) |
|---|---|---|---|
| Dworshak | 3 | 460 | 10.5 |
| Grand Coulee | 24 | 6,494 | 290.5 |
| Brownlee . | 5 | 675 | 33.5 |
| Lower Granite | 6 | 930 | 130 |
| Little Goose | 6 | 930 | 130 |
| Lower Monumental | 6 | 930 | 130 |
| Ice Harbor | 6 | 695 | 106 |
| McNary | 14 | 1,127 | 232 |
| John Day | 16 | 2,484 | 350 |
| The Dalles | 22 | 2,047 | 375 |
| Bonneville | 18 | 1,132 | 270 |
| TOTAL | 126 | 17,904 | -- |

Sources: Corps, 1988 a-d; Corps, 1984; Corps, 1989a; BPA, Corps, BoR, 1991.

Larger, more intensively developed sites often have a variety of facilities to support different activities and most offer boat access and/or access for people. Many provide boat ramps, docks, marinas, campgrounds, and day-use areas with developed swimming and picnicking facilities. These sites typically have paved launch lanes and parking areas, restrooms with running water, retail and service concessions, landscaping, and irrigated lawn areas. There are also many smaller sites that are less developed and support one or two key uses. In addition to developed facilities, there are many informal sites that only provide access to the water or to publicly owned lands.

### 2.12.1.1 Lower Columbia

Recreational facilities on lower Columbia River projects are significant regional resources. The Bonneville and Dalles projects attract large numbers of recreationists from local communities and the Portland metropolitan area. Upriver, the McNary project is likewise a regional resource, attracting recreationists from the Tri-Cities area and other, smaller local communities. Project recreational sites and facilities are important to urban and rural communities. In communities such as Hood River and The Dalles, project recreational sites and facilities are focal points in existing community recreational development efforts and will continue to be in the future. Project recreational sites are equally important to rural and smaller communities and may be the only recreational facilities available to their citizens.

The lower Columbia River area is the setting for a variety of recreational activities (Figure 2.12-1). The most popular in the Columbia Gorge is driving for pleasure and sightseeing. Parks, viewpoints, rest areas, and scenic highways allow drivers to view the spectacular scenery of the Columbia River Gorge National Scenic Area (CRGNSA).

Table 2.12-1. Recreational facility inventory.[a]

| Project | Total No. of Facilities | Sites with Boat Ramps | Moorage and Marina Facilities | Wind Surf Beaches | Sites with Swimming Beach | Sites with Camp-grounds | Sites with Day Use Facilities |
|---|---|---|---|---|---|---|---|
| Bonneville | 20 | 8 | 5 | 9 | 6 | 6 | 14 |
| The Dalles | 11 | 8 | -- | 2 | 4 | 4 | 10 |
| John Day | 16 | 13 | 6 | 2 | 9 | 6 | 12 |
| McNary | 19 | 14 | 7 | -- | 7 | 4 | 8 |
| Ice Harbor | 6 | 6 | 1 | -- | 4 | 3 | 5 |
| Lower Monumental | 6 | 5 | 1 | -- | 1 | 2 | 6 |
| Little Goose | 6 | 6 | 1 | -- | 2 | 2 | 6 |
| Lower Granite | 16 | 13 | 3 | -- | 6 | 3 | 11 |
| Dworshak | 11 | 5 | 1 | -- | 3 | 4[1/] | 5 |
| Brownlee[b/] | 6 | 5 | 4 | | 3 | 6 | 6 |
| Grand Coulee | 35 | 17 | | | 8 | 31 | 13 |

Source: NPS, undated.

a/ Dworshak also has approximately 125 boat-accessible mini-camps.
b/ Exhibit R, FERC Project 1971, Idaho Power Co., Undated, 1990.

The Columbia River Scenic Highway runs along the Oregon side of the river above U.S. Highway 30 and Interstate 84. The section of U.S. Highway 30 above Lake Bonneville between Mosier and Rowena is well known for its vistas of the Columbia Gorge. The scenic highway is perhaps the best known but not the only sightseeing feature. Other sightseeing attractions on the lower Columbia River include visitor centers at the Bonneville, The Dalles, John Day and McNary dams.

Water-oriented attractions are popular at the lower Columbia projects, with almost 30 percent of visitors reporting participation in one or more water-oriented activities (boating, fishing, water skiing, or swimming [see Appendix H]). Activities such as fishing (which is the second most popular recreational activity at these projects) occur at many developed and undeveloped sites. Fishing for cold-water species such as steelhead and salmon is especially popular below the tailraces and at the mouths of tributaries. Embayments, sloughs, and small lakes (seep lakes) separated from the main reservoir by railroad or highway embankments are popular (although generally undeveloped) locations for fishing for warm-water species such as bass. Boating on the lower Columbia projects is primarily a means for fishing. Water skiing and, to a much lesser extent, cruising are also popular boating activities.

Wind surfing is a key activity for observers and participants in the Columbia Gorge, which has become an internationally known location for the sport. The constant wind, flowing river, and sheltered embayments are attractive to beginning

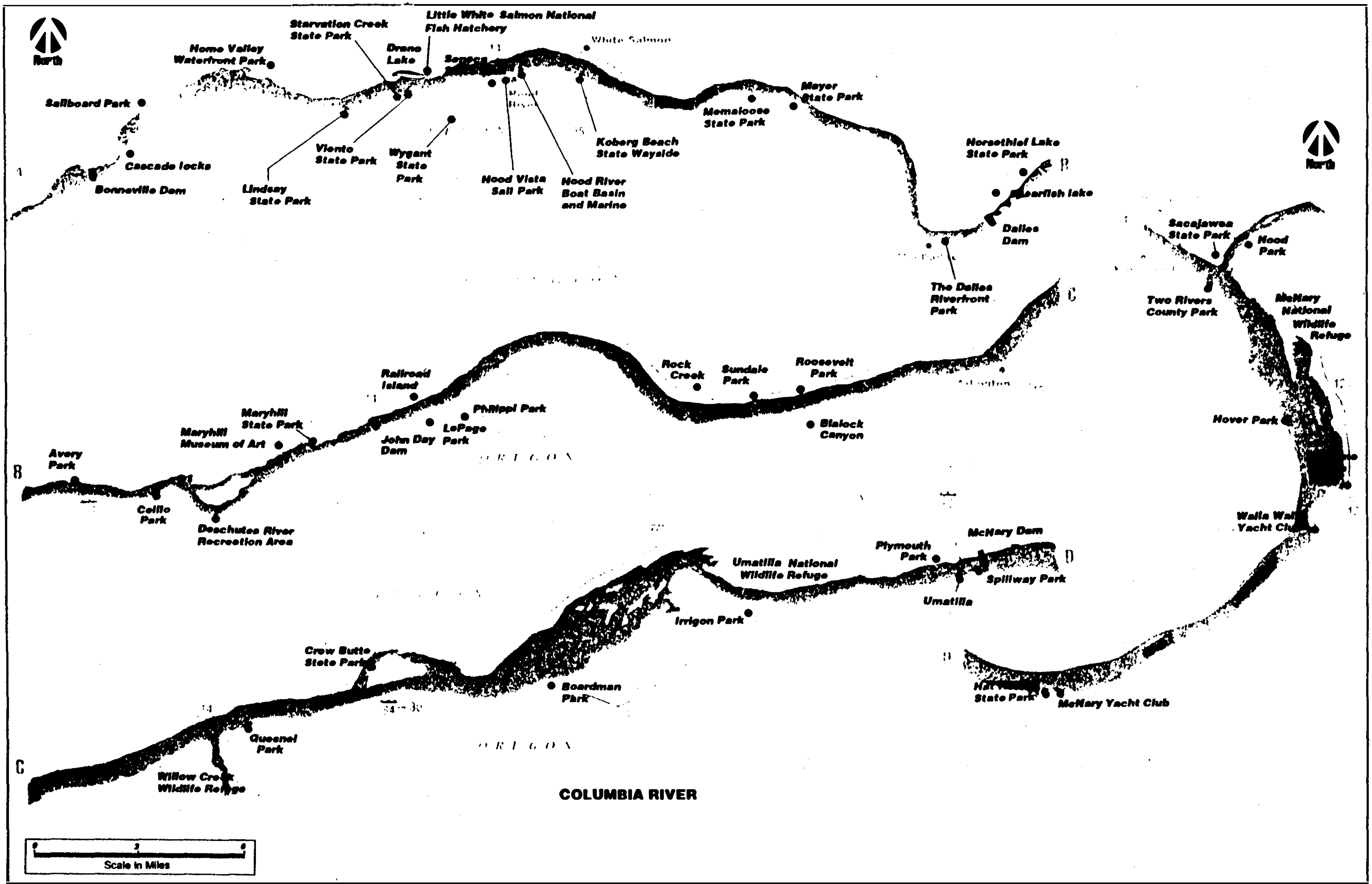



Figure 2.12-1. Selected Columbia River recreation sites (Source: Corps of Engineers; DeLorme, 1988).

and expert windsurfers. Swimming is another water-oriented activity at project recreational sites. It primarily occurs between June and August and accounts for about 8 percent of the visitor use at Corps facilities.

Recreationists who are involved in water-oriented activities also frequently participate in non-water dependent activities such as picnicking, walking trails, and camping. Activities that do not occur on water are often enhanced by proximity to it. That is particularly true at project sites located near urban areas, such as at the McNary project located near the Tri-Cities. Here seven sites are leased by the Corps to cities or counties and used as local parks. Picnicking and trail use are the two most popular forms of recreation. At more remote projects such as John Day, activities such as fishing and boating are predominant.

Facilities at more developed project sites typically include picnic tables, fire grills, group shelters, irrigated lawns and trees, parking, and comfort stations. Most recreational sites at lower Columbia projects also have facilities oriented to water-related activities (see Table 2.12-1). There are 43 sites with one or more boat ramps, 18 moorage facilities, 26 sites with developed swimming beaches, 13 wind-surfing beaches, 20 campgrounds and 44 sites that have day-use amenities. The most highly developed project is Bonneville with 20 formal recreational sites and numerous informal sites.

Lower Columbia River facilities are operated and managed by a variety of agencies and jurisdictions. The Corps is the primary manager of project facilities, although entities that manage recreational facilities adjacent to project reservoirs include the FWS, the Washington and Oregon State Parks Departments, the Washington Department of Wildlife, the Oregon Department of Fish and Wildlife, port authorities, local counties and municipalities, and several private concerns.

Several special recreation, preservation, and natural resource areas are located near lower Columbia River projects. They are primarily concerned with natural resource management and preservation but also support developed recreational sites and provide for dispersed, low-density recreational activities. The best known of these special areas is the CRGNSA, which includes 253,500 acres on both sides of the river from Troutdale to the Deschutes River. The CRGNSA is managed by the U.S. Forest Service (USFS) and the Columbia River Gorge Commission. The FWS manages the Umatilla and McNary National Wildlife Refuges. The States of Oregon and Washington manage several State wildlife areas and HMUs. The refuges generally have minimal visitor facilities and support activities such as hunting, wildlife viewing, and fishing.

Recreational facilities on the Columbia River continue downriver beyond the Bonneville Dam and are affected by upriver operations. The use of boat ramps, moorage facilities, swimming beaches, and other recreational amenities are directly related to the amount of water released from Bonneville.

### 2.12.1.2 Lower Snake

Most of the project recreational sites on the lower Snake River are located in rural, remote areas and are removed from population centers (Figure 2.12-2). The exceptions are the recreational sites at the McNary and Ice Harbor projects that are close enough to be used by residents of the Tri-Cities, and sites at Lower Granite near the Lewiston-Clarkston area. Many Lower Granite sites are located within or close to the central areas of Lewiston and Clarkston and are essentially urban in character and use. Project sites and facilities are important contributors to the quality of life of the two cities. Several lower Snake River project recreational sites are adjacent to very small communities, but most are remote. Recreational sites on project reservoirs represent the bulk of water-oriented recreational opportunities in southeastern Washington, especially for smaller rural communities and residents.

Water-oriented activities such as fishing, boating, and water skiing take place at all four projects. Swimming occurs at all projects and is actually the most popular activity at Little Goose. Land-based activities such as picnicking, trail use, and camping are popular to varying degrees at different projects. Picnicking is the first, second, or third most popular activity at the Ice Harbor, Little Goose, and Lower Monumental projects, respectively. At Lower Granite, trail use is the most popular activity due to the high use of trails at Lewiston-Clarkston riverside parks. Camping occurs at Fishhook and Charbonneau parks and at Lyons Ferry, Central

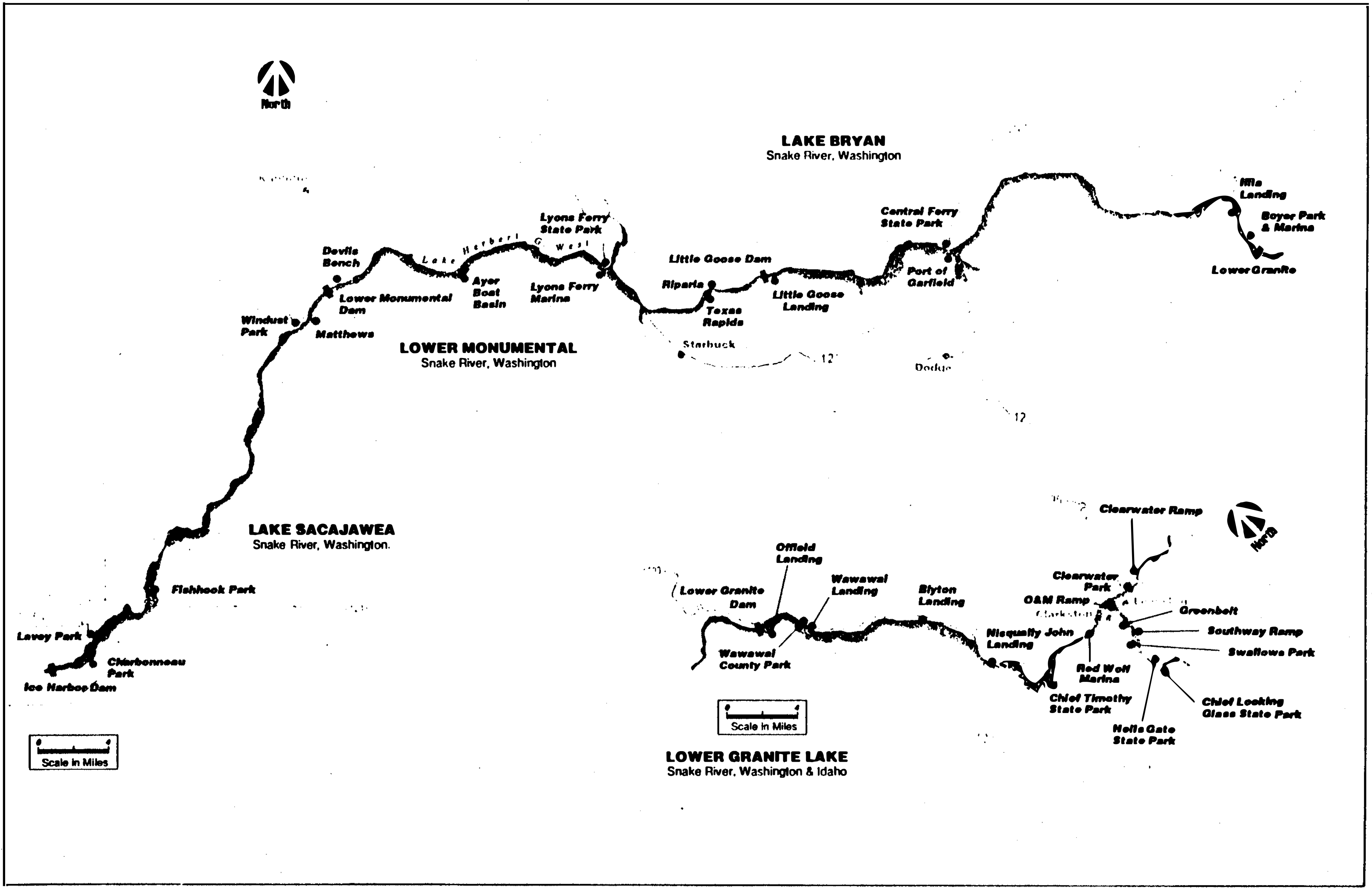



**Figure 2.12-2.** Selected Snake River recreation sites (Source: Corps of Engineers).

Ferry, Chief Timothy, Windust and Hells Gate State Parks.

The number and type of water dependent facilities vary greatly between the four lower Snake projects (see Table 2.12-1). Ice Harbor has four major parks and two boat launching sites. All of the sites are isolated, although the downstream sites (Levey Park, Ice Harbor and Charbonneau) are located within approximately 10 to 15 miles of Pasco and Kennewick. Lower Monumental is more isolated than Ice Harbor. The six developed recreational sites range from a simple fishing access ramp to Lyons Ferry State Park and the Port of Columbia's Lyons Ferry Marina.

Recreational development at Lower Monumental has been restricted by the high basalt cliffs that surround the project. The Little Goose project likewise has had development limited by rugged terrain. The project has two developed sites leased by the Corps to the State of Washington (Central Ferry and Lyons Ferry state parks) and one leased by the Port of Whitman County (Boyer Park and Marina) that offer a variety of recreational facilities. The three other Little Goose sites have boat ramps.

Recreational sites at Lower Granite have the widest variety of activities and greatest number of facilities. The highest concentration of sites at Lower Granite Lake is in the Lewiston-Clarkston area. Most of the recreational areas are urban in character and use. The riverside parks in Lewiston-Clarkston are located between Lower Granite Lake and city neighborhoods. Water-oriented activities such as boating and swimming are popular activities at the parks, but the most popular activity is using the extensive riverside trail systems that are available at Swallows Park, Greenbelt Park, and Lewiston Levee Parkway. Two marinas are located in the Lewiston-Clarkston area (Red Wolf and Hells Gate State Park) and serve local and transient boats. An increasing but unspecified number of private 60-foot-plus boats are reported to be using Clarkston as a destination. Two cruise lines operate from spring to fall between Portland and Clarkston. In addition, several companies operating out of the Lewiston-Clarkston area offer jet boat tours of Hells Canyon.

### 2.12.1.3 Dworshak

The Dworshak project is located far from any major population centers, yet it is within weekend driving distance from a number of smaller communities (Figure 2.12-3). Dworshak is the only large, forested lake found within a 100-mile radius (Corps, 1975). As a result, it is considered an important regional recreational resource for eastern Washington and western Idaho. The Clearwater River below Dworshak is also considered an important regional recreational resource, primarily because of its excellent steelhead fishing (Krumpe, 1987). Operations at Dworshak have significant effects on recreation on the Clearwater.

Because of limited road access to Dworshak, development has been minimal. Also, the time required by most visitors to get to Dworshak and the relatively small local population has placed recreational emphasis at Dworshak on overnight visitation rather than day use. There are three developed campgrounds, Dworshak State Park (leased to the state of Idaho by the Corps), Dent Acres, and the Dent Acres group area, with a total of 240 vehicle sites and 25 tent sites that are accessible to vehicles. The Three Meadows unit of the state park has cabins and a lodge that can accommodate groups of up to 100 people. In addition, Dworshak has the distinction of being one of the few lakes in the Northwest with boat-accessible campsites that contain picnic tables, fire grills, tent pads, outhouses, and trash receptacles.

Most activities at Dworshak are water oriented and there are a number of facilities to provide access to the water. There are six boat ramps at Dworshak that are usable to various elevations and a 140-plus slip marina at Big Eddy that has a restaurant, store, and marine fuel facility. In addition, there are five day use facilities located adjacent to the lake and three developed swimming beaches.

Because Dworshak is a storage reservoir, it has significant seasonal drawdowns of up to 155 feet. As a result, most facilities are not designed to operate to the full extent of the drawdown. The effects of existing drawdowns on facilities are discussed in Section 4.

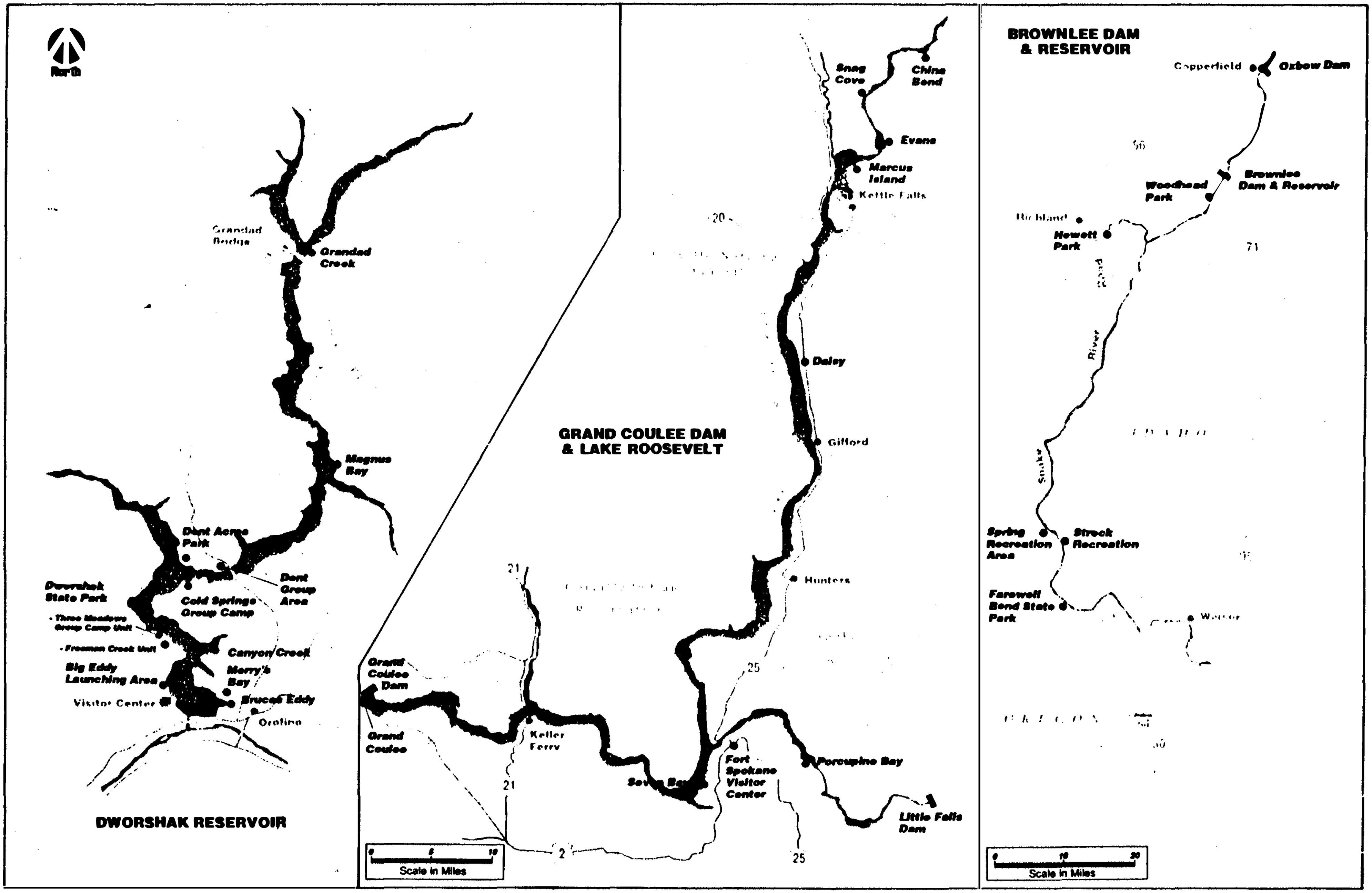



Figure 2.12-3. Selected Dworshak, Grand Coulee, and Brownlee recreation sites (Source: DeLorme, 1988; Rand McNally, 1990; BPA, 1985; Corps of Engineers).

### 2.12.1.4 Brownlee

Brownlee is the most remote of the projects included in this OA/EIS, but was the most popular fishing reservoir in Idaho in 1989 (Zimowsky, 1990). It is located on the Snake River approximately 20 miles upriver from the northern boundary of the Hells Canyon National Recreation Area (HCNRA). Access to the reservoir is best at the northern and southern areas of the project, where developed facilities are located. There are six developed recreational facilities at Brownlee managed by IPC (Copperfield Park, Woodhead Park), Baker County (Hewett Park), BLM (Spring and Steck recreational sites) and the State of Oregon (Farewell Bend State Park). Farewell Bend State Park is the most extensive recreational development on the project. All the above-mentioned facilities have day-use and overnight facilities, and all but one have boat ramps. In addition, there are many primitive sites along the lake, some of which are maintained by IPC. Some recreational sites are accessible only by boat; others can be accessed via the 45-mile-long dirt road that follows much of the west bank of the project. Some of the primitive sites have crude dirt or gravel boat ramps. The middle section of the project adjacent to the road is used mainly by bank anglers and hunters (BPA, 1985). Besides hunting and fishing, other popular activities include motor boating, water skiing, recreational vehicle and tent camping, swimming, and picnicking. A total of 3,200,000 fish was caught at Brownlee between February 1989 and January 1990, which resulted in a rate of 3.77 fish per angler hour.

The HCNRA downstream from the Brownlee project is a major national, regional, and local recreational resource (BPA, 1985). The stretch of river below the Hells Canyon Dam has been designated a Wild and Scenic River and the 33-mile segment of the Snake River north (downstream) of the northern border of the HCNRA is being studied for inclusion in the National System of Wild and Scenic Rivers (BPA, 1985). Most of the recreational activities that occur in the HCNRA are related to the water. These activities include rafting, kayaking, power boating, fishing, camping, and picnicking. Most are dependent on river flow and the amount of water released from the upstream reservoirs, including Brownlee.

### 2.12.1.5 Grand Coulee

Lake Roosevelt, behind Grand Coulee Dam, is one of the most significant recreational resources in the Pacific Northwest (NPS, undated). The project is included in the Coulee Dam National Recreation Area which is managed by the National Park Service (NPS). Most of the project's recreational and interpretive facilities fall under the jurisdiction of the NPS. The NPS manages 17 developed sites with boat ramps and an additional 14 sites without ramps. The Colville Federated Tribes and Spokane Tribe manage several recreational facilities including Keller Park, Pierre campground, Rodgers Bar campground, and Barnaby Island campground. The 130-mile-long lake reaches into Canada and has numerous recreational facilities, which include camp sites accessible by car, campsites accessible by boat only, boat ramps, moorage facilities, boat fuel, waste disposal services, stores, and restaurants. A number of small communities along the lake have businesses that service recreational users, particularly boaters.

Recreational activity is centered around boating, fishing, camping, and swimming. Water-based activities are especially popular at Grand Coulee. Sixteen free boat ramps allow access to the lake from numerous locations. Moorage facilities at places such as Keller Ferry and Seven Bays accommodate a wide variety of boats types and sizes. House boats have become a common sight on Lake Roosevelt in recent years and over 50 are rented by the Colville Federated Tribes from Keller Ferry and Seven Bays marinas (Roosevelt Recreational Enterprises, 1988). Swimming under lifeguard supervision is possible between Memorial Day and Labor Day at six developed beaches. Lake Roosevelt offers many species of game fish, but walleye is the most popular (NPS, undated). Other game fish include rainbow trout, kokanee, small mouth bass, white sturgeon, and yellow perch.

Camping and picnicking are popular land-based activities and are accommodated at 32 campgrounds scattered around the lake, numerous picnic facilities at campgrounds, and other day-use sites. Hunting also occurs in parts of the recreational area during different times of the year. Game species include upland birds such as quail, chucker, and pheasant, and migratory birds such as Canada goose, duck, and mourning dove. Big game species include black bear, whitetail deer, and mule deer.

### 2.12.2 Visitation Patterns

Recreational visitation varies considerably among the projects. The Bonneville project received the highest number of recreation days, an estimated 3,034,000 in 1989. In contrast, the remote Lower Monumental project received the least amount of visitation with 84,000 recreation days in 1990. Unlike visitation, seasonality of use is similar among projects (see Figure 2.12-4). All projects receive their highest amount of visitation during the summer.

#### 2.12.2.1 Lower Columbia

The projects on the lower Columbia River receive the most use of any of the study areas being examined in this OA/EIS. Visitation estimates for these projects were gathered for developed recreational sites managed by the Corps. Visitation data for non-Corps projects are limited, but included when possible. No data are available for dispersed, non-site specific recreation. The lower Columbia River projects are very popular, and all are heavily used, with each receiving over 1,000,000 recreation days per year. The Bonneville project received the highest number of total recreation days with an estimated 3,034,000 in 1989, because of its proximity to the Portland metropolitan area. Because pool levels on lower Columbia River projects fluctuate daily and weekly rather than seasonally, weather is the greatest determining factor in visitation. Although some visitation occurs all year, most recreational activity on lower Columbia River projects occurs during the summer. Fifty-seven percent of all annual visitation occurs during the warm weather months (June through September). August, the warmest month of the year, is the most popular month for visiting lower Columbia River projects and accounts for 17 percent of the annual total.

#### 2.12.2.2 Lower Snake

Visitation at lower Snake River projects varied considerably from project to project. The following are the estimated number of recreation days in 1990 at each project. (A recreation day is defined as the presence of one person on an area of land or water for the purpose of engaging in one or more recreational activities during a portion or all of a 24-hour period).

Ice Harbor - 482,000
Lower Monumental - 84,000
Little Goose - 226,000
Lower Granite - 1,551,000

Use of recreational facilities at lower Snake projects is largely by local people. The majority (approximately 80 to 90 percent) of visitors come from within 100 miles of the project they visit and most come from much less than that. Visitors at the two most popular projects, Lower Granite and Ice Harbor, largely come from the adjacent large metropolitan areas of Lewiston-Clarkston for Lower Granite and the Tri-Cities for Ice Harbor. Visitation at the four projects' recreational sites appears to be closely linked to weather, with most use occurring during the summer.

#### 2.12.2.3 Dworshak

The Dworshak project was the second least visited project of all the projects examined. It had an estimated 212,000 visitors producing 353,600 recreation days of use in 1990. It also had the most pronounced seasonal use patterns. Visitation at Dworshak is influenced by weather and project operations. Historically, Dworshak has reached its lowest pool elevation in March when visitation is low and then is refilled to its highest elevation in July. The Water Control Manual for Dworshak calls for the reservoir to be held on or near maximum pool elevation until Labor Day to benefit recreational use. After Labor Day, an attempt is made to keep the pool above elevation 1,560 until after the fall hunting season to allow hunters to use boat ramps and remote mini-camps. Use increases from 8 percent of annual visitation in May to 14 percent in June. Visitation remains high all summer. Seventy-seven percent of all annual visitation occurs during June through September when the weather is warmest, and the reservoir is at high-pool elevation. After September when the weather is cooler and wetter and the reservoir begins to be lowered, use drops off dramatically until May.

Visitation data for recreational activities on the Clearwater River is primarily concerned with steelhead fishing, the most popular activity. During the prime steelhead months of October and November, releases from Dworshak are regulated and cannot exceed inflow by more than 1,300 cfs, except during emergencies or freshets. Angler hours on the Lower Clearwater from 1986 to 1987 were highest in October (131,000 hours), declined in November (52,600 hours), leveled off from December through March (between 22,700 and 14,740 hours per month), and dropped in April

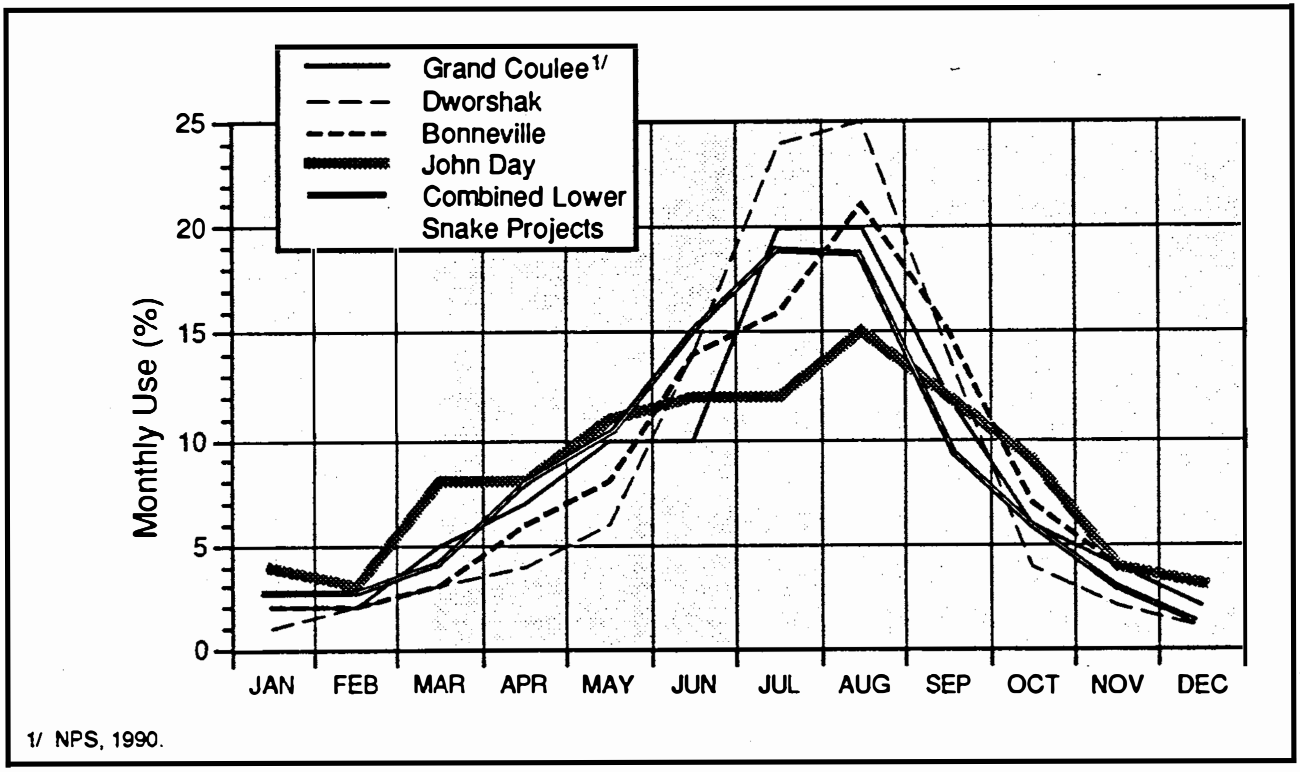



**Figure 2.12-4.** Seasonality of recreation use.

(900 hours) (personal communication, K. Ball, Idaho Department of Fish and Game, January 3, 1991).

### 2.12.2.4 Brownlee

Brownlee is the most isolated of the projects yet it received 279,000 recreation days in 1983 (BPA, 1985). The majority of visitation was by day users (215,000) at Farewell Bend State Park, which is located near Interstate 84 and serves as a convenient rest stop. Visitation at other recreational facilities was much less, approximately 64,000. Visitation by commercial and private power and float boaters in the nearby HCNRA was 42,400 recreation days in 1982.

Available seasonal use data for the Brownlee project are limited to angler surveys. The Idaho Department of Fish and Game conducted a fish harvest survey of boat and bank anglers in 1984. The study revealed that for both boat and bank anglers the most popular period for fishing was between April 1 and May 31. Typically, Brownlee is at its lowest pool elevation in April and then rapidly gains elevation until it reaches its high-pool elevation in June. Fishing hours leveled off during June and July and dropped significantly during August. In September, fishing hours picked up again and then dropped in October (the last month in the survey).

As part of the relicensing efforts for the Brownlee project, the IPC conducted an angler survey of Brownlee Reservoir (Idaho Power Company, 1990). Between February 1989 and January 1990, an estimated 852,000 angler hours were expended at Brownlee (Idaho Power Company, 1990). Of that number, 749,000 angler hours were expended during the "summer" months from April 1, 1989 to September 30, 1989. During the summer 52 percent of the anglers were from Idaho, primarily the southwestern part of the state (21 percent of Idahoans were from Boise.) Oregon residents accounted for 42 percent of the summer anglers and came primarily from northeast Oregon.

#### 2.12.2.5 Grand Coulee

The Grand Coulee project is a major attraction to recreational users. Visitation has steadily grown from 519,300 in 1985 to 1,560,000 in 1990. The number of tents and recreational vehicles has also increased from 87,000 in 1985 to 155,700 in 1990. The number of boat launches tripled from 1985 to 1990, 19,300 to 60,100. The most popular sites in 1990 were Kettle Falls (292,000 visits), Fort Spokane (238,000), Spring Canyon (195,800), Seven Bays (162,700), and Keller Ferry (126,900); all of these sites have a number of water-oriented and other facilities.

Seasonal use is greatest during the summer. In 1990, there were approximately 156,000 visits in May and almost the same number in June. In July, the number increased to 306,900, and by August, it was 318,700. The number of visits dropped to 103,300 in September and continued to decline to a low of 24,800 in February. The number of visits closely parallels the pool elevation of the reservoir. The reservoir normally reaches full pool in July and remains within several feet of it through the end of the year. At the beginning of the year, the reservoir is lowered and does not reach an elevation high enough to allow some water-oriented recreational facilities to be accessed until June.

## 2.13 AESTHETICS

The projects addressed in this OA/EIS are located in arid or semi-arid eastern Washington, eastern Oregon, or western Idaho (Figure 2.1-1). In this open and generally dry land, water features attract much attention and are important aesthetic resources. The general character of these resources is summarized below for five broad units spanning the lower Columbia River, lower Snake River, Dworshak, Brownlee, and Grand Coulee project areas.

### 2.13.1 Aesthetic Resource Characteristics

#### 2.13.1.1 Lower Columbia River

The lower Columbia River landscape unit extends from the Columbia Basalt Plain on the eastern end, to the South Cascades physiographic province at the western end (Galster et al., 1989). The unit is characterized by the high, steep, side walls of the Columbia Gorge. On the Oregon side, these walls have sheer cliffs, tree-covered slopes, and numerous waterfalls in the Bonneville area west of Hood River. The spectacular setting was the key reason the Columbia River Gorge National Scenic Area was established (Figure 2.13-1). The wetter western part of the unit is heavily forested and included in the Douglas-fir/western hemlock association. East of Hood River, the landscape becomes more arid and transits from the Douglas-fir/Oregon white oak association to steppe (with and without stagebrush) vegetation zones (Franklin and Dyrness, 1973; Payne et al., 1976). Land on the Oregon side of the unit is mainly publicly owned and is less intensively developed than the primarily privately-owned Washington side. Land use along the lower Columbia River is varied and includes agricultural, forestry, recreational, port, industrial, fish and wildlife conservation, residential, and commercial development. Several towns are located on benches adjacent to the river or on top of the nearby bluffs. Visual and physical access to the unit is plentiful as a result of major state and interstate highways that follow the Columbia River, towns located adjacent to the river, and a number of recreational access points and parks.

#### 2.13.1.2 Lower Snake River

The lower Snake River passes adjacent to and through the Blue Mountains and Columbia Basalt Plain physiographic provinces (Galster et al., 1989). Vegetation types include the shrub steppe, Ponderosa pine and Idaho white pine series (Franklin and Dyrness, 1973; Daubenmire and Daubenmire, 1984). The western end of the unit near Ice Harbor Dam is composed of low hills covered with steppe vegetation. Upstream, the side walls of the river valley become steeper as the river passes through a high canyon that varies in depth from 200 to 2,000 feet. The steep, rugged buttes and canyon walls framing the river are the

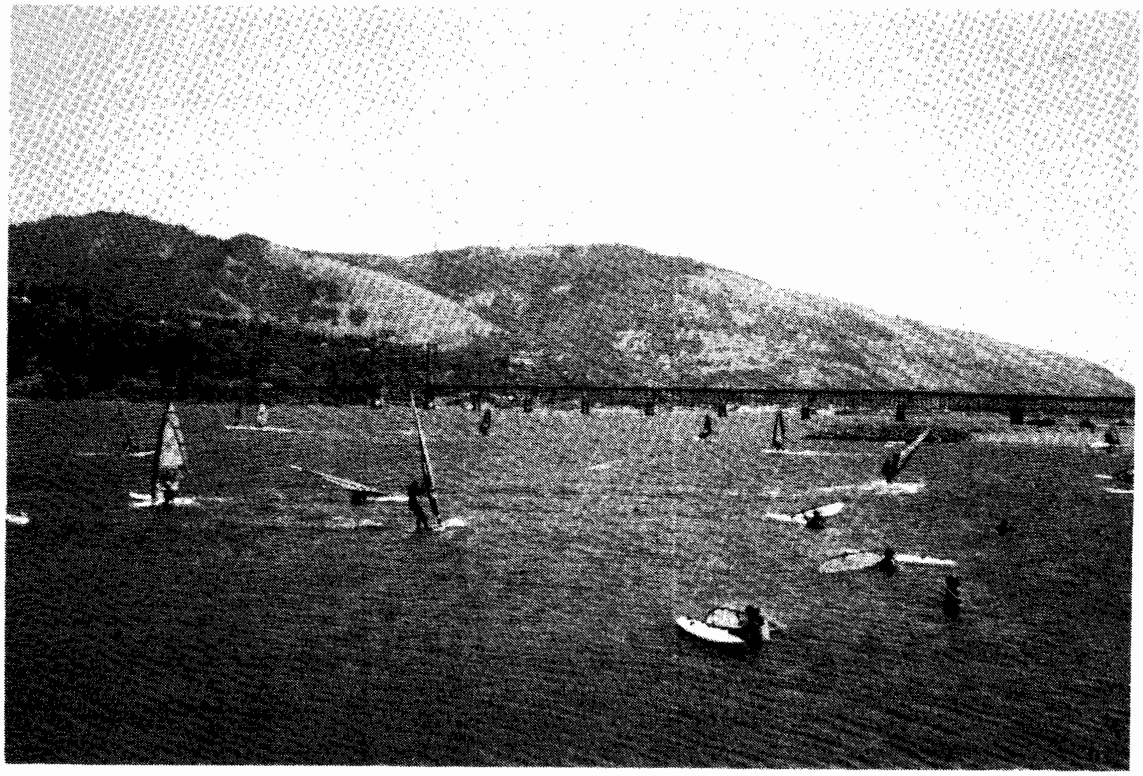


**Figure 2.13-1.** Columbia River landscape unit (looking upstream [east] on Lake Bonneville from Columbia Gorge Sail Park in Hood River, Oregon).

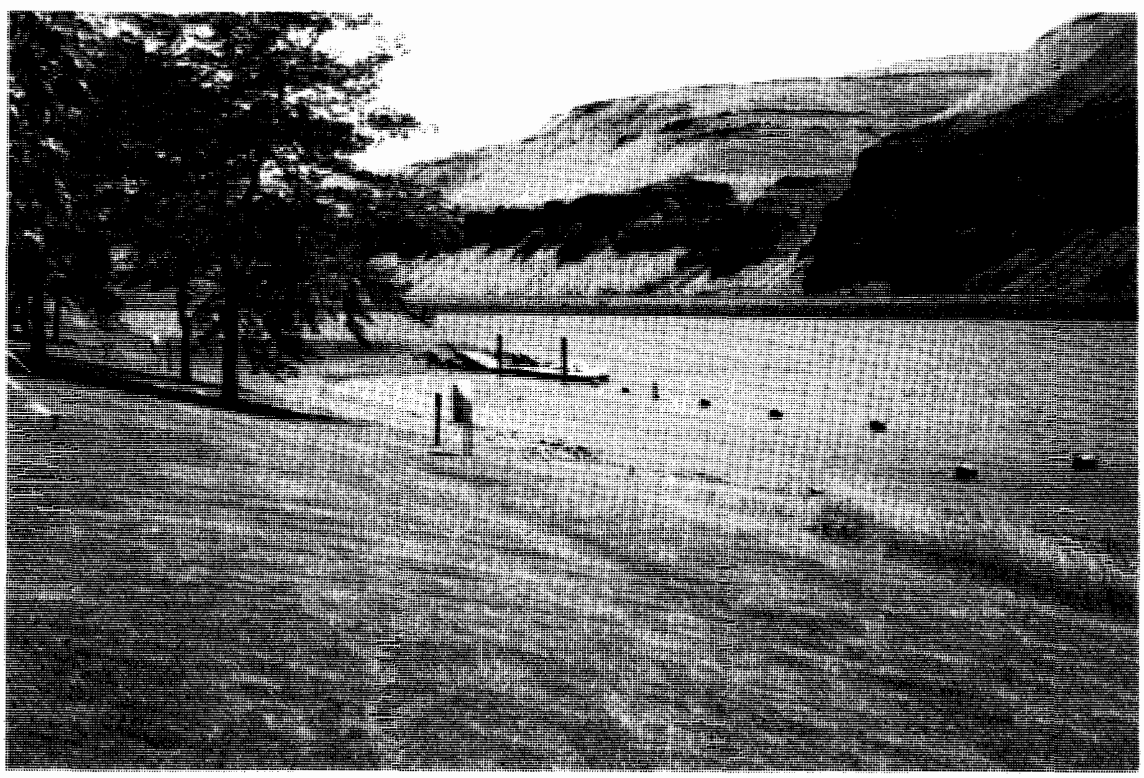


**Figure 2.13-2.** Snake River landscape unit (looking upstream [east] at Winddust Park swimming beach on Lake Sacajawea).

dominant landscape features of the unit (Figure 2.13-2). Land use in the unit is varied. Near and adjacent to the river are agricultural uses, port facilities, residential and recreational developments. Development near the river is fairly intense at the eastern and western ends (Lewiston-Clarkston and the Tri-Cities, respectively). Parks, marinas, and housing developments adjacent to the river create a suburban/urban character in places. In contrast, the more remote interior portion is less developed and relatively difficult to access.

### 2.13.1.3 Dworshak Reservoir

Dworshak Reservoir is located in the North Fork of the Clearwater River valley in the foothills of Idaho's Bitterroot Range, which is a branch of the Rocky Mountains. The reservoir winds its way through remote, hilly terrain covered with coniferous forests (see Figure 2.13-3). The coniferous forests are included in the white pine belt and are composed of mixed stands of white pine, Douglas-fir, Engelmann spruce and western red cedar (Franklin and Dyrness, 1973; Daubenmire and Daubinmire, 1984). Access to Dworshak is limited though most commonly achieved via U.S. Highway 12 near Orofino, Idaho. Other routes include local and county roads, most of which are gravel or dirt. Land uses adjacent to the reservoir include forestry, recreation, power generation operations, industry, fish and wildlife management, and public port; forestry is the primary use and occurs on private and public land. The USFS, Bureau of Land Management (BLM), Idaho State Land Board, Burlington Northern Railroad, and the Potlatch Corporation are the major owners and managers of adjacent lands.

### 2.13.1.4 Brownlee Reservoir

Brownlee Reservoir is located upstream from Hells Canyon National Recreation Area between the Blue Mountains in Oregon and the Seven Devils in Idaho. The sides of the narrow v-shaped canyon are extremely steep and high. The slopes are generally covered with grasses and sagebrush, and the steep canyon walls are the dominant landscape feature (Figure 2.13-4). The BLM and the USFS manage much of the land adjacent to the reservoir. There are also parcels in the southern, more agricultural area that are privately owned. Additional adjacent land use includes livestock grazing, ranching, recreation, and scattered rural residential (BPA, 1985). Access to the north end of the project and the dam is via Idaho Route 71 or Oregon Route 86. South from the dam, access is restricted to a gravel road (Snake River Road) on the west side of the valley. It can only be reached from the north by State Route 86 near the Brownlee Dam or via Richland, Oregon. The southern end terminates near Interstate 84, approximately 15 miles east of Weiser, Idaho. The narrow, winding, steep road is approximately 42 miles from the Brownlee Dam and is travelled primarily by recreational users during the times of the year it is open.

### 2.13.1.5 Grand Coulee

Lake Roosevelt passes through the Okanogan Highlands and Columbia River Basin physiographic zones as it follows the ancient bed of the Columbia River north to Canada (Galster et al., 1989). The four major vegetation zones that are found along the terrain adjacent to Lake Roosevelt include steppes with and without sagebrush, Ponderosa pine forests, and a mixed zone of Douglas-fir and grand fir (Franklin and Dyrness, 1973; Payne et al., 1976). Despite the presence of buttes and steep mountainous terrain, the 0.5- to 1-mile-wide lake is Grand Coulee's dominant landscape feature (Figure 2.13-5). The Colville National Forest and Colville Indian Reservation border most of the west side of Lake Roosevelt. With the exception of several small communities such as Grand Coulee, Hunters, and Kettle Falls, the landscape of the forest and reservation is relatively natural and undeveloped. North of the confluence of the Spokane River is the Spokane Indian Reservation, which also has a predominantly natural character. On the south side of the reservoir between the Spokane River confluence and Grand Coulee, the land is largely privately owned. Orchards and other agricultural lands are located in several places on the bluffs and benches above the river. Physical and visual access to Lake Roosevelt is gained from local communities, developed marina facilities, and campgrounds. Local roads, state highways 25 and 174, and U.S. Route 2 also provide views of the lake.



ACOE/1-4-92/18:54/02123A

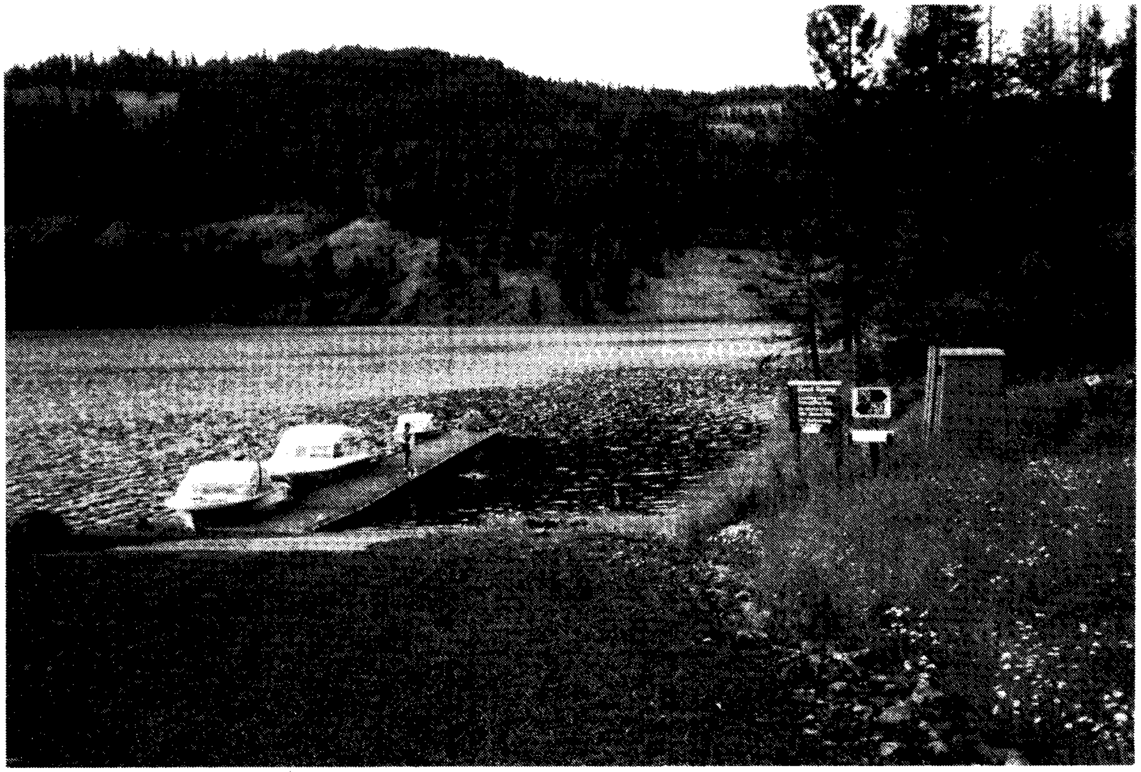


**Figure 2.13-3.** Dworshak landscape unit (looking north at Canyon Creek recreation facility boat ramp).

**Figure 2.13-4.** Brownlee landscape unit (looking east from Snake River Road at informal boat launch).

Figure 2.13-5. Grand Coulee landscape unit (looking west from Seven Bays Marina).

### 2.13.2 Existing Reservoir Visual Conditions

#### 2.13.2.1 Run-of-River Reservoirs

Run-of-river projects such as those on the lower Columbia and Snake rivers have limited storage capacity and tend to fluctuate daily and weekly, rather than seasonally as do storage reservoirs. Pool fluctuations at Columbia and Snake run-of-river projects currently range between 3 and 5 feet on a weekly basis. A 3- to 5-foot pool elevation change is not a significant visual event along most of the lower Columbia and Snake project shores for several reasons. Most of these reservoirs lie in relatively steep, narrow river valleys that have been largely inundated by project pools. The shorelines adjacent to the pools are generally steep, so that for every unit of vertical distance a pool drops, there is a correspondingly small amount of horizontal shoreline exposed (the opposite is true in shallow conditions). Therefore, steeper project shorelines are less visually affected than flatter shorelines. In project areas where the pool is adjacent to railroad or highway embankments, fluctuations are often not noticeable because of the steepness of the embankment slopes and the riprap armament on the embankments. The texture and color of the riprap is consistent at different levels of the embankment, so fluctuations in pool levels do not create much visual contrast.

Areas of more open, less steep terrain are more affected by drawdowns. In such terrain, every vertical unit of shoreline exposed is associated with several horizontal units of exposure. At the lower Snake and Columbia projects, those conditions typically occur where there are flat and low-lying benches adjacent to the river, at embayments, near islands, and where side canyons enter the main river valley. Because these areas are relatively flat and accessible, these are often areas where recreation, transportation, and other types of development have occurred. As a result, riverbeds that are exposed at low-pool elevations in areas that receive heavy recreation, transportation, or other uses are easily observed. At Bonneville, riverbed areas exposed at low-pool elevations that are visually accessible include shallow riverbeds and embayments near Stevenson and Home Valley, Chamberlain Lake, and shallow riverbeds and islands near Hood River and Mosier. Comparable areas at The Dalles include Horsethief Lake, the riverbed around Brown's Island, the mouth of the Deschutes River, and the area on both sides of the river between Biggs and John Day dams. Similar conditions on the John Day Pool occur near Quesnel, Roosevelt, Three-mile Canyon, Crow Butte, Umatilla, Plymouth and the numerous islands and embayments of Umatilla National Wildlife Refuge. McNary has a similar situation, with shallow riverbeds near Wallula, Villard Junction, Burbank, and Casey Pond, various embayments adjacent to the river, and much of the Snake riverbed between Strawberry Island and Ice Harbor Dam.

Riverbeds that are exposed under normal operating conditions at low-pool elevations and are easily observed on Snake River projects include Lyons Ferry State Park and the mouth of the Tucannon River at Lower Monumental; the Meadow Creek embayment and Deadman Creek at Little Goose; and Chief Timothy State Park, shallow riverbeds near Wilma, Lewiston, Clarkston, and Asotin Marina at Lower Granite.

The majority of project users and viewers probably find the reservoirs and recreational facilities more aesthetically pleasing at full pool. However, because of the relatively insignificant elevation changes (3 to 5 feet) that occur with current operations and the short cycle of pool fluctuation, the visual evidence of normal pool fluctuation is probably not very noticeable to the casual viewer.

#### 2.13.2.2 Storage Reservoirs

Drawdowns are much greater at the three storage reservoirs. With pool fluctuation ranging from 30 to 155 feet, a significant amount of shoreline is exposed annually at Dworshak, Brownlee, and Grand Coulee. Exposed shoreline in the storage projects contrasts significantly in color and texture with the adjacent uplands, particularly where there is adjacent dark green shrub and tree cover such as at Dworshak and much of Grand Coulee. Low pool elevations typically are reached in April and refilling does not take place until late June or early July. These reservoirs are generally maintained at high levels throughout the remainder of the summer.

### 2.13.3 Potential Viewers and Viewing Patterns

People viewing a resource will have different perceptions of the resource based upon several factors. Categorizing major user groups by factors that influence perception is a useful way to differentiate groups of viewers with different levels of sensitivity to existing and changing aesthetic situations (Federal Highway Administration, 1983).

The three viewer groups identified and discussed in this OA/EIS are highway travelers, recreational users, and local residents. Highway travelers include people in transit, simply passing by a project, or people sightseeing. Highway travelers tend to view the projects from a distance, for a short time while traveling at high speeds, and thus may not be strongly affected by project operations. Recreationists, on the other hand, tend to view projects for a longer time at close range. Project operations can have a more direct effect on their viewing opportunities and experiences. Local residents may view projects from various roles, such as property owner, recreationist, or simply as they go about their everyday business. Their individual exposures to project visual changes may be brief but would likely occur repeatedly over long periods.

The number of each type of viewer and the total number of potential viewers varies tremendously among projects. The potential of viewer exposure to project operational changes is greatest at Bonneville, which is paralleled on both sides by major highways carrying millions of travelers every year. Bonneville also is close to the Portland metropolitan area and attracts heavy recreational use (over 3 million visitors in 1989), and has a significant residential population within viewing distance. Other projects, such as Lower Monumental are more remote with few nearby residents, limited highway and comparatively little recreational development.

Driving for pleasure and sightseeing are popular recreational activities at most of the projects. These potential viewers can be assumed to be relatively sensitive to visual quality. The percentage of drivers on nearby highways engaged in sightseeing or driving for pleasure is unknown, but is likely to be a substantial minority during the warmer months of the year when recreational travel is most common.

Quarterly breakdowns of annual traffic counts for highways near projects can give a rough idea of the seasonality of potential viewer patterns. Highway traffic counts near three of the projects were examined to review seasonal patterns (Table 2.13-1). The highways examined were Interstate 84 near Rowena, Oregon (adjacent to the Bonneville project); SR 14 near Maryhill, Washington (adjacent to The Dalles project); and U.S. Highway 395 near Kettle Falls, Washington (which crosses Lake Roosevelt). By quarter, the percentage of annual traffic did not vary substantially among the three locations. In each case, summer traffic had the lightest quarterly percentage, at 30 to 32 percent of the annual total. The spring and fall quarter percentages consistently ranged between 24 and 27 percent. In general, these figures indicate that highway travel is more evenly distributed throughout the year than recreational use in most cases. Seasonal recreational use patterns for four selected projects were previously indicated in Figure 2.12-4.

Average recreational use at all four projects increased steadily from February and reached a peak in the summer. July, August, and September were the three most popular months, accounting for 50 percent or more of annual visitation. Grand Coulee and Dworshak received from 40 to 50 percent of their annual visits in only two months, July and August. Bonneville and John Day exhibited a similar summer concentration, although more use occurred in spring and fall at these projects.

Local residents view projects on a year-round basis. The projects with the largest populations and greatest number of potential viewers are run-of-river projects on the lower Snake and Columbia rivers, primarily Bonneville, The Dalles, and Lower Granite. Because the mainstem pools regularly fluctuate from 3 to 5 feet, local residents do not view exposed shorelines for long periods. The relatively small numbers of people who live near the storage reservoirs, view the full aesthetic effects of the large seasonal drawdowns.

## 2.14 CULTURAL RESOURCES

Human occupation of the study area dates back over 10,000 years. Identified cultural resources, both prehistoric and historic, are representative of the total span of human use and occupation of the area. They include villages, fishing sites, trading posts, camp sites, agricultural and industrial communities, railroads, burial sites, homesteads, canneries, mining sites, and military forts.

The following section discusses the kinds of cultural resources that have been recorded along the lower Snake and Columbia rivers, and at the Dworshak, Brownlee, and Grand Coulee projects.

### 2.14.1 Lower Snake River and Dworshak

The following cultural resource information for the four lower Snake River run-of-river reservoirs and Dworshak Reservoir is based on the Corps cultural resource management plan for these five projects.

During the earliest period of human occupation (10,000 to 8,000 years before the present time [BP]), people are believed to have foraged for a wide variety of food resources located in different topographic zones. The next period (8,000 to 4,500 years BP) witnessed a warming trend and an economic shift toward more use of plant foods and aquatic resources including salmon and freshwater clams. From 4,500 to 2,500 years BP, area people gathered into pit house (a semi-subterranean dwelling) villages and intensified the use of plant foods and river clams. From 2,500 to 250 years BP, the number of pit house village sites expanded as did the use of salmon and plant foods. The bow and arrow was also introduced during this time. The last 250 years coincide with the historic and ethnographic period from the acquisition of the horse in the early eighteenth century by native peoples to their relegation to reservations in the late nineteenth century and the settling of the area by Euro-Americans.

Ethnographically, the area was occupied by numerous aboriginal bands who spoke the Sahaptin language. They lived in villages along intermediate and master size streams. Temporary camps were also used but only for short periods and special purposes. Political organization consisted of loosely associated groups of separate bands, each

**Table 2.13-1. Seasonality of potential viewers from selected highways.**

| | Winter (Dec-Feb) | Spring (Mar-May) | Summer (Jun-Aug) | Fall (Sept-Nov) |
|---|---|---|---|---|
| 1. Percentage of Annual Traffic Flow on Interstate 84 at Rowena, OR | 19 | 24 | 31 | 26 |
| 2. Percentage of Annual Traffic Flow on SR 14 at Maryhill Spur, WA | 16 | 27 | 32 | 25 |
| 3. Percentage of Annual Traffic Flow on US 395 at SR 25 junction north of Kettle Falls, WA | 21 | 25 | 30 | 24 |

Sources:

a/ National Park Service, 1990.
b/ Personal communication, C. Pietrok, Oregon Dept. of Transportation, August 1, 1991.
c/ Washington State Dept. of Transportation Summary of Traffic Records R071 in 1990.
d/ Washington State Dept. of Transportation Summary of Traffic Records R071 in 1984.

with its own territory and headmen. These bands shared similar customs, language, some subsistence activity sites, and associated for mutual defense, but remained fairly distinctive otherwise. Food resources consisted of various species of fish (primarily salmon and steelhead), plants, and animals collected within an annual subsistence round based on the time of year when each food source was available. With the introduction of the horse in the mid-1700s, the range of trade and subsistence rounds for some bands (e.g., Nez Perce) greatly increased. Bison-hunting on the Plains became an annual or frequent activity which also resulted in elements of the Plains culture being introduced into the Plateau area.

The historic period began with the arrival of the Lewis and Clark expedition in 1805. This was followed by other expeditions which further explored the region and established trading operations. Missionaries arrived in the 1830s, soon to be followed in the 1840s by increasing numbers of settlers coming west. In 1855, a treaty between the United States and many of the Plateau Indian groups was signed establishing area reservations. Gold was discovered in the 1860s in Idaho leading to a rush of people into the area and further settlement. This was also the era of the steamboat. The 1880s brought construction of railroads and continued settlement. The 1900s has seen the damming of the Snake River, the development of major irrigation projects, and continued growth in the region.

A total of 289 known archaeological sites are located within the four lower Snake run-of-river reservoirs (Lower Granite - 136; Little Goose - 76; Lower Monumental - 42; and Ice Harbor - 35), and 210 within the Dworshak Reservoir. The sites are both prehistoric and historic and range in age from the earliest period of human occupation to recent times. At present, three archaeological districts (Lower Snake River, Windust Caves, and Palouse Canyon) and three sites (Strawberry Island, Marmes Rockshelter, and Hasatino) listed on the National Register of Historic Places (NRHP) are located within the boundaries of these projects. In addition to NRHP status, Marmes Rockshelter located within the Lower Monumental Reservoir also is a designated National Historic Landmark.

## 2.14.2 Lower Columbia

The Corps cultural resources management plans for the four projects along the lower Columbia provide the basis for the information that follows.

Development along the lower Columbia River largely parallels that of the lower Snake River during most of the 10,000 years of occupation. Ethnographically, from The Dalles Reservoir downriver, certain differences from the sites upriver can be found, including dwellings constructed of wood (planks, poles, and bark), heavy reliance on salmon as a food resource, extensive use of dugout canoes, above-ground burials in special structures at centuries-old cemeteries, and use of the Chinookan language. Other than these characteristics, the development of the lower Snake River area parallels the lower Columbia River.

There are a total of 424 known archaeological sites within the four Corps reservoirs on the lower Columbia River (McNary - 124; John Day - 224; The Dalles - 56; and Bonneville - 20). There are two historic properties on the National Register of Historic Places on the Bonneville Pool—the Bonneville Dam Historic District and the North Bonneville Archaeological District. There is also a listed historic property on the John Day Pool—the John Day Archaeological District.

### 2.14.3 Grand Coulee

The following information on Grand Coulee cultural resources is taken from Masten et al. (1986), data collected during excavations for the Chief Joseph Dam Cultural Resources Project for the Corps of Engineers, excavations in the Kettle Falls vicinity conducted for the BoR and the General Management Plan for Grand Coulee National Recreation Area (NPS, 1980).

Archaeological investigations at Kettle Falls and Rufus Woods Lake indicated that the Grand Coulee vicinity has been continuously occupied for at least 7,000 years. Prehistoric populations were semi-sedentary hunters and gatherers who used locally available natural resources from the river flood plain and adjacent uplands, as well as more removed upland areas. The riverine zone was the most intensively used; base camps were maintained there from which smaller groups traveled to collect resources available elsewhere. By 5,100 years before present, occupants constructed substantial semi-subterranean pit houses and processed and stored foods for winter consumption.

At the time of Euro-American contact, the upper Columbia River was occupied by bands speaking the Salish language. Ethnographic studies of the San Poil and Nespelem, who occupied the area, indicated they were semi-sedentary hunters and gatherers who occupied permanent winter villages along the Columbia River and its major tributaries. In the spring through fall, groups of people moved between temporary camps from which small game was hunted, shellfish gathered, and edible roots procured. In 1872, the Colville Indian Reservation was established.

In the early 1800s, the first Euro-Americans entered the area. The Hudson Bay Company established Fort Colvile at Kettle Falls in 1823, and a Catholic mission was established nearby in 1847. Few Euro-Americans resided in the area until the 1870s and 1880s when ranchers started to arrive. In 1882, Fort Spokane, a military post, was built at the confluence of the Spokane and Columbia rivers. More intensive homesteading did not occur until the early twentieth century. Construction of Grand Coulee Dam began in 1933, bringing large numbers of people into the area.

As a result of archaeological investigations, about 300 prehistoric and historic archaeological sites around Lake Roosevelt and an additional 26 sites immediately downstream of Grand Coulee Dam have been recorded. An additional 177 sites have been reported in ethnographic sources, and historic maps and records indicate the locations of an additional 31 unrecorded historic sites. Segments of the reservoir shoreline have never been subjected to systematic survey and, most likely, contain additional unrecorded resources. Prehistoric site types recorded included large villages, smaller habitation sites, activity-specific resource procurement/processing sites, cemeteries, and isolated burials. Small habitation sites are the most common type recorded, many of which appear to have human burial components. Historic site types include homesteads, mines, and towns. Fort Colvile and St. Paul's Mission are maintained by the NPS as interpretive sites and are listed on the NRHP. Twenty prehistoric sites at Kettle Falls have been listed on the NRHP as a National Historic District. Sites below Grand Coulee Dam are included in the Rufus Woods Lake National Historic District. Most other recorded sites around the reservoir have been insufficiently studied to determine if they are eligible for the NRHP.

Although numerous sites have been inundated by the reservoir, clearly many scientifically and culturally significant sites remain within the drawdown zone and around its shoreline.

The Spokane Reservation and the Colville Reservation, adjoining Lake Roosevelt in the State of Washington, are occupied by the Lower Spokane and the eleven Confederated Tribes of the Colville, which includes the Colville, Lake, Nez Perce, Chelan, Methow, Nespelem, Northern Okanogan, San Poil, Sinkaietk, Sinkauise, and Wenatchi tribes. These peoples are part of the Columbia Plateau Culture Area and represent a vital link to the cultural and historic values in the region.

### 2.14.4 Brownlee

Historic and archaeological resources in the Snake River Canyon area that includes the Brownlee Reservoir are of major significance in defining and understanding the cultural history and way of life of people in the region over the last 8,000 years. Site types and themes include prehistoric sites as well as historic Chinese settlements, mining, transportation, ranching, homesteading, and Native American and Euro-American contacts.

Prehistoric site types include pithouse villages, seasonal campsites, rock cairns, pictographs, petroglyphs, fish walls, and sweat lodges. The prehistoric cultural resources of the Snake River Canyon provide a valuable perspective relating to the adaptation and movement of prehistoric populations; the diffusion of cultural traits and elements between the Great Basin, Plateau, and Plains cultural areas; the development of Plateau culture; and the development and changes in Nez Perce subsistence and social patterns over time.

Currently, there are 13 prehistoric sites and 7 historic sites inundated or located between high- and low-pool elevations in the Brownlee Reservoir. A complete inventory of historic or prehistoric sites has not been conducted in the reservoir area.

## 2.15 SOCIOECONOMICS

The socioeconomic influences of the proposed actions will be felt primarily within the communities along the Columbia-Snake River System, in nearby upland areas that draw water supplies from the rivers, and in more extensive commodity production areas that rely on the rivers for transportation. These use relationships define a primary influence zone that can extend up to 30 or 40 miles on either side of the river system. For analytical purposes, the socioeconomic study area for this OA/EIS was defined to include all counties that are adjacent to the 11 projects that could be involved in the proposed actions. The study area therefore incorporates the Washington and Oregon counties along the Columbia River from Bonneville to the Snake River confluence; all of southeastern Washington; the northeastern Washington counties adjacent to Grand Coulee; and seven Idaho counties surrounding Dworshak, Brownlee, and downstream reaches of the Clearwater and Snake rivers.

The majority of the study area is sparsely populated and urbanization ranges from small, rural economies to a major metropolitan area. Part of Portland in Multnomah County, Oregon lies in the western reach of the study area. The land use in this area is heavily urbanized, with major port facilities and heavy and light manufacturing activity. Farther east, the Columbia River becomes a series of slack water pools as it traverses a broad canyon through the plateau country of Oregon and Washington. Land use in this stretch is predominantly agriculture and open space, with large farms prevalent and population centers widely dispersed. The eastern region of the study area, which extends into western Idaho, is largely rural with agriculture and forest products as the primary industries. The local economies in the study area have a strong orientation to the river system. It is not only a source for farmland irrigation and transportation for agricultural and timber products but also is an attraction for recreational users, another primary activity generator in the region. [For a complete inventory of land use in the study area, the reader is referred to the Columbia Basin Water Withdrawal Environmental Review, Appendix A: Land Use (Corps, 1979), which is hereby incorporated by reference.]

The key socioeconomic factors of population characteristics, employment by industry, unemployment, and income measures for these counties are presented below.

### 2.15.1 Population

The total population of the study area in 1990 was 1,215,938. Multnomah County, Oregon, which contains part of the Portland metropolitan area, accounts for almost half this figure with a population of 583,887. In addition to Multnomah County, the larger, more urbanized counties in the study area include Benton (112,560), Grant (54,758), and Walla Walla (48,439) in Washington, and Umatilla (59,249) in Oregon. Of the remaining 25 counties, 12 have populations between 10,000 and 40,000, and 13 have populations of fewer than 10,000 persons. The general population trend in the Pacific Northwest has been away from rural areas toward those more urbanized.

Appendix I displays comparative population data for each county within the study area and total population for the states of Washington, Oregon, and Idaho for 1970, 1980, and 1990. These states experienced respective population growth rates of 17.8 percent, 8.0 percent, and 6.7 percent between 1980 to 1990. Although the population is still growing, the 1980 to 1990 growth rates are significantly lower than those during the previous decade in which Washington's population grew by 21.1 percent, Oregon's by 25.9 percent, and Idaho's by 32.4 percent.

The study area population growth patterns generally mirrored those of the states—high growth rates during the 1970s and slowed growth or actual decline during the 1980s. During the 1970s, counties exhibiting extremely high growth rates included Benton, Ferry, and Stevens Counties in Washington with respective rates of 62.0 percent, 59.0 percent, and 66.5 percent; and in Oregon, Morrow and Umatilla counties with growth rates of 68.4 percent and 31.0 percent, respectively. Only 4 counties in the study area experienced an actual decline in population during this same period; these were Columbia and Garfield in Washington; Gilliam in Oregon; and Clearwater in Idaho.

The population in the study area did not thrive in the 1980s as it had in the previous decade. During this period, none of the counties experienced population growth greater than the state average growth rates. Almost half of the counties experienced a decline in population and only one, Grant County, Washington, had population growth greater than 10 percent. The counties which experienced decline or slowed growth were the smaller, rural areas, while the larger, more urbanized counties were among those that showed consistent growth.

## 2.15.2 Employment

Appendix I presents non-agricultural wage and salary employment by industry for the study area counties in 1990. Reliable agricultural employment data are difficult to obtain and could not be included. In addition, 1990 employment by industry and unemployment data for particular counties in Idaho and Multnomah County, Oregon, were not available in time for this OA/EIS.

Total county non-agricultural employment ranged from a low of 510 employed persons in Gilliam County, Oregon to a high of 62,000 employed in the Benton/Franklin counties area of Washington. The government sector (with an employment share range of 16 to 65 percent) provided the largest share of total employment for all but 6 counties in the study area. Wholesale and retail trade provide the largest share of total employment in Asotin (31 percent), Hood River (28 percent), Malheur (33 percent), and Nez Perce (25 percent) counties. In Benton/Franklin and Morrow counties, manufacturing provided the greatest share (23 percent and 38 percent, respectively).

For several counties, food processing companies are significant employers within the manufacturing industry. In Oregon, food processing accounts for 93 percent of manufacturing employment in Malheur County, 75 percent in Morrow County, and 60 percent in Umatilla County. Similar figures in Washington are 76 percent in Grant County and 53 percent in Walla Walla County. Transportation and public utilities (TPU) provide a relatively small share of total non-agricultural employment in the study area. The greatest share is in Payette County, Idaho, where TPU accounts for 12 percent of total employment; however, the remaining counties have TPU shares in the range of 0 to 6 percent.

All counties in the study area for which unemployment statistics were available experienced a decline in the unemployment rate from 1986 to 1990. However, relative to the statewide unemployment rates for those years, the study area experienced higher unemployment. Only 5 of 30 counties had unemployment rates below the corresponding state level in 1986 compared to 8 of

27 counties in 1990. The relatively low-unemployment counties were Asotin, Garfield, Lincoln, and Whitman in Washington; Gilliam, Malheur, and Multnomah in Oregon; and Nez Perce in Idaho. The lowest 1990 unemployment rate in the region was 2.2 percent in Whitman County, which typically has one of the lowest rates in Washington. The highest unemployment rate in the region for 1990 was 16.0 percent in Skamania County, an area of chronically high unemployment.

### 2.15.3 Income

A common income measure used in describing the relative wealth or well being of an area is per capita personal income (PCPI). In 1989, only two counties in Washington exceeded the state PCPI of $17,696. Garfield and Lincoln counties had respective income levels of $21,190 and $21,792. Six counties in Oregon exceeded the state average of $16,003; these were Gilliam, Morrow, Multnomah, Sherman, Wallowa, and Wasco. Sherman County had by far the highest 1989 PCPI of any county in the study area ($24,474 or 153 percent of the overall Oregon income level). In Idaho, Adams, Lewis, and Nez Perce counties exceeded the state PCPI of $13,760.

### 2.15.4 Key Resource Users

The Columbia-Snake River System provides a variety of resources for public and private use. Key resource users include transportation, logging, agriculture, electric power, and recreation.

The 465-mile waterway represents a key link to the eastern interior region, providing barge transport from the Pacific Ocean to Lewiston, Idaho, the most inland port (see Section 2.9). The transportation system consists of navigation channels and locks, port facilities, and shipping operations. The channels are maintained at authorized dimensions by the Corps, and locks on the mainstem dams provide hydraulic lifts for barge access. Six barge companies operate approximately 40 towboats and 175 barges on the Columbia-Snake River System. Fifty-four port facilities and shipping operations provide transport for the various agricultural and timber products produced in the region.

Logging activity in the study area is localized around the Dworshak project, where the lake provides the best means of transporting timber to market. Dworshak Reservoir is used to transport approximately 20 million board-feet per year of logs to the damsite.

There are approximately 2.8 million acres of cropland in the study area, 720,800 acres of which are irrigated (see Section 2.10). Of this total, 380,000 acres are irrigated from the Columbia and Snake River Pools. Overall, the two primary irrigated crops are hay and wheat, which are valued at $200 to $550 per acre per year. Potatoes and other vegetable row crops grown in the area are valued at $1,500 to $3,800 per acre per year. These and other crops produced through irrigated farming are sold to markets throughout the country and provide substantial revenue to the region. Total value of crops produced from irrigated lands in the study area exceed $263 million (see Section 4.8.3). In addition, farm operations benefit from the relatively inexpensive power provided by the Columbia-Snake River System hydroelectric projects, spending an average $75 per acre per year for electricity to operate irrigation pumps. Large irrigators expend over $1 million per year for electricity (see Section 4.8.2).

The Columbia and Snake rivers are heavily developed for hydroelectric power generation (see Section 2.11). All 11 dams have hydroelectric facilities, which collectively provide an installed capacity of 17,904 MW (45 percent of the hydroelectric resources in the Columbia River Basin).

The reservoirs and adjacent lands of the Columbia-Snake River System provide important recreational resources (see Section 2.12). A total of about 150 sites offer opportunities for boating, swimming, fishing, water skiing, windsurfing, camping, and picnicking. The projects generally are heavily used for recreational purposes, with a total of 14 million recreation days reported on the 11 study area pools. Visitation levels range from a high of about 3 million recreation days per year at Bonneville to a low of 84,000 annual recreation days at Lower Monumental (see Table 2.12-2).

In addition to irrigation of agricultural land, water pumped from the Columbia-Snake River System is used for other purposes as well. Of the 22 non-agricultural water users interviewed, 4 were municipal/industrial users, 7 were recreation-related, 8 were HMUs, and the remaining 3 were residential users who draw water for their lawns and other uses. Municipal users draw from the pools to contribute to the jurisdictions' water supplies. Industrial users, such as Potlach Corporation in Lewiston, incorporate water into their treatment process during production. Recreation-related users include country clubs, which use the water to irrigate golf courses, and various state and county parks, which use the water for irrigation and other water supply. HMUs draw water for maintaining preservation areas.

Municipal and industrial water withdrawals from the river system are concentrated on or near the Lower Granite and McNary pools. Water users withdrawing directly from these pools include the cities of Richland, Kennewick, and Pasco and industrial firms nearby. The City of Lewiston and the Potlatch Corporation have water supply intakes on the Clearwater River above Lower Granite Pool.

The extremely short timeframe for conducting this study and the size of the study area prevented a thorough analysis of individual ports. However, survey data from a Port of Whitman County study provides general information regarding firm activity. Twenty-one of the 24 firms located on or near the Port of Whitman were interviewed with regard to employment, wages, and probable impacts of river drawdown (personal communication, K. Casavant, November 1991). The 21 firms employ about 705 people, 80 percent of whom work at facilities located directly on the river. The average wage bill is $225,000 per firm with a total wage value of $4.3 million. Of the firms interviewed, 11 to 15 indicated that they would be forced to leave their location under a long-term drawdown.

## 2.15.5 Indian Fishing Rights

Native Americans have fished, camped, and lived on the shores of the Columbia River for centuries. Salmon play an important role in the lives of these Native Americans, not only as a food source but also as part of their culture and religious beliefs. In 1939, after completion of the Bonneville Dam, an understanding was reached between various Native American tribes and the Corps that provided lands to compensate for those flooded by the dam. Five sites, known as in lieu sites, were acquired and transferred to the Bureau of Indian Affairs (BIA). These five sites are:

Wind River (23.6 acres)
Cooks Landings (also known as Little White Salmon site; 3.14 acres)
Underwood (also known as Big White Salmon site; 4.19 acres)
Cascade Locks (1.6 acres)
Lone Pine (9.0 acres)

In addition to these in lieu sites, Title IV (Columbia River Treaty Fishing Access Sites) of Public Law (PL) 100-581 authorized the Corps to acquire, develop, and transfer lands along the Columbia River on Bonneville, The Dalles, and John Day pools in support of treaty fishing of four treaty tribes (the Nez Perce Tribe; the Confederated Tribes of the Umatilla Reservation; the Confederated Tribes of the Warm Springs Reservation; and the Confederated Tribes and Bands of the Yakima Indian Nation). A two-phase study is currently underway to address 21 sites under PL 100-581; these sites are known as the Section 401 sites. These are to provide access and facilities in support of treaty fishing use by the tribes. In addition, the law directs the Corps to identify, acquire, and improve six sites adjacent to Bonneville for treaty fishing access and to conduct facility improvements at five existing in lieu sites.

Current fishing techniques are very similar to those practiced hundreds of years ago, although modern equipment has replaced traditional equipment. Fish are taken at or near the Cascade Locks and Lone Pine site by dip-netting from platforms fastened to the steep banks of the river. Active dip-netting sites are concentrated on the Washington shore immediately upstream of Bonneville, but there are also some sites in The Dalles and John Day pools.

Another method used to harvest fish is by setting gill nets with one end secured to the shoreline or buoy and the other end projecting into the river. This method is practiced throughout the three Portland District projects, with operations based primarily at the Underwood, Wind River, and Cooks Landing sites, all in Washington. Some gill netting sites are used primarily for camping during fishing seasons. Boats are launched and moored from these or nearby public launching sites, nets are dried and repaired, and fish are unloaded for transport to local fish buyers or for drying. The fishing season may extend 8 to 9 months for some Native American families. The fisheries are regulated by Federal-State-Indian conservation agreements.

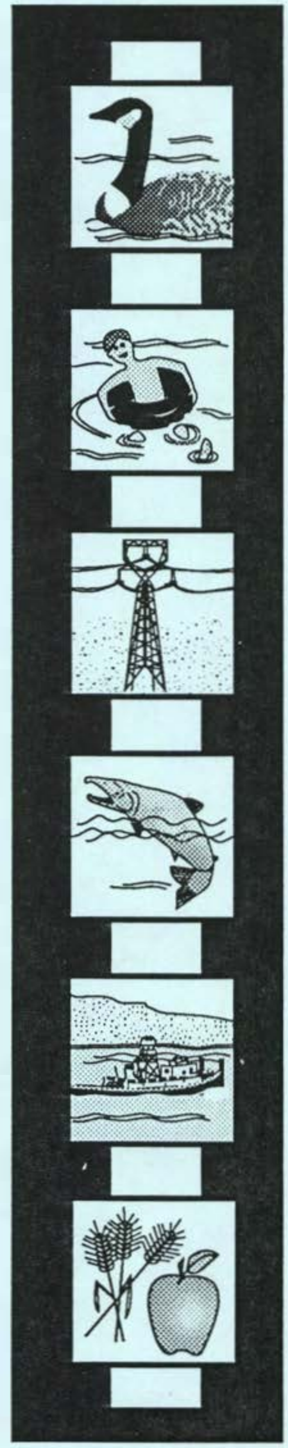
## 2.16 PROJECT STRUCTURES

Structural features of the projects have been described in varying detail in Sections 2.2 and 2.9. Reducing pool elevations below MOP would raise several concerns about the integrity of dam embankments, tailwater stilling basins, bridge abutments, railroad and highway embankments, and levees.

Dams along the Columbia and Snake rivers consist of navigation locks, spillway dams, powerhouse/intake structures, and earth-fill embankments. These features are founded in bedrock, though excavation through surficial sediment was sometimes necessary. The dam embankments are earth-filled, consisting of a heterogeneous mixture of materials from 6 inches in diameter to silt and clay size. The dam embankments are protected by riprap only to MOP. Water that is passed through spillways accelerates greatly, and this energy is dissipated in tailwater stilling basins that were constructed immediately below the spillways.

# 3.0

# Proposed Actions and Alternatives



## 1992 COLUMBIA RIVER SALMON FLOW MEASURES
## OA/EIS

## CONTENTS

CONTENTS (continued)

## TABLES



## FIGURES

CONTENTS (continued)

# 3.0 PROPOSED ACTIONS AND ALTERNATIVES

## 3.1 BACKGROUND

Representatives of the primary river resources in the region came together in 1990 to recommend immediate action to protect declining wild salmon stocks. As presented to the Salmon Summit and in other forums, these recommendations mainly focused on managing river flows to benefit the diminishing numbers of salmon.

Two actions were requested by the governors of Idaho, Oregon, Washington, and Montana and Senator Mark Hatfield of Oregon. The first was for NEPA documentation of sections proposed to improve flow conditions in 1992. This OA/EIS provides the NEPA documentation for the actions requested and those deemed necessary to provide a reasonable range of alternatives. The second request was for the Northwest Power Planning Council to devise long-term strategies to protect key salmon stocks.

The rationale and background for the first request has been addressed in Chapters 1 and 2. The background of the second request is discussed here.

NPPC is charged with preparing a Fish and Wildlife Program for the Columbia River Basin and a regional Electric Power and Conservation Plan, both of which are periodically updated. The NPPC contracted with the region's tribes and fish agencies in 1990 to prepare a plan integrating all of the salmon and steelhead rearing subbasins within the Columbia River System. This includes the lower, middle, and upper mainstem Columbia River, the mainstem Snake River, and 27 major tributaries. The tribes and agencies worked together through their umbrella organization, the Columbia Basin Fish and Wildlife Authority (CBFWA), and devised an "Integrated System Plan." The NPPC stipulated that, in considering its planning goals, the area above Bonneville Dam would have priority (NPPC, 1991a).

The CBFWA proposed a program emphasizing enhanced river flows in the lower Columbia and Snake rivers to increase juvenile salmon survival. The specific flow target recommended for the lower Snake River was 140,000 cubic feet per second (cfs) from April 15 through June 15. This target is considerably higher than the typical flow of about 100,000 cfs at that time of year. The proposal is based on the CBFWA position that downstream migrants are swept along with the river current and their rate of travel is related to water velocity. Velocity, as measured by water particle travel time, is governed in part by the amount of flow in the river (CBFWA, 1991a).

During this same time, Idaho Governor Cecil Andrus proposed the "Idaho Plan," a key feature of which calls for lowering (drawing down) the four lower Snake reservoirs (see below) to increase river velocity equivalent to a flow of 140,000 cfs (140 kcfs) at full pool during downstream migration. This would lower the reservoirs far below current minimum operating levels and significantly affect other river interests. Irrigators and navigators who depend on stable water levels were particularly concerned with the effects of this plan. They proposed more limited flow enhancement options combined with improved habitat, more efficient hatcheries, restricted fish harvests, and improved fish passage facilities at the dams.

The NPPC initially concentrated on habitat and production modifications, while requesting that the Corps and other river management agencies examine flow improvements. The river management agencies developed and considered a number of strategies to modify operation of the river system during salmon migration as documented in this OA/EIS. On December 11, 1991, the NPPC adopted a number of amendments to the Fish and Wildlife Program that included several mainstem survival measures related to river operations. The final OA/EIS has attempted to fully address and coordinate the flow-related elements of the NPPC plan that the river management agencies would need to implement.

## 3.2 ALTERNATIVE ACTIONS

A wide range of potential measures to improve flow conditions during the 1992 salmon and steelhead migration is considered in this OA/EIS. Options available for implementation in 1992 can be grouped into four general alternatives: (1) maintenance of existing conditions ("no action"), (2) reservoir drawdown, (3) flow augmentation, and (4) combination of drawdown and augmentation. The OA/EIS measures the effects of the latter three flow improvement alternatives against the no action alternative (the way the Columbia River System was operated from 1985 through 1990).

Much migration research indicates that survival of juvenile salmonids, particularly those migrating downstream during the spring freshet (streamflow increase from snowmelt runoff) might be related to water flow or velocity (see Section 4.2.1 for details). According to this research, the longer the juveniles remain in the slow-moving reservoirs, the more susceptible they are to predators and other hazards. Furthermore, if they are to survive the transition to saltwater, it is important that they arrive at their saltwater destination when they are physiologically ready for that environment. If the smolts are delayed too long, they might lose their physiological ability to survive in saltwater (although they might smolt again). Thus, the objective of improving flows is to decrease time spent in the reservoirs, and thereby (presumably) increase the survival during downstream migration. If water velocity is increased, smolts should be able to travel downstream faster than has occurred in the past.

Instream velocity can be increased either by reducing the space through which the same amount of water must flow, or by adding water to normal river flow. Reservoir drawdown increases velocity by passing the same amount of water through a smaller cross-sectional channel area. Flow augmentation increases velocity by forcing a greater amount of water through the system.

The overall objective of reservoir drawdown and flow augmentation plans is to reduce water particle travel time. A more specific objective might be to achieve travel times equivalent to those that would be realized if the CBFWA flow recommendations were met. This proposal is discussed in more detail in Section 4.2; briefly, CBFWA has recommended a discharge of 140 kcfs for the lower Snake projects if they are operating in their normal pool fluctuation range. The cooperating agencies have neither adopted nor endorsed the CBFWA proposal as a basis for managing the river system. However, it is a proposal that has widespread recognition within the region, and provides a useful frame of reference and comparison.

In the future, the cooperating agencies will be responsive to the as yet undeveloped NMFS Recovery Plan or Plans for the Snake River salmon. Future operational success will be compared to thresholds identified in the Recovery Plan.

This would produce a water particle travel time of about 148 hours through the four-project reach. This travel time could be achieved in three ways:

- lowering the pool elevations of the lower Snake River projects such that the average water particle velocities would produce a 148-hour travel time given existing (pre-1991) operation of the upstream storage projects (the reservoir drawdown alternative)
- increasing discharges at the lower Snake River projects by augmenting flows with additional releases from upstream storage projects in an effort to obtain a flow of 140 kcfs during migration (the flow augmentation alternative)
- a combination of the two preceding measures that would meet the 148-hour objective by a combination of flow augmentation and reservoir drawdown

### 3.2.1 Existing Conditions (No Action)

NEPA requires that each EIS include an existing conditions or "no action" alternative against which the effects of all "action" alternatives are measured. Under this alternative for 1992, no action would be taken to alter the normal operation of the reservoirs and dams on the lower Columbia and Snake rivers during salmon migration. Normal operations are the manner in which the projects and fish programs were operated from about 1985 to 1990.

The Corps would use the Juvenile Fish Transportation Program as the primary method to move juvenile salmon downstream more rapidly from April through mid-July on the lower Snake River and until mid-September on the lower Columbia River. Mainstem reservoirs would operate within normal ranges (Table 3.2-1). To enhance the movement of fish from dam to dam, river flow would be augmented by releases of stored water between April 15 and June 15 under the Water Budget. Water would be spilled over Lower Monumental, Ice Harbor, John Day, and The Dalles projects in the spring and summer to move fish over the dams instead of through the turbines. Juvenile and adult fish passage facilities at all eight run-of-river projects would continue to operate throughout the fish passage season. The Corps would continue to actively

Table 3.2-1. Key elevations of mainstem reservoirs (feet mean sea level [msl]).

| Project | Normal Operating Range | Minimum Operating Pool (MOP) | Spillway Crest |
|---|---|---|---|
| Lower Granite | 738-733 | 733 | 681 |
| Little Goose | 638-633 | 633 | 581 |
| Lower Monumental | 540-537 | 537 | 483 |
| Ice Harbor | 440-437 | 437 | 391 |
| McNary[a] | 340-337 | 335 | 291 |
| John Day[a] | Varies[b] | 257 | 210 |
| The Dalles[a] | 160-155 | 155 | 121 |
| Bonneville[a] | 76.5-71.5 | 70 | 24 |

Source: Corps, 1989a, 1988a-d, 1968, 1962, 1961a.

a/ Spillway crest elevation included for reference only; options under consideration do not include drawdown near spillway for these projects.

b/ 256-268 from July 1 to October 1.
260-265 from November 1 to March 1 and May 15 to June 1.
262-265 from March 1 to May 15.
June and October are transition months.

monitor the juvenile and adult migration at Corps dams which generally involves counting fish moving through the fish ladders and the collection and bypass facilities and sampling the condition of juvenile fish collected. The Corps would also continue its research activities related to fish migration.

The environmental conditions that would continue under this alternative were previously described in detail in Section 2.0 of the OA/EIS.

### 3.2.2 Reservoir Drawdown

This alternative involves lowering the reservoir elevations at the lower Snake and lower Columbia reservoirs during all or part of the smolt migration. For a fixed flow (volume of water per unit time) through a reservoir, average instream water velocities are increased by lowering the surface elevation. Lowering elevations reduces the cross-sectional area of the reservoir, and allows the flow to travel more rapidly. The increased water velocity results in reduced water particle travel time through the reservoir, which presumably can translate into reduced travel time for migrating smolts.

Reservoir drawdown is considered a potential action for the eight dams on the lower Snake and Columbia rivers. These lock, dam, and reservoir projects are operated as run-of-river projects within the integrated Columbia River Basin System. As such, under normal operations their surface elevations fluctuate on a daily and weekly basis within a relatively narrow range between the minimum and maximum operating pool levels.

Table 3.2-1 shows the normal operating range, minimum pool, and spillway (overflow structure of the dam) crest elevations for the eight projects. In many, but not all cases, the normal operating range extends to the minimum pool level. Graphs of actual operating conditions from April 15 through August 15 of 1988 are presented in Appendix A to illustrate these patterns.

By controlling the spillway gates and flows through the powerhouse, reservoir levels can generally be maintained near virtually any elevation between spillway crest and maximum pool, generally a range of 30 to 50 feet or more. With this degree of physical operating flexibility and eight possible projects at which to implement drawdowns, there are nearly an infinite number of possible combinations of reservoir drawdowns. Based on operating considerations and flow velocity objectives, the Corps has identified nine finite options (in addition to existing conditions and including two different timing scenarios for two of the drawdown concepts) that represent the range of reservoir drawdown alternatives. Seven of these options apply to the lower Snake River projects, while two could be implemented at the lower Columbia River projects. The basic specifications of each of these options are summarized below.

It should be noted that flood control requirements at John Day would not be compromised. Operation for flood control purposes at all projects will override any actions proposed in this OA/EIS.

### 3.2.2.1 Lower Snake River Projects

The options for drawdown on the lower Snake River were developed by regional interests, many of whom participated in the Salmon Summit. Following the conclusion of the Summit, a series of three workshops was held to develop these options. One of the main objectives in developing the options was to obtain biological information associated with juvenile salmon migration.

**Draft Lower Snake Projects to MOP.** Under this option, the Corps would operate the four lower Snake River projects (Lower Granite, Little Goose, Lower Monumental, and Ice Harbor) at MOP from April 1 to July 31. These reservoirs normally fluctuate 3 to 5 feet on a weekly basis; however, under this option, reservoir elevations would remain relatively static. Operation at MOP is defined as operating as close to the normal minimum pool elevation as possible while allowing for the unavoidable fluctuations in inflow and a limited amount of load shaping at the powerplants. More specifically, it is assumed that the pool elevation will be allowed to fluctuate within a 1-foot range above MOP. Operation of the reservoirs at MOP would fall within the authorized operating limits as identified in the respective project water control manuals. The maximum change in elevation from the average operating pool during a typical fish migration season in each case would range from 1.4 to 3.3 feet, as shown in Table 3.2-2.

**Draft Lower Snake Projects to Near Spillway Crest.** The option of lowering the four lower Snake projects to MOP would reduce water particle travel time. But in most years, it would not likely achieve travel times equivalent to the CBFWA flow proposal. To achieve CBFWA travel times, more drastic pool lowering, or flow augmentation in addition to drawdown, would be required.

Opening the spillway gates and allowing the pools to drop to free-flow elevations represents the lowest pool elevations that could be physically achieved without passing some of the flow through the turbines. It would also represent the lowest possible water particle travel time.

Generally, achieving free-flow elevations would require a drawdown of 30 or more feet below the average normal elevation. The projects would be operated totally at run-of-river conditions, with water discharged at the same rate as it enters the reservoir. For a number of reasons (as discussed below), the powerplants would be shut down, and all water would pass over the spillways. This action would increase water velocity by significantly reducing the cross-sectional area of the reservoir.

Spillways are designed in such a way that the pool elevation realized under free-flow operation will vary with discharge. When river flows are high, the pool elevation will go up. When flows decrease or are low, the pool elevation will go down. Thus, the specific elevations that would actually occur at each project in 1992 would depend upon what the streamflows will be, that is, the runoff conditions that would be experienced during the migration season and the flow augmentation program adopted by the agencies.

During May 1990, the streamflow at Lower Granite varied from about 40 to 120 kcfs, which would have resulted in free-flow reservoir elevations ranging from 691.0 to 700.5. A streamflow of 54 kcfs would have produced a travel time at Lower Granite equivalent to the CBFWA streamflow proposal of 140 kcfs at normal

Table 3.2-2. Elevation changes with lower Snake River projects at MOP.

| Project | Spring 1988 Average Elevation (feet msl) | MOP (feet msl) | Change (feet) |
|---|---|---|---|
| Lower Granite | 734.8 | 733 | -1.8 |
| Little Goose | 636.3 | 633 | -3.3 |
| Lower Monumental | 538.7 | 537 | -1.7 |
| Ice Harbor | 438.4 | 437 | -1.4 |

Source: Corps, 1988a-d.

Table 3.2-3. Elevation changes with lower Snake River projects operated near spillway crest.

| Project | Spring 1988 Average Elevation (feet msl) | Free-flow Discharge[a/] (cfs) | Corresponding Free-flow Pool Elevation (feet msl) | Change from Normal |
|---|---|---|---|---|
| Lower Granite | 734.8 | 54,000 | 693 | -41.8 |
| Little Goose | 636.3 | 55,000 | 596 | -40.3 |
| Lower Monumental | 538.7 | 58,000 | 499 | -39.7 |
| Ice Harbor | 438.4 | 45,000 | 404 | -34.4 |

Source: Corps, 1988a-d.

a/ Represents free flow over spillway that would produce same water particle travel time as 140,000 cfs at average pool.

pool operation. Table 3.2-3 shows the free-flow reservoir elevations at each of the four projects for discharges equivalent to the CBFWA flow proposal at full pool. These flows represent the lowest streamflows at which the CBFWA travel times can be achieved.

Drawdown to near spillway crest could be maintained from April 15 through June 15, corresponding to the major portion of the downstream migration period for sockeye and spring and summer chinook. This scenario is similar in this respect to the "Idaho Plan," proposed by the State of Idaho at the Salmon Summit and advocated by numerous parties during scoping for this OA/EIS. Alternatively, this drawdown could be maintained through August 15 to extend the velocity increases through the bulk of the fall chinook migration.

To constrain the risk of river bank failure along the margins of the reservoirs, the Corps has specified a drawdown limit of 2 feet per day. Consequently, attaining the target elevations by April 15 would require that the drawdowns be initiated by approximately March 25.

**Draft Lower Granite to 710 Feet, Remaining Projects to MOP.** Under this option, Lower Granite Reservoir would be drawn down to 710 feet from April 15 to June 15, while Ice Harbor, Little Goose, and Lower Monumental would be drawn down to MOP during the same time.

The 710-foot elevation was selected because this is the lowest reservoir level at which the Lower Granite adult fish ladder can operate. Water could not be supplied at the upstream end of the ladder at elevations below 710 (see Section 4.2 for details). Unlike options with drawdown to near spillway crest, this option would theoretically allow continued upstream migration via fish ladders through the entire lower Snake River reach.

**Four-Week Test: Draft Lower Granite to Spillway Crest.** The objective of this option would be to conduct a 4-week test drawdown when it would not adversely affect adult or juvenile salmon migrations. Lower Granite Reservoir would be dropped to near spillway crest, and the other three Snake River projects would be operated at normal levels. Elevations for the respective projects would be as indicated in Tables 3.2-2 and 3.2-3.

Physical conditions at the projects would be carefully monitored, with primary focus on Lower Granite, to attempt to determine the level of physical effects likely to occur if major drawdowns were implemented in the future for longer periods at one or more lower Snake projects. The primary concerns of the monitoring effort would include quantitative information on bank stability, erosion and sedimentation, water quality, and hydraulics at reduced reservoir levels. Results from this test could be used to better evaluate other reservoir drawdown options and suggest structural or operational measures in response to observed effects.

Two specific times of the year are under consideration for the timing of this test. A test from July 15 to August 15, 1992 would coincide with low levels of upstream adult migration in the transition between the summer and fall runs, and downstream migration would be minimal. Alternatively, a test from February 1 to 28, 1993 would occur at a time of minimal upstream migration and no downstream migration. Because these test drawdowns would occur when few or no downstream migrants were present, the test monitoring program would not include smolt migration studies.

**Two Reservoir Drawdown Test: Draft Lower Granite and Little Goose In March to Simulate Spillway Free Flow.** The basic goal of this test is to gather data on deep reservoir drawdown for use in evaluating long-term reservoir drawdown operations. The main objectives is to evaluate environmental and structural effects of reservoir drawdown to near spillway crest.

Lower Granite Reservoir would be to drawn down to elevation 705 at a maximum rate of 2 feet per day. While Lower Granite is maintained between elevation 705 and 703, Little Goose Reservoir will be drafted 2 feet per day until the tailwater is equivalent to near spillway crest. At this point, Lower Granite would be drafted to near spillway crest at a rate of 2 feet per day. Effects of spill on up to the stilling basin will be tested by spilling up to approximately 100 kcfs for up to 3 hours while drafting to elevation 703 and then shutting off the spill for inspection of the basin. Lower Granite would then be refilled to 705 prior to the next test. This test would be performed each day as Little Goose is drafted from 10 to 20 feet (to whatever elevation is equivalent to near spillway crest). The minimum draft elevation for Lower Granite would be 696 feet, which would occur if actual flows are 100 kcfs. The specific design of the test will be evaluated daily, and adjusted if necessary, depending upon flows, dissolved gas levels, structural problems, etc.

Physical conditions at Lower Granite would be carefully monitored with specific attention given to the impact on bank stability, the Lewiston levee system, and all other physical areas potentially at risk. Riprap and rock fill would be stockpiled at three locations in case repairs to embankments are needed. If extensive repairs are required, refill of the pools could be delayed by several months. Monitoring systems would determine the levels of dissolved gas supersaturation that would occur at consecutive reservoirs. Data would be gathered on water particle velocity at varying pool elevations. Fish conditions such as injury and gas bubble disease would be monitored at all points at which fish are collected. Other environmental resources would be subject to intensive monitoring during the test period. Tests would be stopped and refill would begin if monitoring indicates that fish or other key resources would be harmed by continuing the test.

The time of the test, March 1 through March 31, is the earliest possible time such a test could be undertaken under the current EIS process (the Record of Decision [ROD] is scheduled to be signed February 14). Also, since there will be a few juvenile and adult anadromous fish in the system, the risk of fish injury is minimized. The emergency fish ladder exit will be operated when Lower Granite Pool elevation is at 710 feet and above. Refill to minimum operating pool would be achieved by April 1 to permit fish passage.

#### 3.2.2.2 Lower Columbia River Projects

**Draft Lower Columbia Projects to MOP.** This option would lower all four lower Columbia River projects (Bonneville, The Dalles, John Day, and McNary) to MOP from April 1 to August 31. Reservoir elevations would remain relatively static during this period. The change in elevation from average normal to MOP in each case would range from about 3.5 to 10 feet, as shown in Table 3.2-4. MOP is the lowest reservoir level at which the projects were designed to operate.

**Hold McNary to 337 feet and John Day to 262.5 feet, Lower Bonneville and The Dalles to MOP.** Under this option, McNary and John Day would be operated at elevations somewhat above MOP, while Bonneville and The Dalles would be lowered to MOP. The higher elevations for McNary and John Day correspond to pool levels intended to avoid major disruptions to key water users. Because these elevations have been prevalent conditions, a number of water uses in the McNary and John Day pools have become dependent on these water levels and are not currently viable at minimum pool levels.

### 3.2.3 Flow Augmentation

The principle of flow augmentation is the same as that for the Water Budget. Additional water would be discharged from the storage reservoirs during the spring migration to increase river flow. For a given set of mainstem reservoir elevations, the increased flows would result in higher water velocities through the reservoirs. The increased flows and velocities would presumably flush fish down the river more quickly and reduce their exposure to predators and other hazards in reservoirs.

As with reservoir drawdown, a wide variety of options to increase Snake and Columbia river flows are considered in this OA/EIS. These options vary with respect to source of the water used to augment flows, the volume of storage to be released, and timing of releases. Because of the multiple purposes of the affected projects and the integrated nature of the Columbia River System, a number of these options would affect other projects in the system.

#### 3.2.3.1 Snake River

The Snake River Basin above Lower Granite has a relatively small water storage capacity compared to total runoff. Two of the largest usable storage sources in the basin are Dworshak and Brownlee reservoirs, with storage capacities of 2,016 and 980 KAF, respectively. These reservoirs provide the storage currently used for Water Budget releases and would likely provide the bulk of the storage releases required for 1992 flow augmentation options. Other, smaller storage reservoirs upstream from Brownlee could be used as sources of uncontracted water for flow augmentation. Water that is excess to the needs of various irrigation districts and farmers is allocated to water banks for later withdrawal. If needed for flow augmentation, the cooperating agencies would attempt to purchase such water from willing sellers for use in 1992. Although there are no contracts for such purchases in place now, based on recent experience the cooperating agencies assume (for modeling purposes only) that at least 100 KAF would be available in 1992.

Flow augmentation options for the Snake River consist of a variety of modifications to existing Water Budget releases. In some cases, these would be combined with reservoirs being held to flood control rule curves and/or a shift of flood control capacity from Dworshak and Brownlee to Grand Coulee. Volumes under consideration generally range from 600 KAF to 1,200 KAF from Dworshak, up to 200 KAF from Brownlee, and up to 300 KAF from multiple smaller sources above Brownlee. The most extreme case involves using the full storage available at Brownlee and Dworshak if required to meet a 140 kcfs flow target.

Although storage drafts from Brownlee have been included in several of the options, these drafts are primarily for comparison purposes. The Corps has no authority to require drafts from Brownlee because Brownlee is a privately owned dam operated in accordance with a license issued by the Federal Energy Regulatory Commission. Because this license does not

**Table 3.2-4.** Elevation changes with lower Columbia River projects operated at MOP.

| Project | Spring 1988 Average Elevation (msl) | MOP (msl) | Change (feet) |
|---|---|---|---|
| Bonneville | 73.9 | 70 | -3.9 |
| The Dalles | 158.5 | 155 | -3.5 |
| John Day | 266.9 | 257 | -9.9 |
| McNary | 338.5 | 335 | -3.5 |

Source: Corps, 1989a, 1968, 1962, 1961a.

require release for flow augmentation, any storage drafts made from Brownlee for this purpose would have to be voluntary on the part of Idaho Power Company.

Note that the volume discharges listed for Dworshak refer to the total discharge through the project during the cited time, and this includes both inflow and storage draft (if any). The volumes cited for Brownlee refer to additional storage drafts above those included in the existing operation. The upper Snake River volumes represent drafts from irrigation reservoirs upstream of Brownlee. This water is "loaned" to the lower basin during the juvenile migration season and is replaced in the winter. This arrangement results in increased Brownlee inflows in May (and June for some options) and correspondingly reduced inflows in December, January, and February.

Two additional modifications to the historical operation at Dworshak and Brownlee have also been considered. The first is to require the projects to operate to the mandatory flood control rule curves (MRCs). Historically, the reservoirs have often been drafted below the MRCs during the fall, winter, and early spring for non-firm energy production. By requiring the reservoirs to remain on the MRCs, it would be possible to make water formerly used for non-firm energy production in the winter and early spring available for augmentation during the juvenile migration season. The amount of flow augmentation available in a given year would depend on that year's runoff, but at least some water would be available in most years. In dry years, however, it is usually necessary to draft below the MRCs to meet firm power requirements, so no additional flow augmentation would be possible.

The second modification would allow for the transfer of system flood control storage from Brownlee and Dworshak to Grand Coulee. In some years, this allows for the storage of additional water for flow augmentation in space that would otherwise need to be evacuated to provide flood storage space. This shift is made possible because these projects have regulation objectives for both the Snake River ("local control") and the lower Columbia River ("system control"). Under certain combinations of runoff from the upper Columbia and Snake tributaries, that part of flood control storage space allocated to system control could be transferred to Grand Coulee, leaving space for the local control objective. The 1991 implementation of this operation was described in Section 2.2.5.

Based upon an analysis of the 50-year flow conditions, guidelines have been established to ensure that both flood control objectives and Grand Coulee operating constraints would be maintained. These result in a flood control shift from Dworshak to Grand Coulee being allowed only when the forecast April to July inflow to Dworshak is less than 2.6 MAF, and the Grand Coulee pool elevation would remain above 1,220.2 feet at any time and above 1,240 feet by May 31. A flood control shift from Brownlee to Grand Coulee would be allowed only if the forecast April to

July inflow to Brownlee is 4 MAF or lower and the same Grand Coulee elevation constraints could be met. Based on an examination of the 1928 to 1978 flow conditions, it appears that the flood control shift could be implemented on the average of 1 year out of 3 for either Dworshak or Brownlee.

The various combinations of storage releases and other modifications result in a total of 10 specific Snake River flow augmentation options, including the Base Case (existing condition). These options are described below. Alphabetic designators have been used in this presentation to help track the large number of options.

- **Option A (Base Case).** Discharge of up to 600 KAF from Dworshak as needed to meet a target flow of 85,000 cfs (85 kcfs) at Lower Granite; current flood control operation and no special releases from Brownlee or upper Snake River projects.
- **Option B.** Fixed discharge of 1,200 KAF from Dworshak and fixed drafts of 200 KAF from Brownlee and 300 KAF from upper Snake River projects during May; current flood control operation.
- **Option C.** Same as Option B except that the Dworshak, Brownlee, and upper Snake discharges/drafts would be divided equally between May and June.
- **Option D.** Same as Option B except that operation would be modified for Dworshak and Brownlee to require: (1) operation to MRCs before May 1, and (2) system flood control being transferred to Grand Coulee.
- **Option E.** Same as Option D except that the Dworshak, Brownlee, and upper Snake River discharges/drafts would be divided equally between May and June.
- **Option F.** Draft whatever is necessary from Dworshak and Brownlee to meet a target flow of 140 kcfs at Lower Granite in May, including a fixed draft of 300 KAF from upper Snake River projects and transfer of system flood control to Grand Coulee but not operation to MRCs.
- **Option G.** Variable discharge of up to 900 KAF from Dworshak, a variable storage draft ranging from 50 to 200 KAF from Brownlee, and a fixed storage draft of 100 KAF from upper Snake River projects to meet a target flow of 100 kcfs at Lower Granite in May, including transfer of system flood control to Grand Coulee, but not operation to MRCs.
- **Option H.** Discharge up to 1,200 KAF from Dworshak to meet a target flow of 85 kcfs at Lower Granite from April 15 through May 31; no contribution from Brownlee or upper Snake; also includes operation to MRCs from January 1 until April 30 and transfer of system flood control to Grand Coulee.
- **Option I.** Fixed discharge of 600 KAF from Dworshak and fixed storage draft of 150 KAF from Brownlee in May; no contribution from upper Snake; also includes operation to MRCs and transfer of system flood control to Grand Coulee.
- **Option J.** Variable discharge of 900 KAF or more from Dworshak to meet a target flow of 100 kcfs at Lower Granite from April 15 to May 31; also includes operation to reach MRCs by April 15 and transfer of system flood control to Grand Coulee, but no Water Budget contribution from Brownlee or upper Snake River. Additional water from Dworshak (above 900 KAF) will be released when refill probability is in excess of 70 percent.
- **NPPC Plan.** Variable discharge from Dworshak from April 16 to June 15; includes operation system flood control shift to Grand Coulee and operation to MRCs from January 1 to April 15; amount of Dworshak discharge is function of Lower Granite runoff forecast: (1) up to 16 MAF, 900 KAF plus flood control shift (this is the shapeable Water Budget, which is in addition to the 2 kcfs Dworshak minimum discharge); (2) between 16 and 29 MAF, total discharge (including minimum discharge) is inflow plus storage above 70 percent refill curve on April 15; (3) above 29 MAF, no special operation will be made at Dworshak for Water Budget; Brownlee to be operated for benefit of fall chinook; 190 KAF from upper Snake

River projects. For a more complete description of the NPPC plan, see Appendix J.

It might not be possible to fully implement some of these options during 1992 because operating decisions for 1992 must be made before the OA/EIS process is complete. An example would be requiring Dworshak to operate to MRCs from the fall through early spring. For 1992, the best that could be achieved may be to operate as close to the MRCs as is possible once the OA/EIS process is completed. Full operation to MRCs would be possible only in subsequent years (assuming that it were decided to implement this measure in future years).

Note that Option J and the NPPC Plan have been added since the draft OA/EIS was released. This option was developed in response to comments on the draft OA/EIS and to regional deliberations subsequent to the release of the draft OA/EIS. The intent of Option J is to combine the most attractive features of the original Options G and H. Option J retains the basic 900 KAF Dworshak discharge requirement, flood control shift, and 100 kcfs flow target of Option G. From Option H comes operation to MRCs and broadening the duration of the Water Budget to include the last half of April.

The 900 KAF Dworshak discharge requirement has been redefined somewhat. To take advantage of additional water available in higher water years, the 900 KAF cap may be lifted to allow water above the 70 percent confidence refill curve to be released to increase the Water Budget. To improve the probability of refill in moderate water years, the 900 KAF discharge requirement is reduced by limiting Dworshak discharges to the greater of either (1) the minimum level necessary to ensure that the 100 kcfs flow target will be met at Lower Granite, or (2) the 2 kcfs minimum discharge.

Although Option G included storage releases from the upper Snake River reservoirs and additional releases from Brownlee, these have not been included in Option J. This is because imposing operational changes on these reservoirs is beyond the authority of the three participating Federal agencies. It should be recognized, however, that efforts underway outside of the scope of this OA/EIS may lead to additional Water Budget contributions from these projects.

The NPPC Plan was developed by the Northwest Power Planning Council independently of the OA/EIS. The Council's intent is to develop a plan that can be used to modify the Water Budget operation in their current Fish and Wildlife Program to accommodate current concerns about potentially endangered anadromous fish species.

The Council began their work following the initiation of this OA/EIS and they had the benefit of the work the Corps did on the draft OA/EIS. However, their schedule and the OA/EIS schedule were such that the two agencies did not have an opportunity to coordinate their plans prior to the date the Council had to take action on their plan (December 10 to 11, 1991). The Corps of Engineers is not legally bound by Council actions, but since their actions represent the consensus opinions of the member states, these actions are given careful consideration by the Corps in developing the recommended plan.

The NPPC Plan is in many ways similar to Option J, but it does differ in several important respects. These differences are discussed in Appendix J.

### 3.2.3.2 Columbia River

In addition to the supplemental water that might be added to the Snake River, Columbia River flows could be augmented by releases from Grand Coulee and Arrow. Potential Columbia River actions could involve two strategies. These are a measure designed to achieve a target flow of 200 kcfs at The Dalles (sometimes referred to as "Target 200") the NPPC amendments for Columbia River Operations,and non-treaty storage releases.

The NPPC (1991b) Plan for Columbia River operations, as described in the Amendment to the Columbia River Basin Fish and Wildlife Program (Phase II) December 11, 1991 is as follows. Although three measures are listed, two are essentially the same and will be treated as such, these are the Target 200 and NPPC measures.

- When the adjusted April forecast for the January through July runoff at The Dalles is less than 90 million acre-feet, have water in storage and available for juvenile fish flow augmentation by April 30. The appropriate volume is derived from the curve in Figure 9 (from NPPC, 1991b) based on an official April forecast, adjusted to the National Weather Service 95 percent confidence level. This volume is in addition to the existing water budget volume. When applied to the lowest 20 water years in the historical water record, this volume of water would provide approximately the flows shown in Figure 10 (from NPPC, 1991b).

- This amendment calls for the same amount of storage as does Target 200. It also calls for the same schedule of water budget discharge (May and June). The apparent difference is the manner of accounting for water acquisition and the use of a target flow (200 kcfs at The Dalles). The NPPC plan does not develop an accounting methodology. This does not modify the environmental effects, so this difference is not of importance. Although the NPPC plan does not explicitly address target flows at The Dalles, examination of Figure 10 (from NPPC, 1991a) shows that flows would, on the average, vary from about 120 to about 270 kcfs. Because Target 200 used mean monthly flows as a criteria of meeting flow targets, this apparent difference does not exist. The flows that would be observed under the Target 200 measure would also vary from about 170 to about 270 kcfs on the average. The cooperating agencies have therefore concluded that since the two measures have the same average effects they would be treated as one measure. Because Target 200 was the term used to describe Columbia River flow augmentation for the Draft OA/EIS, the term Target 200 will be used to describe the effects of the NPPC measure in Final OA/EIS.

**Target 200 (Options S, T, and U).** Target 200 is an operational strategy intended to provide a target flow of 200 kcfs at The Dalles in May and June in as many years as possible. In many years, runoff is sufficient to provide the target flows simply by following existing operating procedures. However, during those years when it appears that the target flows could not be met following normal operating procedures, additional storage would be retained in Grand Coulee and Arrow for release in May and June. This would be accomplished by curtailing non-firm sales and/or making spot market purchases of power from January to April, thus, making it possible to retain storage that would otherwise be released for power generation. This would of course be contingent on space being available at Grand Coulee or Arrow to retain this storage.

The release of this storage in May and June would supplement, not replace, the existing Water Budget supply. There would be a limit of 3 MAF on the amount of Target 200 water that could be stored.

Based on three different Snake River operations, corresponding to Options A, G, and H, three Target 200 options were considered.

- **Option S.** Discharge of up to 600 KAF from Dworshak as needed to meet a target flow of 85,000 cfs (85 kcfs) at Lower Granite; current flood control operation and no special releases from Dworshak or upper Snake projects.

- **Option T.** Fixed discharge of 900 KAF from Dworshak, a variable storage draft ranging from 50 to 200 KAF from Brownlee, and a fixed storage draft of 100 KAF from upper Snake River projects; also includes transfer of system flood control to Grand Coulee but not operation to MRCs.

- **Option U.** Discharge up to 1,200 KAF from Dworshak to meet a target flow of 85 kcfs at Lower Granite from April 15 through May 31; no contribution from Brownlee or upper Snake River; also includes operation to MRCs to April 15 and transfer of system flood control to Grand Coulee.

**Non-Treaty Storage Releases.** In 1984, BPA and B.C. Hydro signed a 10-year agreement to coordinate the use of an additional portion of the water stored in the reservoir behind Mica Dam in southeastern British Columbia. Because this was water storage was not covered in the Columbia River Treaty, the agreement is referred to as the "Non-Treaty Storage Agreement." The two agencies agreed in 1990 to expand the Non-Treaty Storage Agreement and extend it until 2003. The new agreement more than doubles the amount of water that can be scheduled for release by the United States from 2 MAF to 4.5 MAF. The power-generating capability represented by the storage will be shared equally by BPA and B.C. Hydro. Additional description of the Non-Treaty Storage Agreement and its implementation is provided in BPA's environmental assessment of the agreement (BPA, 1990), which is hereby incorporated by reference.

In addition to the two signatories, the owners of the five non-Federal mid-Columbia hydroelectric projects and their power purchasers are interested parties to the Non-Treaty Storage Agreement and share its obligations and benefits. BPA has completed a companion agreement with these owners and with many of the utilities that purchase power from these projects, because the hydropower benefits represented by the new non-treaty storage depend on the cooperation of the mid-Columbia dam operators.

A portion of this storage could be made available to augment Columbia River flows. For 1992, the cooperating agencies are considering releasing non-treaty storage in Mica Reservoir to augment Columbia River flows at The Dalles in July and August. The objective of this option would be to maintain somewhat higher flows after the peak of the snowmelt runoff to benefit upstream and downstream fall chinook migrations. About half (1.2 MAF) of the U.S. share of non-treaty storage would be available for summer augmentation. This would increase average inflows at The Dalles by 10 kcfs.

### 3.2.4 Combinations of Drawdown and Augmentation

A complete program of flow improvement measures for 1992 could include a combination of reservoir drawdown and flow augmentation options. The drawdown alternative has options subsets addressing the Snake or Columbia River portions of the system. These would logically be combined in some fashion to effect water travel time changes on both rivers from drawdown. Flow augmentation, if implemented, would also logically be done on both rivers. Finally, it is likely that the most significant changes in water travel time could be accomplished by combining both drawdown and flow augmentation options affecting both rivers.

The large number of drawdown and augmentation options clearly gives rise to an even larger number of possible combination alternatives. It is neither possible nor necessary to specifically evaluate each of these potential combination alternatives in the OA/EIS. The cooperating agencies initially reviewed the basic evaluation results for the various drawdown and augmentation options with respect to changes in water particle travel time and expected environmental impacts. The agencies then selected a small set of combination alternatives considered to be likely scenarios based on significant water particle travel time improvements and avoidance of the most severe impacts. These combination alternatives did not incorporate drawdown to near spillway crest with flow augmentation, for example, because the drawdown alone would provide large reductions in water particle travel time. Furthermore, storage that could otherwise be used for flow augmentation might be needed to refill the lower Snake River reservoirs in this case.

Based on this type of assessment, Combination Options X, Y, and Z have been identified as likely scenarios.

#### 3.2.4.1 Combination Option X

- Release up to 600 KAF from Dworshak to meet a target flow of 85 kcfs at Lower Granite in May (flow augmentation Option A, existing condition).
- Flow augmentation from Grand Coulee and Arrow to meet 200 kcfs at The Dalles from April 15 to June 15 (Target 200, Option S).
- Operate the four lower Snake River projects at MOP from April 1 to July 31.
- Operate John Day at elevation 262.5, McNary at 337, and Bonneville and The Dalles at MOP from April 1 to August 31.

#### 3.2.4.2 Combination Option Y

- Release up to 900 KAF from Dworshak, 150 KAF from Brownlee, and 100 KAF from above Brownlee to meet a target flow of 100 kcfs at Lower Granite in May (flow augmentation Option G).
- Flow augmentation from Grand Coulee and Arrow to meet 200 kcfs at The Dalles from April 15 to June 15 (Target 200, Option T).
- Operate the four lower Snake River projects at MOP from April 1 to July 31.
- Operate John Day at elevation 262.5, McNary at 337, and Bonneville and The Dalles at MOP from April 1 to August 31.

#### 3.2.4.3 Combination Option Z

- Release up to 600 KAF from Dworshak to meet a target flow of 85 kcfs at Lower Granite in May (flow augmentation Option A, existing condition).

- Flow augmentation from Grand Coulee and Arrow to meet 200 kcfs at The Dalles from April 15 to June 15 (Target 200, Option S).
- Operate Lower Monumental, Little Goose, and Ice Harbor at MOP from April 1 to July 31.
- Operate Lower Granite at elevation 710 from April 15 to June 15.
- Operate John Day at elevation 262.5, McNary at 337, and Bonneville and The Dalles at MOP from April 1 to August 31.

### 3.2.5 Storage Releases for Temperature Control

By late summer of most years the temperature of the Snake River as it enters the Columbia River near Pasco, Washington is several degrees warmer than the receiving waters. This can create a temperature block for fall chinook and steelhead adults attempting to migrate upstream, resulting in delayed migration and stress to fish. Releases of large volumes of cool water from Dworshak in late summer to ameliorate these temperature conditions are being considered. The primary objective is to reduce the temperature of the Snake River at its mouth.

A release of cool water was made from Dworshak in August and September 1991. During this period, river/reservoir temperatures and velocities were measured. These data are now being analyzed to determine the ability of Dworshak to reduce Snake River temperatures below Ice Harbor Dam.

Dworshak's ability to provide adequate cooling of the Snake River at Ice Harbor in September of 1992 is dependent on many factors, including the level of Dworshak reservoir and Snake River temperatures.

Another test release of Dworshak water is planned for 1992, with requirements being set by conditions that will exist in August.

A series of HYSSR reservoir simulation studies was performed to determine the impact of three different water temperature release schedules on reservoir levels and refill probabilities in the following year. The three Dworshak release schedules are as follows:

- 10 kcfs from August 1 to August 31
- 25 kcfs from August 1 to August 31
- 25 kcfs from August 1 to August 15

These compare with normal August releases which average 2.4 kcfs and are often at the 2-kcfs minimum.

The 10-kcfs release for all of August resulted in August drawdowns of about 33 feet, which compare with normal drafts which are typically in the 3-foot range. The 25-kcfs draft for all of August caused drafts nearly 100 feet deeper than normal. Limiting the 25-kcfs release to 15 days, resulted in an average draft of 43 feet greater than normal.

In the first and third cases, the reservoir was able to recover by substantially reducing discharges during the fall and winter. However, when releasing 25 kcfs for the entire month of August, the impact on the reservoir was so severe that in low-flow years it adversely affected refill in the following year. Even by reducing discharges to the 2-kcfs minimum from September through mid-April, when Water Budget operation was assumed to begin, the reservoir could not recover.

Although the water temperature release schedules described above are more severe than what will likely be proposed for the 1992 test, they do provide a relationship which will make it possible to determine the impact of other release schedules. Impact analyses in Section 4 are based on a likely 1992 test release of 10 kcfs for 20 days, resulting in a draft of up to 20 feet at Dworshak in August.

### 3.2.6 Preferred Alternative

The cooperating agencies did not elect to identify a preferred alternative for 1992 river operations in the draft OA/EIS. Because of the complexity of the issues and potential options, the agencies wanted to obtain public review of the various options and their effects before selecting a preferred plan. By deferring selection of a preferred plan to the final OA/EIS, the cooperating agencies were able to more efficiently coordinate plan selection and evaluation with the NPPC planning process.

As a result of the analysis presented in the draft OA/EIS, public review of the document, and further analysis in response to review comments, the cooperating agencies have selected a set of options that comprise the preferred alternative for 1992. The preferred alternative includes the following measures discussed previously in Sections 3.2.2 through 3.2.5:

- Drafting all 4 lower Snake River projects to MOP from April 1 to July 31.

- Conducting a two-reservoir drawdown test at Lower Granite and Little Goose reservoirs on the lower Snake River in March.

- John Day Pool would be drafted to near elevation 262.5 starting on May 1 and ending on August 31. This elevation will be maintained for as long as possible without impacting irrigators located on the reservoir. The pool will be raised accordingly to assure that irrigators are not affected.

- Lower Snake River flow augmentation of 900 KAF or more from Dworshak based on total basin runoff forecast (April-July) of 16 MAF (or less) at Lower Granite. This volume of water is in addition to any minimum flow release requirements at Dworshak. When run-off forecasts are above 16 MAF, the above volumes will be provided with the following conditions:

  1) When natural flows at Lower Granite Dam exceed 100 kcfs, the volume of water from Dworshak will be reduced.

  2) Additional water from Dworshak (above 900 KAF) will be released when refill probability is in excess of 70 percent.

  Dworshak will be operated to MRCs and flood control shift to Grand Coulee would occur when the forecast April to July inflow to Dworshak is less than 2.6 MAF.

- Lower Columbia River flow augmentation of up to 6.4 MAF if January through July runoff is 80 MAF or less and 3.4 MAF if runoff is 90 MAF or more during the months of May and June. Mean monthly flows of about 200 kcfs at The Dalles are expected.

- Field studies will be conducted in August 1992 to test the effectiveness of cool water releases from Dworshak Dam to reduce water temperatures in the lower Snake River to benefit adult fall chinook. If Dworshak is full or nearly full by the end of July, draft the reservoir up to 20 feet in August as needed for the temperature control evaluation. This could results in Dworshak releases of up to 360 KAF. In September, beginning immediately after Labor Day, release up to 200,000 acre-feet of additional cool water from Dworshak reservoir, as needed for the temperature control evaluations. If Dworshak reservoir is not full, use of Dworshak for temperature control will be addressed in the July meeting of the Fish Operations Executive Committee.

The environmental effects of these individual components of the preferred alternative are discussed in detail in Section 4. The collective effects and the basis for selecting this plan are addressed in Section 5.

### 3.2.7 Monitoring

Any option selected will include monitoring to observe, measure, and evaluate changes to key resources and concerns. An extensive and comprehensive monitoring program will be developed prior to implementation of 1992 flow improvement operations. It includes biological, physical, water quality, and structural parameters, as well as navigation, recreation, irrigation, and cultural resources. Table 3.2-5 outlines the major elements of an evaluation program for potential reservoir drawdown options on the lower Snake River. Similar elements will be evaluated for any lower Columbia River drawdown options and flow augmentation measures. Additional information on implementation and monitoring is provided in Section 5.5. Development of the detailed program will be coordinated with regional interests, including fish agencies and tribes.

## 3.3 ALTERNATIVES ELIMINATED FROM DETAILED CONSIDERATION

This section of the OA/EIS examines additional alternatives that were not evaluated in detail because they did not appear to be feasible or represented long-

ACOE/1-4-92/19:12/0145A

**Table 3.2-5.** Monitoring plan elements for 1992 lower Snake reservoir drawdown.[1]

| Fisheries/Aquatics | Water Quality | Terrestrial | Cultural Resource | Projects and Structures |
|---|---|---|---|---|
| Juvenile fish travel time and condition | Dissolved gas levels | Waterfowl | Archeological site: erosion and vandalism | Lewiston levees |
| Orifice passage efficiency | Turbidity levels | Wetland/riparian habitat | | Railroad embankments |
| Juvenile fish staging areas | Temperature | Furbearers | | Highway embankments |
| Adult fish | Velocity | | | Hatcheries |
| Resident fish populations | Contaminants | | | Spillways |
| Benthic organisms | | | | Stilling basins |
| Macrophytes | | | | Earthen fill |
| Algal productivity | | | | Bridge abutments and piers |
| Zooplankton productivity | | | | Recreation facilities |
| Habitat | | | | Safety hazards |
| | | | | Irrigation |
| | | | | Navigation |

[1] Not all elements would apply to all drawdown options. For example, a 4-week test drawdown at Lower Granite when juvenile anadromous fish are not present would not be accompanied by juvenile travel time studies.

term actions that could not be implemented in 1992.

### 3.3.1 Additional Reservoir Drawdown Options

Numerous possible scenarios for reservoir drawdown exist in addition to those identified in Section 3.2.2. Two specific options that were identified in scoping but not carried through the full analysis are summarized below.

#### 3.3.1.1 Partial Drawdown of Lower Granite and Lower Monumental Below MOP

This option would drop Lower Granite Reservoir to elevation 710 feet and Lower Monumental Reservoir to elevation 509 from April 15 to June 15. Little Goose and Ice Harbor reservoirs would be maintained at minimum or normal operating levels. A desired element of any reservoir drawdown test is the ability to compare between normal operation and drawdown conditions, particularly with respect to juvenile fish travel time. This alternative was suggested as a means to allow comparison of fish travel times between alternating pools of normal and drawn down elevations to determine if a 23-foot drawdown was effective in reducing juvenile fish travel time.

Juvenile fish would be tagged and released at the head of Lower Granite reservoir. It would then be necessary to record travel time to each of the four lower Snake River dams. Juvenile fish facilities at Lower Granite would not be operational because of the drawdown. Little Goose facilities would be operating, but this would be the only location out of the four dams where juvenile fish could be collected for any tag or mark recognition. A suggestion was made to use juvenile radio tags, which would allow identification of fish throughout the four reservoir system, but further research indicated that this technology is not recommended for juvenile chinook salmon. Radio tags are relatively large in comparison to juvenile chinook body size, and previous test results indicated the possibility that these tags affect fish buoyancy and migrational characteristics.

The inability to compare between drawdown and normal operating conditions essentially eliminated the test value of this option. Furthermore, this option would not significantly reduce juvenile fish travel time because two of the reservoirs would remain full. Consequently, the cooperating agencies decided to remove this option from further consideration as a 1992 flow improvement measure.

#### 3.3.1.2 Cycle Lower Granite Pool Between MOP and Elevation 710

This option would alternately drop Lower Granite Reservoir to elevation 710 and refill to MOP approximately three times from April 15 through June 15. A comparison could then be made between juvenile fish travel time at MOP and at a lowered reservoir elevation. It was suggested that three or more replicates would improve the statistical reliability of the test. The cycles could be arranged on the following schedule:

| | |
|---|---|
| Lower to 710 feet | 12 days |
| Maintain elevation 710 | 3 days |
| Refill to MOP, 733 feet | 1-2 days |
| Maintain at MOP | 3 days |
| Repeat | |

This option was not recommended for two reasons:

(1) It would not be possible to control other factors affecting juvenile fish travel time over the course of the time period, such as increases in flow and temperature.

(2) Individual fish travel time from the head of Lower Granite Reservoir to Lower Granite Dam ranges from less than 1 day to over 40 days. Median travel time, based on both the travel times of individual fish and groups, generally ranges from 4 to 20+ days. Because of the time it takes for fish to traverse the reservoir, tagged groups of fish would be travelling during both MOP and drafted pool conditions, as well as during drafting and refill.

Because of the testing limitations and expected lack of significant travel time change, this option was removed from detailed consideration.

### 3.3.2 Major Structural Measures

A large number of potential structural modifications to the run-of-river projects have been identified as possible measures to help improve fish passage conditions. Many of these potential measures have been identified by the Corps, based on operating experience with the projects. Others were proposed by various Salmon Summit participants or contributors to the scoping process for this OA/EIS.

Structural modifications that have been proposed to date include the following:

- Modifying the juvenile fish bypass systems to allow effective operation over a wider range of reservoir elevations.
- Modifying adult fish ladder entrances and exits to allow effective operation over a wider range of reservoir elevations.
- Constructing an open-channel flume or pipeline for juvenile fish to bypass all of the lower Snake and Columbia River dams.
- Removing turbines and generators to provide safer powerhouse passage for juvenile fish.
- Modifying the entrances to navigation locks to provide a new downstream passage mode, as an alternative to spillway or turbine passage.
- Constructing new sluiceway bypass structures through existing dam embankments.
- Lowering spillway crest elevations to allow the spillways to pass low river flows at desired velocities under free-flow conditions.
- Modifying powerhouses or tailraces to provide acceptable tailwater conditions for operation at reduced reservoir elevations.
- Constructing new low-level outlets at riverbed level to freely pass a portion of spring flows.
- Developing new facilities and equipment for enhanced operation of the juvenile fish transportation program.
- Completely removing one or more of the mainstem dams.

This is a relatively complete, but not exhaustive, list of the possibilities for structural modifications. New proposals will no doubt be identified as the OA/EIS process and future studies continue. As indicated by the list, these proposals focus on ways to improve fish passage conditions, particularly for downstream migrants. One of the major themes to emerge from the Salmon Summit and the OA/EIS scoping process was the desire for successful simultaneous passage of both upstream and downstream migrants. It is clear from the list of structural proposals that there is no consensus as to the best solution.

The apparent feasibility of proposed structural measures is also variable, if understood at all, because little or no evaluation has been conducted. Some potential measures have been reviewed and found to be not feasible. For example, an engineering consultant engaged by the State of Idaho to consider some proposed structural changes to the dams concluded that actions such as modifying navigation locks or removing turbines either had fatal flaws or could not be adequately assessed in a quick preliminary study (Morrison Knudsen Corporation, 1991). Some other actions, such as removing one or more dams, would clearly have major consequences and would require years to develop a regional consensus on feasibility. A number of structural proposals may have technical merit, but plans and effects have not been established to the point where such actions could be implemented soon. To the extent possible, measures relating to project features that are integral to issues addressed in this OA/EIS (primarily fish passage facilities) are noted in the technical discussions in Section 4.0.

The general disposition of the proposed structural measures by the cooperating agencies is that they are measures requiring a relatively long time to study and act upon, and could not be implemented in 1992. Because these measures would take place at Federal projects, they would need to follow the standard Federal implementation process. This would include Congressional authorization and appropriation of funds, detailed design for facility modifications, necessary environmental compliance documents, and development and execution of construction contracts. Even for relatively small actions, this process can take 2 or more years.

Notwithstanding this disposition of proposed structural measures for 1992, the cooperating agencies will continue to evaluate many of the concepts listed above and other ideas as they arise. The agencies feel that a number of these proposals may hold promise as contributions to a future solution for optimal fish passage conditions. Such structural measures have been under consideration for some time under other agency processes separate from this OA/EIS. This evaluation of potential long-term actions will continue as the Corps proceeds with its Columbia River Salmon Mitigation Analysis, and as the three cooperating agencies proceeds with the Columbia River (SOR).

### 3.3.3 Non-Project Measures

Regional deliberations over the status and recovery of salmon stocks have also identified many proposed measures that would not directly involve the Federal projects. Most of these concepts have been under consideration by fisheries managers for a decade or more, and many are in the process of implementation through the NPPC Fish and Wildlife Program. Proposed measures in this category include the following:

- Stream and watershed improvements to restore salmonid spawning and rearing habitat.
- Screening of irrigation and other water intake facilities that present migration hazards for salmonids.
- Water conservation programs to reduce the amount of water diverted from streams for consumptive uses.
- Improved hatchery facilities and operations to increase survival of hatchery fish and reduce competition with wild fish.
- Non-point source water quality controls to improve the quality of runoff entering streams.
- Restrictions on ocean and freshwater harvest of salmon, to protect threatened stocks that are intermingled with more healthy stocks.
- Banning high-seas driftnet fishing for squid, which poses risks to salmonids from incidental capture and provides opportunities for illegal harvest.

All of these measures appear to have some technical merit, and many or all may be required at some time if the region is to make significant progress toward restoring anadromous fish stocks. However, these measures are also outside the scope of this OA/EIS. BPA is supporting various hatchery and habitat measures through its funding of the Fish and Wildlife Program, while the BoR is active in water conservation and screening diversions. These actions are part of ongoing processes that predate this OA/EIS and need not be duplicated in the OA/EIS. Based on these considerations of scope, authority and separate programs, these non-project measures have not been given detailed consideration in this OA/EIS.

## 3.4 SUMMARY OF RESERVOIR REGULATION CHANGES

The reservoir drawdown and flow augmentation options identified in Section 3.2 are specified in terms of reservoir elevations and flow discharges. Implementing these actions would result in changes to reservoir elevations and outflows compared to existing conditions. While these changes might be considered impacts in the normal sense, in reality they are also characteristics of the proposed actions that provide the basis for the impact analyses presented in Section 4.0 of the OA/EIS. Consequently, the expected changes in reservoir conditions with the various options are summarized below, along with a discussion of projected success in meeting target flows and reducing water particle travel time.

### 3.4.1 Mainstem Reservoir Drawdowns

The drawdown options under consideration range from modest reductions below normal pool elevations to more extensive drawdowns resulting in free-flowing spillway conditions. A comparative summary by project of the potential reservoir elevations is found in Table 3.4-1. More detailed information was previously provided in Section 3.2.

### 3.4.2 Mainstem Refill Requirements and Effects

The drawdown of Columbia and Snake River mainstem reservoirs would result in decreases in downstream flow levels during refill periods. Similarly, refill periods

Table 3.4-1. Summary of reservoir elevations and refill requirements from drawdown options.

| Project | Normal Operating Range | Drawdown Elevations: To or Near MOP | Drawdown Elevations: Near Spillway (at 140 kcfs) | Four-Week Test | Refill Requirements (KAF): To or at MOP | Refill Requirements (KAF): Near Spillway Crest |
|---|---|---|---|---|---|---|
| Lower Columbia | | | | | | |
| Bonneville | 71.5-76.5 | 70 | NA | NA | 87 | NA |
| The Dalles | 155-160 | 155 | NA | NA | 52 | NA |
| John Day | variable | 262.5 or 257 | NA | NA | 150 | NA |
| McNary | 337-340 | 337 or 335 | NA | NA | 185 | NA |
| | | | | | 474 | |
| Lower Snake | | | | | | |
| Ice Harbor | 437-440 | 437 | 404 | 437-440 | 9 | 164 |
| Lower Monumental | 537-540 | 537 | 499 | 537-540 | 9 | 145 |
| Little Goose | 633-638 | 633 | 596 | 633-638 | 32 | 229 |
| Lower Granite[a/] | 733-738 | 733 | 693 | 710 | 23 | 276 |
| | | | | | 73 | 814 |

Source: Corps, 1989a, 1988a-d, 1968, 1962, 1961a.

a/ Refill requirement for drafting Lower Granite to elevation 710 is 180 KAF.

would result in temporarily decreased water particle travel time while outflows are reduced below inflows.

Refill requirements for the eight mainstem reservoirs under various drawdown options are summarized in Table 3.4-1. These refill requirements could be met by holding outflow below inflow until the pools had refilled, then returning to true run-of-river operation. Alternatively, refill could be accomplished more quickly and without diminishing downstream flows by releasing water from upstream storage, assuming that sufficient water is available when needed for refill.

Assessing these refill options and their effects requires consideration of river flows at the time refill would occur. Typical flow ranges at Lower Granite and The Dalles with the proposed flow measures would be as follows:

| Month | Flow at Lower Granite (kcfs) | Flow at The Dalles (kcfs) |
|---|---|---|
| May | 105-133 | 295-321 |
| June | 90-105 | 247-262 |
| July | 37-39 | 158-162 |
| August | 20-21 | 111-112 |

The largest refill requirement among the drawdown options considered would result from combined drawdown of the lower Snake River projects to near spillway crest and the lower Columbia River projects to MOP. This case would produce a refill requirement of 814 KAF for the lower Snake River and 474 KAF for the lower Columbia River. Accomplishing refill in 1 month would require continuous flows into storage of 13.5 kcfs and 8 kcfs, respectively. The lower Snake River storage flow corresponds to about 14 percent of typical June flows and 35 percent of typical July flows. With a drawdown to near spillway crest lasting through August 15, the refill requirement would be equivalent to 65 percent of typical August flows. Similarly, the combined lower Snake and Columbia refill requirement would represent about 8 percent of average Columbia River flow at The Dalles in June and 19 percent of average flow in August.

Instantaneous minimum discharge requirements that vary during the year apply to the projects. The minimum flow at Lower Granite in late summer is 11.5 kcfs. Without changing or violating the minimum discharge requirement, refill from inflow in this case would require more than 1 month. Another refill concern is the associated effect of increasing water particle travel time during the refill period. The change in water particle travel time would roughly correspond to the percentage reduction in flow.

Refill requirements raise three issues in addition to flow effects at the mainstem projects. One issue is the effect on Dworshak if refill were accomplished from storage. Release of 814 KAF to refill the lower Snake River projects would require a 50-foot draft at Dworshak during the summer.

The second issue concerns water depths below Bonneville. The maximum combined lower Snake and Columbia refill requirement corresponds to a flow of about 21.5 kcfs. In the extreme refill case during late-summer flow conditions, this represents approximately 19 percent of typical flows at The Dalles. If refill were accomplished within 1 month, the reduced flow could result in a water level reduction of up to approximately 2 feet below Bonneville. Extending the refill period would reduce the effect proportionately. Similarly, refill beginning in mid-June would have less effect on flows because average flow levels are typically much higher in June.

The third refill issue is the lost power generation for the case where the lower Snake River projects are drawn down below MOP. No generation would be possible at these projects until they refill to MOP.

### 3.4.3 Storage Reservoir Elevations

Nine options different from the Base Case were considered for reducing travel time through flow augmentation from Dworshak, Brownlee, and a combination of smaller reservoirs in the Snake River Basin. These options (Options B through J) are described in Section 3.2.3.1. Two additional strategies deal with flow augmentation from Arrow and Grand Coulee on the mainstem Columbia, as described in Section 3.2.3.2.

**Simulation Studies.** The various Snake River alternatives were modeled to determine potential impacts to the reservoir levels, flows, and power generation. The simulation studies were done by the Corps of Engineers using the HYSSR model. Similar studies were performed for the mainstem Columbia strategies by BPA, using the SAM model. Both are complex mathematical models that simulate the operation of the coordinated regional hydro system over a 50-year period of hydrologic record, spanning 1928 through 1978. Although the OA/EIS is focused on alternatives for operations in 1992, the analysis throughout a long period of record reveals what might occur given the fact that the water conditions that will prevail at the initiation of such procedures are as yet unknown. Simulations performed thus reveal what would be expected if the forecast is for high, average, or low water years. Similarly, the analysis provides an indication of what could be expected if a given option were implemented over an extended period of time.

**Flood Control Assumptions.** One of the key assumptions made in these studies was that there would be no degradation in flood protection. In all of the studies, care was taken to ensure that reservoir levels never exceeded the flood control rule curves. Some of the options included the transfer of system flood control storage space from Dworshak and Brownlee to Grand Coulee. However, this shift was made in such a way that there was no reduction in local flood protection for Lewiston and the lower Clearwater, and sufficient additional space was provided at Grand Coulee to ensure that flood protection for Vancouver, Portland, and adjacent areas would not be diminished.

**Base Case.** The purpose of the model studies was to compare the benefits (reduced travel time) and costs (increased reservoir fluctuations and losses in power generation) to current reservoir operations. Reservoir operation procedures have been evolving over the past several years, both in response to the Water Budget and other measures intended to increase survival of downstream migrants and to the dynamic regional power situation. Because some special operations were implemented in 1991 in response to the Salmon Summit deliberations, the operating procedures in place in the previous year were determined to be appropriate for the Base Case. The Base Case was designated as Option A and is described in Section 3.2.3.1.

**Summary of Results.** Accompanying tables summarize the impact of each of the options on drawdown and refill for Dworshak, Brownlee, and Grand Coulee. Impact on reservoir drawdown is described in terms of 10, 50, and 90 percent exceedence levels for May, which is the month in which the reservoir drafts are made for flow augmentation in most of the options. The 50 percent exceedence level, for example, is the median end-of-May elevation from the 50-year simulation. For any given year, there is a 50 percent probability that this elevation will be equaled or exceeded at the end of May. This emphasis on elevation probabilities is the most appropriate evaluation posture in trying to asses the likely outcomes of a 1-year (1992) event. Impact on reservoir refill is expressed in terms of percent of years in which the reservoir fills to within 5 feet of full pool by the end of July. The results are discussed further by project in the following sections.

### 3.4.3.1 Dworshak

Specified discharge or flow augmentation options using storage from Dworshak range from 600 acre-feet to 1,200 acre-feet. One option includes a discharge of whatever is necessary, in conjunction with Brownlee, to meet a target flow of 140 kcfs at Lower Granite during May.

Selected data for the project are:

| | |
|---|---|
| Maximum Operating Pool: | El. 1,600 |
| Top of Inactive Pool: | El. 1,445 |
| Reservoir Storage: | 2,016 KAF |

Under current operations, Dworshak is usually at its maximum elevation in July, following the snowmelt runoff. The objective is to maintain the reservoir at this elevation through Labor Day, although some drafting may be required for hydropower or to maintain minimum flows. After Labor Day, drafts are initiated for hydropower, with the additional objective of reaching elevation 1558.0 by December 15 in order to provide the 700 KAF flood control requirement. On January 1, the first runoff forecasts become available and drafting continues, primarily for power generation, with reservoir elevations being constrained on the high side by the MRCs and on the low side by a rule curve designed to ensure an acceptable refill probability. Drafting below the refill curve would occur only to maintain minimum downstream flow requirements. Further adjustments are made to this operation as new runoff forecasts become available. The reservoir reaches its low point in mid-April. Between mid-April and July the reservoir is allowed to refill with snowmelt runoff, with a gradually diminishing amount of space being provided for flood control and with releases being made for power generation. In addition, up to 600 KAF of Water Budget releases are made during May to help meet an 85 kcfs flow requirement at Lower Granite.

The operation of Dworshak would vary considerably among options. Table 3.4-2 summarizes the reservoir operating characteristics for most of the options. Figures 3.4-1 and 3.4-2 are plots of reservoir elevation for the Base Case and selected options for three water conditions: (1) a multi-year low flow period (1928 to 1931), (2) a high runoff year (1950), and (3) an average runoff year (1951) at Dworshak.

A detailed case-by-case description of the impact of each of the options on the Dworshak reservoir operation is included in Appendix J. The main points are summarized as follows.

Options B through E are similar in that they require a fixed discharge of 1,200 KAF in every year. In Option B, 1,200 KAF must be discharged in May. The basic operating strategy is similar to current operations except for a much higher May discharge requirement. The result is that in all but high runoff years, deeper drafts are experienced in May, and the probability of refill by the end of July is reduced from 68 percent to 8 percent. Furthermore, as can be seen from Figures 3.4-1 and 3.4-2, reservoir elevations remain well below Base Case elevations for much of the year in low to average water years.

Option C is similar to Option B except that the 1,200 KAF is divided between May and June. The result is higher elevations than Case B at the end of May but lower elevations at the end of June. Because 2 months of natural inflow can be included with the 1,200 KAF

Table 3.4-2. Dworshak Reservoir response to flow augmentation options.

| Option | Percent Chance End-of-May Reservoir Elevation Will Be Equal Or Exceed 10% | 50% | 90% | Percent Chance Of Refill At End Of July[a/] |
|---|---|---|---|---|
| A | 1,586 | 1,557 | 1,515 | 68 |
| B | 1,546 | 1,506 | 1,445 | 12 |
| C | 1,581 | 1,548 | 1,504 | 8 |
| D | 1,556 | 1,516 | 1,468 | 14 |
| E | 1,587 | 1,560 | 1,514 | 10 |
| F | 1,512 | 1,445 | 1,445 | 12 |
| G | 1,579 | 1,550 | 1,507 | 58 |
| H | 1,588 | 1,558 | 1,524 | 70 |
| I | 1,588 | 1,555 | 1,511 | 32 |
| J | 1,586 | 1,558 | 1,506 | 74 |
| NPPC Plan | 1,589 | 1,559 | 1,516 | 64 |

a/ Maximum pool at El. 1,600 with refill credited at El. 1,595 or above.

instead of just one, less storage needs to be drafted from Dworshak, with the result that the reservoir is generally higher than for Option B for most of the year. However, because the draft extends into June, the probability of refill by the end of July is reduced.

Options D and E correspond to Options B and C except that the project is operated to the MRCs instead of the power rule curves during the fall, winter, and early spring. This results in higher reservoir elevations and a higher refill probability than for Options B and C, but the refill probabilities are still well below the Base Case.

A major problem with Options B through E is that requiring a fixed discharge in all years means that large releases are sometimes made in years when they are not necessary, when Base Case operation would have already met Lower Granite flow requirements. A better approach would be to make a specified amount of discharge available for Water Budget, but to use it only as required to meet Lower Granite flow targets. Options F, G, and H follow this approach.

Option F demonstrates the maximum contribution that Dworshak and Brownlee could make to reducing travel time by making all of the storage in the reservoirs at the end of April available if needed to meet a 140 kcfs flow target. The result was that Dworshak was drawn to the bottom in 45 out of 50 years. As might be expected, Dworshak seldom refills and would be operating in the bottom portion of the reservoir most of the time in all but high water years (see Figures 3.4-1 and 3.4-2).

Option G is intended to represent an operation that has a high probability of being implementable in 1992. It makes up to 900 KAF of inflow and storage available from Dworshak to meet a 100 kcfs flow target in May at Lower Granite. End-of-May reservoir elevations are generally lower than for the Base Case, as is the refill probability. However, refill performance is much better than for any of the preceding options, and Figures 3.4-1 and 3.4-2 show that year-round reservoir elevations are much closer to current operations.

Option H makes up to 1,200 KAF available from Dworshak, but this discharge is distributed between the last half of April and all of May. The Lower Granite flow target is only 85 kcfs. Because the project is operated to the flood control rule curve in the spring,

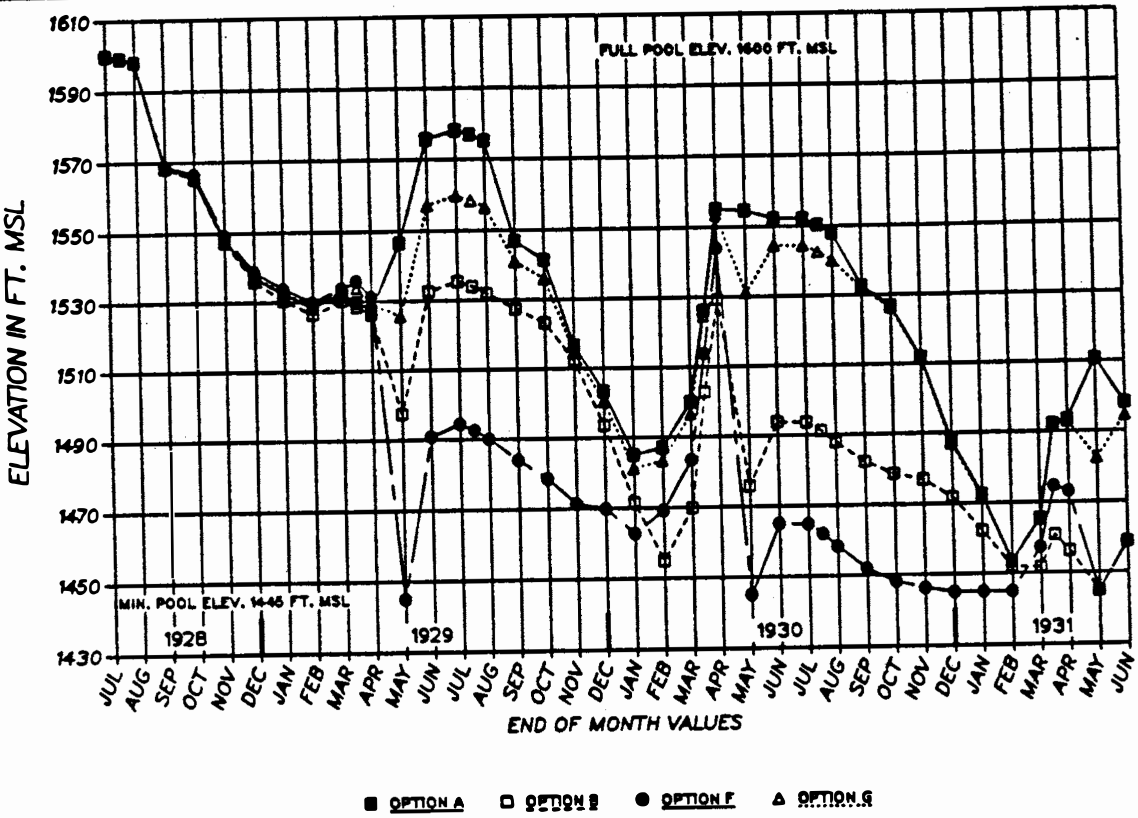



Figure 3.4-1. Dworshak Project elevations, low runoff years: 1928 to 1931.

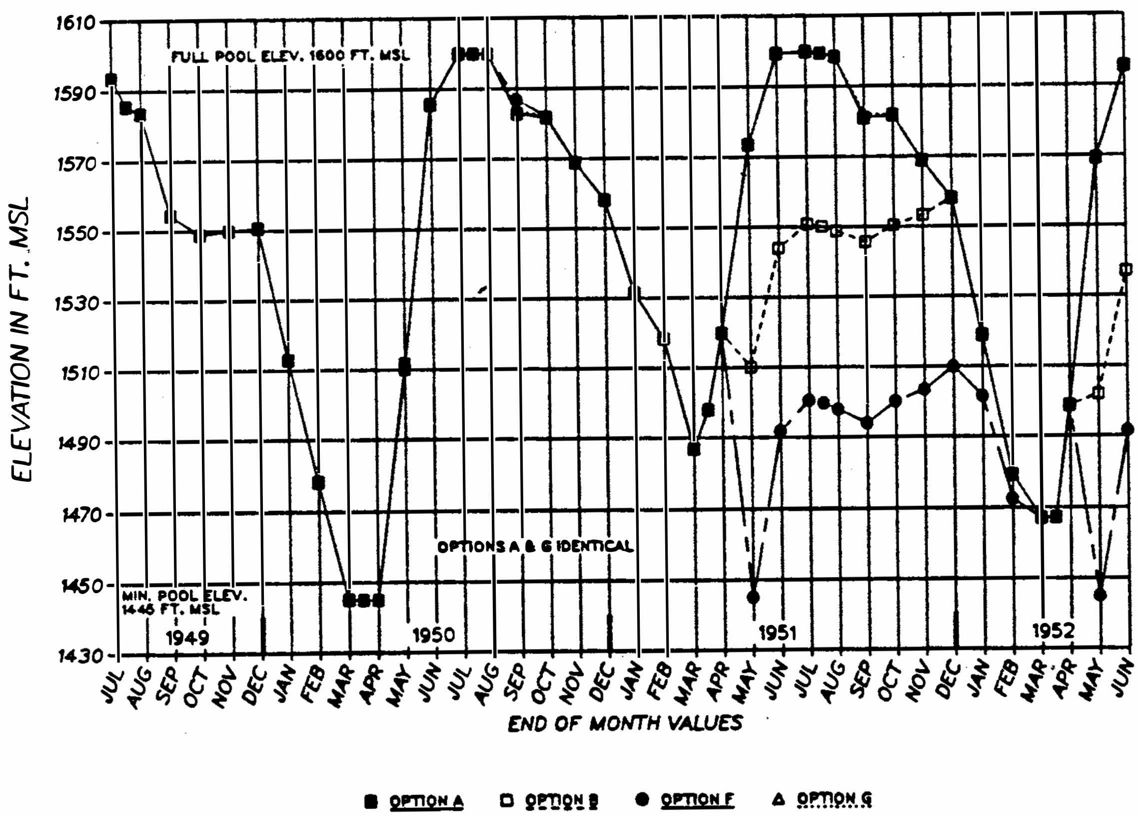



Figure 3.4-2. Dworshak Project elevations, high (1950) and average (1951) runoff years.

the impact of the Water Budget draft is not as great as Option G, and the refill performance is in fact better than even the Base Case.

Option I is generally similar to the Base Case except that the project is forced to operate to the MRCs if water is available. This results in year-round reservoir elevations being generally higher than the Base Case. May drafts are comparable to the Base Case. Although the reservoir does not fully refill as often as the Base Case, it frequently comes to within 10 feet of being full so that the average elevation at the end of July is the highest of any of the options.

Option J is similar to Option H except that the flow target is 100 kcfs instead of 85 kcfs, and the Dworshak discharge requirement is 900 KAF or above. Because of the operation to MRC, summer elevations are higher than Option G in many years, although the overall refill probability is about the same.

Although the refill performance varies in individual years, the effect of the NPPC Plan on Dworshak Reservoir operation is quite similar to Option J overall. Option J has a better refill performance in low runoff years because discharge is limited to 900 KAF instead of 900 KAF plus minimum flow plus flood control shift (if any). The NPPC Plan has better refill in moderate runoff years.

To summarize, the greatest change from historical operations would occur with unlimited withdrawals to meet downstream target flows of 140 kcfs during May (Option F). The next most severe cases are those involving fixed withdrawals of 1,200 KAF during May or May/June. Remaining options (G, H, I, J, and the NPPC Plan) could be judged to have similar and less pronounced effects on reservoir levels and fluctuations.

### 3.4.3.2 Brownlee

Some flow augmentation options using storage from Brownlee involve a fixed draft every year, while others employ a variable draft, based on inflow forecasts, ranging from 50 to 200 KAF. Another option would use whatever storage is necessary, in conjunction with Dworshak, to meet target flows of 140 kcfs at Lower Granite. These drafts would be in addition to current drafts for power and flood control. Most options call for the drafts to be made in May, but some call for a longer period.

Selected data for the project are:

| | |
|---|---|
| Full Pool: | El. 2,077 |
| Empty Reservoir: | El. 1,976 |
| Active Storage: | 980 KAF |

Current operations call for a reservoir drawdown to elevation 2,034 by March 1 of each year to provide 500 KAF for flood control, except in drier years when the flood control requirement is determined by basin conditions. Wet years can result in the requirement to draw down the reservoir below elevation 2,034 and possibly even empty the reservoir to elevation 1,976 by April 1. An attempt is made to fill the reservoir by July 1, and full pool is reached in about 90 percent of the years.

Only six of the options described in Section 3.2.3.1 (Options B through G) call for revisions to the Brownlee reservoir operation. A detailed discussion of the operational impact of each option is included in Appendix J. Table 3.4-3 lists the drawdown and refill characteristics of the various options, and a brief summary of the results follows.

The only months in which there were significant departures from Base Case elevations were May, June, and July. In four of the options, the drafts for flow augmentation were made in May, and refill to current operating levels was accomplished in June and July by reducing releases for power.

As can be seen from Table 3.4-3, Options B, D, and G have similar impacts on drawdown and refill, with end-of-May elevations running nearly 20 feet below the Base Case and the reservoir being restored to Base Case levels by the end of July. In Options C and E, only part of the draft is accomplished in May, so the end-of-May elevations are somewhat higher and the end-of-June elevations somewhat lower. The largest impact occurs under Option F, which calls for unlimited drafts in May if needed. Brownlee was drawn empty in 28 years out of 50. Under this option, the reservoir did not return to Base Case elevations until September in some water years.

### 3.4.3.3 Grand Coulee

Flow augmentation options involve either shifting system flood control storage availability to Grand

Table 3.4-3. Brownlee Reservoir response to flow augmentation options.

| Option | Percent Chance End-of-May Reservoir Elevation Will Be Equal Or Exceed 10% | 50% | 90% | Percent Chance Of Refill At End Of July[a/] |
|---|---|---|---|---|
| A | 2,077 | 2,063 | 2,025 | 34 |
| B | 2,062 | 2,046 | 1,990 | 34 |
| C | 2,070 | 2,055 | 2,014 | 34 |
| D | 2,062 | 2,046 | 2,002 | 34 |
| E | 2,069 | 2,055 | 2,014 | 34 |
| F | 2,045 | 1,976 | 1,976 | 32 |
| G | 2,062 | 2,048 | 1,997 | 32 |
| H | 2,077 | 2,064 | 2,025 | 34 |
| I | 2,066 | 2,058 | 2,008 | 34 |
| J | 2,077 | 2,063 | 2,026 | 34 |
| NPPC Plan | 2,077 | 2,063 | 2,026 | 34 |

a/ Maximum pool at El. 2,077 with refill credited at El. 2,072 or above.

Coulee from Dworshak or Brownlee, thus allowing for the maintenance of increased storage in those projects, or using the storage to meet targeted flows downstream.

Selected data for the project are:

| | |
|---|---|
| Full Pool: | El. 1290 |
| Empty Reservoir: | El. 1208 |
| Active Storage: | 5,185 KAF |

Current operations result in a drawdown from January through June for flood control purposes and to provide power during the peak seasonal demand period. The greatest drawdowns usually occur in April, while the highest reservoir elevations normally occur from July through December. The spring drawdown typically reduces the reservoir storage by approximately 55 percent.

Based on the operational restrictions employed, modeling of the 50-year period between 1928 and 1978 resulted in a potential shift in system flood control to Grand Coulee for 15 years from Brownlee and 17 years from Dworshak. The modeling restrictions included hard constraints that the Grand Coulee Pool elevation remain above 1,220.2 feet at all times and reach 1,240 feet by May 31. Drafts below 1,220.2 feet interrupt crucial ferry service across Lake Roosevelt and adversely affect the ability of the project to meet power emergencies and water supply requirements. Lake Roosevelt must be at elevation 1,240 by May 31 to allow pumping into Banks Lake for irrigation water supplies.

Simulation results for the various options with respect to reservoir elevations are shown in Table 3.4-4. Median reservoir elevations for the end of May are 1,240 feet in all cases, while the 10 percent and 90 percent exceedence levels vary by no more than 5 feet among options. The July refill probability in all cases is either 90 or 94 percent. Significant differences in reservoir elevations were simulated in a few of the water years. However, this generally occurred only in critical period years, a condition that could not be duplicated in 1992 due to 1991 runoff levels.

Simulations of Target 200 cases also indicate only modest changes from the base case. Target 200 scenarios call for augmentation from Grand Coulee storage to achieve flows of 200 kcfs at The Dalles in May and June. Evaluation of Target 200 options revealed negligible changes in reservoir responses from the corresponding case without Target 200 operations.

Table 3.4-4. Grand Coulee Reservoir response to flow augmentation options.

| Option | Percent Chance End-of-May Reservoir Elevation Will Be Equal Or Exceed 10% | 50% | 90% | Percent Chance Of Refill At End Of July[a/] |
|---|---|---|---|---|
| A | 1,267 | 1,240 | 1,229 | 90 |
| B | 1,267 | 1,240 | 1,229 | 90 |
| C | 1,267 | 1,240 | 1,229 | 90 |
| D[b/] | 1,267 | 1,240 | 1,229 | 90 |
| E[b/] | 1,267 | 1,240 | 1,229 | 90 |
| F[b/] | 1,270 | 1,240 | 1,232 | 90 |
| G[b/] | 1,270 | 1,240 | 1,229 | 90 |
| H[b/] | 1,269 | 1,240 | 1,229 | 90 |
| I[b/] | 1,269 | 1,240 | 1,229 | 90 |
| J | 1,272 | 1,240 | 1,229 | 94 |
| NPPC Plan | 1,267 | 1,240 | 1,229 | 90 |

a/ Maximum pool at El. 1290 with refill credited at El. 1285 or above.
b/ Options incorporating possible flood control shifts from Dworshak and Brownlee.

One of the primary effects of Target 200 options would be to increase Grand Coulee elevations during early spring. Because of operating restrictions, however, the May and June target flows were not always met in the analyses. The degree of success in meeting the targets is described in Section 3.4.5.

Use of non-treaty storage releases to augment Columbia River flows would not have a measurable effect on Grand Coulee elevations. These releases would occur in July and August, after any other augmentation measures had been completed. Grand Coulee outflows would be increased in response to higher inflows from releases at Mica, such that normal summer elevations would be maintained at Grand Coulee.

In summary, there appear to be no significant differences in reservoir elevation impacts at Grand Coulee between the Base Case and any other options under consideration.

### 3.4.4 Combinations of Reservoir Drawdown and Flow Augmentation

Three likely combinations of drawdown and augmentation options were presented in Section 3.2.4. The individual elements comprising these combinations, and their reservoir regulation effects, have all been described previously. Mainstem reservoir elevation changes were identified in Section 3.4.1, while storage reservoir responses were summarized in Section 3.4.3. These reservoir effects are generally additive among the individual combination elements. In some cases, Grand Coulee operations are affected by flow augmentation options for both the Columbia and the Snake rivers, but both effects are captured in the model analyses.

### 3.4.5 Target Flows

Fifty-year simulation studies produced the following ranges of average monthly flows at Lower Granite and The Dalles for the various flow augmentation options. These ranges are presented in the table below:

| | Flows (kcfs) | |
|---|---|---|
| Month | Lower Granite | The Dalles |
| July | 37-39 | 158-162 |
| August | 20-21 | 111-112 |
| September | 21-26 | 109-111 |
| October | 24-25 | 120-121 |
| November | 26-30 | 122-125 |
| December | 31-35 | 149-152 |
| January | 37-46 | 241-252 |
| February | 42-47 | 180-187 |
| March | 49-52 | 177-180 |
| April | 82-89 | 219-223 |
| May | 105-133[a/] | 295-321[b/] |
| June | 90-105 | 247-262[b/] |

Sources: HYSSR, SAM analyses.
a/ Target flows vary among 85,100 and 140 kcfs.
b/ Target flows of 200 kcfs in May and June.

The annual probability of meeting various target flows with the respective augmentation options is summarized in Table 3.4-5. The probability of meeting a May target flow of 85 kcfs at Lower Granite in any one year ranges from 68 percent to 100 percent. The latter probability is associated with both Options B and F.

The probability of meeting a 100 kcfs target is better than 50 percent for all options except H, which is 46 percent. In contrast, the probability of meeting a 140 kcfs target is only 46 percent with the unrestricted draft (Option F) and no more than 28 percent with any other option.

Simulation results with respect to target flows at Lower Granite over the range of water conditions are depicted in Figures 3.4-3 and 3.4-4 for four representative options. The results depicted in Figure 3.4-3 indicate that achieving an 85 kcfs target flow from April 15 through June 15 under low flow conditions would be difficult. Achievement of the target flows under these conditions would result in depletion of reservoir storage at Dworshak.

Under average (1951) flow conditions (Figure 3.4-4), the 140 kcfs Lower Granite target flow can be achieved only with Option F. The 140 kcfs target flow was not met at Lower Granite under "high" (1950) water conditions because 1950 was high only on the Clearwater. Flow conditions on the Snake River itself were only average. Thus, even through high flows were contributed by the Clearwater, the combined flows of the Clearwater and Snake rivers could not reach the 140 kcfs flow target.

A review of year-to-year reservoir operation at Dworshak indicates that deep drawdowns, particularly in dry years, can diminish augmentation capacity in following years. Simulation of the same options shows less impact on Brownlee augmentation capability in years immediately following dry years.

### 3.4.6 Water Particle Travel Time

Reducing water particle travel time is the primary objective of most of the alternatives presented in this OA/EIS. As discussed earlier, water particle travel time is a function of two variables: (1) the streamflow rate, and (2) the volume displaced by the streamflow. The reservoir drawdown alternatives are designed to reduce the volume to be displaced, while the objective of the flow augmentation alternatives is to increase the streamflow rate.

This section presents data on the probability of achieving various levels of travel time for some of the key alternatives. The water particle travel time equivalent to the CBFWA flow proposal is used here only as a form of reference, not a measure of success.

Figures 3.4-5 through 3.4-8 show the results achieved by some of the key reservoir drawdown and flow augmentation options, both singly and in combination. Flow augmentation options analyzed singly are Options A, B, F, and G (see Section 3.2.3.1). Options A and F represent the two extremes, and Options B and G are intermediate operations.

The reservoir drawdown options examined include operation at full pool, operation at MOP, and operation with spillways on free flow. Under current operations, average pool elevations are about halfway between full pool and MOP. All three of these reservoir drawdown alternatives were examined in combination with flow augmentation Option A (Base Case or existing conditions) and Option F, to bracket the full range of combinations. Travel times were derived for two reaches: the Snake River from the junction with the Clearwater to the mouth of the Snake, and the entire lower Snake-lower Columbia reach from the junction with the Clearwater to Bonneville Dam.

These figures are "probability" plots of water particle travel time. The plots were constructed for the various options by converting the simulated May monthly flows

Table 3.4-5. Probability of meeting target flows (%).[a]

| Option | Target Flows 85 kcfs | 100 kcfs | 140 kcfs |
|---|---|---|---|
| A | 68 | 44 | 16 |
| B | 98 | 84 | 22 |
| C | 84 | 56 | 16 |
| D | 98 | 84 | 28 |
| E | 84 | 54 | 16 |
| F | 98 | 96 | 46 |
| G | 90 | 56 | 18 |
| H | 84 | 46 | 18 |
| I | 86 | 56 | 16 |
| J | 74 | 52 | 18 |
| NPPC Plan | 76 | 50 | 18 |

a/ Probability applies to meeting flow target during period of release specified for respective options.

for each of the 50 years in the period of record to corresponding travel times. This was done by assuming specific elevations for each of the eight lower Snake River and lower Columbia River projects (i.e., full pool, MOP, or spillway free flow). For each option, the 50 travel time values were ranked and then assigned a relative probability; for example, 2 percent (1/50) was assigned to the lowest particle travel time in the 50 years. Although not probability functions in the strictest sense, these plots give a reasonably good idea of the relative effects of pool levels and flow augmentation measures on water particle travel time. They also show the approximate probability of being able to meet specified travel time objectives in any year.

### 3.4.6.1 Snake River

Figures 3.4-5 and 3.4-6 show the travel time probability distribution for the lower Snake River. Also shown is the water particle travel time equivalent to the CBFWA flow proposal for the Snake River (6.4 days). The probability of achieving this goal in any year is approximately 17 percent for the current Dworshak and Brownlee operations (Option A) with the lower Snake projects at full pool. When the pools are lowered to MOP, the probability increases to 25 percent. For the near spillway crest option, the CBFWA goal is achieved in all years. For this case it was necessary to calculate a specific May pool elevation for each water year, because the free-flow spillway pool elevation is a function of the discharge in that month.)

Similar plots are shown for the three pool alternatives in combination with the most extreme flow augmentation operation, Option F. At maximum pool and MOP, the probability of meeting the CBFWA goal is increased by about 40 percent compared to Base Case flow augmentation. Nothing is gained by combining Option F with the near spillway crest option because the CBFWA goal was already being met 100 percent of the time.

A curve representing pre-dam natural conditions is now shown on Figure 3.4-5 because this is not an alternative

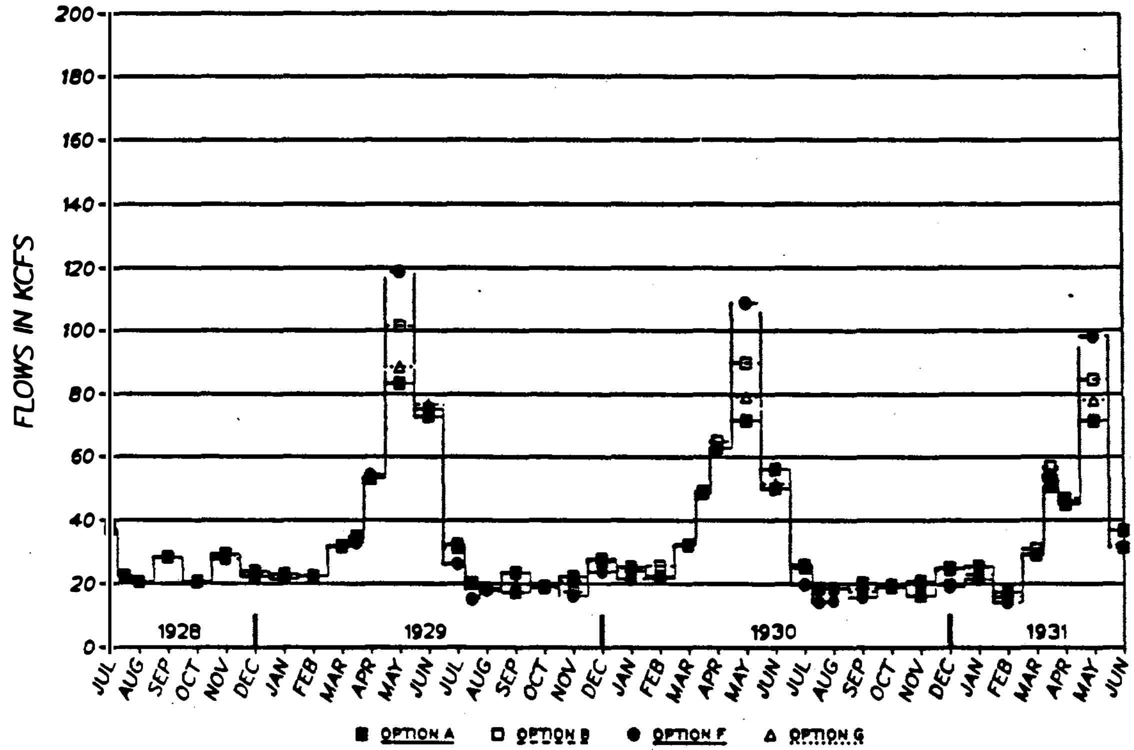



Figure 3.4-3. Lower Granite Project flow, low runoff years: 1928 to 1931.

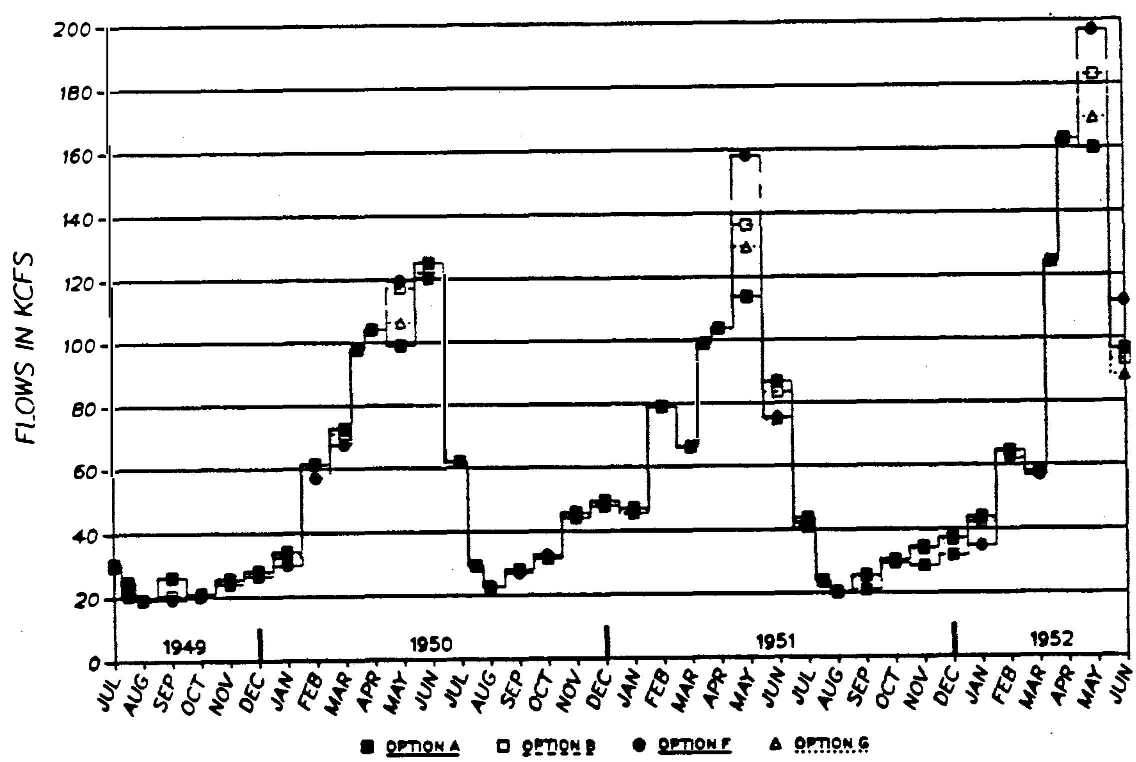



Figure 3.4-4. Lower Granite project flow, high (1950) and average (1951) runoff years.

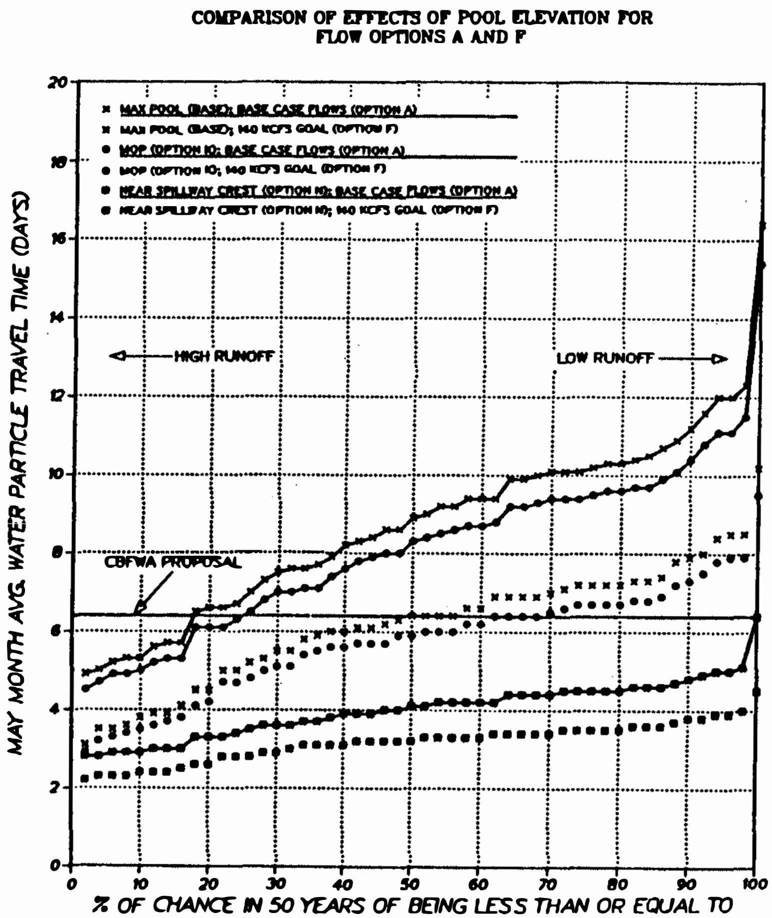



Figure 3.4-5. Lower Snake River water particle travel time probabilities, Clearwater River to mouth.

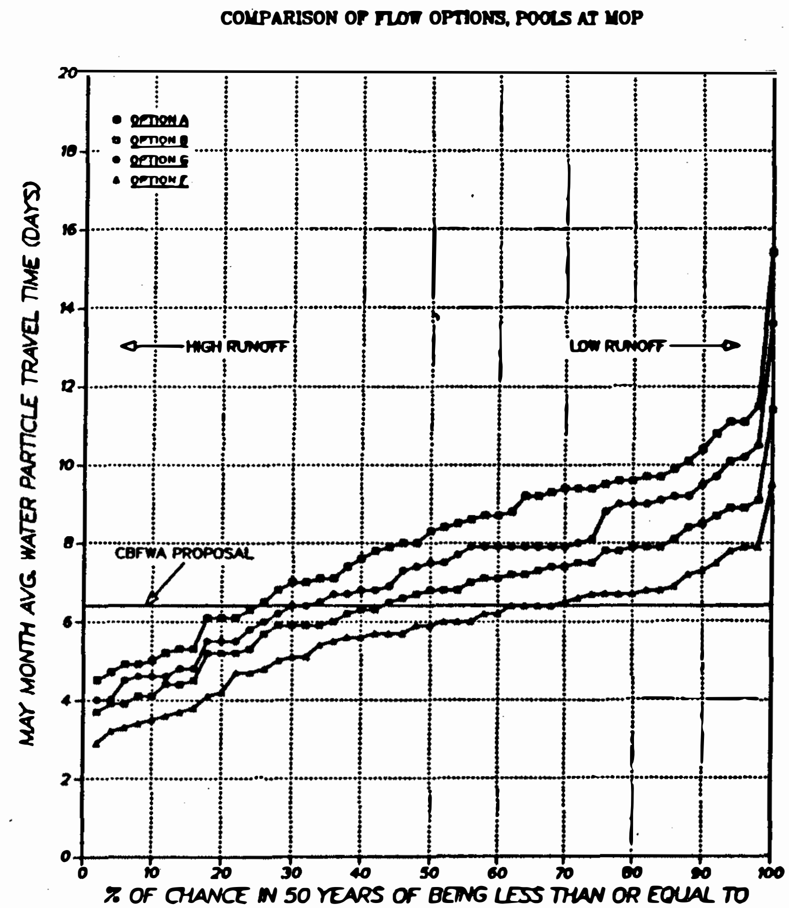



Figure 3.4-6. Lower Snake River water particle travel time probabilities, Clearwater River to mouth.

in this study. For reference purposes, however, under the natural conditions the curve would be virtually a straight line beginning at 1.0 day at 2 percent and extending to about 1.7 days at 100 percent.

Figure 3.4-6 compares the effect on water particle travel time of the four representative flow augmentation options (A, B, G, and F). For simplicity of plotting, the probability curves are shown for only one reservoir drawdown option, MOP. Since Options A and F bracket the other two cases, inferences regarding water particle travel time for Options B and G at other pool elevations can be gained by interpolating between the curves on Figure 3.4-5. For MOP elevations, it can be seen that only a modest reduction in water particle travel time can be obtained by Option G. A greater reduction can be achieved by Option B, and Option F meets the CBFWA goal (during May) almost 70 percent of the time.

### 3.4.6.2 Snake Plus Columbia

Figures 3.4-7 and 3.4-8 show the results of extending the water particle travel time computation through the lower Columbia River projects to Bonneville Dam. The figures reflect base condition operation of the upper Columbia River System and two to four options for Snake River flow augmentation. Also shown on the plots is the water particle travel time associated with the CBFWA flow proposals at maximum pool (15.1 days).

Figure 3.4-7 indicates that for Base Case conditions at maximum pool, there is approximately a 33 percent chance of meeting the objective in any year. Lowering the pools to MOP increases this probability to 43 percent. Implementing Option F in the Snake River provides a significant increase in the probability of achievement during May, to about 90 percent in the case of MOP pool elevations. Figure 3.4-7 does not show the impact on water particle travel time of the combination of drawing the four lower Snake River reservoirs down to spillway free flow and lowering the four lower Columbia River projects to MOP. However, this can be estimated for the Base Case by moving the MOP curve down by the difference between the MOP (Base Case) and near spillway crest (Option F) curves on Figure 3.4-5. The result is that the CBFWA goal would be met in all years without additional flow augmentation.

Figure 3.4-8 compares the four flow augmentation options (A, B, G, and F) for the combined lower Columbia-lower Snake reach given that the eight run-of-river projects are being operated at MOP. The probability of achieving the CBFWA objective during the period of additional releases increases from 43 percent for the Base Case to 56 percent for the Option G flows, and to 66 percent for Option B. For Option F, the probability is further increased to 90 percent.

### 3.4.6.3 Conclusions

In examining opportunities for flow augmentation using Dworshak Reservoir, a wide range of options was tested. Most of these options were designed to test the impact of specific operating strategies, but it was recognized that it would be unlikely that any of the flow augmentation options outlined in the draft OA/EIS would be selected for implementation in their original form.

In the preliminary final OA/EIS, a new option was added (Option J), which incorporated some of the best features of the previous options. Subsequent to issuing the preliminary final OA/EIS, the Northwest Power Planning Council adopted a series of amendments to their Columbia River Basin Fish and Wildlife Program, some of which applied to the Water Budget operation of Dworshak. Their Dworshak operation was also added to the list of flow augmentation options as the NPPC Plan.

The NPPC (1991b) Plan was compared with Option J, and it was found that each plan was strong in certain areas and weak in others. The principal advantage of the NPPC Plan was that it provides more flow augmentation than Option J in low runoff years (forecasted runoff at Lower Granite of 16 MAF or less). The NPPC plan provides a minimum shapeable Water Budget of 900 KAF in addition to Dworshak's 2 kcfs minimum discharge requirement, which would be 242 KAF over the April 16 to June 15 period. Additional water would be available in some years from shifting system flood control from Dworshak to Grand Coulee. Option J provides 900 KAF also, but this volume must provide flow to meet the minimum discharge requirement and the storage gained from the flood control shift would be used to improve refill rather than adding to the Water Budget. Option J will provide more than 900 KAF if the April 15 runoff forecast indicates that this can be done while maintaining a 70 percent probability of refill; this happens in approximately one-third of the water years.

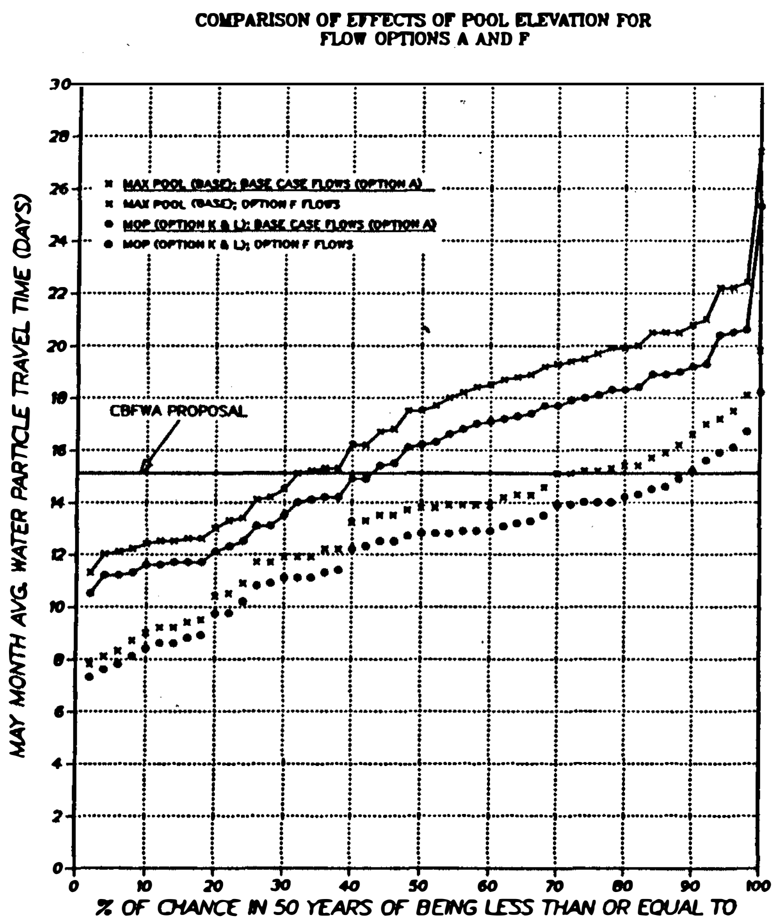



**Figure 3.4-7.** Lower Snake and Columbia rivers water particle travel time probabilities, Clearwater River to Bonneville Dam.

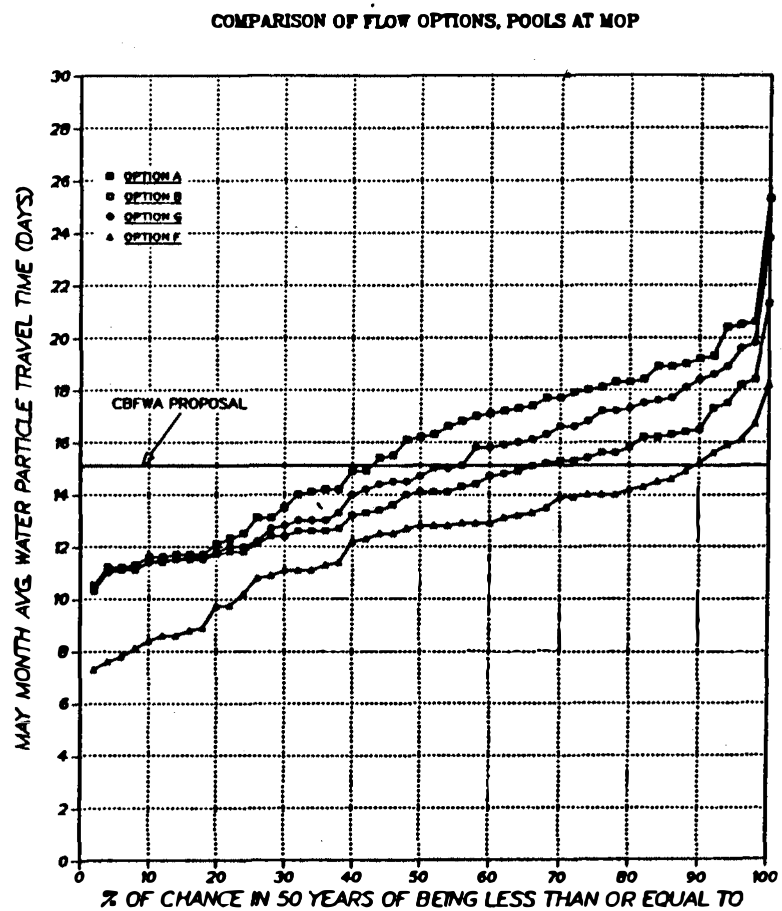



**Figure 3.4-8.** Lower Snake and Columbia rivers water particle travel time probabilities, Clearwater River to Bonneville Dam.

For mid-range runoff forecasts, and in particular those in the 16 to 21 MAF range, Option J provides more Water Budget than the NPPC Plan. Between 19 and 29 MAF, the NPPC Plan limits the Dworshak Water Budget contribution to water in excess of that required to provide 70 percent assurance of refill (as estimated on April 15). Option J provides a guaranteed 900 KAF, regardless of refill probability (unless the combined runoff of all Snake River tributaries is sufficient to provide 100 kcfs at Lower Granite without the full 900 KAF from Dworshak). The result is that of the 12 years in the 16 to 21 MAF forecast range, Option J provides 900 KAF or more in 11 years, while the NPPC Plan falls short of 900 KAF in 7 of the 12 years, sometimes providing 500 KAF or less. In the one year in which Option J provided less than 900 KAF, the discharge at Lower Granite met the 100 kcfs flow target with a Dworshak contribution of less than 900 KAF. In the 7 years in which the NPPC Plan failed to provide 900 KAF, the runoff forecast was low and the 70 percent refill requirement limited the amount of water that could be provided for Water Budget.

For the higher runoff forecasts, the NPPC Plan provides more water from Dworshak than Option J in most years. This is because Option J limits Dworshak discharges when the 100 kcfs Lower Granite flow target is already being met. In such cases, the Dworshak discharge would be limited in Option J to the greater of: (1) the Dworshak discharge required to ensure that 100 kcfs would be met, or (2) the 2 kcfs minimum discharge (higher Dworshak releases would be allowed in those high runoff years when refill is already assured). The intent of this provision is to improve Dworshak refill when flows at Lower Granite are already high. The NPPC Plan makes all water above the 70 percent refill curve (as of April 15) available for Water Budget. The result is that, under the NPPC Plan, there are more years when flows at Lower Granite exceed 100 kcfs. On the negative side, in some of these years Dworshak fails to refill. This is because the actual runoff was lower than the April forecast indicated, and water that could have been used for refill was used to increase Lower Granite flows that were already 100 kcfs or higher.

In comparing Dworshak refill performance associated with the two plans, studies indicate that the Option J would provide better refill performance. In the driest years, July 31 elevations can be expected to be 5 to 10 feet higher under the same water conditions for Option J compared to the NPPC Plan.

Only a short time was available for review of the NPPC Plan, and even now some of the key implementation details have not been worked out. However, the cursory analysis summarized above indicates that the best plan for the 1992 operation would be one that combines the higher Water Budget performance of the NPPC Plan in low runoff years with Option J, which provides more Water Budget flows in years of moderate runoff and a better probability of refill in years when the 100 kcfs flow target can be provided without a large contribution from Dworshak. Analysis of the results of combining Option J and the NPPC Plan indicates that for this plan the probability of refill at Dworshak is 56 percent. This refill probability is lower than that of either Option J (74 percent) or the NPPC Plan (64 percent). This is because the combination plan optimizes the flow augmentation performance of both plans resulting in the slightly lower refill probability. Accordingly, the recommended Dworshak flow augmentation plan for 1992 is one that follows the NPPC Plan if the April Lower Granite runoff forecast is less than 16 MAF and Option J if the forecast is 16 MAF or greater. This plan is summarized in Table 3.4-6.

In terms of long-term implementation, there are still many unanswered questions with respect to the Dworshak operation. One aspect addresses what might be the best operation between the end of the refill season and January 1. This is dependent to some extent on the results of tests to determine if there are significant benefits from drafting Dworshak in August for water temperature. Some tests have already been performed and additional tests are scheduled for 1992.

Another aspect is the fact that the National Marine Fisheries Service has not yet had sufficient time to make a detailed review of the merits of either the options presented in this OA/EIS or the NPPC Plan with respect to their endangered species recovery planning. Furthermore, NPPC staff recognizes that there are many details that must be worked out before their plan could be implemented, and they expect to initiate coordination with the operating agencies and NMFS early in 1992 to further refine their plan and modify it if necessary.

Therefore, it must be emphasized that the proposed Dworshak operation should be viewed strictly as the best option for the 1992, and that the Corps, NMFS,

Table 3.4-6. Variation of water budget operation with runoff forecast for recommended plan.

| Lower Granite April-July Runoff Forecast | up to 16 MAF | 16 to 29 MAF | 29 MAF and up |
|---|---|---|---|
| Operate to MRC 1 Jan - 15 Apr | yes | yes | yes |
| Flood Control Shift to Coulee | yes (as much as can be stored) | yes (as much as can be stored)[a] | not applicable |
| Base Water Budget | 900 KAF | 900 KAF minimum[b] | 900 KAF minimum[c] |
| Add Flood Control Shift | yes | no (included in base water budget) | not applicable |
| Total Shapeable Water Budget | 900 KAF plus shift | base water budget less minimum flow | base water budget less minimum flow |
| Add 2 kcfs Min Flow | 242 KAF | included in base water budget | included in base water budget |
| Total Discharge | 1142 KAF | base water budget | base water budget |
| 15 Jun - 31 Jul Discharge | 2 kcfs | 2 kcfs or more | current operation |
| Lower Granite flow target | 100 kcfs | 100 kcfs | 100 kcfs |

a/ For Dworshak April-July inflow forecasts of up to 2.6 MAF.

b/ 900 KAF minimum Water Budget unless Lower Granite discharge is greater than 100 kcfs, in which case Dworshak discharge is limited to the greater of the 2 kcfs minimum discharge or the discharge required to provide 100 kcfs at Lower Granite; more than 900 KAF will be provided if reservoir is above 70 percent refill curve on April 15.

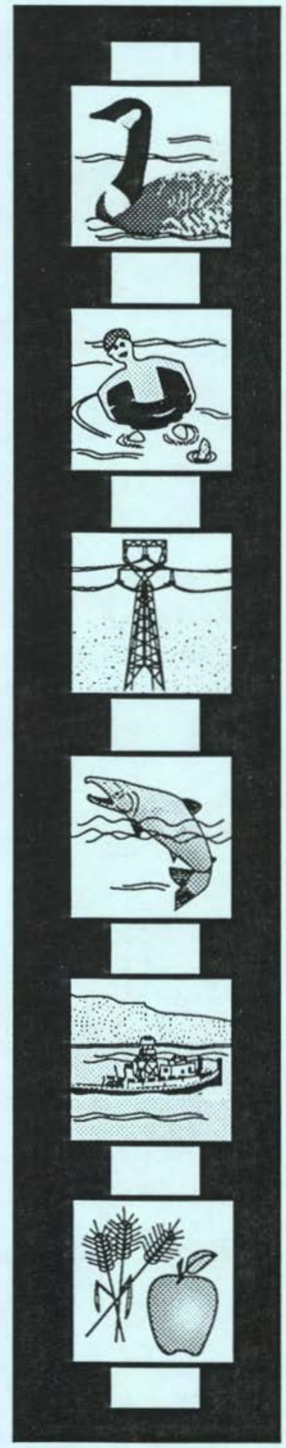
c/ Procedure described in Footnote a/ applies except that in this flow range the 100 kcfs Lower Granite flow target may limit Dworshak contribution to less than 900 KAF.

NPPC, BPA, the BoR, and other interests will continue their analysis and coordination throughout 1992 with the objective of developing a satisfactory long-term operating plan.

This OA/EIS does not recommend specific flow augmentation operations for Brownlee or the upper Snake River reservoirs. This is because the cooperating agencies have no authority over these projects except with regard to flood control and navigation. The Northwest Power Planning Council made some recommendations with respect to these projects in the December 11, 1991 modifications to their Fish and Wildlife Program. It is anticipated that the Council will work with the project operators and other interests to develop operating plan for these projects for 1992.

# 4.0

# Environmental Effects of Alternatives



1992 COLUMBIA RIVER SALMON FLOW MEASURES
OA/EIS

CONTENTS

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

TABLES

TABLES (continued)

TABLES (continued)

FIGURES

FIGURES (continued)

# 4.0 ENVIRONMENTAL EFFECTS OF ALTERNATIVES

This section presents the anticipated effects on the physical, biological, social, and economic environments associated with the implementation of the options outlined in Section 3. It provides the scientific and analytic basis for the comparison of alternatives presented in Section 5.

Section 4 details the effects of the options by the same resource areas used in Section 2, the description of the affected environment (i.e., water quality, anadromous fish, resident fish, etc.). Impacts have been identified for each resource, along with the level of impact per option. The flow augmentation options in general would have little significant impact on all but resident fish, recreation, and aesthetics, and in many cases, the differences in impact among flow augmentation options are minor. Therefore, there is little discussion of the impact of these options on other resource areas. In the interest of space, the analysis does not detail all of the effects from each of the combination alternatives since they are generally additive.

Further, there is minimal discussion of the Non-Treaty Storage Option for the Columbia River. This option would result in a maximum discharge of an additional 10 kcfs on the Columbia River in July and August. Compared to flows at The Dalles typically ranging from about 120 kcfs to 190 kcfs, discharges of this magnitude would not have significant in-river effects at The Dalles. Simulation studies also indicate that such releases would not have significant effects on operations at Grand Coulee. The complete range of impacts from implementation of such an action were previously addressed in BPA's environmental assessment of the Non-Treaty Storage Agreement (BPA, 1990), which is hereby incorporated by reference.

An attempt has been made to tell a complete story for each resource area and impact issue rather than for each option. Because there are so many affected resources and numerous options, the analysis is complex by necessity. In an effort to keep it as coherent as possible, summary tables that identify the significant impacts of each alternative are provided at the beginning of each resource area. Impacts not identified in the table are either not significant or non-existent.

This document was prepared in an extremely short timeframe, allowing for development of little new data or information. Therefore, the analysis presented in this section is based on existing available information. This results in a number of areas of uncertainty, some of which will require several more years of research before answers are known. Where precise information was lacking, the cooperating agencies used their best professional judgment to identify the effects thought most likely to occur.

## 4.1 WATER QUALITY

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown** | |
| ***Snake River*** | |
| All 4 projects to MOP (April 1 to July 31) | • Insignificant changes in gas saturation levels, temperatures, turbidity, and other parameters. |
| All 4 projects to near spillway crest (April 15 to August 15) | • Potential gas saturation increase of up to 130 to 150 percent, gradually increasing from one project to the next (110 acceptable State standard and EPA criteria).<br>• Potential minor temperature change, possible peak shift and reduction.<br>• Noticeable increase in turbidity. |
| All 4 projects to near spillway crest (April 15 to June 15) | • Similar to spillway drawdown to August 15 except with a decrease in duration. |
| Lower Granite to near spillway crest (February 1993 or July 15 to August 15) | • Gas saturation increase but less severe than dropping all 4 to near spillway crest.<br>• Potential increase in turbidity. |
| Lower Granite to 710 feet, others to MOP (April 15 to June 15) | • Gas saturation could rise to 120 percent (and up to 140 percent below Lower Granite); elevated saturation levels also experienced downstream (110 percent acceptable State standard and EPA criteria).<br>• Potential increase in turbidity. |
| Lower Granite/Little Goose drawdown test (March) | • Potential elevated gas saturation levels.<br>• Potential temporal increases in turbidity. |
| ***Lower Columbia*** | |
| All 4 projects to MOP (April 1 to August 31) | • Potential gas saturation slightly higher than existing, possibly rising to 120 percent with maximum up to 130 percent (110 percent acceptable State standard and EPA criteria).<br>• Greater daily fluctuations in temperatures and increased daily maximums.<br>• Temperature maximums potentially reached weeks earlier in Lakes Wallula, Umatilla, Celilo, and Bonneville.<br>• Minimal localized impacts to turbidity. |
| John Day at 262.5 feet, McNary at 337 feet, remainder at MOP (April 1 to August 31) | • Potential gas saturation the same as existing levels between 115 and 120 percent (110 percent acceptable State standard and EPA criteria).<br>• Temperatures remain within typical range. |

Water Quality (continued)

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Flow Augmentation** | |
| *Dworshak* | • Water temperatures expected to decrease below Dworshak Dam, particularly in Clearwater and lower Snake rivers with largest reductions occurring with greatest flow releases (e.g., 1,200 KAF).<br>• Water quality of lower Snake would be slightly improved by dilution from cleaner Northfork water with the less clean mainstem Snake water.<br>• Slight potential increase in dissolved gas levels in mainstem Snake below the dams.<br>• Noticeable differences in thermal profiles at least at Lower Granite with significant Dworshak releases, effect not expected to be significant at Ice Harbor Dam. |
| *Brownlee* | • Chemical water quality of lower Snake River degraded by flow augmentation from Brownlee. |
| *Grand Coulee* | • Greater fluctuations in temperatures and increased daily maximums (still within normal range). |
| **Combination** | • Effects additive; see drawdown and augmentation. |
| **Temperature Control Test (August)** | • Significant positive impact on temperature at Lower Granite. Anticipate shift in temperature profile of approximately 2 to 3 weeks at Lower Granite.<br>• No significant change in temperature expected at Ice Harbor. |

The proposed actions would affect flow conditions on the Columbia and Snake rivers. Because the various alternatives and options are essentially defined by these changes, effects on the key parameters of flows and elevations are summarized in Section 3.4.

The water quality of the affected system, as demonstrated in Section 3.1, is an extremely complex issue because the water is comprised of at least three major distinct systems: the lower/middle Columbia River, the lower/middle Snake River, and the Clearwater River. Each of these rivers contains major reservoirs with unique characteristics. Existing Corps system models, which incorporate some physical water quality parameters, were not calibrated to address the proposed alternatives, or the models are not applicable. Modeling, therefore, bas not been conducted specifically for these alternatives, with the exception of temperature models which are presently under development. Given these constraints, it was not possible to quantify impacts to specific water quality parameters for the proposed alternatives. However, it is possible to identify relative impacts for the major alternatives and infer the order of magnitude or ranges of impact for certain key parameters.

### 4.1.1 Gas Saturation

#### 4.1.1.1 Background

The seriousness of the problem of dissolved gas supersaturation in the Columbia River surfaced in spring 1968 when the powerhouse for John Day Dam was constructed. The project was closed during part of construction and the entire flow of the river was passed over the spillway. Many adult salmon died of gas bubble disease from the spill. Gas supersaturation has probably existed in the Columbia River System since before Bonneville Dam was constructed in 1938. Gas supersaturation has been known to occur in unim-pounded natural streams like the Salmon River in rapids, waterfalls, and at points where a cold stream having high saturation concentration warms to a higher temperature. It is, therefore, likely that gas supersaturation occurred at the confluence of the Snake and Columbia rivers and at Celilo Falls. However, natural supersaturation values were probably much lower than those caused by the dams.

The Columbia River experienced major flood runoff in 1974, resulting in high spills. The level of dissolved gas was generally in excess of 115 percent at nearly all projects from April through July. The highest recorded value was 144 percent nitrogen saturation immediately downstream of Lower Monumental Dam on June 19, 1974. After 1974, the Corps altered its reservoir storage practices to minimize spill at all the Corps dams on the Columbia and Snake rivers, added flip-lips, and redistributed spills to selected projects.

In several reaches of the lower Snake and middle Columbia rivers, dissolved gas levels exceeded 120 percent for short periods in 1986. Warm weather in late May rapidly melted the snow causing unexpectedly increased river flows. About 34 percent of the Snake River flow passed over the spillways of lower Granite Dam and about 41 percent of the Columbia River flow passed over the spillways of Priest Rapids Dam for about 10 days ending in early June.

In spring 1990, a powerhouse fire at John Day Dam forced all of the river flow to be released over the spillways. The resulting dissolved gas saturation levels rose to 140 percent immediately downstream of the dam, but levels dropped rapidly to about 125 percent within 5 miles and stayed there for the next 40 miles of The Dalles Pool.

Maximum total dissolved gas saturation data for 1984 to 1990 are presented in Table 4.1-1. Two factors must be noted in considering these data: (1) flows were below normal for much of the period, reducing saturation because less water was spilled; and (2) the monitoring stations are located almost exclusively in the forebays of the dams. Thus, typical maximum stilling basin (spill side) saturation levels are expected to be higher than the values presented in Table 4.1-1, perhaps by as much as 5 to 10 percent. Data from Boyer (1974) suggested that before flip lips were constructed, maximum nitrogen supersaturation below the spillway ranged from 135 to 155 percent. Note that nitrogen supersaturation can be a few percent higher than total gas saturation.

Figures 4.1-1 through 4.1-4 show the maximum and minimum total dissolved gas percentage of saturation at John Day, The Dalles, and Bonneville dams, and at Warrendale (6 miles downstream of Bonneville Dam) from April through September 1990. This was an example water year where April-to-September flows (at The Dalles) represented 99 percent of average (1926 to 1990, adjusted for upstream storage). The dissolved gas levels in 1990 at John Day Dam generally ranged from 100 to 115 percent of saturation, while The Dalles values generally ranged from 100 to 120 percent and Bonneville values ranged from 100 to 123 percent. The dissolved gas levels 6 miles downstream of Bonneville Dam at Warrendale (RM 140) ranged from about 100 to 118 percent of saturation.

Figures 4.1-1 through 4.1-4 also show the maximum and minimum daily dissolved gas saturation values experienced between 1984 and 1989. These figures serve to illustrate the complex relation of spill flow (highest in late spring and summer) and temperature (highest in mid- to late summer) to gas saturation. Higher flow values induce increased mixing that can reduce supersaturation; however, in unmixed reaches higher flows imply less time to readjust to (equilibrate) gas saturation. For a fixed amount of gas, the lower the temperature the more gas can be dissolved before supersaturation occurs. Although dissolved gas levels dissipate to some degree between projects, levels would become successively

**Table 4.1-1.** Maximum total dissolved gas saturation (in percent) in the Columbia River Basin.

| Location | 1990 | 1989 | 1988 | 1987 | 1986 | 1985 | 1984 |
|---|---|---|---|---|---|---|---|
| International Boundary | 124.6 | 124.6 | 123.5 | 123.1 | 134.2 | 123.6 | 125.6 |
| Below Grand Coulee | 119.9 | 120.5 | 110.7 | 114.3 | 139.2 | 114.9 | 113.1 |
| Chief Joseph | 120.2 | 117.0 | 112.7 | 115.1 | 118.4 | 116.5 | 114.7 |
| Wells | 119.5 | 116.1 | 111.6 | 114.2 | 125.7 | 115.5 | 118.1 |
| Rocky Reach | 132.3 | 113.3 | 110.8 | 115.3 | 123.4 | 114.2 | 122.8 |
| Rock Island and Wanapum | 131.2 | 114.8 | 111.6 | 117.2 | 118.1 | 113.6 | 122.0 |
| Priest Rapids | 133.0 | 121.6 | 126.8 | 122.7 | 128.4 | 123.0 | 128.3 |
| Lower Granite | 111.0 | 111.4 | 111.3 | 116.0 | 112.2 | 111.7 | 121.7 |
| Little Goose | 124.3 | 110.0 | 115.1 | 114.7 | 124.4 | 114.1 | 128.2 |
| Lower Monumental | 124.7 | 119.9 | 110.9 | 113.4 | 130.0 | -- | -- |
| Ice Harbor | 117.9 | 118.9 | 116.3 | 114.6 | 140.6 | 119.0 | 138.3 |
| McNary, WA | 124.4 | 115.7 | 115.3 | 118.0 | 125.9 | 120.6 | 127.7 |
| McNary, OR | 126.0 | 120.6 | 121.1 | 118.9 | 134.1 | 119.8 | 132.8 |
| John Day | 118.3[a] | 119.7 | 115.9 | 114.5 | 124.4 | 111.8 | 121.5 |
| The Dalles | 127.3 | 113.6 | 110.3 | 112.8 | 133.8 | 124.8 | 132.6 |
| Bonneville | 128.9 | 113.6 | 107.2 | 110.8 | 123.5 | -- | -- |
| Warrendale | 130.5 | 116.2 | 109.5 | 113.8 | 134.3 | 113.9 | 127.0 |

Source: Corps, 1990b.

a/ Excludes abnormal levels resulting from excessive spill associated with powerhouse fire.

higher if all projects were spilling.

Dissolved gas levels in the lower Snake River are affected by incoming flow from the Clearwater and middle Snake rivers. Spill from Dworshak, either during periods of high flow or for Water Budget releases, results in an increase in dissolved gas levels in the Clearwater River near Dworshak National Fish Hatchery at higher than estimated (115 percent), but data are very limited and do not describe the downstream extent of these supersaturated waters. Spill at dams in the Hells Canyon complex during higher flow years may also result in elevated dissolved gas levels. The flow from the Clearwater River mixes with the Snake River at Lewiston, at which point high dissolved gas levels, if present, have dissipated to some extent. Higher dissolved gas levels may be diluted by mixing with less saturated flows from the other river. Dissolved gas levels as high as 121.7 percent have been recorded in the Lower Granite forebay, although monthly averages range from

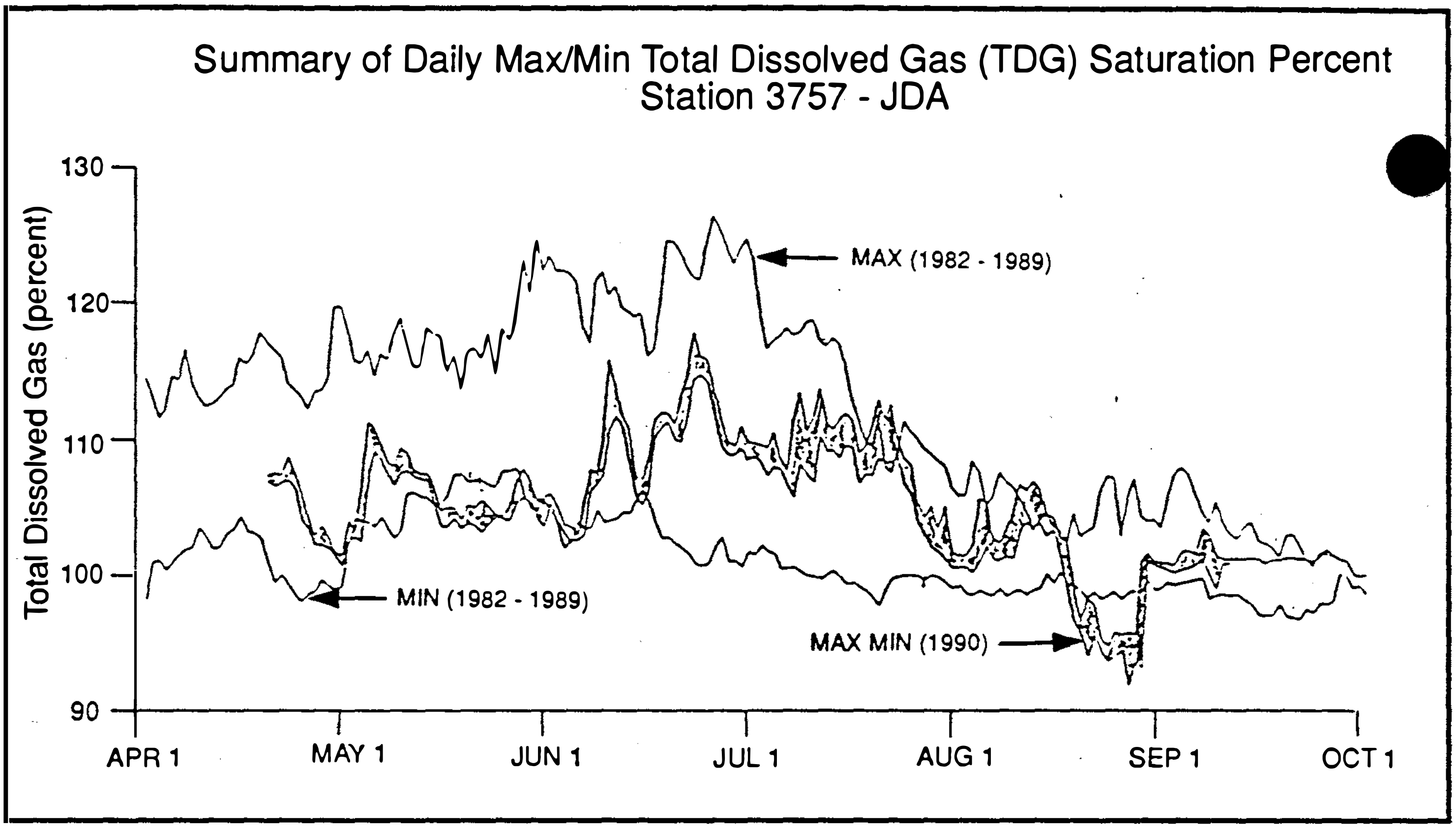



**Figure 4.1-1.** Total dissolved gas percent saturation at John Day Pool.

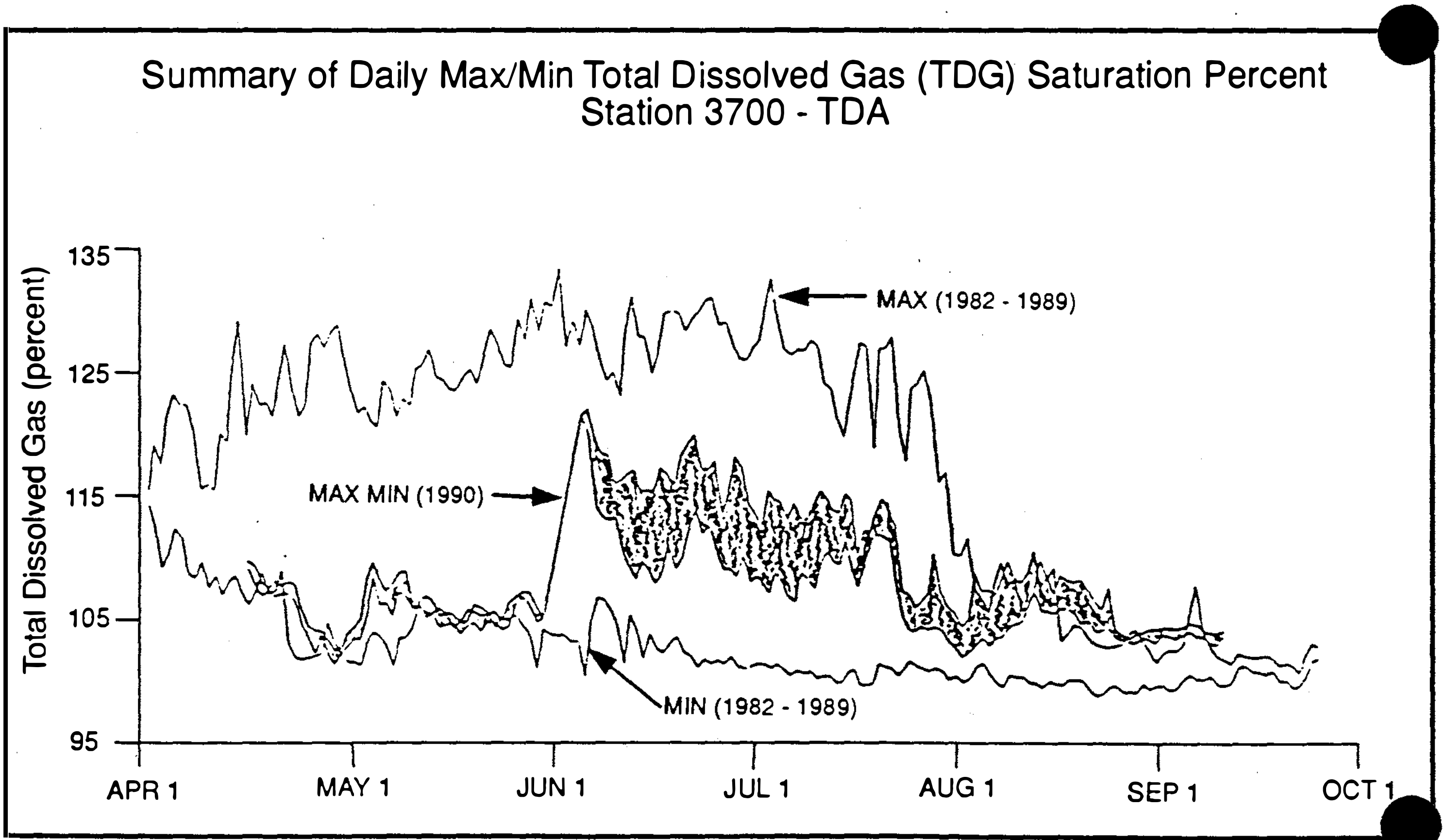



**Figure 4.1-2.** Total dissolved gas percent saturation at The Dalles Pool.

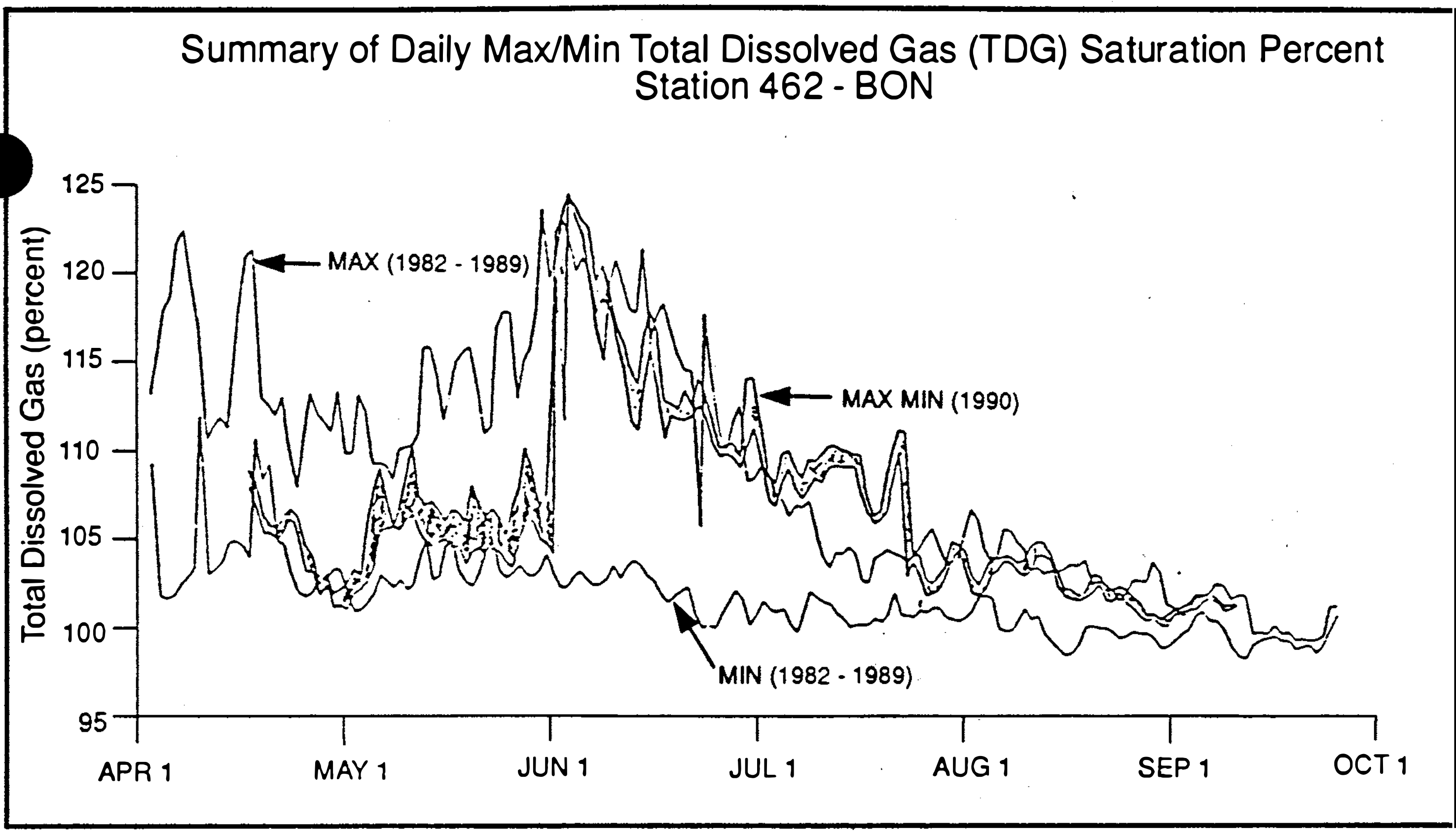



**Figure 4.1-3.** Total dissolved gas percent saturation at Bonneville Pool.

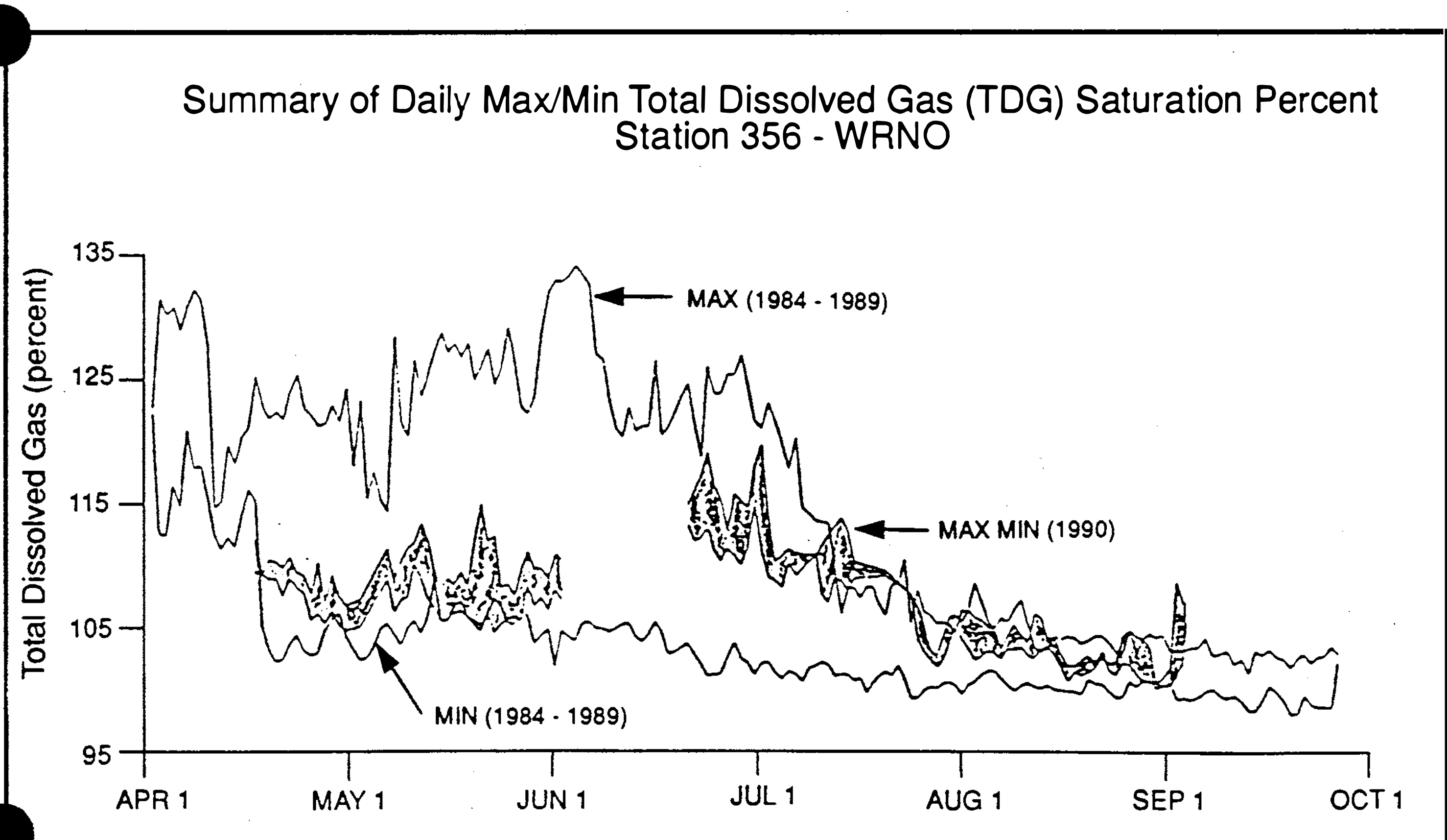



**Figure 4.1-4.** Total dissolved gas percent saturation at Warrendale, Oregon.

approximately 105 to 110 percent during higher flow years, and 100 to 104 during years of no spill.

Under current practices, spill generally occurs at Lower Granite and Little Goose only during high flow conditions, when river flow exceeds powerhouse capacity or electrical energy demand is low. Dissolved gas levels, therefore, are not increased between Lower Granite and Little Goose unless spill occurs. During the night (from 6:00 p.m. to 6:00 a.m.), 70 percent (or more) of flow at Lower Monumental and 25 percent of flow at Ice Harbor is spilled to pass juvenile fish. This spill results in an increase of dissolved gas levels of over 136 percent immediately below Lower Monumental Dam (equivalent data are not available for Ice Harbor at this time), although levels dissipate and spill flow is mixed with turbine flow, both of which result in lower levels present in Ice Harbor forebay.

During years of high spill, dissolved gas levels continue to increase throughout the lower Snake River reaching a maximum at Ice Harbor. In 1984, maximum levels of 111, 125, and 138 percent were recorded in the forebays of Lower Granite, Little Goose, and Ice Harbor dams, respectively. These levels resulted from extended periods of relatively high spill. Monthly averages were considerably lower. The increasing maximum gas levels as one moves downstream illustrate the cumulative impact of multiple dams spilling and suggest that supersaturated dissolved gas is not completely dissipated between projects.

The most comprehensive information on dissolved gas saturation in the middle Snake River came from a study conducted during spill periods from March to July 1972 (BPA, 1985). The results of this monitoring program are summarized below and are illustrated in Figure 4.1-5. Note that these results are reported in terms of percent nitrogen saturation, which is related to dissolved gas saturation by the approximate formula: Dissolved gas percent = 0.21 (percent oxygen saturation) + 0.79 (percent nitrogen saturation). Typically, dissolved nitrogen levels are about 5 percent higher than total dissolved gas at the ranges under discussion for this system. Note also that total dissolved gas, not just nitrogen, is of concern to organisms.

The Snake River exhibits dissolved nitrogen levels typically near saturation, particularly below natural falls. From the Payette River to Brownlee Dam, dissolved nitrogen concentrations remain near 100 percent saturation. Nitrogen saturation consistently increases at least slightly in the forebays of Brownlee and Oxbow dams.

In the Oxbow Reservoir, dissolved nitrogen concentrations ranged from 102 percent to 124 percent saturation during the spill period. In general, the nitrogen concentrations increased downstream from Brownlee Dam and reached a peak in the Oxbow Dam forebay. At Oxbow Dam, dissolved nitrogen concentrations decreased significantly below the spillway and, to a lesser degree, below the powerhouse during the spill period. However, during the non-spill periods, the Oxbow powerhouse increased the nitrogen concentration to a high of 111 percent.

At Hells Canyon Dam, dissolved nitrogen concentrations below the dam were greater than those in the forebay during both the spill period and the non-spill period. Downstream from Hells Canyon Dam, nitrogen levels decreased slowly during the maximum spill period. Dissolved nitrogen levels of less than 110 percent saturation are reached only near the confluence of the Snake and Salmon rivers.

#### 4.1.1.2 Drawdown Options

This group of options would produce the most noticeable impacts to gas saturation. The water release changes would generally cause further departure from the water quality standards for dissolved gas saturation.

Drafting the lower Snake River reservoirs to MOP would potentially result in some degree of additional spill because of the reduced peaking capacity of the powerplants at or near MOP. This is because a relatively static water level would be maintained. Spill would not likely be continuous for an extended time except in a high water year, in which case, spill would continue for weeks to months. Also, nighttime spills might be required because of the lower regional power demands at night. If a continuous spill occurred, the potential for extended periods of gas supersaturation in the stilling basins exists, resulting in downstream dissolved gas supersaturation in the project forebay. Maximum values would likely fall within the range observed for existing conditions, typically 111 to

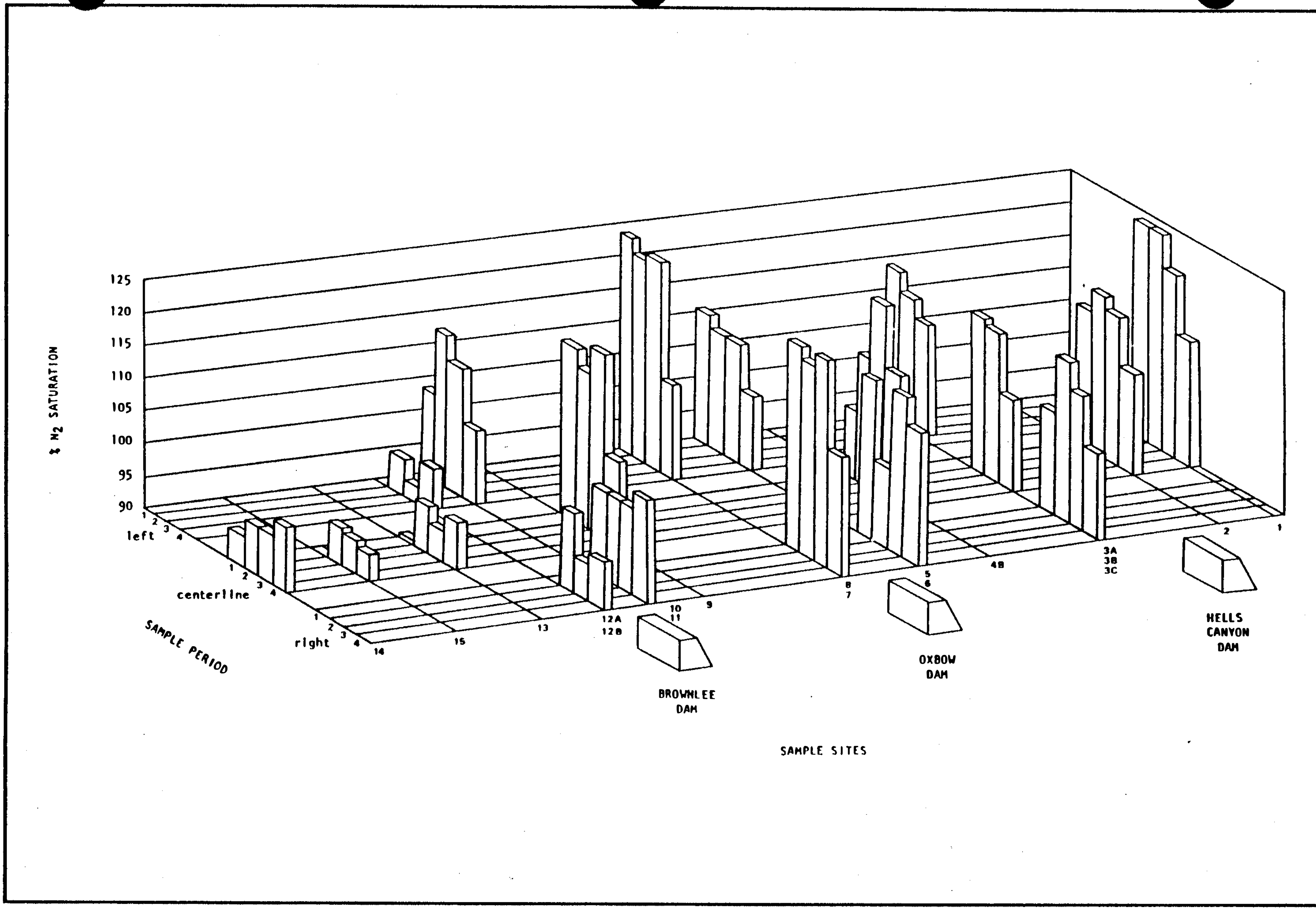



**Figure 4.1-5.** Nitrogen saturation of the Snake River at routine surface sampling sites from the Payette River to below Hells Canyon Dam (Source: Seattle Marine Laboratories, 1972).

125 percent, with infrequent occurrences of up to 140 percent saturation.

Drafting the lower Snake River reservoirs to near spillway crest (for 2 to 4 months at spillway crest and an additional 1 to 3 months to account for drawdown and refill) would require the entire river discharge to be passed over the spillway at each of the four projects. Because pool elevations would be reduced compared to normal operating conditions (and those under which the June 1 spill test were conducted), the plunge pool in the stilling basin of the dam immediately upstream would be shallower because of reduced tailwaters. Both factors would tend to reduce dissolved gas levels. However, unusually low tailraces would make the deflectors ineffective (at Lower Granite, Little Goose, and Lower Monumental dams), causing a substantial increase in the downstream dissolved gas levels. It is not possible to predict the overall effect of these interacting factors, but it is likely that dissolved gas levels would increase above 120 percent from Lower Granite downstream and could reach levels of 140 percent during periods of spill caused by drafting. The problem would be exaggerated over historical high dissolved gas levels as there would not be significant mixing with turbine discharge flows (which do not elevate background dissolved gas levels). Higher gas levels would dissipate to some degree, but water would still be supersaturated with dissolved gas when it enters the forebay of the next dam downstream. Based on past monitoring efforts, dissolved gas levels would become progressively higher as the water passed over the four lower Snake River spillways. It is possible to have dissolved gas levels ranging up to 135 to 150 percent maximums for the entire spill period in the lower dam forebays. The level would greatly exceed State standards of 110 percent saturation. See Section 4.2.1.7 for potential impacts of these levels.

Drafting Lower Granite to near spillway crest and the other Snake River projects to MOP might require the entire river discharge to be passed over the spillway at Lower Granite Dam only. In this event, gas supersaturation would again likely occur, but the effect is not expected to be as severe as drafting all four reservoirs to spillway crest. Because of the pool elevation in Little Goose Reservoir, the Lower Granite spillway deflectors might remain partially functional. Colder water temperatures during the winter test window would also likely result in lower gas levels compared to a summer action. In addition, the lack of spill downstream would allow dissolved gasses to continue to dissipate through each successive project, rather than building up.

Overall, impacts would be significant but less than that caused by spilling at all dams, with maximum dissolved gas levels at Lower Granite perhaps as high as 140 percent. State dissolved gas standards of 110 percent saturation would be exceeded.

At the request of those who participated in the development of the lower Snake reservoir drawdown alternatives, a test of 100 percent spill at Lower Granite was conducted on June 1, 1991. The primary purpose of this test was to observe flow conditions below the dam that may occur if Lower Granite Reservoir was drawn down to elevation 710, and the other three lower Snake reservoirs were maintained at MOP. Although Lower Granite Reservoir was maintained at MOP, general flow patterns should have been indicative of what would occur if the reservoir was operated at 23 feet below MOP. Three spill patterns were tested over four hours, and flows were observed downstream of the powerhouse and the adult fish collection facilities. During all spill patterns, a large counter-clockwise eddy was formed downstream of the powerhouse. Dissolved gas levels measured during the spill test were initially approximately 101 percent and reached a high of 137.9 percent at the conclusion of the test. Although the head would be less under a drawdown scenario, levels of dissolved gas are likely to exceed 120 percent because the spillway deflectors (flip lips) are ineffective under these conditions. Concentrations of dissolved gas would also depend upon flows. A level of 100 kcfs was chosen for the test. This represents a likely maximum during a low flow year, but could be greatly exceeded if higher flows are present in 1992.

Drafting Lower Granite Pool to elevation 710 feet during the fish migration and the other lower Snake River dams to MOP would likewise require the entire river discharge to be passed over the spillway at Lower Granite Dam only. Although head would be reduced when compared to normal operation, high flows and ineffective spillway deflectors could result in dissolved levels in excess of 120 percent and up to 140 percent. These levels would again dissipate downriver, although insufficient data exist to allow prediction of longitudinal profiles of saturation values. This would exceed State dissolved gas standards.

Drafting Lower Granite Reservoir to 705 and Little Goose to an elevation at which the tailwater would be equivalent to near spillway (two-reservoir test) from March 1 through 31 could have similar effects on gas saturation, but the test is designed to pass all flow through the powerhouse as long as possible. If spill was used to draft the reservoirs, the spillway deflectors would likely be ineffective, tending to increase saturation levels, while the shallower depth of the plunge pool would tend to decrease saturation levels. While one purpose of this test is to obtain information on gas saturation, it is expected that supersaturation will occur, and the actual test design may have to be adjusted to minimize supersaturation and to protect fall chinook below Lower Granite.

Drafting lower Columbia River projects would result in higher dissolved gas saturation levels over existing conditions downstream of the lower Columbia River dams. More water, over and above the spill agreement, would be released over the spillways during the night because of low nighttime power demands. Consequently, a larger volume of water over a longer period would elevate dissolved gas saturation values near or above 120 percent, with maximums up to 125 to 130 percent.

Partial drawdowns (e.g., McNary to 337 feet, John Day to 262.5 feet, and the balance of lower Columbia River projects to MOP) would generally exhibit dissolved gas levels that are between the existing conditions and drawing all four lower Columbia River project pools to MOP. Nighttime spills would again be anticipated. Thus, supersaturation of 115 to 120 percent could be expected.

#### 4.1.1.3 Flow Augmentation

Dissolved gas supersaturation levels in the vicinity of the stilling basins would likely increase with augmented flows and would be proportional to the additional amount of water released over the spillways. No increases are anticipated in a low flow year (i.e., no spilling). Water passed through the turbines does not increase dissolved gas saturation. Although data were not readily available, it is expected the levels would correspond to those of a high flow year under present spill conditions, perhaps 115 to 130 percent saturation in the Snake River System for portions of the season. Levels in the lower Columbia River would likely correspond to maximum levels observed during peak flow discharges as described for drafting of lower Columbia River projects. Nighttime spilling, which increases saturation, would be expected because of the power demand curves. If flow augmentation is used in conjunction with drawdown, gas supersaturation would be increased relative to the additional flow over the spillways and would likely be similar to that projected for drawdown. A similar effect may be anticipated for Brownlee although supporting data were not available.

### 4.1.2 Temperature

#### 4.1.2.1 Background

The major effect of the dams on the Columbia River System on water temperature has been to delay the thermal maximums occurring in late summer, plus perhaps a slight increase in overall average temperature (Vigg and Watkins, 1991). This is because of two factors. First, upper Snake and Clearwater river reservoirs store heat in the surface layers. This heat is released in late summer to early fall. Second, the lower Snake River pools gain heat from the large surface area (larger than pre-dam) available for heat gain and the slower travel time of water (increased hydraulic residence time) in the pool (slower than pre-dam). However, Chapman et al. (1991) suggested that average temperatures are slightly lower than pre-dam conditions, indicating additional factors are involved.

The water temperature monitoring at the Corps projects has been part of the same program as dissolved gas monitoring. Table 4.1-2 shows the maximum water temperatures at the 17 monitoring sites. Figures 4.1-6 through 4.1-9 show the maximum and minimum water temperature at John Day, The Dalles, and Bonneville dams, and Warrendale for 1982 through 1990.

Water temperatures for 1990 in the John Day Pool ranged from about 50°F (10°C) in early April to daily maximums of between 68 and 75°F (20 to 24°C) in late July and early August. The Dalles Pool varied from 52°F (11°C) in late April to a

**Table 4.1-2.** Maximum water temperature (°C) Columbia River Basin.

| Location | 1990 | 1989 | 1988 | 1987 | 1986 | 1985 | 1984 |
|---|---|---|---|---|---|---|---|
| International Boundary | 17.6 | 19.1 | 18.7 | 16.9 | 24.1 | 22.1 | 20.3 |
| Below Grand Coulee | 19.7 | 19.4 | 17.9 | 18.6 | 18.4 | -- | -- |
| Chief Joseph | 19.9 | 19.4 | 19.3 | 20.3 | 18.2 | 24.7 | 23.0 |
| Wells | 20.0 | 20.0 | 16.5 | 16.1 | 15.5 | -- | 22.3 |
| Rocky Reach | 21.0 | 20.2 | 15.7 | 17.4 | 16.9 | 26.5 | 22.3 |
| Rock Island and Wanapum | 23.8 | 21.3 | 17.0 | 18.2 | 17.8 | -- | -- |
| Priest Rapids | 22.9 | 22.5 | 21.2 | 20.1 | 19.6 | 25.0 | 24.9 |
| Lower Granite | 26.5 | 21.7 | 24.4 | 23.5 | 24.8 | 25.5 | 22.9 |
| Little Goose | 26.9 | 24.7 | 25.5 | 25.9 | 25.8 | 19.9 | 18.5 |
| Lower Monumental | 25.9 | 25.0 | 24.3 | 24.8 | 24.8 | 19.1 | 18.5 |
| Ice Harbor | 26.7 | 25.4 | 23.1 | 24.8 | 26.7 | 15.7 | 18.2 |
| McNary, WA | 23.9 | 24.1 | 23.9 | 25.2 | 23.0 | 14.8 | 16.8 |
| McNary, OR | 23.8 | 23.4 | 24.5 | 23.4 | 24.7 | 19.9 | 16.2 |
| John Day | 25.2 | 22.3 | 23.7 | 25.0 | 22.8 | 17.9 | 15.5 |
| The Dalles | 24.2 | 21.7 | 23.4 | 23.6 | 23.3 | 22.7 | 19.3 |
| Bonneville | 23.2 | 25.4 | 22.2 | 22.2 | 23.2 | 21.8 | 20.3 |
| Warrendale | 23.2 | 21.5 | 22.0 | 22.0 | 22.8 | 25.0 | 23.4 |

Source: Corps, 1990b.

maximum of about 73°F (23°C) in early August. The Bonneville Pool varied from about 50°F (10°C) in early April to maximum daily values of about 73°F (23°C) in early August. Downstream of Bonneville (at Warrendale) temperatures varied from about 52°F (11°C) in late April to daily maximums of about 73°F (23°C) in early August. The air temperature for this period was 4.7°F (2.6°C) warmer than average in April, 1.1°F (0.6°C) cooler than average in May, and 5°F (2.8°C) warmer than average in September. June, July, and August were slightly below average. A comparison with the earlier year's data suggests the significant influence air temperature has on the overall water temperature.

Table 4.1-3 provides temperature ranges during the spring and summer of a typical low and high flow year (1987 and 1984, respectively). These data illustrated the noticeable effect flow can have on temperature, although air temperature also accounts for variation in these profiles.

### 4.1.2.2 Drawdown Alternatives

If the Snake River dams are drafted to MOP, water temperatures might be altered because of decreased surface area in the backwaters and hence reduced solar heating, as well as increased water particle velocity (flow through the system). It is likely that such changes would fall within the range of typical temperatures for the existing system. A drawdown extending into August would result in the most noticeable elevation in temperature.

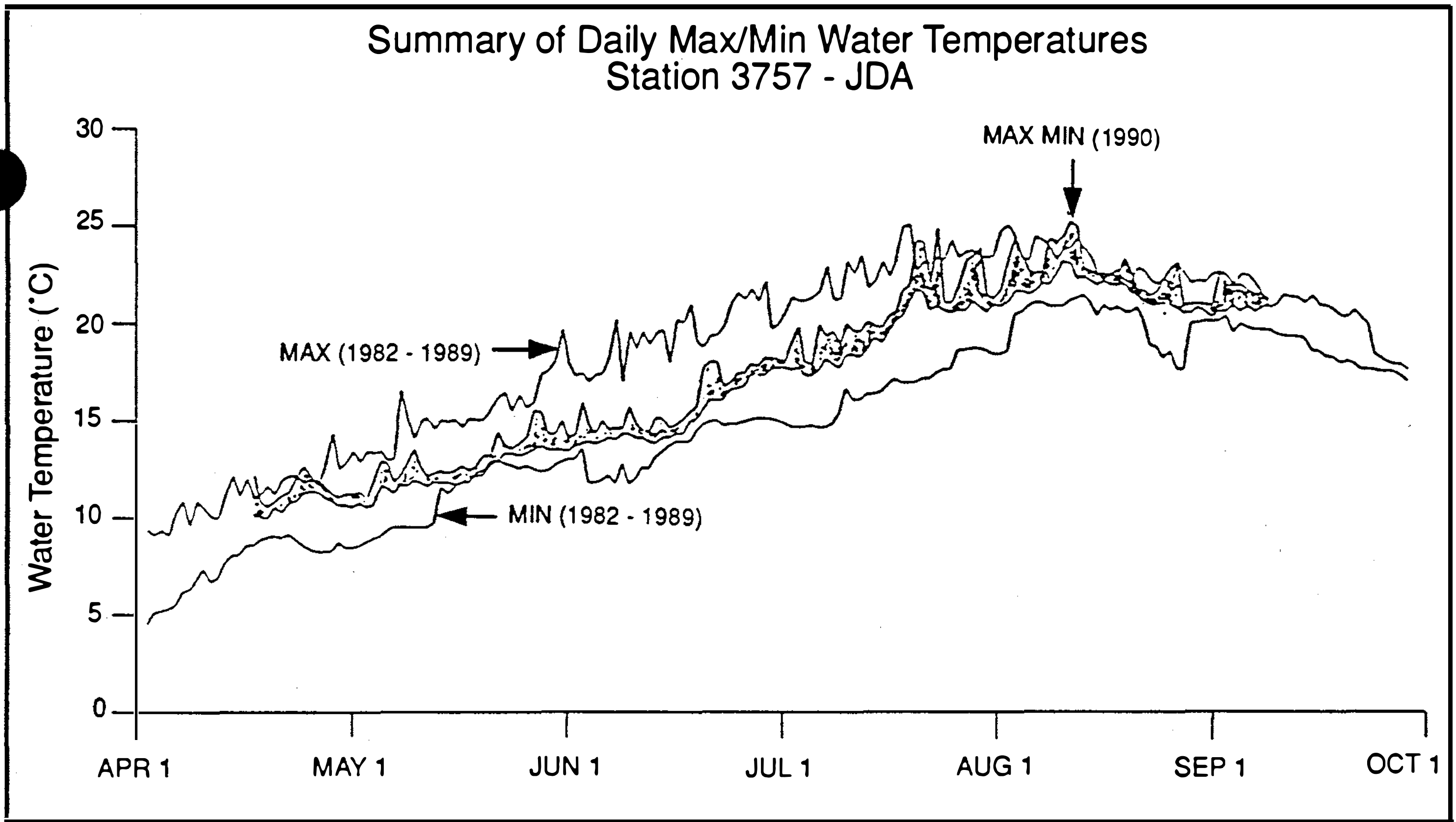



**Figure 4.1-6.** Maximum and minimum water temperatures at John Day Pool.

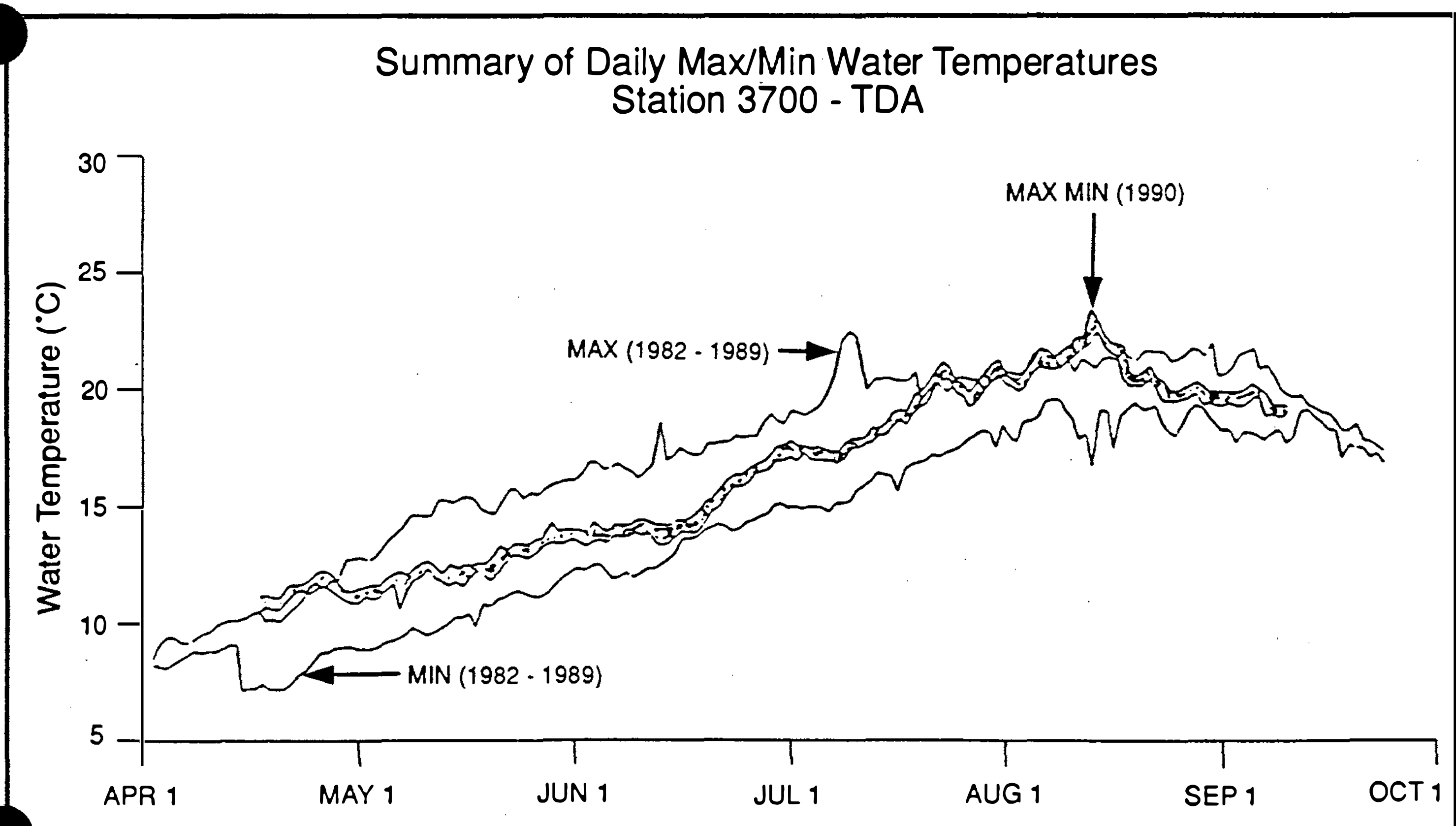



**Figure 4.1-7.** Maximum and minimum water temperatures at The Dalles Pool.

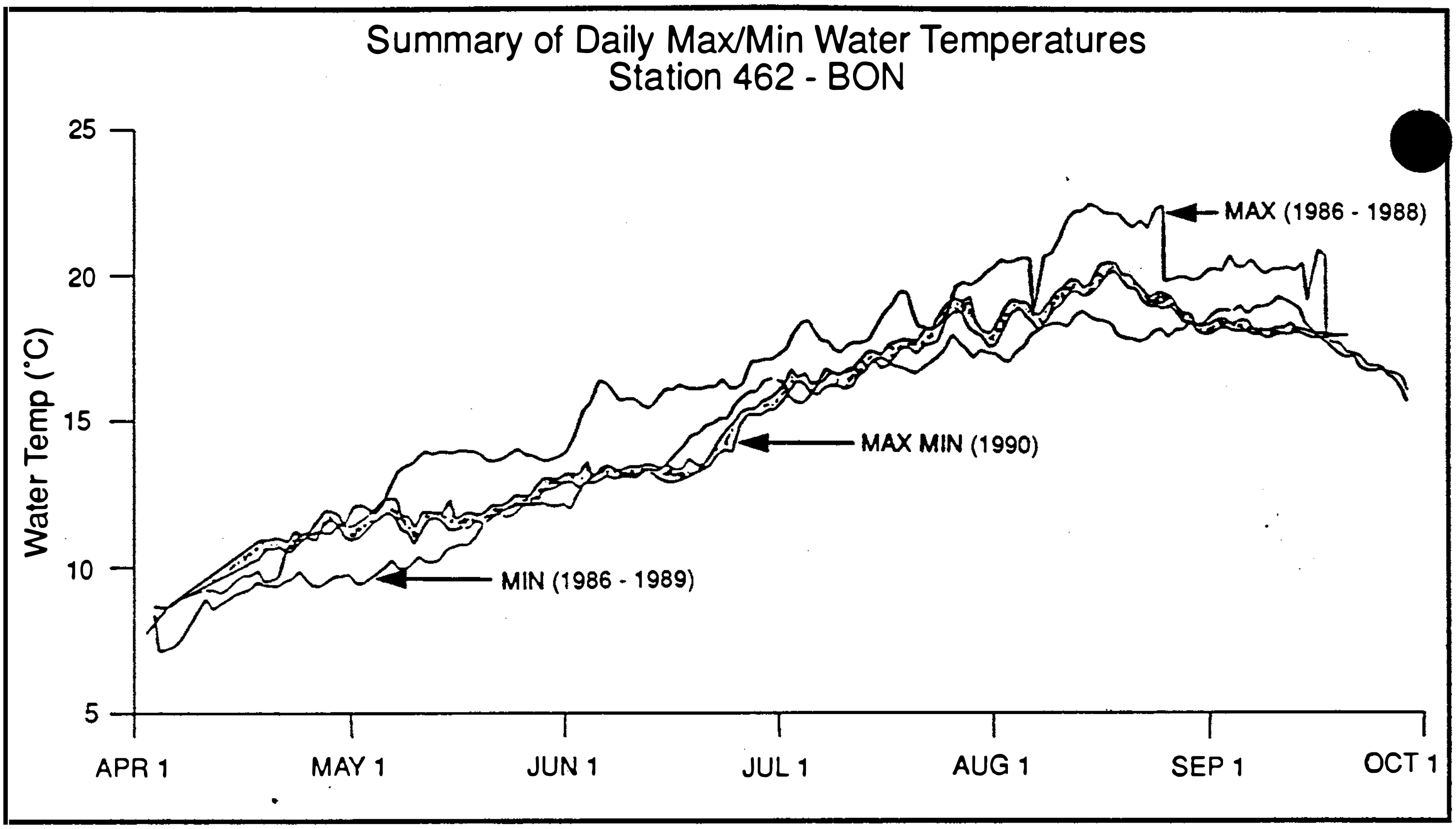



**Figure 4.1-8.** Maximum and minimum water temperatures at Bonneville Pool.

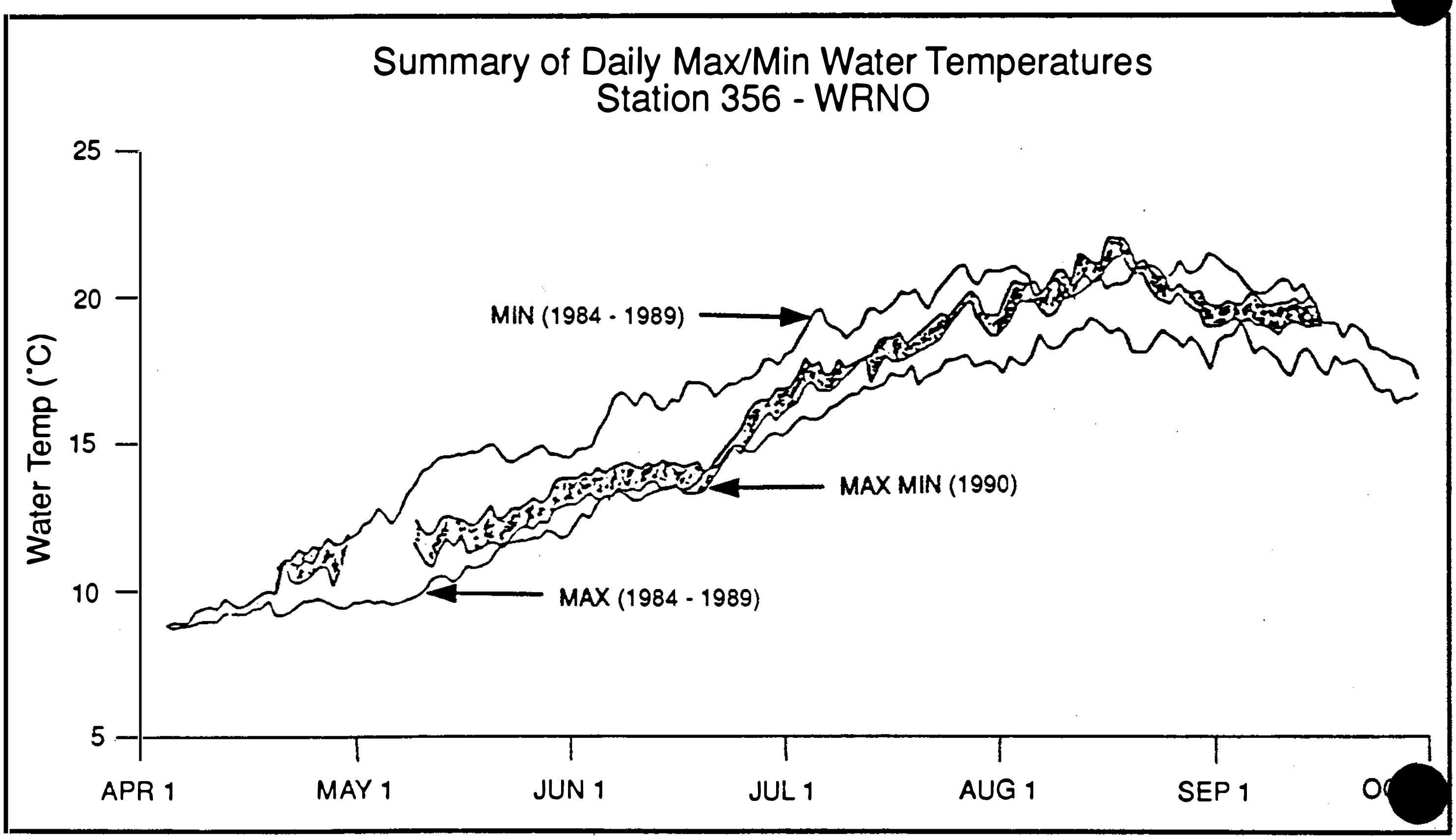



**Figure 4.1-9.** Maximum and minimum water temperatures at Warrendale, Oregon.

Table 4.1-3. Temperature data for lower Snake River, typical low-flow and high-flow year.

| | 1987 | 1984 |
|---|---|---|
| Project/Month | Temp. (°F) | Temp. (°F) |
| McNary | | |
| April | 45-52 | 47-49 |
| May | 52-56 | 48-55 |
| June | 56-66 | 54-60 |
| July | 66-69 | 60-67 |
| August | 69-70 | 67-72 |
| September | 66-70 | 63-69 |
| Ice Harbor | | |
| April | 46-56 | — |
| May | 55-59 | 52-54 |
| June | 59-67 | 54-60 |
| July | 68-70 | 60-70 |
| August | 70-72 | 70-72 |
| September | 67-71 | 63-71 |
| Lower Monumental | | |
| April | 45-53 | 45-50 |
| May | 54-58 | 50-54 |
| June | 57-66 | 54-61 |
| July | 66-71 | 61-71 |
| August | 70-71 | 72-73 |
| September | 66-71 | 63-73 |
| Lower Granite | | |
| April | 46-53 | |
| May | 51-59 | |
| June | 58-72 | |
| July | 68-72 | |
| August | 70-72 | |
| September | 62-73 | |

Source: Corps, Walla Walla District, unpublished data.

Drafting lower Snake projects to near spillway crest might alter thermal characteristics because of reduced heat exchange and increased water particle velocity (flow). While it is not possible to predict the overall effect with certainty, a shift of several degrees 34 to 36°F (1 to 2°C) could occur during the summer months, with thermal maximums occurring earlier in the season (Vigg and Watkins, 1991). Daily temperature maximums might increase because of decreased mixing time of reservoirs at drawdown, and loss of heat buffering capacity because of decreased reservoir size. However, average water temperatures might decrease if increased water particle velocity (flow) is sufficient to prevent thermal equilibrium with the atmospheric temperature. If drawdown is extended into August, more noticeable increases in temperature might be observed. Recent unpublished Corps modeling data (COLTEMP Model) suggested that a slight increase in average temperature may occur.

Impacts associated with other operating scenarios on the Snake River (e.g., drafting Lower Granite to 710 or spillway crest) would be similar but less pronounced. Minor impacts might occur to thermal characteristics, perhaps with a temporal shift in maximum system temperature, a slight increase or decrease in daily maximums and minimums, and limited changes in overall system average temperatures.

Drafting Lower Granite Reservoir to near spillway crest and Little Goose to an elevation at which the tailwater would be equivalent to near spillway (two-reservoir test) from March 1 through 31 is not expected to have pronounced effects on system temperature. The downstream reservoirs have not yet experienced the summer warming cycle and are closer in temperature to the released water. Perhaps a 1 to 2°F(0.6 to 1.1°C) shift may be noted, well within normal temperature variation.

Drafting the lower Columbia projects to MOP would also exhibit similar effects. The decreased water volume (mass) and decreased depth would reduce the heat buffering capacity of the reservoir pools. Thus, they would more rapidly come into equilibrium with air temperature. The water temperature would thus be subject to greater fluctuations, and daily maximums could increase and minimums decrease. However, the increased water particle velocity and decreased surface area would tend to offset increases in average temperatures. Thus, daily maximums would likely increase to levels near those recorded as the maximum (1982 to 1989) daily water temperatures during July, August, and even September. These maximums could be reached several weeks earlier than usual in Lake Umatilla because of its shallowness, and somewhat earlier in lakes Celilo and Bonneville. However, average water temperatures might not significantly change, but could be lower or higher depending upon surface to volume ratios, depth profiles, and hydraulic residence time. It is likely that each reservoir would experience a slightly different impact, because of these factors. An extended drawdown in August would exhibit the most noticeable changes.

Partial drawdown of the John Day and McNary pools would not be as dramatic as drawing down all four lower Columbia reservoirs. The water temperatures in the John Day and McNary pools would be closer to existing conditions. The water temperatures in The Dalles and Bonneville pools might reach daily water temperature maximum levels that are slightly higher than existing conditions. The maximum water temperatures at Warrendale might, therefore, generally be warmer than existing conditions. Changes of up to few degrees Fahrenheit might be observed. However, average temperatures might not exceed the range found under existing conditions. An extended drawdown into August would exhibit the most noticeable changes.

### 4.1.2.3 Flow Augmentation

Flow augmentation may significantly affect temperature characteristics, especially associated with releases from Dworshak Reservoir. Data from the September 1990 flow releases test illustrated potential thermal impacts of flow augmentation from Dworshak. It must be noted, however, that because the test was conducted in the fall, atmospheric temperatures and average water temperatures were dropping. Excerpts from a memorandum for record (Turner, 1990) detailing these impacts follow:

> "On September 4, 1990, the Reservoir Control Center increased the Dworshak Dam discharge, achieving full powerhouse discharge of 9.5 kcfs on September 8. Along with this flow increase, water temperature was decreased from 53 to 47°F (11.6 to 8.3°C) over 4 days, then this temperature was held at 47°F (8.3°C) until September 17, after which it was increased again to 53°F (11.6°C) by September 21. The temperature schedule was based primarily on coordination with the Dworshak National Fish Hatchery. They withdraw water from the north fork Clearwater River for hatchery supply. The implemented schedule was based on the maximum temperature decreases that hatchery biologists felt fish could tolerate without creating unacceptable impacts on fish growth in raceways and egg development. Thus, a cold-water discharge was provided for 17 days, with a total

release volume of about 320 KAF into the lower Snake River in an attempt to cool the river down. Average Ice Harbor discharge for the month of September was 25.9 kcfs.

The Dworshak releases had a significant effect on water temperatures at the Dworshak hatchery and Potlatch. Clearwater River temperatures dropped to 53 to 54°F (11.6 to 12.2°C) and entered the Lower Granite reservoir along with Snake River water which was considerably warmer, holding 72°F (22°C) during the early days of the test (Figure 4.1-10). Following test releases, Clearwater River temperatures increased to 57°F (14°C), about 8 degrees cooler than at the beginning of the release.

Lower Granite temperatures were not affected very swiftly by the Dworshak releases. Project temperatures remained at 70 to 71 °F (21.1 to 21.6°C) until September 17, when temperatures dropped to 67°F (19.4°C) by September 20 (Figure 4.1-10). This was about 2 weeks after beginning the cold Dworshak releases. Temperature profiles showed surface reservoir temperatures similar to Snake River inflows, dropping gradually with depth and showing a more pronounced decrease with depth in the upper portions of the reservoir (Figures 4.1-11 and 4.1-12). These effects became more pronounced on the September 24 sampling trip, which indicated that the colder Clearwater River water, rather than mixing with the much warmer Snake River water at the confluence, flowed under the Snake River water because of its higher density and flowed in a density current to essentially fill the dead storage space in the reservoir. It took about 2 weeks for the first of this deep water to reach the project and influence temperature there."

The Corps evaluated on a preliminary basis the feasibility of using cool water releases to moderate late summer temperatures at the mouth of the Snake River. This was done by operating temperature and hydrologic models to simulate the effects of such releases. This analysis was developed specifically in response to a request from the Columbia River Intertribal Fish Commission (CRITFC) to lower Snake River temperatures in late summer to a target level of 68°F (20°C). The scenario was to release cold water from Dworshak and store warm water, to the extent possible, at Brownlee. This combination of actions was felt to have the greatest opportunity to achieve the target temperatures at Ice Harbor.

Preliminary modeling results (see Appendix K) question whether the temperature objectives could be satisfied. There are further questions over the availability of large volumes of water for release in late summer, given potential use of storage for spring flow augmentation or for refill of mainstem reservoirs after drawdown, effects on Dworshak hatchery operations, and other issues. In view of these questions, the cooperating agencies were not able to complete the full level of environmental analysis on this alternative in the draft OA/EIS; however, the agencies remain committed to investigating this concept.

The proposed temperature control test, drafting up to 20 feet from Dworshak in August (10 kcfs for 20 days) is expected to have a significant impact on temperature at Lower Granite, but a negligible impact at Ice Harbor Dam. Figures 4.1-10 and 4.1-11 present the results of the most recent Corps modeling using the COLTEMP model. These results suggest the primary impact is an anticipated shift in the temperature profile of approximately 2 to 3 weeks at Lower Granite, but no noticeable differences at Ice Harbor Dam.

Discharges from Dworshak in the spring (e.g., May 100 kcfs/900 KAF) would not be expected to have as pronounced an effect on the system thermal profiles, as summer warming of the Snake River and reservoirs has not yet occurred, which creates the larger temperature differential. However, depending upon release point, noticeable decreases (perhaps 5 to 10°F [2.8 to 5.6°C] maximum) may be observed in the Clearwater River, depending upon spring air temperature profiles. Detailed modeling results were not available for this scenario.

Vigg and Watkins (1991) noted that cold-water releases from Dworshak Dam directly conflict with the downstream requirements of the Dworshak National Fish Hatchery for warmer water to rear summer steelhead and spring chinook. A water

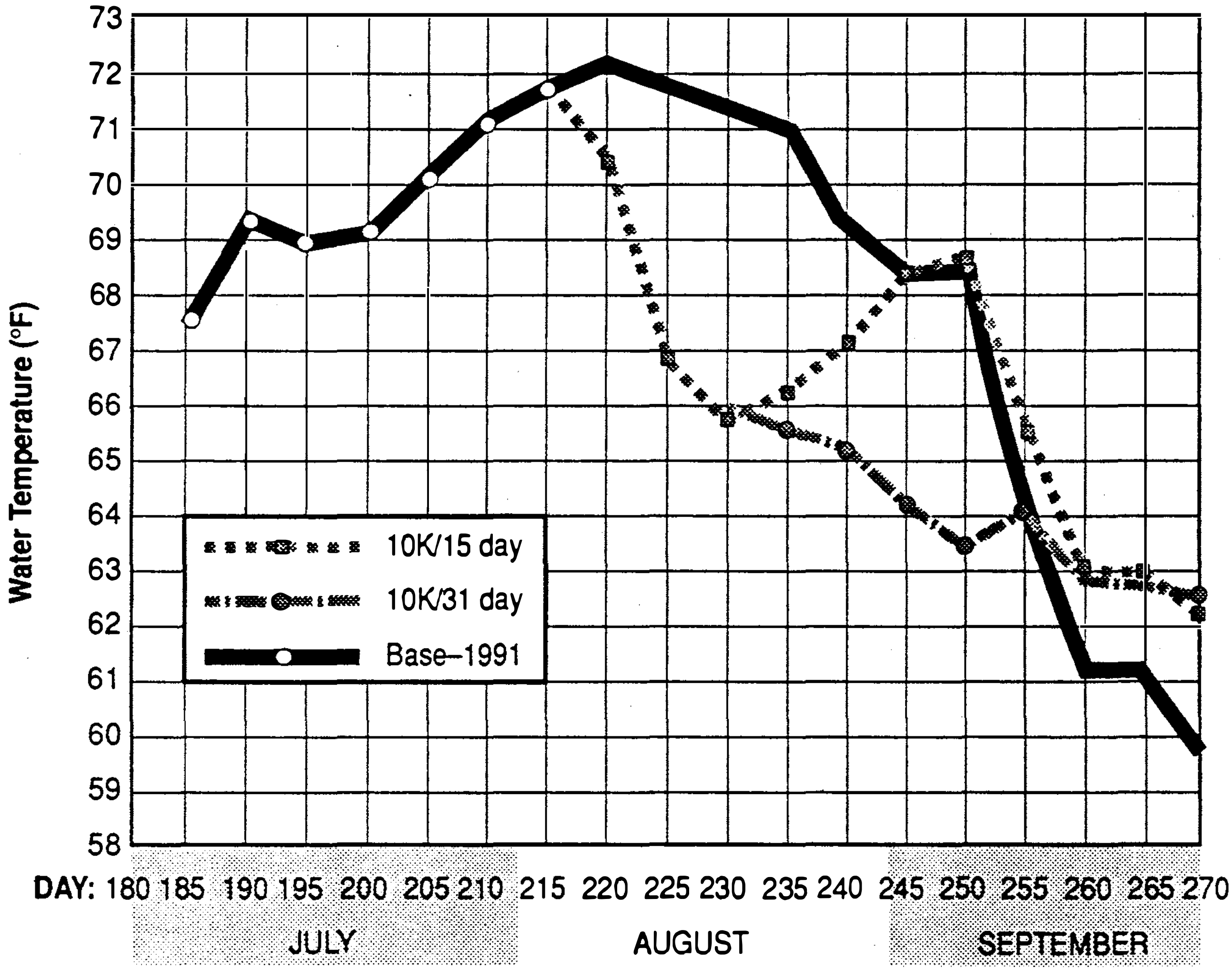



Figure 4.1-10. Modelled temperature at Lower Granite under the following conditions: Dworshak: 10 kcfs releases for 15 and 31 days at 45°F.

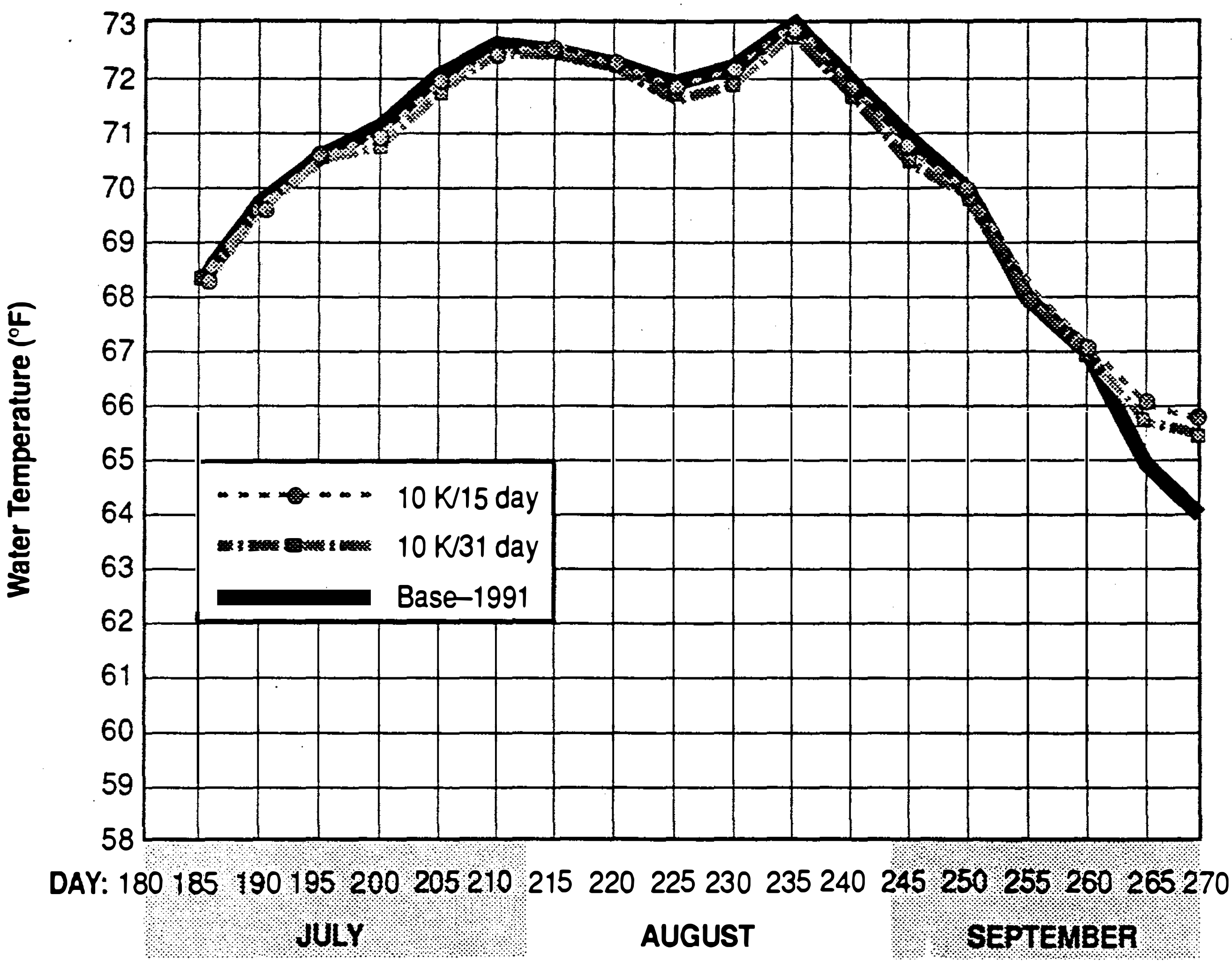



Figure 4.1-11. Modelled temperature at Ice Harbor under the following conditions: Dworshak: 10 kcfs releases for 15 and 31 days at 45°F.

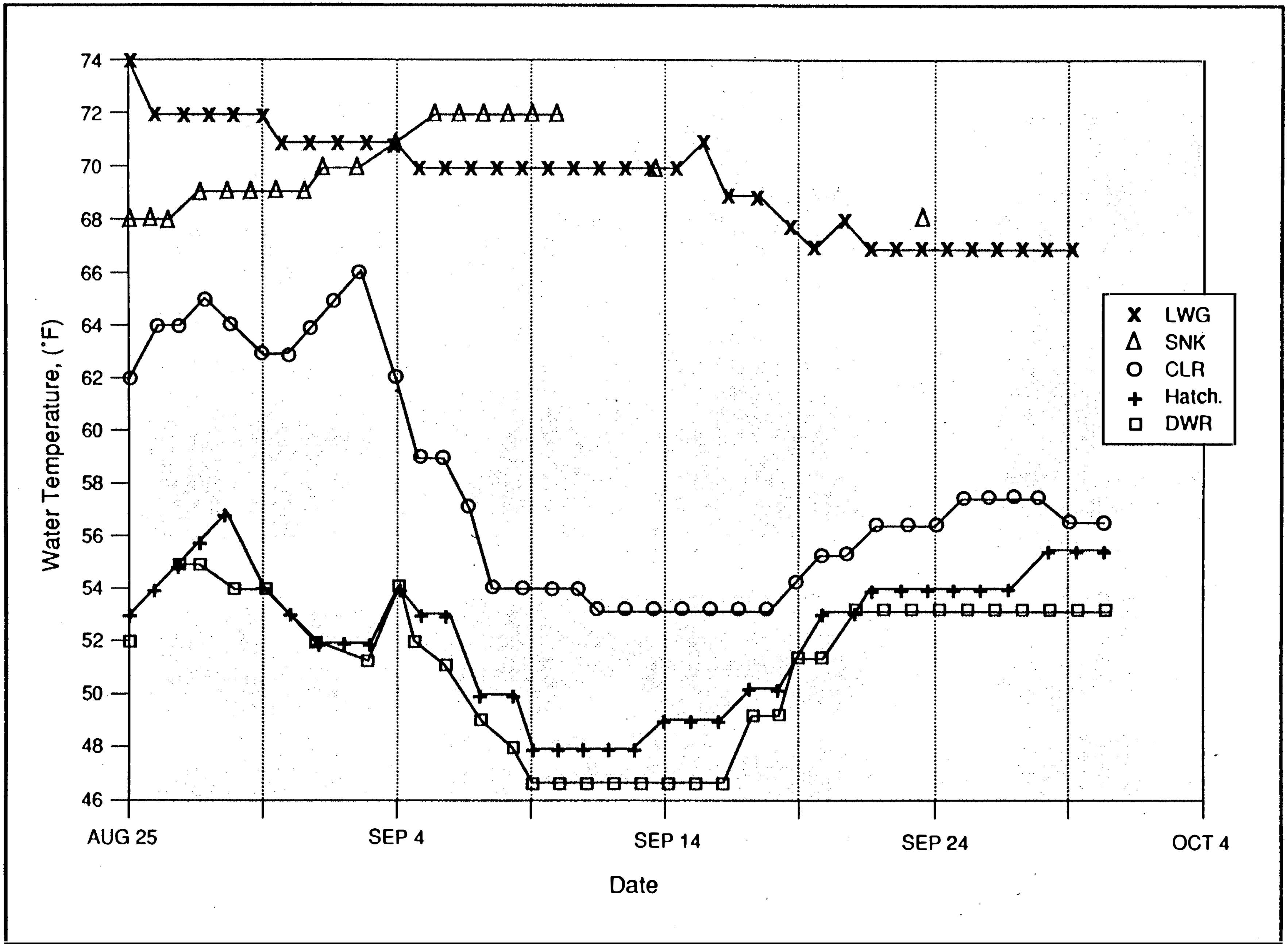



Figure 4.1-12. Clearwater and Snake River temperatures (August 25 to September 30, 1990).

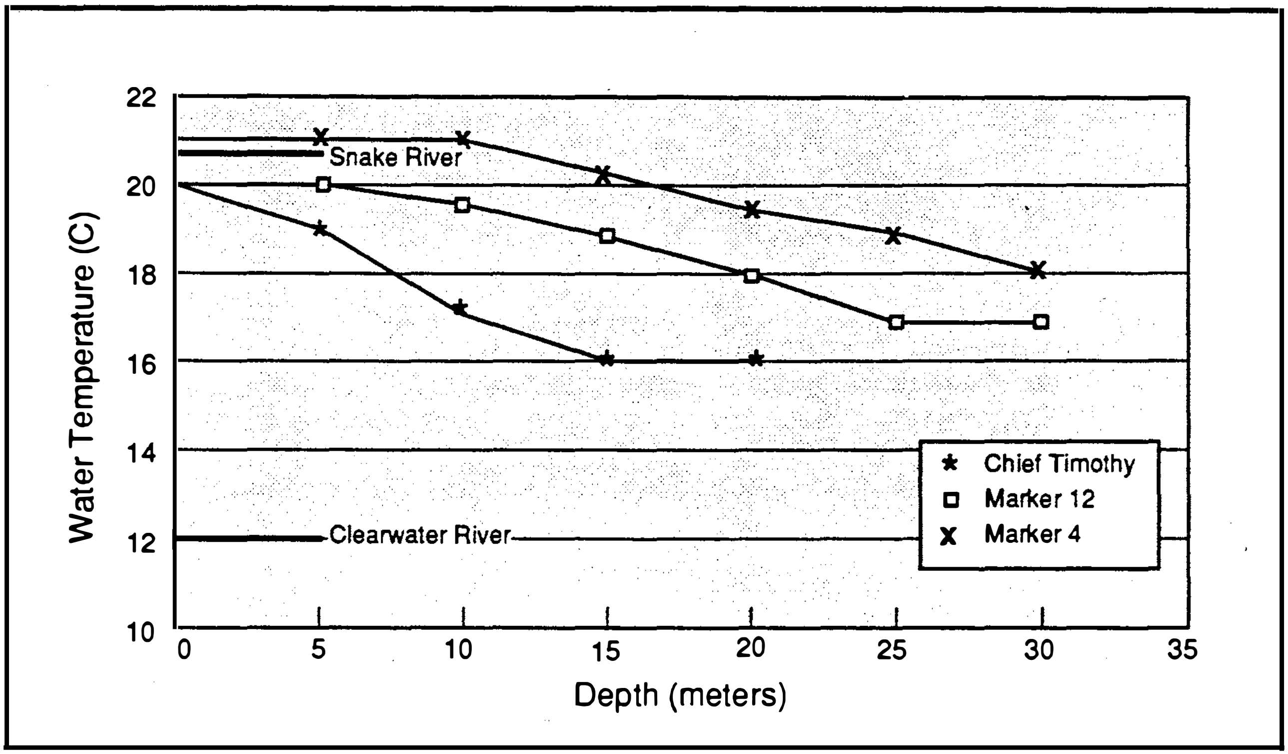



Figure 4.1-13. Water temperature profiles from the Snake and Clearwater rivers and Lower Granite Reservoir, 9/14/90.

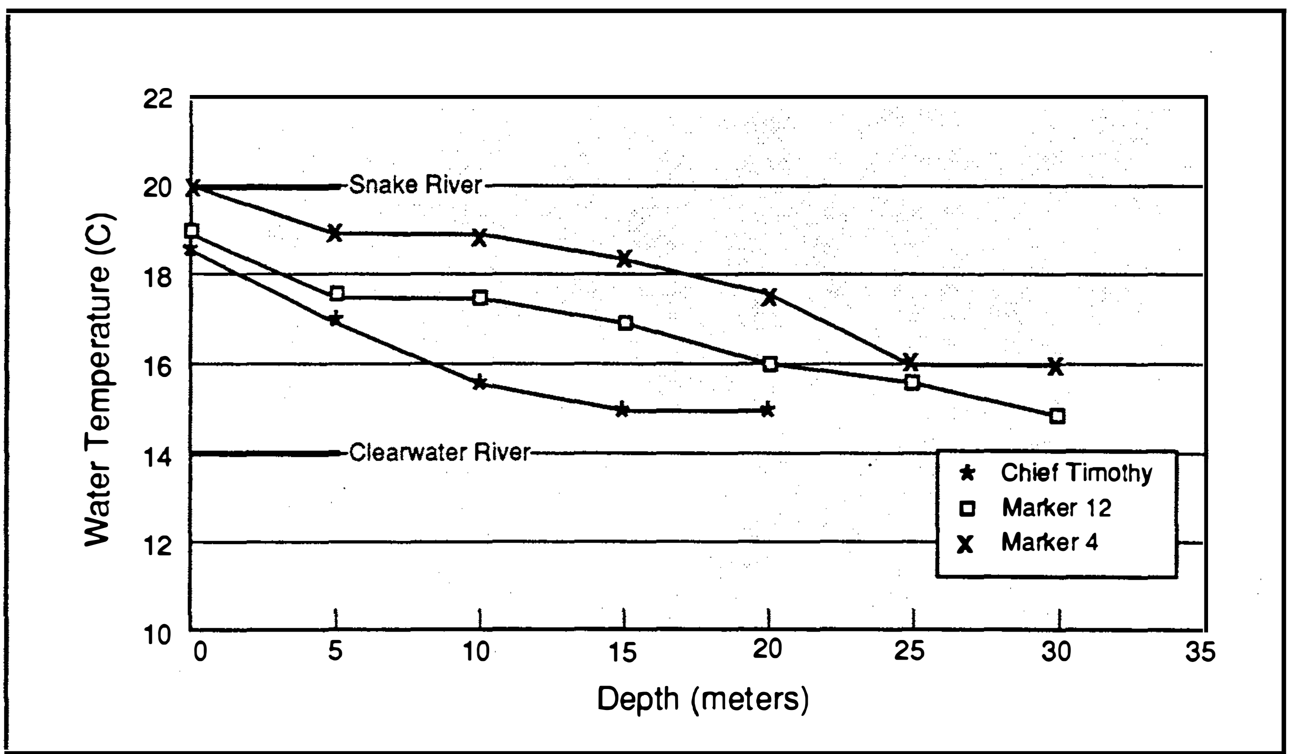



Figure 4.1-14. Water temperature profiles from the Snake and Clearwater rivers and Lower Granite Reservoir, 9/24/90.

temperature study sponsored by the Nez Perce Tribe for the Clearwater River is currently underway; this study might yield additional useful information on potential thermal impacts.

Flow augmentation from the Columbia River mainstem would come from the Grand Coulee and Mica. This would result in the spillway release of water above normal operating conditions. It is likely that this would shift water quality parameters to values normally observed during a high flow year (i.e., still within the range reported for the existing Columbia River System). Thermal profiles would likely be shifted, as described for drafting of lower Columbia River projects. This effect is not expected to be nearly as significant as that described and tested for Dworshak Reservoir because of the differences in source locations of the reservoir water and their topographic profiles. Because water from Grand Coulee is expected to be warmer than water at Dworshak when released, it will warm further as it moves downstream.

### 4.1.3 Turbidity and Other Water Quality Parameters

#### 4.1.3.1 Drawdown Options

Effects to turbidity and other water quality parameters would be minimal as the result of drafting Snake River projects to MOP. Increased dissolved oxygen levels might be observed if continuous spill were required, and localized increases in turbidity noticed for short periods. Other parameters would be expected to fall within historical ranges for the existing system.

Drafting several reservoirs to near spillway crest might have noticeable effects. Higher flows, increased velocity, and exposed reservoir littoral areas would all serve to increase turbidity. Depositional areas would be altered, and noticeable clarity changes are anticipated. An initial flush of previously deposited sediments might occur resulting in temporary but noticeable increases to turbidity. Dissolved oxygen levels would also increase, paralleling dissolved gas increases. Other water quality parameters are not expected to be greatly affected. These effects would also be anticipated for the March two-reservoir test at Lower Granite and Little Goose.

However, localized mixing zone areas could experience radical changes (e.g., pure effluent) if permitted (and unpermitted) point source discharges (i.e., discharge pipes) are exposed because of drawdown. This would be a violation of State standards. Increased flushing might increase phytoplankton density because of nutrient loading. This increased density might be offset by a reduction in the critical depth (depth to which phytoplankton growth could occur) because of increased sediment turbidity and decreased clarity. Decreased pool elevation would limit the aquatic weed growth zone, reducing opacity resulting from the organisms. The pH would also be lowered because of changes in the organisms, and the day to night variations in dissolved oxygen would be reduced.

Drafting the lower Columbia River dams to MOP might result in a few noticeable effects to water quality. There would be localized water quality changes because of exposed sewer outfalls in the John Day, Bonneville, and The Dalles pools. Also, there would be a change in the corresponding mixing zone characteristics because discharges would occur near or at the surface as compared to the submerged discharges of the existing conditions. This could result in a violation of State and Federal standards and conditions of NPDES permits. During low flow years, further flow reduction from mid-July through mid-September could create opportunity for localized proliferation of algae, which can cause localized changes in pH and dissolved oxygen levels. Localized elevated turbidity levels along some shorelines, quiescent embayments, and near tributary entrances to the mainstem Columbia River might also occur but are not expected to be a system-wide water quality issue.

#### 4.1.3.2 Flow Augmentation

Water quality effects to additional parameters would be more noticeable in the Snake River system. This is because Brownlee and Dworshak have radically different water quality. Brownlee Reservoir is dominated by middle Snake River water, which is considered to be poor quality because of high nutrients, very high dissolved solids, and possible contaminants (e.g., pesticides) associated with the high percentage of irrigation return water. The summer water temperature of the Snake River mainstem is also elevated (up to approximately 10°F [5.6°C]) in comparison to surrounding rivers.

In contrast, Dworshak Reservoir is oligotrophic and the water quality of the Clearwater River is excellent (i.e., pristine). The reservoir is also deep and stratified, with a large body of constant temperature cold water (39 to 41°F; 4 to 5°C). Therefore, excluding the effects of the Salmon River (also pristine) and the Grande Ronde, the general chemical quality of the lower Snake River (below Clearwater confluence) is expected to reflect the differential releases from Brownlee and Dworshak. Hence, flow augmentation from Brownlee would tend to degrade the existing chemical water quality of the lower Snake River, with the lower bound water quality slightly superior to that of the existing Brownlee Reservoir. Conversely, flow augmentation from Dworshak would tend to slightly improve the existing chemical water quality of the lower Snake River. Combinations of releases from both reservoirs would likely not alter most chemical quality parameters significantly beyond the typical ranges and fluctuations now observed on the lower Snake River.

A controlled-flow study (Bayha, 1974), performed between March 20 and March 25, 1973, illustrated the relationship between flow and water quality in the Snake River from Hells Canyon Dam to the mouth of the Grande Ronde River. The data obtained during the study were not completely adequate to describe reservoir water quality or year-round conditions in the Snake River. However, these data provided a summary view of non-summer conditions at various flow levels below Hells Canyon Dam. Appendix A presents water quality of samples from above and below Brownlee, Oxbow, and Hells Canyon dams. The waters of the reservoirs are homogeneous in the spring, and no changes in the chemistry of waters released from these reservoirs at various flow rates were reported.

The data in Appendix A do not indicate what conditions would exist during warm summer months, but earlier reports described summer reservoir conditions. For example, Goodnight (1971) performed limnological and water quality sampling (Appendix A). Using total dissolved solids and total alkalinity as indices of productivity of lake waters, it was concluded that the waters of Brownlee Reservoir are extremely productive in the summer and the reservoir is essentially eutrophic, with low levels of oxygen at depths over 100 feet and has a distinct thermocline (thermally stratified). Oxygen and temperature problems also preclude the development of any significant salmonid fishery in the reservoir. During August and early September, water temperature above 100 feet exceed 70°F (21°C). Below 100 feet, where suitable temperatures for salmonids are found, dissolved oxygen concentrations of 0 to 3 ppm limit the ability of fish to use this zone.

### 4.1.4 Toxics and Disease Organisms

During scoping and deliberations before the scoping process, contaminated sediment in the Snake-Clearwater River confluence area was identified as a possible concern with reservoir drawdown. Drawdown could cause sediment to be resuspended and carried downstream, posing a possible hazard to those who use the Columbia Snake River waters for a variety of purposes. Potential risks from existing waste dumps and exposed sewer outfalls also could result from the proposed actions.

#### 4.1.4.1 Contaminated Sediments

In order to evaluate potential chemicals posing a possible health hazard in the Columbia-Snake River System, a preliminary human health risk evaluation based on EPA Risk Assessment Guidance (EPA, 1989) was conducted. People most likely to be exposed are residents and visitors from surrounding communities using the system for recreation. Potential pathways for exposure to chemicals are eating fish, incidental drinking of surface water while swimming, skin contact with surface water while swimming, sediment ingestion from exposed mud flats, and skin contact with sediment in exposed mudflats.

Maximum chemical concentrations in sediments for the Snake-Clearwater River confluence area were evaluated (Battelle, 1986; Corps, 1987). Interstitial water concentrations (i.e., water within the sediment) were calculated using equilibrium partitioning coefficients. These coefficients allow estimates of contaminant distribution between sediments and water (interstitial). The interstitial water concentrations estimated were then assumed to represent surface water concentrations in the river. This is an extremely conservative assumption (i.e., overestimation of risk) because it does not consider factors that would dilute concentrations due to river volume and other diminishing effects. If dilution and diminishing effects were considered, the surface water exposure concentrations would be reduced by several orders of magnitude.

The human health risk evaluation indicated potential concern (i.e, cancer risk in excess of one chance in 1,000,000 of contracting cancer in a lifetime) for several chemicals including polyaromatic hydrocarbons (PAHs), pesticides (e.g., DDD and DDE), and metals. Organic constituents (i.e., PAHs and polychlorinated biphenyls (PCBs)) showed potential concern to human health through fish ingestion, skin contact from swimming and sediments. Cancer risk ranged from a low of 4.13E-08 (incidental ingestion of surface water) (e.g., approximately four chances in 100,000,000 of contracting cancer or 4.13 x $10^{-8}$) to a high of 1.13E+00 (dermal contact with sediment). Non-carcinogenic effects ranged from a low of 1.81E-05 (incidental ingestion of surface water) to a high of 1.15E+02 (dermal contact with sediments). Summary tables of intakes and estimated risk are presented in Appendix B. However, these risks can be brought into perspective through some comparison with commonplace risks. For example, over a 70 year lifetime a person has a 1.9E-01 chance of dying from complications induced by smoking.

Metals were not evaluated for potential health effects from water exposure. Generally, metals have a low absorption rate. Thus, water contact activities (e.g., swimming) are not of concern. Because most metals do not accumulate in most aquatic organisms, eating fish may also not be a concern. Metals can be picked up through direct skin contact with sediments. However, mercury can be converted in aquatic sediments to a form that is both more toxic (methylated mercury) and readily accumulated in fish. The potential for toxic effects from organic mercury cannot be evaluated with the available exposure concentration information.

There is considerable uncertainty in the evaluation. Generally, uncertainty is due to variability in exposure input parameters, contaminant transport modeling, toxicological evaluation of contaminants, and analytical data. A lack of system modeling for determining realistic exposure concentrations results in overestimates of potential health risks. It should also be noted that dilution and diminishing effects associated with increased water release from upriver hydro facilities were not considered in the development of water column concentrations. These factors would significantly reduce potential concentrations and, thus, reduce potential health risks. Increased sediment suspension and deposition would be expected with large influxes of water, though the significance of these levels cannot be assessed based on available information.

To provide a more realistic evaluation of potential health effects associated with exposure to Columbia-Snake River water and sediment, additional media-specific data (i.e., sediment, water column, and fish tissue concentrations) would be required. In addition, specific demographic information would allow a more realistic characterization of populations or sensitive subgroups that may be at potential risk.

### 4.1.4.2 Existing Waste Dumps

During construction of the Lewiston levees, a considerable amount of toxic and organic waste material was placed in a landfill. The fill location is on the north bank of the Snake River at the mouth of the Clearwater. The site was used as a source of fill material for the Lewiston levees.

The composition of the buried contaminants is unknown. The Corps will initiate contact with the EPA and the proper Idaho authorities to begin investigating these contaminants. The Corps (Walla Walla District) is expecting to check its sampling design and schedule with the Seattle District, which is the Hazardous and Toxic Waste Design District for the North Pacific Division.

Normal pool elevation of Lower Granite Reservoir causes approximately half the fill area to be submerged. By lowering the pool, groundwater enclosed within the fill area might migrate through the landfill liner and into the river. However, health risks from potential exposure to encapsulated waste cannot be evaluated at this time because of insufficient contaminant concentration information.

### 4.1.4.3 Exposed Sewer Outfalls

Lowering reservoir levels on the Columbia-Snake River could expose sewer outfalls. Localized water quality changes could be expected because of these exposed outfalls, particularly in the more developed lower Columbia River pools. There would be a change in the mixing zone characteristics because a reduced pool level would cause surface discharges, as compared to the submerged discharges of the existing conditions. This action might cause health impacts as well as violations of permit regulations. Health risks from such potential exposures cannot be fully evaluated at this time because of insufficient information on outfall locations and elevations, and on contaminant concentrations.

Two specific potential exposures have been identified through review of the draft OA/EIS. The existing outfall pipe from the City of Bingen (Washington) wastewater treatment facility has an invert elevation of 71.8 feet in the Bonneville Pool. Due to the water surface profile, a reservoir elevation at Bonneville Dam of 70 feet (MOP) corresponds to a surface elevation of about 72.3 feet at Bingen. Consequently, it is possible that the Bingen outfall would be near or at the surface if Bonneville were lowered to MOP. The City of Bingen has expressed concern over their ability to meet water quality discharge criteria under these conditions (personal communication, Charles B. Long, Mayor, City of Bingen, November 11, 1991).

The other known potential exposure is the City of Clarkston sewage outfall. The Clarkston treatment plant has two outfall pipes at different elevations in the Lower Granite Pool (personal communication, John Sims and Larry Esvelt, City of Clarkston, October 31, 1991). The higher outfall, which may be used primarily for overflow, appears to be between 6 and 15 feet below the existing normal water level (about elevation 735 to 737 feet). Consequently, this pipe could be exposed with any of the drawdown options that would draft Lower Granite below approximately 720 to 730 feet. The significance of this exposure would depend upon the City's ability to use the lower pipe, and on the duration of the drawdown.

## 4.1.5 Summary

The water quality of the system is complex; however, impacts are identifiable on a generalized basis. Key impacts to water quality associated with drawdown or flow augmentation (or combinations thereof) involve dissolved gas saturation, temperature, and possibly turbidity. Dissolved gas levels already exceed State standards of 110 percent and are expected to increase under almost all options. Some dissolved gas levels would result in a greater deviation from standard, with potential maximums greater than 140 percent in some cases. Thermal characteristics would be altered. Annual temperature maximums might occur earlier. Daily temperature variations would be greater. On average, Snake River reaches might be cooled slightly, and lower Columbia reaches warmed slightly. State temperature standards might be exceeded in limited instances. Turbidity may not be noticeably affected on a systemwide basis; however, small localized impacts would occur with potential for exceedence of State standards at these locations. Other water quality parameters are not expected to be significantly changed on a system-wide basis. Reduced water levels might expose effluent discharge pipes, affecting mixing zones and resulting in potential exceedence of water quality criteria or standards and violation of NPDES permit requirements at discharge points.

Finally, considerable uncertainty exists with regard to conditions affecting the risk from contaminated sediment to humans. Additional information must be gathered before an accurate appraisal of health risk can be made.

## 4.1.6 Mitigation

The primary water quality impact would be associated with gas supersaturation caused by increased spill. This impact could be minimized by reducing spill amounts as problems develop. An additional measure developed to reduce gas supersaturation associated with spill are flip lips in spill bays. These devices, however, are only effective over a limited flow range. A potential longer term mitigation measure could be to construct additional flip lips and to develop devices that might function under higher spill conditions and reduced reservoir elevations.

Turbidity effects might be reduced by additional shoreline protection. Potential problems associated with sewer outfall exposure might be mitigated by extension of such facilities so that they function under lower pool elevations.

No readily implementable measure to ameliorate temperature effects is available.

## 4.2 ANADROMOUS FISH

Considerable uncertainty exists regarding the relationship between water particle travel time, juvenile travel time, and juvenile survival; this uncertainty is greatest for flows generally above 85 kcfs in the Snake River and 220 kcfs in the Columbia River. Reported are differing comparisons of this relationship that bracket the range of values that may be expected primarily for yearling juveniles. No clear relationship exists for subyearling fall chinook or sockeye juveniles, although increased flow rate appears to reduce travel time. The information presented encompasses differing juvenile travel time estimates and calculates the corresponding juvenile survival relationship for yearling juveniles by utilizing either a 0.7 percent increase in survival per day travel time is reduced or models depicting historical survival.

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown** | |
| *Snake River* | |
| All 4 projects to MOP (April 1 to July 31) | • Water particle travel time reduced by a maximum 7 percent (normally half of this) over entire range of flows.<br>• Smolt travel time reductions through Lower Granite Pool (assuming, because of lack of specific data, that smolt travel time is equal to water particle travel time) would be the same as changes in water particle travel time over the entire flow range (maximum 7 percent reduction [normally half of this]).<br>• Minor potential smolt travel time changes would occur from Lower Granite Dam to Ice Harbor, most changes less than 1 day reduction, or 6 percent maximum change from existing conditions.<br>• Absolute percent smolt survival increases from Lower Granite Pool to Ice Harbor Dam, depending on the models used, ranges from 3.9 to 0.2 percent maximum (normally half these values) at medium flow (80 kcfs), with lower percent increases at higher flows.<br>• Minor reduction in rearing habitat for subyearling chinook. |
| All 4 projects to near spillway crest (April 15 to August 15) | • Water particle travel time reduced by about 54 percent over entire range of flows.<br>• Smolt travel time from Lower Granite Pool potentially reduced significantly, depending on the model, by 17.4 to 10.8 days at a low flow of 40 kcfs, by 4.6 to 3.7 days at a medium flow of 80 kcfs, and greater than 2.2 days to less than 0.7 days at a high flow of 120 kcfs.<br>• Absolute smolt survival change is unknown but may be worsened from existing conditions by 1) elimination of fish transport from all Snake River facilities subjecting typically transported fish to longer travel times, 2) increased mortality from significantly increased high gas supersaturation levels, 3) increased downstream predation and turbine mortality for typically transported fish, 4) significant loss of shallow-water rearing habitat in the Snake River, and 5) reduced benthic and pelagic food production.<br>• Elimination of all adult fish passage during drawdown and reservoir refilling period, eliminating passage of all spring and summer chinook.<br>• Temperature peak would be shifted several weeks earlier, possibly impeding early portion of the adult run. Cooler temperatures could benefit later portions of the run. |

Anadromous Fish (continued)

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown (continued)** | |
| ***Snake River (continued)*** | |
| All 4 projects to near spillway crest (April 15 to June 15) | • Similar to spillway drawdown to August 15 except with a decrease in duration of certain negative effects (e.g., reduced food production, increased predation, gas supersaturation mortality, effects from elimination of bypass/collection/transport facilities).<br>• Reduced adverse effects to adults and subyearling chinook relative to longer drawdown as discussed above. |
| Lower Granite to near spillway crest (February 1993 or July 15 to August 15) | • Effects similar to reduction to MOP except as discussed below.<br>• Water particle travel time reduced by about 3.5, 1.6, and 0.8 days over flows of 40, 80, and 120 kcfs through Lower Granite pool (others see above).<br>• Survival increases, similar to reduction to MOP for all Snake River Projects, would occur with summer test (no fish in February) but may be less for reasons presented for reduction to near spillway crest (see above).<br>• The July option of this alternative proposed to be conducted during the latter part of the subyearling smolt migration. Effects on travel time and survival of these fish are unknown.<br>• During the July and August alternative although turbine mortality would be eliminated at Lower Granite Dam, juvenile subyearling survival may be worsened because 1) no juvenile fish transport from Lower Granite Dam, 2) increased mortality from high gas supersaturation in Little Goose Pool, 3) increased predation in Lower Granite Pool from predator concentration, 4) possible increased spillway passage mortality, 5) increased downstream turbine passage and predation mortality for fish typically transported, and 6) reduced shallow-water rearing habitat in Lower Granite Pool.<br>• No adult passage above Lower Granite during drawdown periods, affecting adult summer chinook and lesser portions of fall chinook and summer steelhead. |

Anadromous Fish (continued)

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown (continued)** | |
| *Snake River (continued)* | |
| Lower Granite to 710 feet, others to MOP (April 15 to June 15) | • Effects similar to reduction to MOP except as discussed below.<br>• Water particle travel time reduced by 2.3, 1.2, and 0.8 days for flows ranging from 40, 80, and 120 kcfs, respectively, in Lower Granite Pool or about 44 percent from existing (others shown above).<br>• Assume smolt travel time potentially reduced through Lower Granite Pool the same as water particle travel time.<br>• Absolute smolt mortality through Lower Granite Pool potentially reduced by 1.6, 0.8, and 0.6 percent for flows 40, 80, and 120 kcfs, respectively, if <u>only</u> travel time is considered.<br>• Although turbine mortality would be reduced at Lower Granite Dam, other factors will possibly reduce overall survival including: 1) no transport of fish from Lower Granite Dam, 2) increased mortality from higher gas supersaturation levels in Little Goose Pool, 3) increased predation in Lower Granite Pool on subyearlings from predator concentration, 4) possible increased mortality from spillway passage, 5) increased downstream turbine and predation mortality for fish typically transported at Lower Granite, and 6) reduced shallow-water rearing habitat in Lower Granite Pool for subyearling chinook.<br>• Adult migration may be greatly impeded or eliminated at Lower Granite. |
| Lower Granite/Little Goose drawdown test (March) | • Effects similar to reduction to MOP except as discussed below.<br>• Water particle travel time reduced by about 3.5, 1.6, and 0.8 days over flows of 40, 80, and 120 kcfs through Lower Granite Pool. Little Goose water particle travel reduced between MOP and spillway crest (see above).<br>• Juvenile and adult passage survival not affected as limited passage occurring.<br>• Potential reduced rearing habitat and habitat quality for fall chinook in Little Goose and Lower Granite pools.<br>• Potential partial stranding of fall chinook fry or alevins in gravel in Little Goose Pool.<br>• No adult passage above Little Goose during drawdown periods delaying less than 3 percent of summer steelhead. |

Anadromous Fish (continued)

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown (continued)** | |
| *Lower Columbia*<br>All 4 projects to MOP<br>(April 1 to August 31) | • Water particle travel time reduced by about 16 to 19 percent from maximum pool over entire range of flows. Actual reduction about 10 percent relative to existing operation.<br>• Smolt travel time through lower Columbia system potentially reduced by 2.5 to 2.0 days at 160 kcfs, 2.0 to 1.2 days at 200 kcfs, and 1.6 to -0.5 at 260 kcfs.<br>• Absolute smolt survival through lower Columbia System potentially increased by 1.8 to 1.4 percent at 160 kcfs, from 1.4 to 0.8 percent at 200 kcfs, and from 1.6 to -0.4 percent at 260 kcfs.<br>• At The Dalles, efficiency of sluiceway bypass could be reduced forcing more fish through turbines increasing mortality.<br>• At John Day and McNary, turbine efficiency is reduced, potentially increasing mortality of fish passing through turbines by about 1.3 and 1 percent, respectively.<br>• Slight increase in gas saturation, especially under high flows, with minor effects on fish.<br>• Minor reduction in shallow-water habitat reduces rearing habitat for subyearling chinook. |
| John Day at 262.5 feet, McNary at 337 feet, remainder at MOP<br>(April 1 to August 31) | • Water particle travel time reduced by about 12 to 14 percent from maximum pool over entire flow range.<br>• Smolt survival through lower Columbia System reduced by slightly less than reduction for all at MOP.<br>• At The Dalles, efficiency of sluiceway bypass could be reduced forcing more fish through turbines, increasing mortality.<br>• Slight increase in gas saturation at The Dalles and Bonneville with minor effects on fish, especially under high flows.<br>• Minor reduction in shallow-water habitat at The Dalles and Bonneville not expected to cause adverse effects on rearing to any stock. |
| **Flow Augmentation** | • Although some alternatives include flow from Grand Coulee, most flow augmentation alternatives occur primarily with water from Dworshak, Hells Canyon, or a combination increasing flow in the Snake River into the Columbia below the confluence of the Snake and Columbia rivers. Available storage and discharge capability will allow for a flow rate increase of 0 to 38 kcfs from these two Snake River reservoirs. Available storage will allow for limited periods of flow at these rates over what currently occurs. As an example, only one of the alternatives will allow for more than 1 month of continuous flow increase of 20 kcfs over what currently occurs from these projects. All of the alternatives |

Anadromous Fish (continued)

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
| --- | --- |
| Flow Augmentation (continued) | are designed to increase flow in May, with some including parts of April and June without consideration of the available flow for later periods. The exact flow will dependent on what is currently available and target flows selected. The alternative with flow from Grand Coulee could increase flow by 0 kcfs to more than 30 kcfs in the Columbia River only.<br>• Greatest effect on water particle travel time from high augmentation of 20 kcfs: in the Snake River during low flow (60 kcfs) at maximum pool reduction would be 8 days, or 22 percent; at medium flow (100 kcfs), the reduction would be 2.8 days, or 14 percent. In the Columbia River reach, the reduction is from 5 days at low flow (100 kcfs) to 7 days at high flow (300 kcfs).<br>• Smolt travel time in the Snake River would be reduced by 4 to 8 days at low flow (40 kcfs) and 1 to 2 days at medium flow (80 kcfs).<br>• In the Columbia River reach the reduction of smolt travel time would be 2 to 3 days at low flow (160 kcfs) and 1 to 2 days at medium flow (200 kcfs).<br>• Flow augmentation reduces available flow in the summer (July to September) possibly affecting summer downstream migrants.<br>• Minor potential gas saturation level increases.<br>• No effect on adult migration.<br>• Effects on absolute smolt survival for both Columbia and Snake River combined for a flow augmentation of 20 kcfs range from 5.6 to 14.2 percent for low flows (Snake 40 kcfs, Columbia 160 kcfs); 1.1 to 11.5 percent for medium flows (Snake 80 kcfs, Columbia 200 kcfs); and 0.1 to 2.8 for high flows (Snake 120 kcfs, Columbia 260 kcfs). |
| Combination | • Effects additive; see drawdown and augmentation. |
| Temperature Control Test (August) | • Enhance upstream migration success of some fall chinook and steelhead in late August through early September by potentially lowering temperature 2 weeks earlier than current condition.<br>• Reduced growth of part of Dworshak hatchery steelhead.<br>• Possible less water available for following spring releases. |

## 4.2 ANADROMOUS FISH

Considerable uncertainty exists regarding the relationship between water particle travel time, juvenile travel time, and juvenile survival; this uncertainty is greatest for flows generally above 85 kcfs in the Snake River and 220 kcfs in the Columbia River. Reported are differing comparisons of this relationship that bracket the range of values that may be expected primarily for yearling juveniles. No clear relationship exists for subyearling fall chinook or sockeye juveniles, although increased flow rate appears to reduce travel time. The information presented encompasses differing juvenile travel time estimates and calculates the corresponding juvenile survival relationship for yearling juveniles by utilizing either a 0.7 percent increase in survival per day travel time is reduced or models depicting historical survival.

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown** | |
| ***Snake River*** | |
| All 4 projects to MOP (April 1 to July 31) | • Water particle travel time reduced by a maximum 7 percent (normally half of this) over entire range of flows.<br>• Smolt travel time reductions through Lower Granite Pool (assuming, because of lack of specific data, that smolt travel time is equal to water particle travel time) would be the same as changes in water particle travel time over the entire flow range (maximum 7 percent reduction [normally half of this]).<br>• Minor potential smolt travel time changes would occur from Lower Granite Dam to Ice Harbor, most changes less than 1 day reduction, or 6 percent maximum change from existing conditions.<br>• Absolute percent smolt survival increases from Lower Granite Pool to Ice Harbor Dam, depending on the models used, ranges from 3.9 to 0.2 percent maximum (normally half these values) at medium flow (80 kcfs), with lower percent increases at higher flows.<br>• Minor reduction in rearing habitat for subyearling chinook. |
| All 4 projects to near spillway crest (April 15 to August 15) | • Water particle travel time reduced by about 54 percent over entire range of flows.<br>• Smolt travel time from Lower Granite Pool potentially reduced significantly, depending on the model, by 17.4 to 10.8 days at a low flow of 40 kcfs, by 4.6 to 3.7 days at a medium flow of 80 kcfs, and greater than 2.2 days to less than 0.7 days at a high flow of 120 kcfs.<br>• Absolute smolt survival change is unknown but may be worsened from existing conditions by 1) elimination of fish transport from all Snake River facilities subjecting typically transported fish to longer travel times, 2) increased mortality from significantly increased high gas supersaturation levels, 3) increased downstream predation and turbine mortality for typically transported fish, 4) significant loss of shallow-water rearing habitat in the Snake River, and 5) reduced benthic and pelagic food production.<br>• Elimination of all adult fish passage during drawdown and reservoir refilling period, eliminating passage of all spring and summer chinook.<br>• Temperature peak would be shifted several weeks earlier, possibly impeding early portion of the adult run. Cooler temperatures could benefit later portions of the run. |

Proposed actions assessed in this OA/EIS are centered on the concept of reducing the water particle travel time (time it takes a unit of water to get from one point to another) down the Columbia-Snake River System. (The traditional and generally accepted way to calculate theoretical water particle travel time is to divide reservoir or river reach volume by daily discharge rate.) These alternatives are being considered primarily because of statements made and data presented by the Columbia Basin Fish and Wildlife Authority (CBFWA, 1991a) concerning the relationship between flow, water particle travel time, and juvenile (smolt) salmon and steelhead survival. The effect of flow on adult upstream migration is also considered.

To evaluate the effects of the various options, a primary understanding of the relationship between water particle travel time (or flow) and fish travel time (or survival) is discussed, followed by an assessment of other effects of the various options. This evaluation is based on the most recent analysis of these relationships.

### 4.2.1 Juvenile Anadromous Fish

The following sections discuss the various factors affecting smolt survival resulting from the alternatives. The analysis is limited to the affects that may occur while fish are passing through the mainstem Snake and Lower Columbia River projects.

It is important to note that factors outside of the project area have significant effects on downstream migrating smolt survival before they arrive at these projects. There are indications that, historically, mortality that occurred during migration in this system may have been quite low. Raymond (1979) found mortality of chinook yearlings from Whitebird on the Salmon River to Ice Harbor Dam (about 223 miles, with no intervening dams at the time) averaged 11 percent for three years. The portions of this mortality that occurred in the river and in the reservoir are not known. However, recent information on smolts that migrate down the rivers above Lower Granite Pool indicates these fish may have higher mortality. For example, Kiefer and Forster (1990a) estimated 60 and 47 percent mortality of chinook and steelhead, respectively, during spring outmigration in 1989 from the Crooked River to the head of Lower Granite Pool (about 120 miles). From a similar study in 1988 (Kiefer and Forster, 1990b), spring chinook mortality and steelhead mortality from the upper Salmon River to the head of Lower Granite Pool (about 420 miles) were estimated to be 63 and 85 percent, respectively. These results need to be considered with caution, as they were not intended to be used as an estimate of migration mortality; however, they suggest that significant smolt mortality can and does occur independent of effects at the Federal projects. The sources of their mortality are not completely known. But Giorgi (1991a) suggested several possible causes of this high mortality that may not have been present historically. These factors include high BKD disease among hatcheries and wild spring chinook stock, high numbers of hatchery-released fish depleting the food source of the migration corridor (currently, 5 to 10 times the number of smolts are present in the region than was there in the 1960s), large numbers of hatchery smolts adversely affecting migration behavior of wild fish, and low vitality of hatchery stocks.

#### 4.2.1.1 Flow Effects on Survival

This section contains four parts: (1) a summary of current knowledge of the effects of flow on smolt travel time and survival, (2) a summary of the effects of the various alternatives on water particle travel time, (3) effects of the alternatives on smolt travel time, and (4) attempts to apply this information to the various alternatives to assess effects on smolt travel time and survival.

**Current Knowledge of Flow, Travel Time, and Survival Relationships.** Overall, this OA/EIS presents the scientific uncertainty that exists regarding the relationship between flow, travel time, and survival. This discussion presents a wide range in analyses among regional experts and their interpretations of the biological data. One analysis was not selected as right or wrong, since all are based on the same database, which is very limited. The Corps believes the public should be aware of this issue since the flow/travel time/survival relationships are the basis for the drawdown experiment. Several primary sources have been used to assess the relationship between flow, fish travel time, and survival: *The Biological and Technical Justification for the Flow Proposal of the Columbia Basin Fish and Wildlife Authority*, by the CBFWA (CBFWA, 1991a); (2) *The Flow/Survival/*

*Travel Time Relationship; Review and Analysis of Supportinf Ifnormationand Rationale For Flows for Juvenile Spring and Summer Chinook Migrations* by Ray Kindley of the Pacific Northwest Utilities Conference Committee (Kindley, 1991); and (3) *Biological Issues Pertaining to Smolt Migration and Reservoir Drawdown in the Snake and Columbia Rivers with Special Reference to Salmon Petitioned for Listing Under the Endangered Species Act* (Giorgi, 1991b) by Al Giorgi of Don Chapman Consultants Inc. Several other sources were also reviewed but were used less extensively in the analysis. A brief summary of some of these sources and their conclusions are presented below.

The basic conclusion of the following reports is that there is a statistically significant relationship between smolt travel time and water flow, at least to some threshold flow level (80 to 100 kcfs in the Snake River and 190 to 240 kcfs in the Columbia River). The degree of this correlation varies by species, location, season, and flow. While flow is strongly correlated with smolt travel speed or survival at lower flows, its importance at higher flows is less well defined and may not correspond with increased travel speed or survival in these flow ranges. Also, the importance of flow in affecting the migration rate of some endangered or potentially endangered stocks is less clear (fall chinook and sockeye). There are various other factors that also correlate significantly with migration rate, including the level of smolt development.

Reference is made throughout this section to the terms "significant" and "correlated." These terms are used according to their statistical definitions. If a relationship is significant, this indicates a relationship other than just "random chance" is occurring between two variables. It does not indicate the strength of the relationship between the variables. Correlation (described by an $r^2$ value) indicates the strength, or how closely matched, the measured data follow a predicted relationship. A regression line is the most common method used of predicting the relationship between variables. A low correlation ($r^2$ near 0) means the predicted line is not a good fit with the measured data. A high correlation ($r^2$ near 1) does fit the measured data well. Two variables can be significant, but be either weakly or highly correlated. The higher the correlation, the stronger the relationship.

*CBFWA (1991a)* - The authors conclude that "Travel time is a key migrational characteristic reflecting the dynamics of the downstream migration of juvenile salmonids. The physiological condition of smolts changes over the time they are migrating. Travel time determines whether the smolts arrive at the estuary during the biological window, so they can successfully survive the transition to salt water. Travel time is inversely related to flow. With the present hydrosystem, even extremely high flows cannot achieve pre-dam water velocities."

The authors recommend flows of up to 300 kcfs in the Columbia River and 140 kcfs in the Snake River during peak spring outmigration (April 1 to June 15) to protect downstream migrating smolts of steelhead, chinook, sockeye, and coho. The authors state, "The similarity of fish travel time to water particle travel time indicates a causative, rather than simply a correlative, relation between flow and travel time of juvenile salmonids."

The primary basis for these recommendations is data concerning flow, travel time, and survival. The primary data presented are developed from older (1973 to 1979) study data (Sims and Ossiander, 1981) that show significance and strong correlation (usually P=less than 0.01, and $r^2$ greater than 0.8), based on seven annual data points, for the relationship between flow and travel time and the relationship between flow and survival of yearling chinook and steelhead from the upper Snake River Dam to The Dalles Dam. The flow range of this analysis was 40 to 160 kcfs on the Snake River and 115 to 340 kcfs on the Columbia River.

The authors conclude that flow affects survival of all species and life stages even though spill was found to significantly relate to survival in these earlier studies, and other factors recently found to correlate with travel time had not been tested in earlier studies.

There are several possibly negative effects of delay in migration. Delay reduces success of survival in the ocean either because the smolts do not arrive in the ocean when food is abundant or their physiological development has proceeded improperly, leaving them unable to complete the normal transition from freshwater to saltwater. The authors also suggest that predation may increase with lower flows because predators may have easier access to smolts or because higher water temperatures associated with lower flows increase the food intake by the predators. Higher temperatures occurring later in the migration season are believed to be detrimental because they indirectly adversely affect survival (e.g., increase predation and food requirements).

*Berggren and Filardo* (1991) examined the relationships between flow and other variables to the travel time of yearling chinook salmon and steelhead in the Snake River and subyearling chinook in John Day Pool. They conducted univariate analysis with just flow and then multivariate analysis using flow and other variables. The Snake River analysis used data from 1982 through 1990 and found yearling chinook travel time correlated with the reciprocal of flow ($r^2 = 0.43$). Subyearling chinook travel time in the John Day Pool (data from 1981 to 1983 and 1986 to 1988) was statistically significant but weakly correlated with the reciprocal of flow ($r^2 = 0.33$). Multiple regression analysis for yearling chinook in the Snake River was significant and increased the correlation ($r^2 = 0.74$) with the addition of two variables, days to prior arrival at the trap (as an indication of stage of smolt development) and change in flow. For subyearling chinook in John Day Pool multiple regression analysis was significant and increased correlation ($r^2 = 0.60$) with addition of change in flow and release date (also as an indication of smolt development). Flow remained the primary component in both the Snake River and John Day Pool analysis. Berggren and Filardo did not attempt any bivariate analysis with any other factor than flow.

The data sets predicted reduced travel time with increased flow. The greatest effect on travel time occurred at lower flows, while changes were less pronounced at higher flows. Berggren and Filardo concluded that the similarities in water particle travel time and smolt travel time suggest a causative and not a simple correlative relationship.

*Kindley, 1991* - Using analysis of recent data (1986 to 1990) from the Snake and Columbia rivers, Kindley concluded "Flow levels up to certain flow ranges decrease the travel times for migrating juvenile chinook salmon. Travel time estimates indicate that flows in excess of a range from 85 to 95 kcfs in the lower Snake River and greater than a range of 190 to 240 kcfs in the lower Columbia River do not appreciably reduce travel time."

Kindley analyzed three regions for yearling chinook smolt travel time relationships: the head of Lower Granite Pool to Lower Granite Dam, Lower Granite Dam to McNary Dam, and McNary Dam to John Day Dam (John Day Pool). Generally, when the data were available, Kindley found significant relationships between travel time and flow, release date, and ATPase activity level (adenosine triphosphatase, a measure of smolt development). Because there are significant correlations among these factors, it is not possible to determine which factor is the cause of the change in migration rate. Kindley found a negative relationship (i.e., slower migration correlated with higher flow) in one (nine fish recaptured) of the two sets of data for Lower Granite Pool, 1989. Flow was significantly correlated with yearling chinook travel time (with $r^2$ values less than 0.66). Another significant but strongly correlated factors were gill ATPase level and release date ($r^2$ value greater than 0.8).

In studies that evaluated travel times for tagged yearling chinook released at Lower Granite and recaptured at McNary Dam, flow (measured at Ice Harbor) versus smolt travel time did not have a significant ($p = 0.55$, $r^2 = 0.03$) relationship while ATPase levels were significant and strongly correlated ($r^2 = 0.79$). Kindley suggested that part of the flow problem might be that Columbia River flows did not correlate with Snake River flows.

Kindley used data from 1986 to 1988 to assess flow versus yearling chinook travel time relationships in John Day Pool. Flow did have a significant and strongly correlated relationship ($p=.0001$, $r^2 = 0.88$) for the flow range of 135 to 285 kcfs. Analysis conducted only on flows greater than 195 kcfs revealed no significant relationship between travel time and flow, while the release date was significant for this reduced data set. A polynomial regression of the whole data set indicated little reduction in travel time for flows above 240 kcfs. Kindley concluded that travel time in John Day Pool improved as flows increased, but only to flows in the 190 to 240 kcfs range.

Kindley concluded, "Water particle travel time is an unreliable predictor of juvenile spring and summer chinook travel time. Travel time is a product of many factors; flow is merely one factor. State of physiological development, or smoltification, significantly influences travel time."

*Giorgi, 1991b* - Giorgi examined the available information on yearling chinook responses to flow in three regions: the Lower Granite Pool, the Snake River from Lower Granite to McNary Dam, and John Day Pool. He found that while there are some significant relationships between flow and migration rate, they are not clear. He also found very limited data demonstrating a relationship between increased flow and increased smolt survival.

Giorgi's review of data on the Lower Granite Pool yearling chinook migration rate indicated that there is a relationship between flow and migration rate, but the relationship is not consistent. This is demonstrated by the fact that fish entering from the Clearwater River migrate much more slowly than fish entering from the Snake River. Although there are differences between studies, some studies found that yearling chinook smolts generally moved twice as fast at 100 kcfs as at 50 kcfs. Other studies examining the data indicated that other factors showed stronger correlations between travel time and flow, including release date and level of smolt development (as measured by gill ATPase activity).

Giorgi (1991b) found that yearling chinook smolt travel time data for the Snake River reach to McNary Dam also had varying results. While some data indicated a relationship between flow and travel time, other sets showed no relationship but had strong correlations to release date or level of smolt development. In one case, strong downstream migration occurred at flows of 31 to 78 kcfs. The analysis of flow or other effects is confounded because they are often correlated, but the cause cannot be determined.

Giorgi (1991b) developed and examined varying sets of regressions from historical to present data (1972 to 1987) to predict yearling chinook travel time through Snake River to McNary Dam. The highest correlation model was a third order polynomial ($r^2$=0.90) indicating no reduction in travel time at flows over 110 kcfs. In general, all models indicated that little change in smolt travel time occurs at flows greater than 80 to 100 kcfs.

Giorgi (1991b) also summarized data on yearling chinook smolt travel time through John Day Pool. The Fish Passage Center's (FPC's) analysis of data from 1986 to 1988 indicated a significant and strong relationship between flow and travel time and recommended that flows remain above 220 kcfs during this below-average-flow year. Different approaches to these data resulted in different conclusions. For example, Kindley (1991) found that a flow threshold may exist near 190 to 240 kcfs. Analysis of later data (1989 and 1990) by Kindley did not find consistent relationships between flow and travel time. Two regression models, log and polynomial, were evaluated to predict yearling chinook smolt travel time. The log model, developed by the FPC (1989), continues to show reduced travel times with increased flow, but the relationship greatly diminishes at higher flows. The polynomial showed that travel time decreases up to 200 to 240 kcfs.

In Giorgi's (1991b) assessment of survival data, he questioned the validity of relating these historical values to flow because many other factors have also varied among years (e.g., flows through turbines, bypass flows, and environmental factors). Giorgi re-analyzed the historical survival versus flow indices and found the best fit of the data was a quadratic regression ($r^2$=0.77). His analysis indicated that the rate of survival rose little at flows greater than 100 kcfs in the Snake River.

Petrosky (undated) reanalyzed data from 1970 to 1980 estimating smolt survival in the Snake River primarily using data from Raymond (1979). His analysis suggested increased survival would occur at flows higher than 85 kcfs. He concluded that an exponential analysis (that is one that continues to increase with increasing flow) best fits the data indicating significant and strong correlation to increasing smolt survival with increasing flow ($r^2$ = 0.71). When he applied polynomial analysis (which he believed was not the best way to analyze the data) to the data, his figures indicated increasing survival even in the range of 85 to 110 kcfs. He believed the exponential analysis is most valid based on the fact that historical survival without dams was much higher for the same stretch of river. Also, some of the data that suggested a leveling off of survival at flows in the range of 80 to 120 were from years when high mortality was occurring in the river from increased gas supersaturation. The total effect of this gas supersaturation cannot be determined, but at present under normal project operation it is generally not believed to be a problem, although it could be.

Few of the data examined demonstrated a positive relationship between travel time and increased flow for subyearling chinook. In addition, one study (Sims and Miller, 1982; Miller and Sims, 1983, 1984) found no significant relationship or correlation between travel times and flows for subyearling chinook (flows ranging from 112 to 393 kcfs in John Day Pool). These authors also found that many of these fish remained in the same region or moved upstream in the reservoir over time. One study of data from 1981 to 1983 and 1986 to 1988 found a statistically significant but weak correlation between flow and travel time ($r^2=0.33$) (Berggren and Filardo, 1991). Giorgi (1991b) concluded, "of the analyses conducted to date, none have identified a convincing substantive relationship between subyearling chinook migration speed and river flow/water velocity." In addition, Giorgi found that no data are available specifically for the Snake River subyearling chinook.

In 1991 a study on the Snake River with 104 subyearling chinook (presumably fall chinook) found a positive significant relation to travel time through Lower Granite Pool with flow and fish length (memorandum from Michele DeHart, FPC, to Merritt Tuttle, NMFS, October 16, 1991). The relationship was significant and correlated ($r^2 = 0.58$) with the two parameters. About equal explanation could be assigned to the two variables (i.e., correlation with just flow may be about 0.3, although this was not presented). This indicates that a significant but weakly correlated relationship would exist between just flow rate and rate of migration of fall chinook in the Snake River. Giorgi noted that other factors such as temperature and date of release also correlated with travel time.

Limited data are available on sockeye salmon migration rate in the Snake River. During 1991, 20 PIT-tagged sockeye released from Redfish Lake, 462 miles above Lower Granite Dam were recaptured. These data indicate a significant relationship with weak correlation ($r^2 = 0.28$) between flow rate and migration rate of these fish (memorandum from Michele DeHart, FPC, to Bert Bowler, Idaho Department of Fish and Game, July 19, 1991). The range of flow when fish were captured varied from 85 to 103 kcfs at Lower Granite Dam.

### 4.2.1.2 Effects of Flow Options on Water Particle Travel Time

Based on the previous discussion, it is apparent that water particle travel time may affect fish travel time and survival. Water particle travel times for the various pool elevations for the Snake and lower Columbia projects are shown in Tables 4.2-1 and 4.2-2.

**Snake River.** Water particle travel time is similar among Snake River project pools, ranging from 21 percent of the total water particle travel time for the reach in Lower Monumental to 30 percent in Little Goose (at maximum pool) within the Lower Snake River reach. At typical medium spring flows of 100 kcfs in the Snake River, decreasing all reservoirs to MOP from maximum pool reduces water particle travel time by 0.6 day (from 8.5 to 7.9 days). At high flows of 140 kcfs, the change is 0.4 day(from 6.2 to 5.8 days), and at low flow of 60 kcfs, the change is 1 day (from 14.2 to 13.2 days). At all three flow levels, the decrease in water particle travel time relative to maximum pool is 6 to 7 percent.

The largest effect on water particle travel time in the Snake River, without flow augmentation, occurs when all reservoirs are lowered from full pool to near spillway crest. At medium flow, the change is 4.5 days (from 8.5 to 4.0 days); at high flow the change is 3 days (from 6.2 to 3.2 days); and at low flow, it is 8.5 days (from 14.2 to 5.7 days) (Table 4.2-1). The range in percent decrease in water particle travel time is from 48 percent at high flow to 60 percent at low flow.

Intermediate reservoir elevations would have lesser effects on water particle travel time in the Snake River. For example, lowering Lower Granite to 710 feet and others to MOP from maximum pool reduces travel time from 0.9 to 2.3 days from high to low flow, or 15 to 16 percent from maximum pool (Table 4.2-3).

Several flow augmentation alternatives for the Snake River were modeled based on predicted available flow releases from Dworshak and Brownlee reservoirs, different goals of flow releases, and expected restrictions on the available

**Table 4.2-1.** Estimated water particle travel time in the lower Snake River reach.

| | | | Theoretical Travel Time (Days) by Discharge (kcfs) Category | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Project Reach | Miles | Elevation (ft) | 20 kcfs | 40 kcfs | 60 kcfs | 80 kcfs | 100 kcfs | 120 kcfs | 140 kcfs |
| Lower Granite | 32 | 738 | 10.8 days | 5.4 days | 3.6 days | 2.7 days | 2.2 days | 1.8 days | 1.5 days |
| | | 733 | 9.9 | 5.0 | 3.3 | 2.5 | 2.0 | 1.7 | 1.4 |
| | | 710 | 6.0 | 3.1 | 2.0 | 1.5 | 1.3 | 1.0 | 0.9 |
| | | 681[b] | 3.4 | 1.9 | 1.4 | 1.1 | 1.0 | 0.8 | 0.8 |
| Little Goose | 37 | 638 | 12.8 | 6.4 | 4.3 | 3.2 | 2.6 | 2.1 | 1.8 |
| | | 633 | 11.7 | 5.8 | 3.9 | 2.9 | 2.3 | 2.0 | 1.7 |
| | | 581[b] | 4.0 | 2.3 | 1.7 | 1.4 | 1.2 | 1.0 | 0.9 |
| Lower Monumental | 29 | 540 | 8.7 | 4.3 | 2.9 | 2.2 | 1.8 | 1.5 | 1.3 |
| | | 537 | 8.3 | 4.1 | 2.8 | 2.0 | 1.7 | 1.4 | 1.2 |
| | | 483[b] | 3.0 | 1.7 | 1.2 | 1.0 | 0.8 | 0.8 | 0.7 |
| Ice Harbor | 32 | 440 | 9.5 | 4.9 | 3.2 | 2.5 | 1.9 | 1.7 | 1.4 |
| | | 437 | 9.0 | 4.6 | 3.0 | 2.3 | 1.8 | 1.5 | 1.3 |
| | | 391[b] | 2.9 | 1.7 | 1.2 | 1.0 | 0.9 | 0.8 | 0.7 |
| Clearwater River[a] | 139 | Max. Pools | 42.3 | 21.4 | 14.2 | 10.7 | 8.5 | 7.2 | 6.2 |
| Confluence to | | Min. Pools | 39.4 | 19.8 | 13.2 | 10.0 | 7.9 | 6.7 | 5.8 |
| Snake-Columbia | | L. Gran. (710)[c] | 35.5 | 18.2 | 12.1 | 9.3 | 7.3 | 6.1 | 5.5 |
| River Confluence | | Spillway | 13.9 | 7.8 | 5.7 | 4.6 | 4.0 | 3.5 | 3.2 |

Source: Calculated using Corps backwater models.

a/ Included water particle travel time from Ice Harbor Dam to confluence with Columbia River.

b/ Spillway crest elevation; actual water level would be somewhat higher and variable, depending upon inflow.

c/ All pools minimum pool except Lower Granite at 710 feet.

**Table 4.2-2.** Estimated water particle travel time in the lower Columbia River reach.

| | | | Theoretical Travel Time (Days) by Discharge (kcfs) Category | | |
|---|---|---|---|---|---|
| Project Pool | Miles | Elevation (ft) | 100 kcfs | 200 kcfs | 300 kcfs |
| Columbia-Snake River Confluence to McNary | 32 | 340 | 4.3 days | 2.2 days | 1.4 days |
| | | 337 | 4.0 | 2.0 | 1.3 |
| | | 335 | 3.8 | 1.9 | 1.3 |
| John Day | 75 | 268 | 12.7 | 6.4 | 4.3 |
| | | 262 | 11.0 | 5.5 | 3.7 |
| | | 257 | 10.1 | 5.0 | 3.4 |
| The Dalles | 24 | 160 | 1.8 | 0.9 | 0.6 |
| | | 155 | 1.5 | 0.8 | 0.6 |
| Bonneville | 45 | 77 | 3.5 | 1.8 | 1.2 |
| | | 70 | 2.9 | 1.5 | 1.0 |
| Confluence of Snake River to Bonneville Dam | 176 | Max. | 22.3 | 11.3 | 7.5 |
| | | Inter.[a] | 19.4 | 9.8 | 6.6 |
| | | Min. | 18.3 | 9.2 | 6.3 |

Source: Corps, Walla Walla District.

a/ Uses two intermediate drawdown elevations at McNary and John Day and lower elevations at other projects.

Table 4.2-3. Estimated water particle travel time with different combinations of options.

| Flow[a] and Alternatives[b] | Snake | | | Columbia | | | Snake and Columbia | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total Days | Change From Maximum Days | Change From Maximum % | Total Days | Change From Maximum Days | Change From Maximum % | Total Days | Change From Maximum Days | Change From Maximum % |
| **High Flow** | | | | | | | | | |
| Maximum Pool | 6.2 | - | - | 7.5 | - | - | 13.7 | - | - |
| All at MOP | 5.8 | 0.4 | 6 | 6.3 | 1.2 | 16 | 12.1 | 1.6 | 12 |
| MOP, except John Day, McNary, and L. Granite | 5.3 | 0.9 | 15 | 6.6 | 0.9 | 12 | 11.9 | 1.8 | 13 |
| Columbia at MOP, Snake at Spillway | 3.2 | 3.0 | 48 | 6.3 | 1.2 | 16 | 9.5 | 4.2 | 31 |
| **Medium Flow** | | | | | | | | | |
| Maximum Pool | 8.5 | - | - | 11.3 | - | - | 19.8 | - | - |
| All at MOP | 7.9 | 0.6 | 7 | 9.2 | 2.1 | 19 | 17.1 | 1.7 | 14 |
| MOP, except John Day, McNary, and L. Granite | 7.2 | 1.3 | 15 | 9.7 | 1.6 | 14 | 16.9 | 2.9 | 15 |
| Columbia at MOP, Snake at Spillway | 4.0 | 4.5 | 53 | 9.2 | 2.1 | 19 | 13.2 | 6.6 | 33 |
| **Low Flow** | | | | | | | | | |
| Maximum Pool | 14.2 | - | - | 22.3 | - | - | 36.5 | - | - |
| All at MOP | 13.2 | 1.0 | 7 | 18.3 | 4.0 | 18 | 31.5 | 5.0 | 14 |
| MOP, except John Day, McNary, and L. Granite | 11.9 | 2.3 | 16 | 19.2 | 3.1 | 14 | 31.1 | 5.4 | 15 |
| Columbia at MOP, Snake at Spillway | 5.7 | 8.5 | 60 | 18.3 | 4.0 | 18 | 24.0 | 12.5 | 34 |

Source: Based on data from Tables 4.2-1 and 4.2-2.

a/ High flow: Snake River = 140 kcfs; Columbia River = 300 kcfs;
Medium flow: Snake River = 100 kcfs; Columbia River = 200 kcfs;
Low flow: Snake River = 60 kcfs; Columbia River = 100 kcfs;

b/ Maximum Pool = All pools, Columbia and Snake at full pool.
All at MOP = All pools, Columbia and Snake at minimum operating pool.
MOP at Except John Day and Lower Granite = John Day at elevation 262 and Lower Granite at elevation 710.
Columbia at MOP, Snake at Spillway = All Columbia dams at MOP and all Snake dams at spillway crest.

storage and reservoir levels. Ten flow augmentation alternatives were modeled to assess what the average change in flow would be for the second half of April and all of May, and June. The purposes of the alternatives evaluated were to increase flows for different periods including May, April, and May, and April through June.

Based on the model analysis, additional flows in May above what normally occurs (baseline) ranged from 1 to 37 kcfs. Only three alternatives had flows of 20 kcfs or higher, while seven estimated flow increases of less than 8 kcfs in May at Lower Granite Dam. The highest flow increase alternative (an additional 37 kcfs in May) used a target flow of 140 kcfs for Lower Granite Dam in May. The other two alternatives with high flow releases of about 20 kcfs used the goal of increasing flow in May only with no target flow but an increase in available storage volume from Dworshak (600 KAF) and Brownlee (200 KAF) reservoirs over a normal May flow release. The alternatives with lower additional flows in May assumed one or more of the following factors: less available storage water for release from the two upper reservoirs; extended flow release periods; different target flow goals; greater restrictions on instantaneous flow releases from Dworshak Reservoir; and other operational restrictions. Depending on the goals of each model, flow could be less in other months than what currently occurs. At least four of the models indicated reduced June flows of 4 to 6 kcfs over baseline through the process of increasing flows in May.

The example of 20 kcfs was used as representative of a high flow augmentation in water particle travel time calculations and related analysis.

The length of time that 20 kcfs could be delivered depends on available storage used for flow augmentation. For all but one of the augmentation options, a flow of an additional 20 kcfs could be supplied for 28 days or less in an average water supply year. With the allocation of this flow increase to May or June, lower flows than typical would occur in summer months.

Flow augmentation would have varying effects on water particle travel time depending on existing flow, reservoir elevation, and quantity added. For example, if augmentation of 20 kcfs were possible during a low flow year (60 kcfs), travel time at maximum pool would be reduced 3.5 days or 25 percent (from 14.2 to 10.7 days), which is one of the largest reductions in water particle travel time with flow augmentation. During a more typical flow year (100 kcfs), at maximum operating pool, an additional 20 kcfs would reduce water particle travel time by 1.3 days or 15 percent (from 8.5 to 7.2 days).

The March test drawdown option would reduce water particle travel time in Lower Granite Pool slightly more than the 710 alternative (because minimum elevations will be from 705 to 696 feet). Also, water particle travel time in Little Goose Pool would be reduced about midway between the MOP and spillway options as the pool would be up to 15 feet below minimum pool. However, the objective of this option is to provide test data on physical parameters rather than travel time benefits to the few migrating fish that will be present.

**Columbia River.** At typical Columbia River spring flows of 200 kcfs, lowering the four lower Columbia River pools to MOP would decrease water particle travel time by 2.1 days (from 11.3 to 9.2 days) from the Snake River confluence to Bonneville Dam (Table 4.2-2). The reduction at high flows of 300 kcfs would be 1.2 days (from 7.5 to 6.3 days), and at a low flow of 100 kcfs, the reduction would be 5.0 days (from 22.3 to 18.3 days). All three flow levels have similar decreases of 16 to 19 percent in water particle travel time relative to maximum pool.

Leaving John Day Pool at elevation 262.5 feet would have lesser effects, reducing existing travel time by 0.9 to 3.1 days or 12 to 14 percent from high to low flows, respectively (Table 4.2-3). Because John Day Pool has the largest volume of the lower Columbia reservoirs, from 54 to 57 percent of the total water particle travel time for a given flow occurs here. The Dalles Pool, the smallest reservoir, accounts for less than 10 percent of the theoretical water particle travel time in the lower Columbia reach.

Although the estimated decreases in water particle travel time are from 16 to 19 percent for the Columbia River reach, this is based on reducing the reservoirs from maximum to minimum pool. In normal operations, reservoirs operate below full pool. For example, John Day Pool, which has the largest volume, operates near 262 feet for part of the year. Lowering this pool from normal operation to MOP (257 feet) would result in a decrease in water particle travel time of about 9 percent. Considering that all projects normally are operated between full pool and MOP, a more reasonable estimate of reduction in water particle travel time by lowering the projects to MOP is about 10 percent.

Augmenting flow by 20 kcfs in the Columbia River during a low flow period (100 kcfs) would reduce the water particle travel time by 5 to 5.5 days or 25 to 27 percent for the Columbia River reach, over the potential range of reservoir operations considered. At high flow (300 kcfs), the reduction for this reach would be less than 0.7 day, or 10 percent over considered operations.

**Snake and Columbia Rivers.** Combined alternatives for the Snake and Columbia rivers have a wide variety of effects on theoretical water particle travel time (Table 4.2-3). Through the project area from the Clearwater River to Bonneville Dam, the water particle travel time is 36.5, 19.8, and 13.7 days, respectively for low (60 kcfs Snake River, 100 kcfs Columbia River), medium (100 kcfs Snake River, 200 kcfs Columbia River), and high (140 and 300 kcfs, respectively) flows at maximum pool elevations (Table 4.2-3). Maximum reduction in water particle travel time would occur with the combination options of Columbia River projects at MOP and all Snake River projects at spillway crest, resulting in water particle travel time of 24.0, 13.2, and 9.5 days for low, medium, and high flows, respectively (Table 4.2-3). Overall, for low, medium, and high flow, this would reduce water particle travel time by 12.5, 6.6, and 4.2 days, respectively, or 34 to 31 percent over maximum pool. Combinations of intermediate options would reduce water particle travel time by 5.4, 2.9, or 1.8 days, respectively, or 15 to 13 percent relative to maximum pool (Table 4.2-3).

A high augmentation of 20 kcfs in May or June during low flow (i.e., increasing Snake River flow from 60 to 80 kcfs and Columbia River flow from 100 to 120 kcfs) at maximum pool would reduce the water particle travel time by 8 days (from 36.5 to 27 days), or 22 percent. During medium flow at maximum pool, the reduction would be 2.8 days (19.8 to 17 days), or 14 percent. Effects are relatively less with reduced pool elevation options. In nearly all cases, an augmentation flow of 20 kcfs in May or June will result in increased water particle travel time in summer months (July to September). This is because increased spring releases would likely use some water that would otherwise be available later, resulting in below-normal summer flows.

### 4.2.1.3 Effects of Flow Options on Smolt Travel Time

#### Yearling Chinook.

*Snake River - Lower Granite Pool* - Because many variables affect yearling chinook smolt travel time, accurate predictive models of travel time through Lower Granite Pool have not been developed. While the relationship between flow and travel time is not consistent in this pool, the strongest single factor correlating with travel time has been found to be flow (Buettner, undated). So for purposes of this OA/EIS, the ability to predict smolt responses to water particle travel time is needed. Therefore, making the assumption that smolt migration rates are directly related to water particle travel time for lack of appropriate data provides a relative estimate of smolt travel time (Table 4.2-1) and a basis for comparison without definitive data.

Reducing pools to MOP at 40, 80, and 120 kcfs would result in an estimated reduction of yearling chinook smolt travel time of 0.4, 0.2, and 0.1 days, respectively, through the pool. Because the Lower Granite Pool is usually operated at less than full pool during migration periods, the reduction in travel time would be about half those values. If augmentation flows of 20 kcfs were added at maximum pool, smolt travel time would be reduced by 1.8, 0.5, and 0.3 days, respectively, at initial flows of 40, 80, and 120 kcfs.

The apparent reduction in smolt travel time by lowering Lower Granite to elevation 710 feet over flow ranges of 40 to 120 kcfs is 2.3 to 0.8 days. The March drawdown alternative (705 to 696 feet) will reduce migration rate to a similar level; however, few fish will be present. In addition, based on these same assumptions, reduction to near spillway crest would reduce travel time by 3.5 to 1.0 days. Estimated changes in smolt travel time resulting from these two options must be weighed carefully against potential negative effects of dissolved gas supersaturation, physical injury, loss of bypass and transport operation, and other factors (discussed in later sections). Therefore, apparent reductions in smolt travel time may be outweighed by other factors for which there are no previous experience to develop predictions on survival benefits.

*Snake River - Lower Granite Dam to Ice Harbor Dam* - No studies on yearling chinook smolts have been specifically conducted on just the Snake River under existing conditions (all dams in place with current operating programs). Raymond (1979) conducted studies in this reach from 1966 to 1975. While this data may also have been used, the Corps chose to use the more recent data. However, varied relationships have been found between flow and travel time for yearling chinook from Lower Granite Dam to McNary or John Day dams. Although factors such as smolt development have also been found to correlate strongly with travel time in this area, different models (regressions) were developed to determine the relationship between flow and travel time in this region. Giorgi (1991b) presented the results of the various models (Figure 4.2-1).

Using models based on past operations to determine changes in smolt travel time for different project alternatives on the Snake River relies on many tenuous assumptions. Most models developed show significant relationships between flow and smolt travel time, at least to a threshold level (80 to 100 kcfs in the Snake River and 190 to 240 kcfs in the Columbia River). However, they differ in what this relationship is and to what level of flow the relationship either is positive, or shows marked changes with flow increase. For the following analysis, several models were examined to obtain examples of how these 1992 options may alter smolt travel time. The travel times of various groups of fish from Lower Granite to McNary Dam have been evaluated by several authors. Differences of opinion exist over how to interpret the data, as discussed previously. To summarize the range of estimates for this reach of the Snake River, Giorgi (1991b) compared water particle travel time at MOP for Little Goose, Lower Monumental, and Ice Harbor. This reach was selected for comparison because it has the historical data gathered and analyzed by several groups (Sims et al., 1983; Chapman et al., 1991; Kindley, 1991). Other data sets from the same region were analyzed by CBFWA (1991a) and Berggren and Filardo (1991). Giorgi (1991b) presented four different regression models based on the above analysis (Figure 4.2-1). With these models, he analyzed the relationship between flow and travel time in this reach. Giorgi (1991b) suggested that because of the general and limited nature of the data, the polynomial model that he developed and the reciprocal flow model developed by Berggren and Filardo (1991) encompassed the range of flow/migration rate values that may be expected in this region.

The polynomial model developed by Giorgi (1991b) indicated no reduction in travel time at flow greater than 110 kcfs. The reciprocal flow model developed by Berggren and Filardo (1991) indicated that travel times decreased with increasing flow. In general, however, at water particle travel time greater than 1.9 to 2.4 days per project (which corresponds to 80 to 100 kcfs at normal pool levels), the decrease in travel time is small (Giorgi, 1991b). Thus, Giorgi (1991b) concluded this range of travel times should be suitable for effective migratory conditions.

A summary of the relationships of these two models (Giorgi, 1991b and Berggren and Filardo, 1991) and a corresponding calculated average per project (three lower Snake River pools) water particle travel times resulting from the models are presented in Table 4.2-4.

Using Table 4.2-4, examples of the relationship between changes in project operation and smolt travel times can be estimated. Although projects are operated normally at less than full pool in this region operation at full pool condition is assumed to be an optimistic estimate of gains expected from changes in operation. Over the range of flows typically occurring in the Snake River during outmigrations, the reduction in water particle travel time when projects are reduced from maximum pool to MOP is 6 to 7 percent. The Corps assumed in the example that a reduction to MOP resulted in a change in water particle travel time of 7 percent over the entire range. To be consistent with the water particle travel time changes presented earlier, all calculations are presented for reduction from maximum to minimum pool levels. Actual reduction would be about half of this because pool levels are normally maintained between maximum and minimum levels.

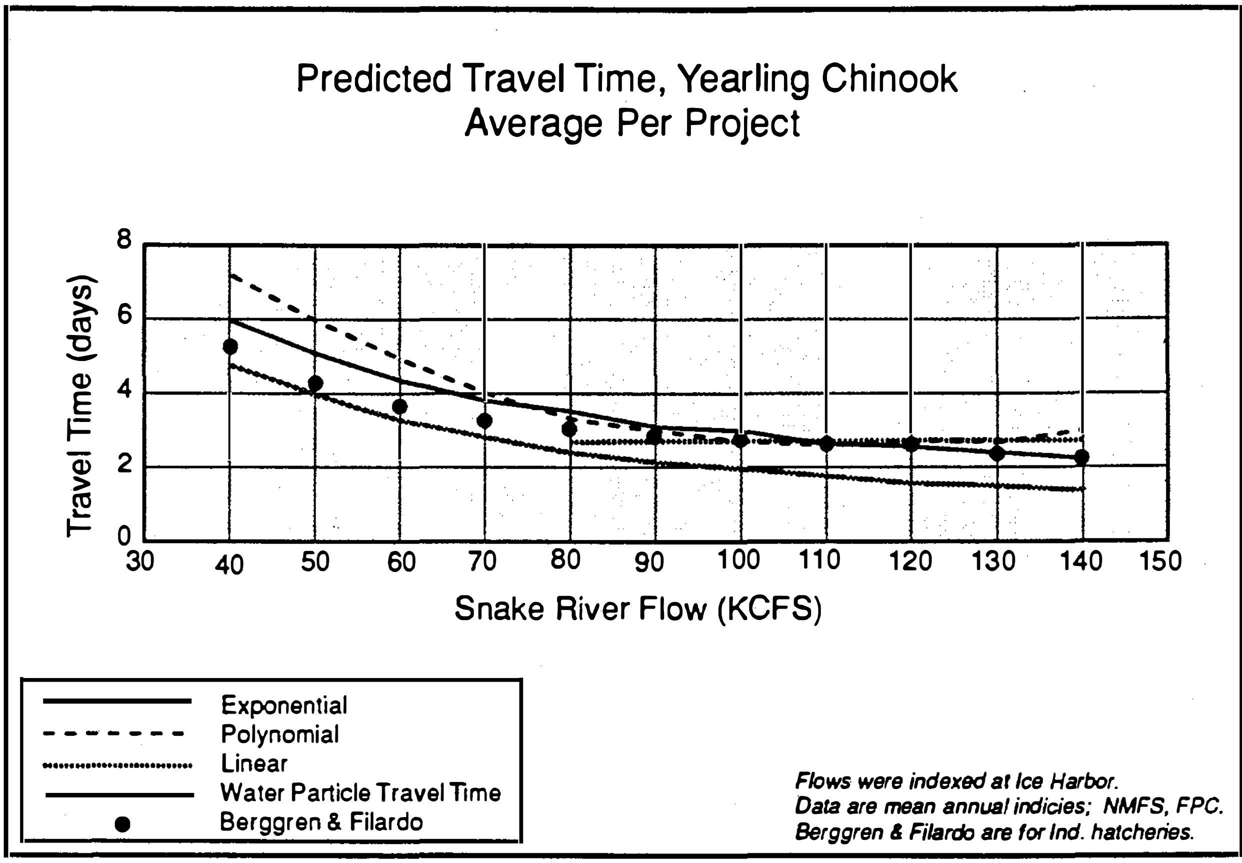



**Figure 4.2-1.** Comparison of four models describing the relationship between yearling chinook travel time and flow in the Snake River, plus water particle travel time (Source: modified from Giorgi, 1991b).

As examples of the changes that may be expected with different alternatives, three flow levels (40, 80, and 120 kcfs) were used to show estimates in smolt travel time (Table 4.2-5). These changes were estimated by comparing the proportional change in water particle travel time to proportional change in smolt travel time predicted by the reciprocal flow and polynomial models. Reducing projects to MOP from maximum pool would reduce estimated smolt travel time from Lower Granite Dam to Ice Harbor Dam (by 1.8 to 0.9 days) at 40 kcfs for the two models. At the high flow of 120 kcfs, the estimated reduction in smolt travel time ranges from -0.1 to 0.3 day. The intermediate flow of 80 kcfs results in the same change (0.6 day reduction) under both models. Actual changes would be about half at those shown because normal operation is less than full pool. The polynomial model indicates an increase in travel time at higher flows. With flow augmentation of 20 kcfs as an example, at a base of 40 kcfs, the reduction in travel time would be from 7.2 to 3.9 days. At a high flow of 120 kcfs, reductions would range from -0.3 to 0.6 day smolt travel time for the two models. Intermediate changes would range from 0.8 to 1.2 days. If both projects were lowered to MOP and had 20 kcfs augmentation flow, reductions in travel time at the three flows would be approximately additive. Therefore, at 40 kcfs with both pools lowered and 20 kcfs additional flow

**Table 4.2-4.** Predicted average median yearling chinook travel time per Snake River project.

| Flow (kcfs) | Water Particle Travel Time (Days)[b] | Smolt Travel Time (Days)[a] | |
|---|---|---|---|
| | | Polynomial[c] | Reciprocal Flow[d] |
| 40 | 5.2 | 7.3 | 5.0 |
| 50 | | 5.9 | 4.2 |
| 60 | 3.5 | 4.9 | 3.7 |
| 70 | | 4.0 | 3.4 |
| 80 | 2.6 | 3.4 | 3.1 |
| 90 | | 3.0 | 2.9 |
| 100 | 2.1 | 2.8 | 2.7 |
| 110 | | 2.6 | 2.6 |
| 120 | 1.8 | 2.6 | 2.5 |
| 130 | | 2.6 | 2.4 |
| 140 | 1.5 | 2.7 | 2.3 |

a/ Estimates are based on models that were fit to the data set presented in Giorgi (1991b).
b/ Average water particle travel times calculated from Corps travel time curves at maximum pool for Little Goose, Lower Monumental, and Ice Harbor pools.
c/ Described in Giorgi (1991b).
d/ Derived from different data set than polynomial model; by Berggren and Filardo (1991). The values they calculated were for travel time from Lower Granite to McNary Dam. These values presented are their estimates divided by 4 to obtain estimate per project.

changes, the reduction in travel time would be about 9 and 4 days for the polynomial and reciprocal flow models, respectively. At high flows, the change would be less than 1 day increase or reduction in travel time for this reach, while at intermediate flow it would be less than 2 days reduction.

Table 4.2-5 also presents the change in smolt travel time estimates based on a reduction to near spillway crest at the three flows; however, this condition has never been tested and is outside the normal range of activities at these projects. Therefore, use of these models to measure actual reductions (or increases as predicted by the polynomial model at intermediate and higher flows) is not appropriate, especially when considering models that predict changes in survival based on changes in travel time, as will be discussed later. However, in an effort to provide some basis for comparison, yearling chinook smolt travel times based on these models are presented.

Smolt travel time changes through Little Goose Pool would be between MOP and spillway crest for the March downstream test; however, few fish will be present then.

Table 4.2-5. Estimated changes in yearling chinook travel time from Lower Granite Dam to Ice Harbor Dam.

| | | Yearling Chinook Travel Time (Days) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Polynomial Model[a] | | | Reciprocal Flow Model[a] | | |
| Starting Flow (kcfs) | Option[b] | Start | New | Change | Start | New | Change |
| 40 | To MOP[c] | 21.9 | 20.1 | 1.8 | 15.0 | 14.1 | 0.9 |
| 40 | +20 kcfs | 21.9 | 14.7 | 7.2 | 15.0 | 11.1 | 3.9 |
| 40 | Near Spillway | 21.9 | 8.0 | 13.9 | 15.0 | 7.7 | 7.3 |
| 80 | To MOP[c] | 10.2 | 9.6 | 0.6 | 9.3 | 8.7 | 0.6 |
| 80 | + 20 kcfs | 10.2 | 8.4 | 0.8 | 9.3 | 8.1 | 1.2 |
| 80 | Near Spillway | 10.2 | 8.1 | 2.1 | 9.3 | 6.3 | 3.0 |
| 120 | To MOP[c] | 7.8 | 7.9 | -0.1 | 7.5 | 7.2 | 0.3 |
| 120 | +20 kcfs | 7.8 | 8.1 | -0.3 | 7.5 | 6.9 | 0.6 |
| 120 | Near Spillway[d] | 7.8 | >8.1 | <-0.3 | 7.5 | <6.3 | >1.2 |

a/ Based on respective models presented in Giorgi (1991b).
b/ Options are lowering reservoirs to MOP, adding 20 kcfs flow at maximum pool, and reducing to spillway crest.
c/ Based on the difference from maximum to minimum pool, actual changes would be about half of those shown because pools are normally operating at less than full pool.
d/ Values out of range of models.

*Columbia River* - The only data available, independent of Snake River data, to evaluate the yearling chinook migration rate in the lower Columbia River are for the John Day Pool (Giorgi, 1991b). Giorgi (1991b) pointed out that none of the available data measured smolt development, which has been closely correlated with the smolt migration rate.

Giorgi (1991b) presented two models developed to predict yearling chinook smolt travel time based only on flow in the John Day Pool. One is the logarithmic model developed by the FPC (1989) and the other is a polynomial regression developed by Kindley (1991) of the Pacific Northwest Utilities Conference Committee (PNUCC), which uses bias-corrected data, not used by the FPC (Figure 4.2-2). Kindley (1991) concluded from his analysis that at a flow greater than 190 to 240 kcfs, little change occurs in travel time. The shortest travel time with this model occurred at 260 kcfs. The FPC model indicates that travel time continues to decrease with increased flow, but at reduced rates at higher flow. In contrast, the estimated water particle travel time decreases almost linearly with increased flow. The polynomial regression more closely followed this relationship. In Giorgi's discussion of the two models, he stated, "The models are so disparate,

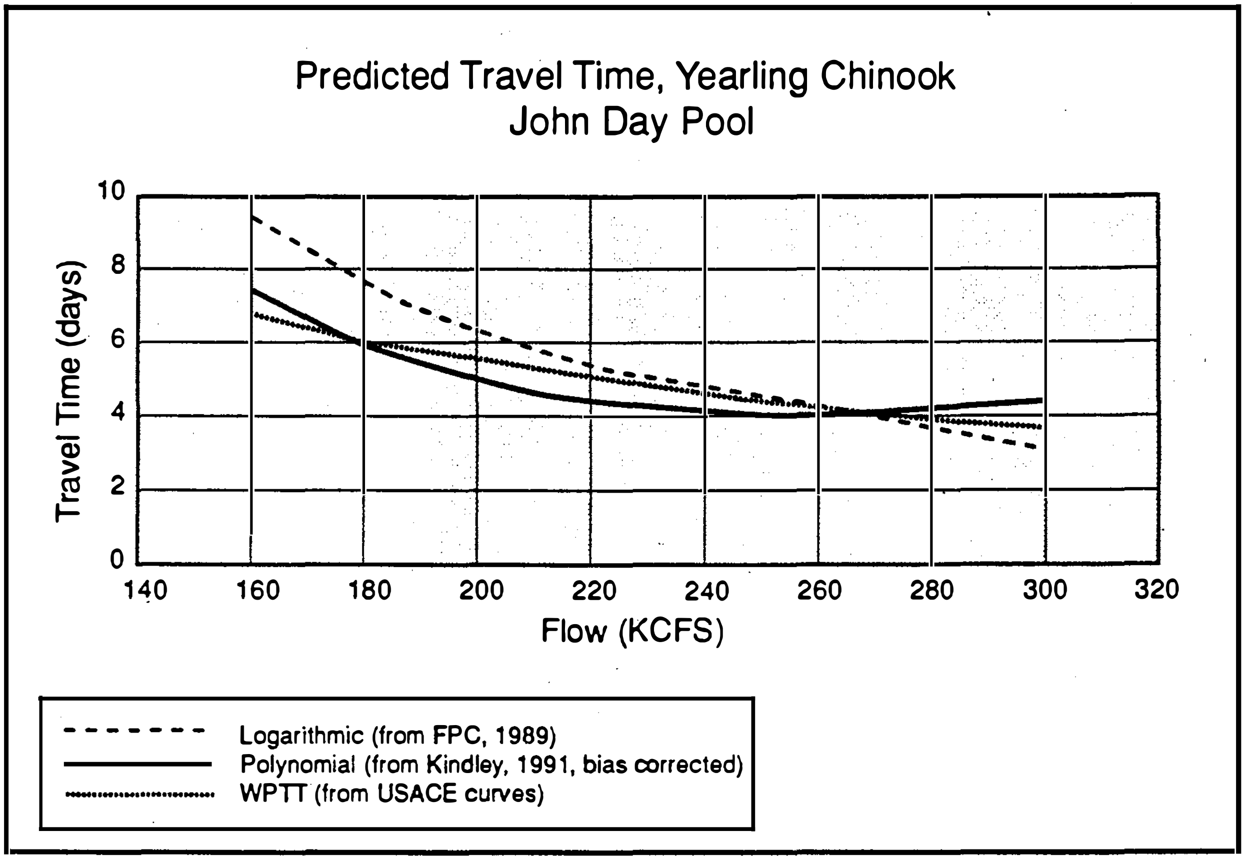



Figure 4.2-2. Relationship between yearling chinook travel time and flow between McNary Dam and John Day Dam. Freeze-branded fish were released in the tailrace and recovered at John Day Dam (Source: Georgi, 1991b).

any alternative actually implemented will be cloaked in uncertainty and require thorough and extensive evaluation studies."

The extrapolation of these data to the entire lower Columbia River has many potential problems. John Day Reservoir is the largest of the four lower Columbia reservoirs and generally accounts for about 56 percent of the total water particle travel time in this region (Table 4.2-2). The overall effect on travel time of the fish and how they behave in different reservoirs at the same flow could lead to spurious conclusions. For comparison purposes, a range of possible values based on the two models at a typical flow level is presented (Table 4.2-6).

Examples of how smolt travel time might vary in the lower Columbia River with some of the options is presented in Table 4.2-7, based on the determination that water particle travel time decreases by 10 percent over all flow ranges when projects are lowered to MOP. Reductions to MOP at a relatively low flow (160 kcfs) reduces estimated smolt travel time by 2.5 and 2.0 days for the FPC and PNUCC models, respectively. Changes at the upper flow range of 260 kcfs would be less, ranging from 1.6 days to a -0.5 day for the two models. Augmentation flow of 20 kcfs has an effect similar to lowering the projects to MOP. If flows were augmented and the reservoirs were lowered to MOP, the net effect would be similar to adding the two effects shown; at 160 kcfs, the net reduction would be 4 to 5 days. At a flow of 260

**Table 4.2-6.** Predicted yearling chinook travel time through John Day Pool.

| Flow (kcfs) | Water Particle Travel Time [a] | Smolt Travel Time (Days) FPC[b] | Smolt Travel Time (Days) PNUCC[c] |
|---|---|---|---|
| 160 | 6.7 | 9.1 | 7.2 |
| 180 | 5.9 | 7.5 | 5.9 |
| 200 | 5.5 | 6.3 | 5.0 |
| 220 | 5.0 | 5.4 | 4.4 |
| 240 | 4.5 | 4.6 | 4.1 |
| 260 | 4.1 | 4.1 | 3.9 |
| 280 | 3.8 | 3.6 | 4.0 |
| 300 | 3.7 | 3.2 | 4.2 |

Source: Modified from Table 3 in Giorgi (1991b).

a/ Water particle travel time at elevation 262 estimated from Corps travel time curves.

b/ The FPC model is a logarithmic function (FPC, 1989).

c/ The PNUCC model is the polynomial function presented by Kindley (1991).

kcfs, the smolt migration rate might be reduced by about 3 days or increased by 1 day under the two models.

**Subyearling Chinook.** There are no studies available for fall chinook migration in the region from Lower Granite Dam to Ice Harbor Dam, and only one recent study (in 1991) is available for fall chinook migration in the Lower Granite Pool (memorandum from Michele DeHart, FPC, to Merrit Tuttle, NMFS, October 16, 1991). This study, using multiple regression, found a significant relationship between fall chinook travel time and the independent variable flow and fish length. It did not examine the effects of just flow but stated the two variables (flow and fish length) accounted for about equal portions of the variability in fish migration rate. No investigations describing the relationship between survival and flow for fall chinook salmon have been conducted in the Snake River. Studies conducted on the lower Columbia River indicated varied benefits from increased flow (see below). Therefore, benefits to fall chinook from increased flow are less clear.

Studies performed on the Columbia River for subyearlings include fall chinook and upper Columbia summer chinook (Giorgi, 1991b). They suggested that the relationship between subyearling chinook travel time and flow range from statistically significant but weakly correlated to not statistically significant in the Columbia River. NMFS studied subyearling chinook travel behavior in the John Day Pool from 1981 through 1983. Based on these studies (Sims and Miller, 1982; Miller and Sims, 1983, 1984), the authors concluded there was no relationship between flow and travel time between the flow range of 112 to 393 kcfs. The researchers noted that 54 percent of the fish tagged for identification were recaptured at or upstream from the original release site. Subyearlings did not appear to be actively migrating. Giorgi et al. (1990a) examined the adult contribution data from the NMFS studies and

**Table 4.2-7.** Estimated changes in yearling chinook travel time in the Columbia River from the Snake River confluence to Bonneville Dam.

| | | FPC Model[a] | | | PNUCC Model[a] | | |
|---|---|---|---|---|---|---|---|
| | | Smolt Travel Time (Days) | | | Smolt Travel Time (Days) | | |
| Starting Flow | Option[b] | Start | New | Change | Start | New | Change |
| 160 | To MOP | 16.3 | 13.8 | 2.5 | 12.9 | 10.9 | 2.0 |
| 160 | +20 kcfs | 16.3 | 13.4 | 2.9 | 12.9 | 10.5 | 2.3 |
| 200 | To MOP | 11.3 | 9.3 | 2.0 | 8.9 | 7.7 | 1.2 |
| 200 | +20 kcfs | 11.3 | 9.6 | 1.7 | 8.9 | 7.9 | 1.0 |
| 260 | To MOP | 7.3 | 5.7 | 1.6 | 7.0 | 7.5 | -0.5 |
| 260 | +20 kcfs | 7.3 | 6.4 | 0.9 | 7.0 | 7.1 | -0.1 |

a/ Based on models summarized in Giorgi (1991b).
b/ Options are lowering reservoirs to MOP or adding 20 kcfs flow at maximum pool.

included two variables, temperature and release date, in addition to flow. The authors found no relationship between travel time and flow.

Berggren and Filardo (1991) regressed subyearling chinook travel time in the John Day Pool against a subset of the groups tagged in 1981 to 1983, and 1986 to 1988 by NMFS, as well as against transport controls released at the McNary tailrace. The correlation between travel time and flow was statistically significant but weakly correlated ($r^2$=0.33). This low correlation indicates that the measured migration rate for smolts at any given flow is wide.

This reduces the ability to accurately predict specific changes in travel time with changes in flow. The implication is that with an increased flow, some reduction in travel time will occur but the level of this reduction is unclear.

Based on Berggren and Filardo, CBFWA (1991a) concluded that increased flow benefits subyearling chinook travel time, although the benefit diminishes at higher flows.

**Sockeye.** One limited study (20 fish in 1991) as presented in a memorandum from Michele DeHart, FPC, to Bert Bowler, Idaho Department of Fish and Game, July 19, 1991 on sockeye salmon indicated a significant but weak correlation in the Snake River between migration rate and flow from Redfish Lake to Lower Granite and Little Goose dams. No information is available for the Columbia River.

### 4.2.1.4 Effects of Flow Options on Juvenile Survival

**General.** Smolt travel time has been used as the primary index of non-transported smolt survival, in part because of the difficulty in measuring smolt survival through a pool or reach where multiple variables confound the analysis.

Annual indices of smolt survival in the river during migration without transport were plotted against an index of flow based on studies conducted by Sims and Ossiander (1981), Committee on Fisheries Operations (COFO) (1982), and Sims et al. (1983), as described by Giorgi (1991b). The results indicated that survival increased historically to a point and then decreased with increasing flow (a polynomial regression). Based on this and other data, associated travel time/flow relationships have been used to identify the minimum flows for fish protection of 85 kcfs at Lower Granite Dam and 220 kcfs at McNary Dam (Giorgi, 1991b).

Most of these analyses of flow/survival of yearling chinook and steelhead were based on studies using release points in the Snake River (Lower Granite or Little Goose) downstream to recovery points in the Columbia River (The Dalles). As pointed out by Giorgi (1991b) and discussed earlier, there are several serious concerns with using these data to predict flow/survival relationships (e.g., lack of estimates of variance, annual changes in the hydrosystem, confounding effects of spill, variations in fish guidance efficiency, and number of turbines in operation).

Sims and Ossiander (1981) provided some of the early data that correlated survival of yearling chinook and steelhead to flow quantity in the Snake River. They also found a significant relationship between spill quantity and survival. Because flow and spill are highly correlated, it is not possible to differentiate which has the greater effect on survival. However, they did not examine effects of any other variables on survival.

CBFWA (1991a), based extensively on Sims and Ossiander's (1981) work, provided estimates of benefits to survival associated with increased flow, which are the regressions of Snake River chinook and steelhead annual survival indices versus flow at The Dalles Dam. The relationship proposed in figures presented by CBFWA suggests that increasing Columbia River flow from 200 kcfs to 220 kcfs would increase absolute survival rates of non-transported Snake River yearling chinook salmon (traveling from Lower Granite or Little Goose downstream to The Dalles) from 11 percent to 13 percent based on the annual survival indices (derived by interpolation). For steelhead, the survival rate would increase from 8 to 10 percent.

Because of the nature of the annual survival indices, it is not possible to isolate benefits that can be associated with the Snake River reach and lower Columbia River reach. It is not possible to define the precision of these estimates, because none are provided with the CBFWA document. Finally, it is not possible to estimate which portion of the system survival response can be attributed entirely to flow, because there were so many changes made to the system and volumes spilled during the period tested. Sims and Ossiander (1981) attributed a larger effect on survival from spill than flow. For these reasons, the annual survival indices only provide a general indication of survival responses to flow. They do not account for annual variation in factors such as smolt development, spill, temperature, number of turbines operating, and number of bypasses installed.

Using an alternative method, Bell et al. (1976) tried to estimate the relationship between travel time and flow by taking the available survival reach information, subtracting estimated mortality associated with turbines, nitrogen saturation, and spillway passage, and comparing the resultant reservoir survival to flow. These authors calculated daily reservoir losses to be 0.7 percent for smolts that were about 5 inches long.

Estimates of change in yearling chinook survival will be presented by river segments for different alternatives in the following subsections. Survival is calculated as changes in absolute percent (not relative) survival for fish that are not transported for each of the river segments.

Estimates of changes in survival due to increased flow or reduced water particle travel time are highly speculative. Many other factors influence survival independent of flow or travel time. Therefore, the following calculations of changes in survival based on changes in travel time or flow should be viewed with caution as the level of accuracy and precision cannot be determined. Because of the many variables affecting survival, the calculations of survival shown to the nearest 0.1 percent are only presented to show general trends and magnitude of differences between different alternatives and should not be consider a statistical level of precision. The values are simply the results from the models used rounded to the nearest 0.1percent.

**Snake River - Lower Granite Pool.** Using Bell's estimate of reservoir attrition (0.7 percent per day), general estimates of changes in survival from different options can be estimated based on estimated changes in travel time through Lower Granite Pool (as presented in the previous section). Lowering this pool from maximum pool to MOP would increase estimated absolute survival from 0.3 to 0.1 percent at flows of 40, 80, and 120 kcfs, respectively. Values would actually be about half because normal pool levels are less than maximum. It could be predicted that increasing flow by 20 kcfs would increase absolute survival by 1.3, 0.4 to 0.2 percent for the same flow values. For all but one flow augmentation option, a flow increase of 20 kcfs over baseline flow would only be available for less than 1 month of continuous release in an average water year. If it was assumed that other factors have no effect, based <u>only</u> on travel time, absolute survival would increase by 2.4, 1.1, and 0.7 percent with pool reduction from maximum to near spillway at flows of 40, 80, and 120 kcfs, respectively. It must be emphasized that operation at 710 feet or near spillway crest would cause other negative factors (discussed later) that would likely outweigh the benefits of estimated reduced travel time though this pool.

**Snake River - Lower Granite Dam to Ice Harbor Dam.** Two ways of estimating in river survival of non-transported fish are presented in the literature. The first uses the values from Bell et al. (1976), 0.7 percent loss per day of estimated smolt travel time, and the estimated smolt travel time values from the polynomial model and reciprocal flow model (Table 4.2-5). To use the reciprocal flow model of Berggren and Filardo (1991), the estimated migration rate measured from Lower Granite to McNary Dam was equally apportioned among the four pools. The second method uses the quadratic and linear models discussed by Giorgi (1991b) that directly predict changes in survival from changes in flow. The estimates of these two methods are shown for selected options at flows of 40, 80, and 120 kcfs (Table 4.2-8).

The estimated changes from the two methods in chinook yearling traveling time from Lower Granite Dam to Ice Harbor Dam (from the smolt travel time section) times an estimated mortality rate of 0.7 percent per day (Bell et al., 1976) will predict changes in absolute survival with selected options. Reducing pools from maximum pool to MOP at 40 kcfs will increase absolute survival by 1.2 or 0.6 percent based on the polynomial and reciprocal flow models, respectively (Table 4.2-8). Lowering the projects to MOP at 80 kcfs increases absolute survival by 0.6 percent for both models. Operating at MOP at higher flows may actually decrease survival. Actual calculated changes in survival would be about half because the pool level is

Table 4.2-8. Estimated hypothetical changes in absolute survival of non-transported yearling chinook from Lower Granite Dam to Ice Harbor Dam.[a]

| | | Smolt Survival Change (Percent) | | | |
|---|---|---|---|---|---|
| | | Smolt Travel Time Models[b] | | Flow Models[c] | |
| Starting Flow (kcfs) | Option[d] | Polynomial | Reciprocal Flow | Quadratic | Linear[e] |
| 40 | To MOP[f] | 1.3 | 0.6 | 2.1 | – |
| 40 | +20 kcfs | 4.9 | 2.7 | 10.9 | – |
| 80 | To MOP[f] | 0.4 | 0.4 | 3.7 | 0 |
| 80 | +20 kcfs | 0.6 | 0.8 | 9.9 | 0 |
| 120 | To MOP[f] | -0.1 | 0.2 | 0.8 | 0 |
| 120 | +20 kcfs | -0.2 | 0.4 | 2.0 | 0 |

a/ Precision less than the 0.1 percent displayed.
b/ Survival based on estimated smolt travel time changes by using the polynomial or reciprocal flow models, from Giorgi (1991b) shown earlier (Table M-4) and multiplying by mortality of 0.7 percent/day from Bell et al. (1976).
c/ Estimated survival based on models shown in Giorgi (1991b) for effects of flow changes directly on survival.
d/ Options are lowering reservoirs from maximum to MOP or adding 20 kcfs flow at maximum pool.
e/ Model from Chapman et al., 1991; only used data from flows greater than 84 kcfs.
f/ Predicted changes relative to normal pool levels would be about half of those as pools are normally operated at less than full pool.

typically operated at less than full pool. The addition of 20 kcfs to a flow of 40 kcfs would increase absolute survival by an estimated 5.0 to 2.7 percent. At 80 kcfs, the increase would be about 0.6 to 0.8 percent, and at higher flows, gains would be less and possibly negative. If flow augmentation of 20 kcfs and lowering the reservoir to MOP were both implemented, the effects would be nearly additive; therefore, at low flow (40 kcfs), the change may be at its highest at 6.3 to 3.4 percent based on the two models. Increases at higher flow (80 kcfs and above) with both drawdown and flow augmentation are much lower, about 1 percent or less.

Using the quadratic formula presented by Giorgi (see Table 4 in Giorgi, 1991b), changes in survival can be estimated from changes in water particle travel time resulting from various options. For the calculations for this OA/EIS, it was assumed that the water particle travel time for each flow level used in this model was at maximum pool (Giorgi's Table 4 shows water particle travel time at MOP). Changes in the predicted survival were calculated by extrapolating the relative change in water particle travel time to proportional change in absolute survival of the quadratic model. Based on the quadratic model, lowering the reservoirs to MOP increases absolute survival from 0.8 percent (40 kcfs) to 3.7 percent (80 kcfs) (Table 4.2-8).

Again, real estimated changes would be about half because normal pool operations are less than maximum pool level.

Augmenting flow by 20 kcfs has a greater effect on increasing absolute survival, resulting in an increase of an estimated 10.9 percent (at 40 kcfs) to 2.0 percent (120 kcfs). Lowering pool level and augmenting flow of 20 kcfs would be nearly additive in its effect on absolute survival at a specific flow; therefore, by lowering reservoirs to MOP and adding 20 kcfs, increased absolute survival could be calculated to be about 13 to 14 percent increase at flows of 40 and 80 kcfs, respectively, and less than 3 percent at the higher flow (120 kcfs). Water to augment flows by 20 kcfs would be available for less than 1 month of continuous operation with all but one option. In addition, the use of an additional 20 kcfs in spring would reduce typical flows in the summer, which would negatively affect later outmigrating smolts.

Based on the linear model developed by Chapman et al. (1991), which used only data for flows over 84 kcfs, no increase in survival would be predicted for any activity at flows over 80 kcfs (Table 4.2-8).

Survival estimates for yearling chinook with the lower Snake River reservoirs operated near spillway crest were not calculated because none of the models used above were developed under such radically different project operations. Also, many potentially negative effects not accounted for in these models (see later discussion) may occur to smolts with this option. Therefore, no reasonable estimate of changes in survival of yearling chinook smolts can be estimated for the near spillway crest option.

**Columbia River.** Estimated mortality rates for selected options were calculated for the lower Columbia reach using estimated daily reservoir attrition values developed by Bell et al. (1976) or changes in absolute survival (Table 4.2-7). These rates were based on changes in predicted smolt travel time (Table 4.2-7). At a flow of 160 kcfs, the predicted increase in survival by lowering the projects to MOP would be 1.8 and 1.4 percent, based on changes in the number of days yearling chinook smolts spent migrating through the reservoir, as determined by the FPC (1989) and PNUCC (Kindley, 1991) models, respectively (Table 4.2-9). At higher flows, the predicted absolute survival increases range from 1.4 to 0.8 percent at 200 kcfs to 1.6 to -0.4 percent at 260 kcfs for the two models, respectively. Adding a 20-kcfs flow has nearly the same estimated effect as lowering the reservoirs to MOP for the same flows. Benefits are greatest at lower flows. For example, survival changes range from 2.0 to 1.6 percent at 160 kcfs and from 0.9 to -0.1 percent at 260 kcfs. Lowering the reservoirs to MOP and adding 20 kcfs would have nearly additive effects on survival. For example, at 160 kcfs increased survival would be about 4 to 3 percent, while at 260 kcfs, there would be a change in survival of about 3 to 1 percent, based on the two models. However, use of augmentation flow of 20 kcfs in the spring may reduce
flow in the summer, adversely affecting later outmigrants.

The March drawdown of Lower Granite and Little Goose pools would not affect survival during migration, as few smolts will be migrating during this time.

**Summary.** Estimated changes in river survival of non-transported fish, based on water particle travel time changes, should be considered only as an index because many factors that affect survival are independent of water particle travel time. But, based on these estimates, the greatest benefit would occur at lower flows in both systems. The largest increase in estimated survival from any single alternative would occur by augmenting flows by 20 kcfs during low flow years. However, flow augmentation of 20 kcfs above baseline would be limited to less than 1 month of continuous operation per year for all but one option. In addition, its use in the spring reduces flow in summer and may adversely affect any summer outmigrants. Further, water for flow augmentation is likely to be less available during a low flow year when it would have the most benefit. Many assumptions were used to estimate survival rates for the various alternatives. Many factors besides water travel time affect survival. Therefore, estimates of survival should be considered more as an index of change than as absolute estimates.

Based on the values presented for each alternative in the survival section, as applied to the various regions of the study area, a range of survival estimates can be made. The lowest estimated increase in survival was calculated by adding

Table 4.2-9. Summary of estimated hypothetical high and low range of changes in yearling chinook total percent survival from Lower Granite Pool to Bonneville Dam.[a]

| | Region[b] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Lower Granite Pool[e] | | Lower Granite Dam to Ice Harbor Dam[e] | | Columbia River | | Total | |
| Flow[c] and Alternatives[d] | Low | High | Low | High | Low | High | Low | High |
| Low Flow | | | | | | | | |
| To MOP | 0.3 | 0.3 | 0.6 | 2.1 | 1.4 | 1.8 | 2.3 | 4.2 |
| + 20 kcfs | 1.3 | 1.3 | 2.7 | 10.9 | 1.6 | 2.0 | 5.6 | 14.2 |
| Medium Flow | | | | | | | | |
| To MOP | 0.1 | 0.1 | 0 | 3.7 | 0.8 | 1.4 | 0.9 | 5.2 |
| + 20 kcfs | 0.4 | 0.4 | 0 | 9.9 | 0.7 | 1.2 | 1.1 | 11.5 |
| High Flow | | | | | | | | |
| To MOP | 0.1 | 0.1 | -0.1 | 0.8 | -0.4 | 1.1 | -0.4 | 2.0 |
| + 20 kcfs | 0.2 | 0.2 | -0.2 | 2.0 | -0.1 | 0.6 | -0.1 | 2.8 |

a/ Precision less than the 0.1% reported.

b/ Values can be found in the text section discussing survival through Lower Granite Pool and Tables 4.2-8 and 4.2-9. The low and high values correspond to those values found for each model estimate by alternative.

c/ Low flow: Snake = 40 kcfs; Columbia = 160 kcfs.
Medium flow: Snake = 80 kcfs; Columbia = 200 kcfs.
High flow: Snake = 120 kcfs; Columbia = 260 kcfs.

d/ Alternatives are lowering reservoirs from maximum to minimum operations pool (MOP) or adding 20 kcfs at maximum pool.

e/ Actual changes to MOP for the Snake River are about half because pools typically operated at less than maximum pool.

together the lowest values from any of the models used within each of the three regions where estimates were made [i.e., Lower Granite Pool in the smolt survival section, Lower Granite Dam to Ice Harbor Dam (Table 4.2-8), and McNary Pool to Bonneville Dam (Table 4.2-9)] for respective flows and options. This was done in the same manner for the highest values. A summary of these calculations is presented in Table 4.2-9.

For lower flow conditions (Snake River at 40 kcfs, Columbia River at 160 kcfs), lowering all Columbia and Snake River projects to MOP would result in an estimated increase in survival of 2 to 4 percent for fish originating above Lower Granite Dam (Table 4.2-9). Estimated changes in survival would be even less than those as Snake River projects are normally operated at less than full pool. Survival benefits would be expected to increase with lower flows in both systems. In general, the benefits decrease at higher flows with a range of 1 to 5 percent increase in survival at intermediate flows (Snake River at 80 kcfs, Columbia River at 200 kcfs), and 0 to 2 percent at higher flows (Snake River at 120 kcfs and Columbia River at 260 kcfs).

Flow augmentation of 20 kcfs would generally have greater potential for increasing survival than lowering projects to MOP over the same flow ranges (Table 4.2-9). At low flows (see above), the estimated increase in absolute survival for Snake River fish from 20 kcfs of augmented flow would be 6 to 14 percent. At intermediate and high flows, the range of survival increase would be 1 to 12 percent and 0 to 3 percent, respectively.

The options that would draft all Snake River projects to near spillway crest or Lower Granite to elevation 710 feet would greatly reduce water particle travel time, particularly at low flow; however, specific changes in juvenile survival based on these estimated reductions cannot be made because survival changes would not be occurring in isolation. Other factors associated with these options (e.g., lack of smolt transport, increased gas saturation, and increased spillway mortality) would be expected to offset velocity-related improvements by increasing mortality of migrating fish. No models that estimate survival have been developed for the Snake River System for full spill conditions, because all existing models have been developed with flows through turbines. Therefore, none of these models was suitable to predict changes in survival.

The available information regarding the relationship between increased flow (or decreased pool elevations) and survival is limited and subject to a great deal of scientific uncertainty. The relationship between increased flow and reduced smolt travel time is more clear. Therefore, a considerable amount of attention has been focused on this measurement as a general evaluator of migration success.

While some studies suggest increasing reductions in yearling chinook smolt travel time with increasing flow in the Snake and Columbia rivers (e.g., Filardo and Berggren, 1991), some other recent analyses suggest there is a threshold for flow, or possibly water particle travel time, above which reductions in smolt travel time does not occur. Giorgi (1991b) suggested water particle travel time equivalent to flows above about 80 to 100 kcfs does not substantially reduce yearling chinook travel time in the Snake River. Kindley (1991) suggested from his analysis of John Day Pool data that yearling chinook travel time does not decrease substantially at Columbia River flows above about 190 to 240 kcfs.

The issue of quantifying the effects of lowering the lower Columbia River pools on smolt survival still remains. Simply stated, there is very little data on the survival of smolts through the lower river. The annual survival indices, which reflect the reach from Lower Granite to The Dalles, are the best data sets available, but their utility in predicting smolt survival has been a subject of debate.

Although some benefits to spring and summer chinook may be achieved with the alternatives considered, the benefits to Snake River sockeye (endangered) and Snake River fall chinook (proposed as threatened) are less clear, based solely on water particle travel time reductions. Only limited data (1991 only) are available from portions of the Snake River that suggest a significant relationship between flow and smolt travel time. Although potential benefits seem apparent, data and analyses to support these benefits are few. Also, there is sufficient uncertainty, even in the data that exist for the more abundant species, to make reasonable estimates of gains in travel time reduction or survival from the proposed alternatives.

### 4.2.1.5 Effects of Flow Options on Juvenile Bypass, Collection, and Transport

Fish bypass facilities and transport could be negatively affected by most alternatives. Fish bypass facilities (including submerged traveling screens and sluiceways), which divert juvenile fish from entering the turbines, are located at all project dams except Lower Monumental (which has a facility under construction with operation by spring 1992). Ice Harbor and The Dalles currently only have sluiceways for fish bypass. These will be replaced with submerged traveling screens by 1994 and 1998, respectively. A description of how these facilities operate and where they are located is presented in Section 2.2. These facilities are mostly traveling screens while some have sluiceways. Additionally, juvenile fish are captured at Lower Granite, Little Goose, and McNary dams and transported for release downstream of Bonneville Dam. The efficiency of the collection and bypass facilities varies by project (Table 4.2-10). In 1991, for example, 8.4 million and 2.2 million smolts were transported from Lower Granite and Little Goose dams, respectively, to below Bonneville Dam (FPC, 1991b).

The percentage of total downstream migrants that arrive at the dams that are transported around dams is high and can be more than 60 percent of Snake River smolt migration. This is true at least for yearling spring and summer chinook and possibly 40 percent for subyearling fall chinook when no spill occurs, and fish guidance efficiency (as indicated below) is used as a reasonable representation of proportion of stocks collected and transported. Generally during migration periods, little involuntary spill occurs at Lower Granite Dam.

<u>Fish Guidance Efficiency</u>

| | |
|---|---|
| Yearling Chinook | 63% |
| Fall Chinook | 40% |
| Steelhead | 81% |

Therefore, these percentages of the Snake River stocks are typically transported at Lower Granite. The efficiency of capture for subyearling chinook and sockeye is less than 50 percent (Table 4.2-10). Under the current operating regime, significant increases have been found in survival of transported fall chinook and spring chinook (Park and Athearn, 1985; Matthews et al., 1990) compared to untransported. For example, although wide variability occurs among test results, the following transport benefit ratios of transported to untransported fish (i.e., relative survival between transported marked fish to marked control fish not transported) from McNary Dam for test years 1978 to 1980 (Park and Athearn, 1985) and recent data for Lower Granite Dam for 1986 (Matthews et al., 1990) are presented:

| | McNary | Lower Granite |
|---|---|---|
| Subyearling Chinook | 4:1 | — |
| Yearling Chinook | — | 1.6:1* |
| Steelhead | 2.5:1 | 1.9:1 |
| Coho | 2:1 | — |

* C.I. (95% 1.01 to 2.46)

However, the overall survival from smolt to adult remains low for all fish. The reasons for the low survival are not totally known but may be partly the result of bacterial kidney disease (BKD) that could be causing high mortality of fish even after they arrive below Bonneville Dam (Raymond, 1988). Generally in the Columbia and Snake rivers, hatchery fish have much lower survival rates from smolts to adults than do wild fish of the same species and region (Raymond, 1988).

Drafting all Snake River pools to near spillway crest would eliminate all transport of fish because the collection systems would not be operational. The collection facilities for transport at Lower Granite and Little Goose dams rely on operation of the submerged traveling screens located in the openings to the turbines. The screens rely on the turbines being in operation, as they separate the fish from the upper portion of the water flowing toward the turbines. Also, at water levels below MOP, there would not be sufficient head (water elevation) within the system to allow water with the

**Table 4.2-10.** Fish guiding efficiency (FGE) (in percent) of passage systems at mainstem dams (1992 condition).

| Project | Species: Chinook Yearling | Chinook Subyearling | Steelhead | Sockeye | Coho | Bypass Systems and Transportation |
|---|---|---|---|---|---|---|
| Lower Granite | 63 | 40 | 81 | -- | -- | Submerged traveling screen (STS), mechanical bypass, raised gates (extended length screen 1996). Transportation. |
| Little Goose | 73 | 40 | 74 | -- | -- | Submerged traveling screen (STS), mechanical bypass, raised gates (extended length screen 1996). Transportation. |
| Lower Monumental[a] | 60 | 35 | 79 | -- | -- | STS, mechanical bypass 1992 (raised gates by 1994)[d] (Transportation facilities available in 1993). |
| Ice Harbor[a] | 51 | 51 | 51 | -- | -- | Sluiceway (STS mechanical bypass system operational by 1994). |
| McNary | 75 | 40 | 75 | -- | -- | STS, mechanical bypass (extended raised screen gates length 1995). Transportation. |
| John Day | 72 | 30 | 86 | -- | -- | STS, mechanical bypass. |
| The Dalles[b] | 43 | 43 | 43 | -- | -- | Sluiceway (extended length, mechanical bypass 1998). |
| Bonneville, Powerhouse 1 | 42 | 39, 10[c] | 56 | 23 | 63 | Sluiceway and STS mechanical bypass system. |
| Bonneville, Powerhouse 2[a] | 19 | 20, 24[c] | 35 | 14 | 25 | STS (Improvements 1993).[d] |

Source: Corps, Walla Walla District.
a/ As projected by prototype FGE study, (Ledgerwood et al., 1986) with no raised gate.
b/ Sluiceway system.
c/ First and second value before and after June 15, respectively.
d/ FGE with raised gates 73% yearling chinook, 83% steelhead.

fish to flow through the orifices and the bypass conduits in the dam to the collection or discharge location.

Under these conditions juvenile fish that would normally be bypassed or transported downstream would instead pass through the turbines. In general, passing through turbines is considerably worse for fish than passing over spillways or through collection or bypass systems except at Bonneville Dam. Turbine mortality would presumably be so high at reservoir elevations below MOP as to defeat the purpose of pool lowering, requiring that power generation cease during the drawdown period for these options.

Spilling the entire flow at all dams would eliminate turbine mortality in the Snake River. The level of mortality from spillage injuries could increase, but no data currently exist to assess if or how much greater this would be. Additional mortality could also occur from increased dissolved gas supersaturation (see Section 4.2.1.7). If fish are not transported, they would also be subject to natural mortality (by predation) that would occur during passage through each reservoir. Fish that pass through the four Snake River dams would be collected at McNary, or they would have to pass through the remaining four dams and reservoirs and be subject to any additional mortality that may occur during this passage. Additionally, even with Snake River projects lowered to near spillway crest and the lower Columbia projects to MOP, smolt travel time would be much longer for fish not transported that for those than would have been transported. Typical travel time from collection, holding, and barge transport from Lower Granite to below Bonneville Dam is less than 3 to 5 days. Under the above condition, even if smolts traveled at the same rate as water particles, their travel time would be considerably longer under most flows. For example, at medium and low flows, water particle travel time would be 13 and 24 days, respectively, from Lower Granite Pool to Bonneville Dam with this alternative (see Table 4.2-3).

Reducing Lower Granite Pool to elevation 710 would make it impossible to collect and transport fish from this facility. The majority of fish transported from the Snake River are collected at Lower Granite Dam. Therefore, a majority of the juvenile outmigrants would have to travel through an additional reservoir before they could be collected at Little Goose Dam.

Reducing Lower Granite to the range of 705 to 696 feet and Little Goose up to 15 feet below minimum pool in March would eliminate the transport facility use. However, less than 10 percent of yearly chinook or even fewer of other fish (underyearling chinook, steelhead, and sockeye) typically migrate before mid-April and transportation typically does not begin until March 25. Effects on transported fish would be minor.

The lowering of any of these projects to MOP should have minor effects on fish. Although the fish passage systems are designed to work over the entire range of operating pools, the efficiency (defined as the portion of smolts diverted from the turbine intakes) might change with lower pools.

At The Dalles Dam, 43 percent of the daytime migrating fish pass through a sluiceway. Lowering this pool could reduce efficiency of the sluiceway bypass because flow in the sluiceway would be reduced from 4,800 to 3,600 cfs, thus reducing attraction flow. Survival of fish passing through these sluiceway systems is generally considered to be close to 99 percent. Therefore, any reduction in the efficiency of this system could result in an increase in fish passing through turbines where the fish have an assumed survival rate of about 85 percent. As a result of the reduced efficiency, there would be an increase in the overall project mortality.

Augmented flow would have no significant effects on bypass or transportation of fish.

#### 4.2.1.6 Effects of Flow Options on Turbine and Spillway Survival

Under some of the options, significant numbers of juvenile salmon and steelhead could suffer from increased turbine mortality. Although the current operating plans for the Columbia and Snake rivers are designed to minimize turbine passage by juvenile fish, large portions of the migrants still pass through the turbines. Estimates of turbine mortality during passage on the Columbia River System have ranged from 2 to 4 percent (Ledgerwood et al., 1990; Weber, 1954) to 33 percent including predation (Long et al., 1968).

The generally assumed value is about 15 percent direct and indirect mortality (NPPC, 1989).

Turbine mortality is affected by several factors. The two factors considered to be of primary importance are the efficiency of the turbine and the depth that it is submerged. Lowering pools from 3 to 5 feet in most Columbia and Snake River projects would not change the existing mortality because turbines operate at optimum efficiency within these pool levels. The exception is when John Day is lowered to 257 feet (reducing head from 111 to 98 feet). At John Day, this decreased pool elevation would cause a reduction in turbine efficiency and a resulting increase in mortality of about 1.3 percent (based on estimates that decreases in the percent survival are proportional to decreases in turbine efficiency, U.S. Army Corps of Engineers, Progress Report No. 6). Lowering John Day also would reduce submergence on McNary turbines, which is estimated to increase mortality at this facility by as much as 1 percent (Cramer and Oligher, 1961). Overall, if John Day is lowered to 257 feet, additional mortality to fish would be about 1.3 percent at John Day, and 1 percent at McNary.

If the Snake River projects are lowered to near spillway crest and turbines were not operated, all turbine mortality at these projects would be eliminated. However, a larger number of fish would pass through operating turbines in the lower Columbia River because juvenile fish transport facilities could not operate, except at McNary Dam (see discussion on juvenile transport, Section 2.2.4.2). In addition, increased gas saturation from spill may increase mortality when fish pass through the turbines (see Section 4.2.4.3, Dissolved Gas Saturation). This mortality increase is caused by a sudden drop in pressure that would occur when water passes through the turbines, which would increase the effects of gas supersaturation.

Additional flow would have no direct effects on turbine mortality because the operating efficiency and depth of submergence for the turbines would not change.

Based on studies at McNary and Big Cliff Dam, estimates of direct mortality of smolts passing over spillways average about 2 percent (Shoeneman et al., 1961). These test results are believed to be characteristic of current operating ranges on the Columbia River projects. However, this mortality does not account for any delayed mortality that could occur from passing over spillways. Under the spillway crest alternatives considered for the Snake River projects, direct and indirect mortality of fish passing over the spillways could increase. Some factors indicate higher mortality (e.g., lower tailwater, higher nitrogen, less efficient energy dissipation causing greater turbulence and possibly shear) and others lower mortality with less head. This increase in mortality cannot be determined from existing information.

The test drawdown of Lower Granite and Little Goose in March may have minor effect on survival of fish because less than 10 percent of all smolts will be migrating at this time, although most of the fish that migrate during this period are wild summer chinook.

#### 4.2.1.7 Dissolved Gas Saturation

Some alternatives could result in increased mortalities of juvenile salmon and steelhead from increased dissolved gas saturation. The incidence of gas bubble disease is well documented on the Columbia River System. Incidence of gas bubble disease in fish depends on the level of super-saturation, duration of exposure to the fish, water temperature, general physical condition of the fish, and the swimming depth maintained by the fish (Ebel and Raymond, 1976). Weitkamp and Katz (1980) also suggested that fish tolerance to supersaturation depends on their life history stage and follows two general trends: (1) tolerance decreases from very great in the egg stage to very low in older juveniles; and (2) tolerance increases following the juvenile life stage, with adults being the most tolerant free-swimming life stage. They also reported that juvenile fish subjected to sublethal levels of supersaturation may recover when returned to normal saturation levels, but adult salmonids do not recover.

Current standards recommend levels below 110 percent saturation. Weitkamp and Katz (1980) reviewed the literature on effects of dissolved gas saturation. They cited a study on the Columbia River that found 50 percent mortality occurred to juvenile chinook in 10 days at gas saturation levels of 118 to 123 percent, while similar mortality occurred in two days at concentrations above 125 percent. Both tests were conducted with fish in water less than 3 feet. In their review summary, they stated, "The above studies indicate that a dramatic change occurs in both the number of deaths and time of death at approximately 120 to 125 percent saturation in shallow water (3 feet or less)." At higher concentrations, mortalities increased dramatically. For fish in deeper water, dissolved gas concentrations would have to be higher because for every 3 feet of depth, the effective gas saturation is reduced by 10 percent.

Intensive laboratory and field investigations on the effects of supersaturation were conducted from 1966 through the mid-1970s. Some of the results of these investigations were summarized by Ebel et al. (1975). Exposure of juvenile spring chinook and steelhead to 120 percent saturation for 3 days in shallow tanks resulted in 100 percent mortality. A threshold level where mortality significantly increased was 115 percent saturation. Follow-up studies reported by Ebel et al. (1975) suggested that mortality decreased when juveniles were given the option to sound (swim deeper in the water), but that substantial mortality still occurred at levels above 120 percent. Field evaluations confirmed these results. Live cage tests conducted by several agencies and summarized by Ebel et al. (1975) suggested that nearly 100 percent mortality occurred in surface cages and ranged from 6 to 68 percent in deep cages, depending on the level of saturation and stock of fish used in the test. Substantial mortality occurred in the deep cages when saturation levels exceeded 125 percent. Free-swimming juveniles were also evaluated by sampling gatewell catches in 1970 and 1971 at Ice Harbor Dam. Incidence of gas bubble disease symptoms on chinook migrants ranged from 25 to 45 percent in 1970; estimates of survival of chinook from the Salmon River to Ice Harbor was 30 percent. In 1971, incidence of gas bubble disease ranged from 10 to 32 percent during the main migration season, and estimates of survival were 50 percent. However, Ebel et al. (1975) suggested that incidence of symptoms of gas bubble disease cannot be directly correlated to percent mortality, but is indicative of the level of stress a population is suffering from exposure to supersaturated atmospheric gas.

Ebel et al. (1975) reported estimates of percent mortality associated with supersaturation of gases relative to the factors known to affect juvenile survival. These estimates were calculated from the upper Snake to Ice Harbor Dam and from the upper dam (this dam varied during other years of tests) to The Dalles Dam. However, other known causes of mortality such as disease, turbine-related factors, or predation were included in these estimates.

Relationships between juvenile travel time, supersaturation of nitrogen, and survival of juvenile chinook from the Salmon River to Ice Harbor were developed (Ebel et al., 1975). Decreasing the travel time from 25 to 12 days, even with an increase from 130 to 136 percent of nitrogen saturation, was reported to increase survival from 25 to 50 percent. Reducing the overall saturation levels to 109 percent for part of the migration also increased the survival from 25 to 37 percent. These estimates should be used cautiously, because other mortality factors were not measured. However, it appears that in years when river flows were normal to high and corresponding gas saturation levels were high, mortality from gas supersaturation can override other mortality factors and result in substantial losses of juvenile salmonids, ranging from 40 to 95 percent.

During 1990, all the flow was released over the John Day spillway because of a fire that occurred at this project. The FPC (1991) reported, "There were no reports of major injury to fish as a result of gas supersaturation. However, large numbers of sockeye, coho, and steelhead exhibited symptoms of the disease, with the highest incidence recorded from the group of steelhead released from the barge above John Day Dam subsequent to the fire in the John Day Powerhouse. These fish passed John Day Dam when 100 percent of the flow at the project was being spilled and dissolved gas levels reached 135 percent supersaturation." Currently, the dissolved gas level below the dams peaks annually at close to 120 percent, although high levels in the spring are closer to 110 percent. The current gas saturation monitoring stations (Water Quality, Section 4.1) may not be measuring the higher levels because they are located in the forebays. Therefore, actual concentrations below the spillways may be higher because the gas often dissipates as it moves downstream. For example, in 1991 a newly placed monitoring station below the spillway at Lower Monumental recorded peak levels of 136 percent during spill specifically provided for fish passage.

These results suggest that current levels may be a problem for juvenile salmonids, particularly during periods of high spill. Therefore, increases in gas saturation could contribute to mortality of downstream migrating smolts.

Overall, operation at MOP might increase exposure to supersaturated gas because more spill might occur at night than under current operations. Projects would have reduced ability to store water at night if the water levels were maintained at MOP. Because nightly power demands are not as great as daytime, more flow could go over the spillway at night. However, some flexibility is available so that spill may not increase at night. The degree of supersaturation may also increase because the reduction of the water levels in pools below each project would reduce the effectiveness of the flip lips and, hence, increase gas saturation. These changes in gas supersaturation levels and exposures could result in minor negative effects on fish, especially under higher than average flow conditions.

Reducing all reservoirs on the Snake River to near spillway crest would most likely have significant adverse effects on juveniles during high spring flows. Predicted dissolved gas saturation levels would be over 120 percent and could be over 140 percent (see Water Quality Impacts, Section 4.1). Because all flow would be passing over all four projects, the gas saturation would tend to increase from one project to the next, with the highest levels below Ice Harbor. Without the fish transport system, all smolts originating above Lower Granite Dam would be subject to increased dissolved gas levels as they travel downstream. As discussed above, based on the work done by Ebel et al. (1975), increased gas saturation levels in this range, during spring of normal and high flow years could increase gas saturation to where it is the overriding survival factor in the system, possibly causing mortality in the range of 40 to 95 percent.

Adverse effects from dissolved gas would likely be less from lowering Lower Granite to 710 feet and operating the others at MOP than from lowering projects to spillway crest, although levels below this dam would still be in the range of measured mortality in tests. Some dissipation of dissolved gas level is likely to occur below Lower Granite as downstream reservoirs would be at MOP and have lower spill quantity because most of the flow would be going through the turbines instead of over the spillway.

The test drawdown of Lower Granite and Little Goose in March would be conducted in a manner to minimize increases in dissolved gas levels. Few fish are present in the reservoir (less than 10 percent of smolts occur there)but potential impact could be to the fall chinook fry present in the reservoir or alevins still in the gravel during these periods. An estimated 4,000 rearing fall chinook were present in 1991 in Little Goose Pool prior to the migration period (Bennett et al., 1991). This number of rearing fall chinook is substantial relative to their numbers currently migrating through the system (about 14,000 collected in 1991 at Lower Granite Dam [FPC, 1991b]). These fish would be especially susceptible to injury from gas supersaturation because these smaller fish rear in shallow water and alevins in the gravel may also be in shallow water where effects of supersaturation are the worst.

#### 4.2.1.8 Predation

Predation is currently considered one of the major sources of smolt mortality during migration in the Columbia and Snake River System (Poe and Rieman, 1988) and is believed to cause mortality equal to or greater than that caused by passage at the dams (Rieman et al., 1991). Changes in predation rates for the various options will vary by option and fish species. Bennett (1991), in his assessment of effects of lowering all Snake River projects to near spillway crest, stated that although predators would be concentrated, the reduced residence time experienced by steelhead and yearling smolts and increased turbidity would probably result in reduced predation in this system. There is some information on the Columbia River that suggests that within the normal range of operations, an increased flushing rate may not reduce predation (Beamesderfer et al., 1990). Bennett also stated that lowering the Lower Granite Pool to elevation 710 would reduce predation in this pool. Yearling chinook and steelhead appear to "stage" or remain in this pool for longer periods than lower Snake River pools. Consequently, the effect of lowering this pool may be greater than other pools because staging may be reduced, shortening the time fish might be subject to predation. Whether fish would actually migrate more rapidly from this pool if it were lowered cannot be determined.

In contrast, reducing pool levels to near spillway crest or Lower Granite to elevation 710 feet may increase predation on fall chinook in the Snake River pools. Unlike most steelhead and yearling chinook, the migration rate of fall chinook through reservoirs is either minimally affected or not affected at all by flow because they are actively rearing in these regions. Therefore, reduced reservoir volume would concentrate the predators and rearing fall chinook in the same regions, while not causing significant increases in migration rates through the reservoirs. These effects would be most apparent in Lower Granite Pool relative to other reservoirs. This is because increased spill would create higher velocities below spillways that may reduce predator concentrations below the dams (Faler et al., 1988) which are traditionally regions of high predation (Poe and Rieman, 1988). Bennett (1991) concluded that there may be no effect on predation from reducing Snake River reservoirs to MOP because predators are concentrated in tailwater and forebay areas and distribution is not likely to change substantially.

Lowering the Columbia and Snake river projects to MOP might have no significant direct effects on predation for the same reasons, although any increased temperatures resulting from drawdown could result in increased predation. Changes in flow may not alter predation activities. Beamesderfer et al. (1990) developed a model to determine factors affecting predation rates in the John Day Pool, which covers the range of flows expected at MOP. The authors stated, "Changes in flow are not expected to cause large changes in predation in John Day Reservoir. Survival was not sensitive to residence time." This conclusion suggested other factors, such as increases in predation, may outweigh any benefits from reduction in smolt travel time. They found that the major factor correlating with predation was temperature, mainly because the consumption rate of squawfish (the main predator in this region) increases dramatically with increasing spring and summer temperature up to 72°F (22°C). For example, the number of smolts that could be consumed by a squawfish daily increased from about 1 to 4, with a corresponding temperature increase of 54 to 63°F (12 to 17°C). It is possible that factors not included in the model, such as changes in relative predator distribution in tailwaters and forebays, may be influenced by flow and ultimately affect predation.

Based on the information by Beamesderfer et al., (1990), increased temperature could significantly increase predation. Predation is currently a major source of loss of juvenile fish in the Columbia River. For example, Columbia River subyearling chinook losses may be as high as 61 percent during August in the John Day Pool. Overall loss in this pool during a season has been estimated at 14 percent of all smolts (Rieman and Beamesderfer, 1988). It has been estimated that the annual temperature might peak 2 weeks earlier if the reservoirs in the lower Columbia were lowered (see Water Quality, Section 4.1). If this occurs, predation might increase on earlier stocks such as yearling chinook and steelhead but decrease on fall summer and upper Columbia summer chinook. However, temperatures might remain higher, which would maintain predation levels on fall chinook. The temperature changes have not been modeled, so predictions of effects on fish are also unknown. However, these effects are a possibility. With reservoirs on the Snake River at MOP, temperatures are also expected to shift earlier, but may be lower later. The net effect of these changes is that predation might be slightly reduced, although the outcome is not clear. Reducing all Snake River reservoirs to near spillway crest might result in a net reduction in temperature, which might also reduce mortalities from predation. However, the overall effect of temperature changes on predation (which have not been accurately predicted at this time), concentrating predators and juvenile salmonids in smaller pool areas, and increasing water particle travel time cannot be reasonably predicted at this time.

Flow augmentation may also reduce temperature but changes are likely to be small. Therefore, effects on predation may be minor.

Reservoir drawdown to spillway crest or Lower Granite to 710 feet could enhance predation control by concentrating predators. However, turbidity and possibly redistribution of predators could reduce predator control. Northern squawfish populations may be less directly affected from drawdown than other resident species because they are typically abundant under lotic conditions. However, the reduction of rearing habitat for juveniles and reduced food production could reduce population, primarily of younger age-classes, which would probably have limited direct effects on predation rates.

### 4.2.1.9 Effect on Habitat

Drawdown of any form would reduce rearing habitat quality and possibly quantity for salmon and steelhead in the Columbia-Snake River System. The most detrimental effects would be drawdown to near spillway crest of the four Snake River reservoirs. Fall chinook would be affected most because they spend longer periods rearing in reservoirs before migrating than other stocks. Shallow-water, low velocity habitat in these reservoirs (less than 20 feet deep and sandy) is the preferred rearing area for fall chinook (Bennett, 1991). All of the current shallow-water regions would be lost with drawdown to spillway crest in each reservoir. These areas are also the most productive for benthic food sources, which are used heavily by salmon and steelhead during rearing and migration. Although other shallow water areas will be present with the drawdown, these areas will be less productive because the benthic food density will be less. Also, the decreased channel area will increase velocity, further reducing preferred habitat of fall chinook. Because of increased flushing, reduced zooplankton abundance would reduce food resources. Drawdown to elevation 710 feet in Lower Granite would still dewater most of the currently used habitat for fall chinook in this region. Reduction of Lower Granite ranging from 705 to 696 feet and Little Goose 10 to 20 feet below full pool would have similar effects as the 710 option. However, because the drawdown test will occur in early spring, very few or no juvenile fall chinook originating from above Lower Granite Dam will be present in Lower Granite Pool(personal communication, David H. Bennett, Department of Fish and Wildlife Resources, University of Idaho, Moscow, Idaho, December 6, 1991). Although some fall chinook juveniles originating from spawning directly in Little Goose Pool may be present during the March test, they are expected to begin to emerge from the gravel about mid-March. The habitat will still be less productive when fish arrive because of lost benthic production. Also, Little Goose fry of fall chinook could be affected the most because they would be out of the gravel during the March drawdown test. During this period, these smaller fish would likely remain in very shallow-water, low-velocity areas that would be most affected by the drawdown, thus reducing the quantity of their rearing habitat.

Reducing pool levels to MOP in the lower Columbia River or Snake River would have lesser effects than drawdown to near spillway crest on the Snake River, because much of the shallow-water habitat would still remain in both systems (see Resident Fish discussion concerning shallow-water habitat). However, the level of impact cannot be determined accurately at this time and may still be significant.

In different studies on the lower Columbia River pools, it was found that some juvenile salmonids reside for various periods in backwaters and sloughs along the river, particularly in the spring and summer (Zimmerman and Rasmussen, 1981; Parente and Smith, 1981). The most abundant and longest residents of these backwaters are subyearling chinook (most likely fall or upper Columbia River summer chinook). Predation by resident fish in these backwaters is apparently low (Parente and Smith, 1981). Residency varies among backwaters from a few days to weeks, and sometimes longer in systems where fish cannot find the outlet. Growth is apparently good in these regions, with food sources varying mostly between zooplankton and benthic insects. The importance of these shallow backwater areas to total populations of salmonids in the Columbia and Snake rivers is not known but is probably most important for subyearling chinook, which typically rear in the mainstem Columbia and Snake rivers from early spring to early or late summer before migrating as smolts.

Reduction of pool levels to MOP on the lower Columbia River will result in loss of some shallow-water habitat used for rearing. The importance of this loss cannot be assessed since the quantity and importance of other suitable habitat is not known. As discussed above, fall chinook and upper Columbia river summer chinook will be most heavily affected.

Stranding of salmonids from any alternative is unlikely with the possible exception of stilled backwater areas. Drawdown with any alternative will be no more than 2 feet per day. This rate should allow fish to move out of any shallow, shoreline areas before becoming stranded.

Backwater areas in the regions of potentially the highest drawdown, the Snake River, are uncommon. Thus, the potential for rearing fish, such as underyearling chinook, being stranded in these regions is unlikely.

Stranding of fall chinook eggs or alevins in redds from the drawdown of Little Goose Pool in March is of concern. A search for redds will be made prior to these tests and, if redds are found in the potential drawdown zone, drawdown will not occur beyond this elevation. However, there is the possibility that redds could be missed which could result in potential impacts to these life stages from the drawdown test. Additional monitoring will occur during drawdown to ensure protection of redds.

Other miscellaneous factors could affect habitat for juvenile salmonids. Suspended sediment levels will increase with drawdown alternatives that lower pools below MOP. Under the worst case scenarios, it was estimated suspended sediment could average 200 mg/l for 27 days in Lower Granite Pool. These levels could reduce food supply for juvenile fish but are not high enough over the short term to cause direct mortality (Alabaster and Lloyd, 1982). If concentrations were to remain in this range for a whole month, they could cause some direct mortality of juvenile salmonids (Newcombe and MacDonald, 1991). However, the higher turbidity would also increase cover protection from predators.

The direction and magnitude of temperature change with deep drawdowns is not well known. It is thought that drawdowns to spillway crest might produce hotter temperatures earlier in the year, and that highs may be higher and lows lower than at present. If temperatures shift to higher levels earlier, this could be detrimental to rearing and migrating stocks of salmonids.

Nothing is known about potential changes in fish disease organisms from drawdown, so no assessment can be made.

Increased dissolved gas saturation from high spill that would occur with deep drawdowns would also reduce invertebrate food supply for fish. Many of these invertebrate organisms (pelagic crustaceans, benthic insects) suffer mortalities from gas supersaturation at levels similar to juvenile salmonids (greater than 110 to 130 percent saturation).

### 4.2.1.10 Summary of Effects on Juveniles

Benefits associated with any option considered in this OA/EIS are based on past studies of the Columbia and Snake River System which indicated that increases in flow increase the rate of downstream migration and, therefore, presumably increase juvenile fish survival. An underlying assumption in these studies has been that changes in flow are the cause for changes in migration rate and, consequently, survival.

In conducting the analyses for this OA/EIS, a major assumption in most of the determinations has been that changes in water particle travel time, proportional to past calculated flow effects, would equal the same changes in either migration rate or survival of smolts. While this assumption seems reasonable for the reservoirs under the range of normal operation, it is not reasonable to apply the assumptions to radically different operations. This is because (1) all models that predict changes in migration rate and survival were determined under the normal range of project operation, and (2) many potential and real additional impacts are likely to occur from options designed to increase water particle travel time by radical changes in operation.

Based on a variety of different models for conditions other than reducing Snake River projects to near spillway crest, even the highest estimates of increased survival are relatively low (Table 4.2-9). Reducing all projects to MOP is predicted at maximum to increase absolute survival by 4, 5, and 2 percent from Lower Granite Pool to Bonneville Dam at low, medium, and high flows, respectively. Augmenting flows by 20 kcfs, which could only occur for limited periods (less than one month for all but one alternative) would at most increase absolute survival by 14, 12, and 3 percent at low, medium, and high flows, respectively.

If water particle travel time is the only significant factor affecting smolt survival during passage down the Snake and Columbia rivers, then options that cause the greatest reduction in water particle travel time would show the greatest benefit to migrating smolts. However, available information and lack of knowledge of the total effects of some of the various options suggest that some options designed to reduce water particle travel time would have significant negative effects or minor or unknown benefits on smolt survival.

The combination of reducing the Snake River projects to near spillway crest, augmenting flow, and reducing the Columbia River projects to MOP would cause the greatest total reduction in water particle travel time. However, different studies suggest that the effects on smolt travel time and survival from reducing water particle travel time (i.e., based on effects with changing flow) are varied. Therefore, a simple reduction in water particle travel time may not benefit smolt survival. Some information suggests that there may be a water particle travel time plateau in both the Snake and Columbia rivers above which no reductions or minor reductions in smolt travel time occur. That range in the water particle travel time may be the equivalent of 80 to 100 kcfs in the Snake River and 190 to 240 kcfs in the Columbia River at full pool. Other analyses of the data suggest that smolt travel time will continue to decrease proportional to water particle travel time. Regardless, with all options other than spillway crest, smolt travel time reduction will be very slight at flows above those projected at the plateau levels. These values are based on yearling chinook studies.

Effects on subyearling chinook (includes fall, and Columbia River summer chinook) of reducing the water particle travel time are not clear; they range from significant but weakly correlated to no effect on smolt travel time. Limited data on the Snake River (one study in 1991) in Lower Granite Pool suggest that sockeye salmon smolt travel time is significantly related to flow when fish size is considered. There have been no tests on Columbia River sockeye, but their similar migration timing and size suggest they may have similar responses to water particle travel time as yearling chinook. However, this has not been tested. Other analyses suggest that lowering reservoirs to spillway crest, even at high flows, could cause significant reduction in smolt travel time. Based on these studies, a reduction in water particle travel time for all Snake River projects to near spillway crest would have the effect of reducing water particle travel time to levels above the threshold values (equivalent to 100 to 140 kcfs) when river flows are in the low range (possibly 40 to 60 kcfs) on the Snake River.

Reducing the Columbia to MOP and augmenting flow may also reduce smolt travel time, particularly at low flows (in the range of 160 to 200 kcfs or less). Overall reduction in smolt travel time in this reach would be small, particularly at medium and higher flows.

With each of the options, other factors affecting survival would also change. If Snake River projects are operated at near spillway crest, fish survival might be positively affected by reduced smolt travel time and possible reduced predation. However, two additional negative factors may occur to reduce smolt survival. First, it is probable that gas saturation would increase to toxic levels in the Snake River, thus causing increased mortality because all smolts would pass down the Snake River under relatively higher gas saturation. Because the fish collection facilities at Lower Granite and Little Goose would not be operational with this alternative, even if dissolved gas saturation is not a problem, a high proportion of fish from the upper region would be subject to increased injury and mortality from passing the dams because they would not be transported. Second, eliminating transport would increase the travel time significantly for the fish that would normally have been transported. Fish transported from Lower Granite take at most 3 to 5 days from collection to release below Bonneville Dam. Even with moderate and high flows with Snake River projects at spillway crest, smolt travel time would be 24 and 13 days, respectively, assuming that travel time is directly proportional to water particle travel time. This alternative would also reduce rearing habitat for fall chinook and possibly increase predation on these stocks, because they do not move directly with reduced water particle travel time.

Operating Lower Granite at elevation 710 feet would have some of the same effects as lowering it to near spillway crest at similar flow levels. Moderate to minor reductions in migration rate would occur for some stocks, but probably not for fall chinook. Some increased dissolved gas saturation could cause mortality below Lower Granite, but these levels would be reduced downstream. All downstream migrants from the Snake River would be exposed to these elevated gas levels present below Lower Granite. Some fish would not be transported, but many would be captured at Little Goose Dam, the next dam downstream. Habitat quality for fall chinook would be reduced and predation probably would increase in Lower Granite Pool. These factors would probably remain negative at moderate to high flows because fall chinook movement is not well correlated with flow changes.

Reducing reservoirs to MOP or augmenting flow would have minor benefits on smolt survival in the Snake and Columbia rivers. Changes in water particle travel time by reducing reservoirs to MOP are about 10 percent on the Columbia River and 7 percent on the Snake River. Therefore, smolt travel times cannot be changed markedly, even if there is a one-to-one relationship between smolt travel time and water particle travel time. Flow augmentation of 20 kcfs has a greater effect on reducing water particle travel time in the Snake River than reducing reservoirs to MOP. The effects on water particle travel time of both flow augmentations and operating reservoirs at MOP are similar to the Columbia River. The benefits are most apparent at low flow in the range of 40 to 60 kcfs in the Snake River and less than about 160 kcfs on the Columbia River. With all but one flow augmentation option, the ability to supply additional flow of 20 kcfs is limited to less than 1 month of continuous operations in an average flow year.

Other factors affected by these options are generally neutral although there may be minor negative effects on fish diversion from turbines, possible gas level increase effects, and slight reduction in rearing habitat quantity for subyearling chinook in the Columbia River. Flow augmentation would result in greater benefits if augmentations are relatively high (e.g., 20 kcfs), particularly during low flow migration periods.

The test drawdown of Lower Granite and Little Goose in March could have similar effects to lowering the pools to spillway crest. These effects would mostly be insignificant because of the season, and the duration restrictions placed on the tests to protect fish resources. The most significant impact would be to rearing fall chinook which are spawned in Little Goose Pool. Lowering could desiccate redds before fry have emerged in the spring. However, a search will be made for redds prior to sampling, and lowering will not occur if redds are found. Currently, the location, abundance, and depth of spawning areas are not known for this pool. Rearing habitat in this pool would experience desiccation and loss of benthic food organisms before fry are present. The rearing area for early emerging fry, which prefer low velocity, shallow waters, would also be reduced. Gas supersaturation from the spill could also affect eggs, alevins, and fry. However, the tests will be conducted in a manner to prevent excessive levels of supersaturation. Effects would be worse on fry because they prefer shallow water where supersaturation effects are most severe to fish. Lower Granite rearing habitat would also be adversely affected because of loss of benthic resources from the drawdown. However, the current shallow-water habitat will still be present for other important uses (e.g., predator and high-flow avoidance) when the majority of fall chinook arrive, after the drawdown test. Loss of transport facilities and traveling screen operation will have a minor effect because less than 10 percent of any stock is likely to pass Lower Granite Dam before the systems are operating (starting typically March 25).

## 4.2.2 Adult Anadromous Fish

### 4.2.2.1 Adult Passage

Adult fish passage would be affected differently under various options. The most detrimental effects would occur from lowering all Snake River projects to near spillway crest. The least detrimental is under current conditions.

If all Snake River projects are lowered to near spillway crest, no adult fish passage would be possible at any Snake River dam. This is because several functions critical to ladder operation would not be possible (see Section 2.2 for additional information on fish ladder operation). The specific reasons the ladders would not function include:

- insufficient water depth in the forebay to cover the exit and allow water to flow into the ladder for fish to exit
- insufficient water depth in the forebay to supply auxiliary pumps
- insufficient tailwater elevation to allow auxiliary flow tailwater pumps to operate

- insufficient tailwater elevation to cover fish entrance
- unsuitable tailwater hydraulics for adult fishway attraction

For a ladder to function, flow needs to get into the top end of the ladder (the exit). With the pool lowered to near spillway crest, no flow would enter the top end of the ladder unless the volume of flow is high enough in the river to cause the river level to rise to the exit level.

At all projects, flow would have to exceed 300 kcfs for the water level to be at the same elevation as the primary fish ladder exits under spillway crest drawdown. Substantially higher flows would be needed to cover exits. Flows of this magnitude do not occur in the Snake River, so no water would flow naturally into the fish ladder exit. Additionally, the ability to add water to the ladder by auxiliary pumps at the forebay would require at least 161 kcfs to bring the river level up high enough for the pumps to function. The inability to use these pumps, even with the flow from the upstream end of the ladder, would reduce the ability of fish to migrate up the ladder.

With the lowering of tailwater levels, most ladder entrances would be out of the water. The fish ladder entrance at Ice Harbor would not be affected by flow quantity because the tailwater is not affected. Because of the free-flow conditions, tailwater elevations would drop at the other three projects, leaving ladder entrances out of the water except at higher flows. Minimum flow required for ladder entrances to be at least even with water level are 54 kcfs, 148 kcfs, and 102 kcfs at Lower Monumental, Little Goose, and Lower Granite, respectively. Even higher flows would be needed to attain an elevation suitable for fish to swim into the ladder.

Additional flow at the ladder entrance, above what is needed to allow fish to swim up the ladder, is essential for fish to detect the entrance to the ladder when higher river flows (relative to flow coming down the ladder) and turbulence occur. Without this additional flow, fish will have great difficulty detecting the entrance and entering the ladder. To ensure that proper attraction flow occurs at the ladder entrance, additional water is pumped to the entrance regions by auxiliary pumps. To ensure that the ladder works, specific flow and velocity criteria must be provided both at the entrances and in the ladder.

Although some of the flows needed for these facilities are in the range of typical spring flows (generally average 100 kcfs during peak flow months), most are not, which generally eliminates the ladder use under these options. None of these conditions could be changed by altering ladder construction, pump design, or adding more pumps by the proposed test period in 1992. Planning, design, funding, and procurement processes would require more time than is available.

Drawdown to near spillway crest would affect upstream migration of different stocks depending on the duration of the drawdown. The drawdown from mid-April to mid-June would affect mostly spring chinook, eliminating all upstream migration of this stock. If drawdown goes into mid-August, all summer chinook stocks would also be affected. Sockeye, which typically migrate upstream mainly in June and July, would be affected with both options. Most steelhead would not be affected as most pass upstream in September and October, although summer stocks would be affected. However, if the refill period is lengthy, some portions of the September run could be adversely affected. Even after spillway drawdown tests are stopped, several days or weeks delay, depending on the flow, would occur until all reservoirs are refilled to levels allowing the operation of ladders. Even the early spring drawdown tests may affect summer chinook, while later tests may cause extended delays on stocks arriving later, including fall chinook.

Even if fish ladders were functional, the proposed spill regime would greatly limit fish migration. The spill test of 100 kcfs at Lower Granite Dam in June 1991 indicated very poor conditions for adult fish attraction to the ladders. The primary purpose of this test was to observe flow conditions below the dam that may occur if Lower Granite Reservoir is drawn down to elevation 710, and the other three lower Snake reservoirs are maintained at MOP. Although Lower Granite Reservoir was maintained at MOP during this test, general flow patterns should be indicative of what will occur if the reservoir is operated at 23 feet below MOP (elevation 710). Three spill patterns were tested over a 4-hour period, and flows were observed downstream of the powerhouse and the adult fish collection facilities. During all spill patterns, a large counter-clockwise eddy was formed downstream of the powerhouse. During the spill test, the north and south shore entrances were washed out. The north powerhouse entrances were not blocked, but extreme turbulence and high velocities would likely make access for fish very difficult. Part of the problem is that flow patterns assumed for ladder entrance design are based on operation of the turbines; when the turbines are not operated, flow patterns are not favorable for successful ladder operation. Therefore, based on these tests, it was concluded that fish would generally have a very difficult time migrating upstream at these flow levels, under any pattern of spill (letter from Ted Bjornn, University of Idaho, Moscow, Idaho, June 6, 1991). In former tests of radio-tagged adult chinook, it was found that at spill levels of 40 kcfs at Lower Granite Dam, adult spring chinook delayed migration. Similar delays were noted during high spills at Ice Harbor and Lower Monumental (Turner et al., 1983, 1984). These results suggest that impediments to migration are likely at the other projects, and may occur even at lower spill volumes. These delays could potentially affect spawning success.

Operating Lower Granite at elevation 710 and others at MOP would greatly impede or eliminate upstream migration at Lower Granite Dam only. Although the fish ladder exit and entrance could be maintained with water, the tailwater flow hydraulics from spilling all the flow and not operating the turbines would be disrupted.

The test drawdown of Lower Granite and Little Goose in March will have minor effects on the passage of adult salmon and steelhead. Ladders at Lower Granite and Little Goose dams will be inoperable during about half of the test period, but few adult fish pass at this time of year. Typically, no spring chinook pass Lower Granite Dam prior to the end of March (Corps, 1991). About 3 percent of all steelhead pass Lower Granite in March, and probably only half of these would be delayed by the test. This delay may cause some additional pre-spawning mortality of these steelhead. Other stocks will not arrive at Little Goose until after the tests are complete.

The operation of the lower Columbia and Snake rivers at MOP are not likely to have any effect on adult migration because the ladders were designed to operate over the array of flow, elevation, and turbine operation that would occur.

Augmented flow in the high range of 20 kcfs would probably have no effect on migration or survival. The CBFWA (1991a) suggested that flow increases may benefit upstream migrants. Gibson et al. (1979) found that increased flow correlated with apparent reduced survival between lower Columbia River projects. However, the flow ranges where the effects were noted were over a much wider range, and many of the losses may have been from ladder deficiencies that have been corrected. Analysis by Bjornn (personal communication, Ted Bjornn, Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho, Moscow, Idaho, October 1991) on past Snake River passage suggested that better adult passage occurs with lower flows. Chapman et al. (1991) examined recent data on apparent losses of adult chinook migrants between Columbia River projects and found no correlations (i.e., no increase or decrease in adult chinook losses between dams with changes in flow) with flows between approximately 100 to 400 kcfs.

### 4.2.2.2 Dissolved Gas Saturation

Negative effects similar to those described for juvenile fish would occur to adult salmon and steelhead from the various alternatives. As Weitkamp and Katz (1980) stated in their literature review of gas saturation effects, results from studies of the Columbia River from 1965 through 1970 showed that 6 to 60 percent of adult salmon during this period were killed by high gas saturation levels. The authors stated that carcasses of adults were found in the river when nitrogen gas saturation was higher than 120 percent, while few were found when saturation was less than 112 percent. They also stated that adult salmon were more tolerant of gas bubble effects than juveniles, although few studies were available forconfirmation. Information from laboratory and field evaluations suggests that adults have similar symptoms and exposures to juveniles, but adults can avoid the disease better due to their sounding capability. Ebel et al. (1975) reported that in laboratory tests, coho salmon were the most susceptible of the adults tested and spring chinook were the most tolerant with 50 percent mortality occurring in both groups after 7 days and 22 days, respectively, at 115 percent saturation.

Field evaluations have confirmed that substantial losses of adult salmonids occur in the river environment. Ebel et al. (1975) reported that in 1962, large numbers of adult prespawning mortalities occurred in the McNary spawning channel. Further investigation revealed that large numbers of the adults were blind as a result from high levels of gas saturation. In levels of high saturation (116 to 130 percent), 34 percent of the test fish were blind within 10 days and 88 percent of these fish died before spawning. It was determined that blinded females did not dig redds, and males were unsuccessful in covering eggs with milt. Ebel also reported that in 1968, levels of saturated gas were measured from 123 to 143 percent below John Day Dam. Thirteen sockeye and 365 chinook salmon were recovered in one day below the project. Based on the recovery of dead salmon, Ebel et al. (1975) reported that the Oregon Fish Commission estimated that over 20,000 summer chinook were missing below John Day project.

Additional flow control and spill deflectors (flip lips) were in place at some dams by the late 1970s. These reduced the level of nitrogen saturation and, consequently, reduced the amount of time salmonids were exposed to high levels of saturated gasses in the Columbia and Snake rivers. Levels above those considered safe (less than 110 percent) still occur annually on the Columbia and Snake rivers, but most of the mortalities associated with gas saturation are believed to have been eliminated (Ebel, 1979).

Currently, there are few reports of recent impacts from gas saturation on the Columbia and Snake rivers, but there have been reports of upstream migrant salmon at the Snake River projects arriving at ladders with open sores on their heads (personal communication, Jerry Harmon, NMFS, Lower Granite Dam, July 1991). This type of injury may be caused by high gas saturation levels.

Lowering all pool elevations on the Snake River would have the greatest negative effect because dissolved gas levels would probably be higher than 120 percent, and possibly higher than 140 percent in the spring (see water quality section). Levels would increase downstream from one pool to the next, with the highest levels below Ice Harbor. Lowering the Lower Granite Pool to elevation 710 would still result in elevated dissolved gas levels that could be harmful to adults passing through the pool (see juvenile discussion). The effects would be worse if adult migration was delayed or stopped past this area, subjecting the fish to extended periods of high gas supersaturation. Duration of exposure as well as percent is a contributing factor. Projects at MOP could also cause some negative affects; but currently, it is not expected they will be significantly out of the range of what normally exist.

The test drawdown of Lower Granite and Little Goose in March would have minor impacts on adults from gas supersaturation. This is because very few fish would be present in Little Goose Pool when gas levels may be elevated; elevated gas levels will be minimized (planned spill will occur less than 4 times during the month) but may be more frequent, and if high, tests will be stopped (see passage discussion).

Augmented flow should not affect these values or increase adverse effects.

### 4.2.2.3 Spawning Habitat

Some options may affect fall chinook salmon spawning areas on the Snake River. Currently, about 30 percent of fall chinook that pass Ice Harbor Dam do not pass Lower Monumental. Although these fish could be suffering mortality or be over-counted at Ice Harbor due to fall back, it is also possible that a majority of these fish is spawning below Lower Monumental. Further, it has been reported that spawning of fall chinook may be occurring below Lower Granite Dam (Bennett, 1991). If fall chinook spawn in these areas, it is probably in water 10 to 30 feet deep just downstream of the dams. Drawdown to near spillway at either of the dams, or Lower Granite to elevation 710 feet, in places upstream of the pools would not directly affect the availability of spawning habitat in these areas because they would be back to pre-testing water levels during the fall spawning and fall-winter incubation periods. However, if the lower reservoirs disrupt bottom structure in the spawning areas, they may be unsuitable for spawning. There is currently no way to estimate these effects. No other spawning areas would be affected by any alternative because they are all above the eight reservoirs of the project area.

Drawdowns of the reservoirs to the spillway crest level or Lower Granite Pool to 710 feet could temporarily delay upstream migration at the deltas of the Snake and Clearwater rivers, and the Tucannon which drains into Lower Monumental Pool. However, all migration, except for fish already in the pools, would have stopped prior to major delta erosion due to inoperation of ladders from the drawdown.

The Snake and Clearwater deltas would not be a problem because they have been dredged on a consistent basis. Therefore, these large flows and fine sediment will cut rapidly through the remaining sediments and prevent passage delays. Passage may be more of a problem at the mouth of the Tucannon River because this river delta has not been dredged. Also, it is a small stream so it may take longer for the flow to cut through the delta to a sufficient level to allow upstream passage of adults. This river has spring chinook and some fall chinook. It is unlikely that fish could get to this pool because of lower dam passage problems with the drawdown. If fish did reach the Tucannon during such a drawdown, they may be delayed until late summer, either after the delta has cut a new channel or the reservoir has returned to full pool. This would be more of a problem for spring chinook, which typically enter the Tucannon River in May and June. Fall chinook do not enter until late summer.

The delta erosion and increased sediment concentration are not likely to prevent adult fish from homing during migration. However, because of the prevention of migration from lack of ladder operation, very few or no fish would be present in the pool during the delta erosion. The high average suspended sediment concentration predicted for full drawdown of Lower Granite Pool is 200 mg/l. Whitman et al. (1982) found that it took suspended volcanic ash of 650 mg/l to disrupt homing behavior of chinook salmon in the Toutle River, Washington. If the 200 mg/l were maintained for a whole month in the reservoir, some mortality of adult salmon and steelhead could occur (Newcombe and MacDonald, 1991).

If Little Goose is lowered by up to 15 feet below minimum pool in the March drawdown test, it would have minor effects on potential spawning habitat for fall chinook in this pool. The region that contains potential conditions suitable for fall chinook spawning is about 4 miles long along the north shore from Lower Granite Dam downstream. Most of this area is not expected to be physically disrupted from drawdown and will be completely covered with water prior to fall spawning. However, any spawning redds that may be present in water less than 10 to 20 feet deep could be left dry before all of the fry have emerged in the spring. Expected emergence is probably from mid-March to mid-April personal communication, David H. Bennett, Department of Fish and Wildlife Resources, University of Idaho, Moscow, Idaho, December 6, 1991). However, surveys are planned prior to conducting experiments to locate any redds. If redds are found in the potential drawdown zone, reservoir lowering will not occur. Monitoring will occur during the test to attempt to ensure redds are protected.

#### 4.2.2.4 Temperature

The various options that result from changes in temperature could affect adult migration. In general, adult salmon and steelhead migration is impeded at temperatures above 70°F (21°C) (EPA, 1971). In 1967 and 1968, high temperatures (75 to 79°F, 24 to 26°C) at the mouth of the Snake River blocked upstream migration of summer chinook and steelhead. Currently, lower Snake River temperatures from 1985 to 1989 averaged higher than 70°F (21°C) from July 19 to August 19 (Vigg and Watkins, 1991). However, there has been a general decrease in the trend of late summer temperatures in the Snake River from 1962 to 1989 (Chapman et al., 1991). No reliable estimates of temperature changes from any of the drawdown alternatives can be made; only the general direction of possible changes can be estimated. Therefore, the effects on salmon and steelhead are difficult to predict. It is expected that only slight changes in temperature would occur from lowering the reservoirs to MOP on the Columbia and Snake Rivers. Temperature is not currently considered a problem for migrants in the Columbia River, so minor changes should have no effect.

Changes at MOP on the Snake River should not change adult migration unless they cause temperature increases during the period of highest temperature in the summer, when summer and fall chinook and steelhead migration could be impeded. Drawing the reservoirs to spillway crest is believed to shift the temperature peak to several weeks earlier. This may impede migration of an earlier portion of the run, possibly affecting more summer chinook migrants if temperatures are high, but effects on later portions of the runs, including fall chinook which typically migrate after mid-August, could be reduced if temperatures are cooler. Temperature increase, even below lethal levels, could reduce the spawning success of fish that pass through the region.

Flow augmentation that occurs in spring and mid-summer may have little effect on temperature and, therefore, little effect on adult migration. Tests from Dworshak Dam (Vigg and Watkins, 1991) were conducted in September when flows are low. The authors found that temperatures were reduced by about 4°F (2.2°C), but the temperature changes were not conclusive. Considering that base flows in the Snake River would be higher during most of the flow augmentation period (April to mid-July), any effects of Dworshak releases would be reduced to less than that found by Vigg and Watkins (1991) due to dilution. Based on the available information on temperature changes, it appears flow augmentation would have little effect on migration.

Temperature control test releases of 10 kcfs from Dworshak Reservoir in August for 20 days could help passage of adult summer or fall chinook and steelhead up the Snake River by cooling Snake River temperatures. Various scenarios of cold-water flow releases from Dworshak Reservoir were evaluated to determine which would be most beneficial to adult fall chinook given specific operation constraints on the reservoir (Karr et al., (1991). Since these model runs were made, reservoir operations have changed so that alternative flows were available to evaluate. These latest flow alternatives were evaluated. The results of this latest evaluation indicated a proposed flow releases of approximately 10 kcfs for 20 days in August from Dworshak Reservoir will reduce water temperatures at Ice Harbor Dam about 2 to 3°F in a year like 1991. This would assist upstream migration of fall chinook and some steelhead by lowering temperatures to 70°F about two weeks earlier than would occur without this flow (in 1991, temperatures would have been lowered to 70°F by August 23 compared to September 8). Currently, some fish migrate upstream when temperatures exceed 70°F, so the real effect of lowering these temperatures on migration is not known.

### 4.2.3 Other Anadromous Stocks

American shad rearing habitat and spawning success might be affected by some of the alternatives, but effects would be minor except for a small portion of population that uses the Snake River. Lowering the lower Columbia River projects to MOP would reduce the rearing area for these fish and reduce food supply by dewatering some shallow areas that are typically watered. However, some benefit to food production could occur by stabilizing the water level and reducing the chance of stranding fish in the shallows from daily drawdown of 0.5 to 1.5 feet. Velocity through the pools would increase slightly during spawning, possibly affecting spawning success. However mid-summer changes even with augmentation flow would not be expected to change overall velocity by more than about 20 percent.

American shad typically spawn over a wide range of flows, apparently successfully, so minor changes from proposed actions should not have significant effects. Similar effects would occur on the Snake River, but any effects to the population would be reduced because relatively few fish use the Snake River. Lowering all Snake River projects to spillway crest would eliminate upstream migration into this system in the spring and summer. Lowering Lower Granite to elevation 710 would prevent migration above this dam because the fish would have difficulty finding the ladder entrance caused by turbulence from total spill; however, this is a small region of habitat for the species and the majority stay in the Columbia River.

Lamprey rearing and migration could be possibly significantly affected from some of the alternatives. Lowering the Snake River projects to spillway crest would eliminate any upstream migration in the Snake River System as they would be migrating during spring. Some effects could occur to the juveniles from drawdown to MOP in the lower Columbia or Snake rivers. They typically rear as ammocoetes (larvae) inhabiting fine silts and backwaters of streams. Some of these areas would be dewatered, but much of this habitat typically is partially dewatered daily under normal conditions; under MOP conditions, the likely relative habitat area not currently affected is relatively small.

However, rearing larvae currently in the Snake River would be adversely affected from drawdown to spillway crest as all of the suitable habitat would be dewatered. Lowering Lower Granite to elevation 710 feet might have the same effect as to spillway crest in this pool.

White sturgeon are present in the anadromous form below Bonneville Dam, and as mostly non-anadromous isolated populations of resident stocks in the Columbia and Snake River pools. None of the alternatives should affect the anadromous form because conditions below Bonneville would not change. However, resident stocks could be affected by various alternatives. Lowering all Snake River projects to near spillway crest could affect spawning and rearing habitat; however, the net effect is not known. Sturgeon apparently prefer the fast water areas below dams for spawning. With the drawdown near spillway crest, the distribution of this habitat would be larger, possibly increasing suitable spawning area. Rearing habitat in these reservoirs is typically the deeper portions of the reservoirs (Nigro, 1990), but juveniles have been found in shallow-water regions (Bennett, 1991). This option will have less effect on deep-water habitat than on shallow-water habitat so, other than reducing the net depth of this area, there would be little effect on these regions. However, the importance of the loss of shallow-water habitat for rearing is not known and this habitat could be important to the survival of young sturgeon. Whether the reduced depth will make these regions unsuitable for rearing older fish is not known. Lowering only Lower Granite to near spillway crest or to 710 feet will reduce the depth of rearing habitat only in Lower Granite Pool, possibly affecting only that population. Drafting of Lower Granite to 705 and lower Little Goose to 10 to 20 feet below full pool in the March to mid-April period will have similar effects as lowering the pools to spillway crest in these two only pools, with major effects limited to early spring. The effects of all other alternatives are likely to be insignificant because they have little effect on deep-water habitat or high-velocity spawning areas below each projects. However, some loss of shallow-water habitat, possibly important to young sturgeon, will occur with any of the drawdown alternatives in the Snake and Columbia rivers.

Flow augmentation is not likely to have any effect on these three species.

### 4.2.4 Hatcheries

Hatchery operations could experience a variety of direct and indirect effects from the proposed actions, including operational difficulties from changed water levels, temperature effects on hatchery water supplies, and possible lowering of water table levels near hatchery wells. Impacts to the hatcheries and rearing ponds are generally expected to be minor. However, there is an uncertain possibility that water-related changes could result in moderate impacts to hatchery stocks produced at some of the facilities.

Corps staff postulate that water temperatures at the lower Columbia River projects would increase earlier in the summer and possibly reach higher levels with operation at MOP. Water temperature in the aquifer supplying the Bonneville Hatchery ranges from 47 to 53°F (8 to 12°C). If river temperatures increased sufficiently to raise aquifer temperatures more than 1 or 2°F (-17.2°C), growth of juveniles and survival of adult salmon at the Bonneville Hatchery might be of concern. Temperatures above 54°F (12°C) significantly increase holding mortality of chinook salmon, which already have a mortality rate of 19 percent. Increased temperatures would induce a higher juvenile growth rate, requiring early release that could affect survival.

Releases of coho from Wahkeena Pond below Bonneville Dam could be affected with projects operated at MOP or with significantly increased spring flow augmentation. River flows below Bonneville Dam must be below 200 kcfs for coho to leave the rearing pond because the pond cannot be drained at higher flows. Typical operation of reservoirs allows for some storage of water by fluctuations of 0.5 to 1.0 feet per day. Without this storage capability (if leaving reservoir at MOP), all flow coming downstream must be passed through the project. If flows are higher than 200 kcfs in May, which is common, operating the lower river projects at MOP allows for no storage, so all flow would continue down the river and coho releases from this facility could not occur.

Lowering the Bonneville Pool to MOP could increase predation on fish released from the Little White Salmon facility. Released smolts tend to hold in Draino Lake, a backwater area of the pool, which would be greatly reduced in volume. This lowered water depth would concentrate smolts and predatory fish, as well as increase access to fish for predatory birds. The adult hatchery ladder entrance at Spring Creek Hatchery might not be effective with drawdown of the lower Columbia River projects to MOP because rocks emerge at the entrance at an elevation of 70 feet in the Bonneville Pool.

Water supply to the Irrigon and possibly Umatilla hatcheries could be reduced by lowering John Day Pool to MOP or to 262.5 feet. The Ranney Well water supply system currently in place appeared to be at its limit of supply when the pool was lowered to 262.5 feet this year. The supply quantity appears to be correlated to the pool level. Pool reductions might therefore limit water supply and ultimately reduce the capacity of the facilities or necessitate earlier releases of fish.

Drawdown of the Lower Monumental Pool would threaten the water supply pipeline to the Lyons Ferry Hatchery (see Section 4.14.6). Loss of this water supply would severely reduce the rearing capacity of the hatchery, which is designed to rear 116,400 pounds of steelhead, 101,800 pounds of fall chinook, 45,000 pounds of rainbow trout, and 8,800 pounds of spring chinook.

All hatchery facilities above Ice Harbor, including Lyons Ferry in the Lower Monumental Pool, would not have spring run brood stock (spring/summer chinook, some steelhead) with the Snake River projects drawn down to near spillway crest. None of the spring stocks would be able to pass upstream because the adult fish ladders would not be operational under these conditions. If only Lower Granite were drawn down to near spillway crest, only Lyons Ferry would have access to adult spring stocks. Drafting Lower Granite to elevation 710 feet would nearly or totally prevent spring run stocks from getting to hatcheries above this dam. Also some steelhead stocks, mostly those migrating in the mid-summer, would not arrive at the hatcheries. But the proportion affected would be a small portion of the runs because most migrate upstream in September and October, after the drawdown period. Operating Lower Monumental to spillway crest would also cause structural damage to the water supply system to Lyons Ferry hatchery. This would eliminate production of fall and spring chinook and steelhead at this facility even after the tests were done and the pools returned to normal levels.

Release of 45°F water during August would affect juvenile steelhead production at Dworshak Hatchery. The naturally warmer waters (versus recirculation) available August 1 through October 1 provide for the best fish growth. The progeny from the groups of fish spawned last will not have attained adequate size before the cool water release and thus will be 10 to 15 mm below the desired size of 200 mm. This would affect approximately 750,000 fish out of the total approximate production of 1,750,000. Effects on the hatchery can be minimized by minimizing the duration of the release (volume does not have an effect).

### 4.2.5 Mitigation

#### 4.2.5.1 Juveniles

Juveniles would be significantly affected when alternatives are implemented which preclude operation of juvenile fish bypass facilities and, as a result, operation of the juvenile fish transportation program. No readily implementable measure could be provided by 1992 to allow operation of these facilities under these drawdowns alternatives. Juvenile bypass systems function within specific reservoir levels; operating outside these levels would result in an inoperable system or increased juvenile mortality.

For the transportation system to operate, juveniles must first be collected. This is currently accomplished by using juvenile bypass systems at three projects. The loss of juvenile bypass system operation would preclude transport at the inoperable facility. While upstream juvenile traps might be deployed to mitigate this loss of collection capability, effective traps could not be provided by 1992. Part of the benefit of the juvenile transportation program is avoiding increased losses from predation. To offset these losses, the predator removal program could be intensified but not implementable by 1992 to offset loss of transport.

Another significant impact to juveniles would be gas supersaturation. As discussed in the water quality section, little can be done to mitigate this impact except for reducing spill volumes when problems are encountered.

### 4.2.5.2 Adults

Impacts of alternatives which preclude adult passage (pool levels to spillway crest or high spill conditions) cannot be readily mitigated. The effective operation of fish ladders requires maintaining a carefully balanced flow volume and velocity to first attract adults into the system and then to ensure their movement through the system. The volume of water required and criteria that must be met does not readily allow a "quick fix" to provide passage.

Another alternative discussed to mitigate the loss of ladder function is to use a trap and haul facility. A trap, however, requires flow conditions for attraction and collection similar to those required for ladders. In addition, the large number of adults that would require handling (approximately 34,000 chinook and 6,000 steelhead at Ice Harbor) makes this approach infeasible for 1992. Furthermore, the destination of these adults would not be known and the effect of such handling may be deleterious.

The potential loss of adult entrance into Spring Creek hatchery was further identified as a potential problem. This might be mitigated by removing rock outcroppings which create this problem.

Temperature impacts could not be mitigated without modifying release strategies.

## 4.3 RESIDENT FISH AND AQUATIC ECOLOGY

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown** | |
| ***Snake River*** | |
| All 4 projects to MOP (April 1 to July 31) | • Spawning and rearing habitat reduced.<br>• Possible benefits to spawning success due to stabilized water surface elevations. |
| All 4 projects to near spillway crest (April 15 to August 15) | • Large reductions in suitable shallow-water spawning habitat.<br>• Reduced benthic and plankton production and, hence, prey availability, with reduced fish growth.<br>• Increased gas saturation.<br>• Increased fish mortality. |
| All 4 projects to near spillway crest (April 15 to June 15) | • Similar to all projects near spillway with decrease in duration. |
| Lower Granite to near spillway crest (February 1993 or July 15 to August 15) | • Similar effects on Lower Granite as in all projects to near spillway and other projects similar to that described under MOP. |
| Lower Granite to 710 feet, others to MOP (April 15 to June 15) | • Greatly reduced spawning habitat in Lower Granite.<br>• Reduced benthic and plankton production in Lower Granite.<br>• Reduced fish growth in Lower Granite.<br>• Other projects as in MOP. |
| Lower Granite/Little Goose drawdown test (March) | • Potential shifting of resident fish populations between pools.<br>• Reduction in suitable shallow-water foraging habitat.<br>• Reduced benthic production and, hence, prey availability.<br>• Increased gas saturation and predation. |
| ***Lower Columbia*** | |
| All 4 projects to MOP (April 1 to August 31) | • Spawning and rearing habitat reduced.<br>• Possible benefits to spawning success due to stabilized water surface elevations.<br>• Possible reduction in plankton production. |
| John Day at 262.5 feet, McNary at 337 feet, remainder at MOP (April 1 to August 31) | • Possible enhanced spawning and rearing conditions. |

Resident Fish (continued)

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Flow Augmentation** | |
| *Dworshak* | • Increased entrainment of kokanee and trout.<br>• Reduced plankton production thereby reducing food sources for fish.<br>• Reduced spawning success<br>• Slight cooling of Clearwater River, delaying biological processes.<br>• Reduced effects with flood control shift. |
| *Brownlee* | • Increases in entrainment of fish with small to moderate withdrawals.<br>• Reduced benthic and planktonic production with moderate releases.<br>• Impacts on spawning success, feeding success, and survival with unrestricted draft increasing with magnitude of withdrawal.<br>• Reduced effects with flood control shift. |
| *Grand Coulee* | • Potential significant impacts (positive and adverse) to net pen operations.<br>• Increased entrainment of fish.<br>• Delayed zooplankton development. |
| Combination Alternatives | • Effects additive; see drawdown and augmentation. |
| Temperature Control Test (August) | • Reduced abundance of zooplankton and terrestrial insects.<br>• Reduced feeding success of resident fish.<br>• Delay of biological processes in the Clearwater River and reduced growth of riverine species.<br>• Probable loss of habitat for riverine fish species.<br>• Reduced temperature stress in fish of Lower Granite and Ice Harbor reservoirs. |

### 4.3.1 Potential Impact Mechanisms

Variations in existing operations at Snake and Columbia River dams might potentially affect resident fish populations. Most of these potential impacts are related to spawning success, early survival of juveniles, and availability of prey.

Changes in water surface elevations that drain backwater areas can have immediate and long-term effects on resident populations. Decreased water surface elevations before spawning can affect the amount of shallow-water habitat available for spawning. Drawdown might reduce the total amount of spawning area available by drying areas normally used by resident fish populations. Alternatively, they might increase spawning habitat by reducing water depth over broad areas ordinarily at intermediate depth.

Suitability of habitat within a reservoir for spawning is not only a function of depth, but also substrate and flow. Most of the shallow-water spawning species spawn over coarse sand or gravel. Flow is also often a factor in the selection of spawning areas. Therefore, the effects of decreasing water surface elevations on the availability of spawning habitat depends on the available shallow-water habitat following drawdown and the substrate and flow characteristics of that habitat.

Decreasing water surface elevations could result in desiccation of eggs and reduced survival to juvenile stages (Bennett et al., 1983; Hjort et al., 1981; Bennett and Shrier, 1986; Mullan et al., 1986; Peone et al., 1990; Stull and Emery, 1985). Increases in water velocity can further influence distribution of eggs and larvae and might result in lower survival if the eggs and larvae are carried to unfavorable habitats (Hjort et al., 1981).

Increases in spring temperatures in the reservoirs could accelerate spawning, increase planktonic and benthic production, increase growth rates of fish species, possibly increase survival of warm-water species, and possibly decrease survival of cold- or cool-water species. In reservoirs with species that are currently temperature limited (e.g., mountain whitefish), small increases might raise temperatures in excess of tolerable levels and result in increased mortality of these species. Long-term changes in species composition could result.

The number of fish entrained into turbines or lost over spillways can be affected by changes in flow regimes that tend to carry increased numbers of eggs and juvenile fish through the forebay of dams. Loss of fish over or through the dams can also be affected by the depth of water at those facilities. The majority of the fish in the open waters of the forebay tend to be concentrated in the upper water column. Therefore, decreases in water surface elevation increases the probability of entraining fish.

Macrophyte abundance could be either increased or decreased by the proposed actions. Constant water surface elevations would tend to encourage macrophyte development, while the loss of shallow-water habitat might reduce the area where macrophytes can develop and/or decimate portions of the existing macrophyte production. Macrophyte production can be important because it provides substrates for invertebrate development, spawning substrates for some fish species, and cover for rearing fishes.

Decreased water retention time affects phytoplankton and zooplankton in the reservoirs through decreased availability to nutrients. Reduced plankton production, in turn, has the potential of affecting fish production as a result of decreased prey availability.

Reductions in water surface elevation below normal pool levels might reduce benthic production because of reductions in availability of shallow-water habitat and possible differences in substrate of remaining or resulting shallow-water habitat.

Higher turbidities would tend to decrease plankton production as a result of reduced light penetration in the water column. This, in combination with reduced retention times, could affect food availability for larval fishes, juveniles, and other planktivorous fishes.

Each of these avenues for effects to aquatic organisms has the potential to affect individuals in the populations. Although individuals in a population might be affected, the overall population might remain undisturbed. The potential that these mechanisms have to change overall populations depends upon whether the populations are limited by the impact mechanism. For instance, if spawning habitat is amply available and, under normal circumstances, underused, reductions in the available habitat might not have a negative impact on the population as a whole. Likewise, reductions in food availability might not affect populations if food levels normally present in the reservoir far exceed levels required to maintain the populations.

Gas supersaturation is expected to increase if spill is dramatically increased at the reservoirs. If supersaturation levels exceed 115 to 120 percent, resident fish present in the surface water of the tailrace might suffer substantial mortalities. Generally, shiners and crappies have a tolerance similar to salmonids; blue gills and northern squawfish are more tolerant than salmonids; and bullheads, carp, and bass are among the most tolerant of the Snake and Columbia River System species (Weitkamp and Katz, 1980).

## 4.3.2 Lower Snake River Reservoirs

### 4.3.2.1 Operation at Minimum Operating Pool

With all four reservoirs at MOP from April 1 through July 31, water surface elevations would be held near the lower elevation of the normal April to August operating range. Although the average water levels would be reduced by up to 3 feet during this time, they would be held fairly constant relative to normal operations (Appendix D).

Most of the resident fish in the Snake River reservoirs spawn from April 1 to July 31. Larger amounts of shallow-water spawning habitat would generally be available at all four reservoirs at MOP water surface elevations relative to the amount of habitat available at full pool elevations (Table 4.3-1). Full pool elevations, however, do not represent actual shallow-water habitat normally available because elevations normally fluctuate widely (Appendix D). All pool elevations but Little Goose fluctuate between full pool and MOP during the spring. Fluctuations at Little Goose are not as pronounced. Truly viable spawning habitat available under normal conditions at most of the reservoirs is probably similar to or slightly greater than levels available under MOP. Stabilized water surface elevations would tend to ensure that most spawning activity occurs in areas that would be inundated throughout incubation. Hence, operations at MOP should have a small positive effect on successful egg incubation. However, reductions in shallow-water habitat, particularly at Little Goose Reservoir, would tend to negatively affect spawning success. The net effect of drawdown on spawning and incubation success is uncertain. At Little Goose, the effect is expected to be negative. At the other reservoirs, populations may be slightly enhanced by operations at MOP.

The drawdown might slightly increase the amount of tailwater spawning habitat that in turn might increase the spawning success of resident cold-water species. These species, however, are primarily tributary spawners and any increase in spawning success is expected to be insubstantial. Northern squawfish spawn in either running water or along the shores of the reservoirs. Little change in spawning success of squawfish is anticipated.

Larval fish abundance in Lower Granite Reservoir in 1991 tends to support this conclusion. The reservoir has been operated under MOP conditions in 1991 and larval fish abundance in the reservoir appears to be exceptionally high. This is believed to be related to the reduced but constant water levels. Initial identification of these larval fishes indicated that most are suckers, but northern squawfish also appear to be abundant. These initial results suggested that northern squawfish and sucker abundance might be somewhat enhanced as a result of the more favorable rearing conditions. Other shallow-water spawning species might also be benefitted.

Water retention times in the reservoirs would be adequate to enable zooplankton populations to increase to densities high enough to provide food for larval fishes. Turbidity might increase slightly when water levels are initially reduced to MOP around the first of April, which could temporarily reduce productivity. However, turbidity should return to and remain at ambient levels for the remainder of the drawdown. Therefore, turbidity should have little overall effect on plankton productivity (Bennett, 1991).

Benthic community production would probably not be affected under operation at MOP at any of the reservoirs except Little Goose. Present operating conditions routinely include water level fluctuations between full pool and MOP, which have probably eliminated the benthic community within the fluctuation range. Therefore, under constant water levels at MOP, the benthic community would not

**Table 4.3-1. Percent change in available shallow-water area at Snake River reservoirs with MOP and spillway crest water surface elevations relative to availability of shallow-water area at full pool.[a]**

| Reservoir | Water Depth | | | | | |
|---|---|---|---|---|---|---|
| | Spillway Crest | | MOP | | 710 | |
| | 0-9 ft | 10-19 ft | 0-9 ft | 10-19 ft | 0-9 ft | 10-19 ft |
| Ice Harbor | 321 | 159 | 124 | 179 | — | — |
| Little Goose | 56 | 36 | 154 | 74 | — | — |
| Lower Granite | 107 | 45 | 122 | 105 | 181 | 71 |
| Lower Monumental | 333 | 124 | 140 | 127 | — | — |

a/ Calculations are based on HEC 2 transect data and assume depths along transects represent the entire reservoir.

be affected and might temporarily increase in shallow water. At Little Goose, the reduced available habitat would likely result in reduced benthic production.

Constant water surface elevations might also benefit macrophyte production by providing relatively stable water depths over shallow-water areas. Increased macrophyte abundance could enhance invertebrate production and provide cover for rearing fishes. This, in turn, could positively affect survival of juvenile fish.

Significant water temperature changes would not be anticipated with this option; hence, temperature is not expected to affect existing annual growth rates of fish. Additionally, food availability (benthic and planktonic) is expected to be unchanged. Therefore feeding success, which affects growth, should be unchanged, and turbidity is not anticipated to be great enough to affect feeding success. Annual growth increments of fishes would probably be similar to current conditions in the reservoirs.

Neither water levels nor water flows during this operation at MOP would be sufficient to result in increased loss of juveniles/adults from the reservoir through the turbines or over the spillways (Bennett, 1991). Similarly, flows in the river and spill levels would not change significantly. Therefore, river populations should also be unaffected by operations at MOP.

In summary, operation of all four lower Snake River reservoirs at MOP from April 1 to July 31 would not be expected to activate any of the mechanisms that would affect resident fish populations. Therefore, operations at MOP are anticipated to have minimal and possibly positive effects on resident populations.

An alternative to drawing all four Snake River reservoirs to MOP is to draw Lower Granite Reservoir to a level midway between MOP and spillway crest water surface elevations (elevation 710) and draw the other three reservoirs to MOP. This option should result in significant increases in the amount of shallow water in Lower Granite Reservoir. However, most of this shallow water would have substrates of silt and mud, unsuitable for most resident fish. In additional, silt and mud does not to support much benthic production. Drawdown of Lower Granite to 710 feet would also increase flushing time sufficiently to have a significant negative effect on plankton production. The net result of this drawdown would most likely be the production of a very weak yearclass of most resident fish species in Lower Granite Reservoir. Feeding success and growth would also be affected.

### 4.3.2.2 Operation Near Spillway Crest

One of the existing key changes under either of the options for spillway crest operation would be the general loss of available shallow-water habitat. The large drawdowns associated with operations of spillway crest would expose all of the shallow-water habitat present under existing conditions. Ice Harbor and Lower Monumental reservoirs, however, would have substantially larger amounts of shallow water area available at spillway elevations (Table 4.3-1). The shallow water in Little Goose Reservoir would be greatly reduced and the area of shallow water in Lower Granite Reservoir would be lower than under MOP elevations.

Substrates in shallow areas present at the new lower water elevation would consist of silt and fine material, which has been deposited over the lifetime of the reservoirs. These substrates likely would not provide suitable spawning area for most shallow-water spawning species.

The change in shallow-water area and in substrate present in those areas in the reservoirs would likely have large effects on aquatic productivity. Although of very limited area, shallow water represents the most productive areas of the lower Snake River reservoirs. Benthic abundance is generally higher in shallow water where sandy substrates are available and, hence, would tend to be reduced below existing conditions with operations at spillway crest. This reduction would represent a direct reduction in food availability for organisms that normally prey upon the benthic community. It would also reduce the production of crayfish, the primary food item for most predatory species in the lower Snake River reservoirs (Bennett et al., 1983).

Higher velocities and lower retention times through the reservoirs would result in substantial reductions in zooplankton production, a major food item of these fishes during their larval and early juvenile rearing. Expected higher turbidities would further reduce plankton production and, subsequently, food availability for larval fishes.

The overall change in shallow-water areas, increased flows in the much of the shallow area that would be available, and the presence of fine substrates would be expected to significantly affect most resident fish spawning. The five major sport fish in the system—smallmouth bass, black and white crappies, channel catfish, and largemouth bass—probably would not successfully spawn because of the decreased water levels, increased velocities through the reservoirs, loss of backwater habitat, and high abundance of finer substrate (Bennett, 1991). Other species commonly classified as non-game species that are typically more abundant under riverine conditions are redside shiners, chiselmouth, mountain whitefish, and white sturgeon. These species spawn in flowing waters so their spawning would probably not be affected. If sufficient rearing habitat were available for juveniles, these species could increase by a small amount. Because northern squawfish spawn in reservoirs and also in flowing water, squawfish spawning success is anticipated to be affected very little.

Aquatic macrophytes would be largely eliminated in each of the reservoirs under this scenario. Under current conditions, aquatic macrophytes provide cover and constitute attachment media for aquatic invertebrates used by juvenile and some adult fishes. Loss of macrophytes would further reduce food and cover for species such as largemouth and smallmouth bass, pumpkinseed, northern squawfish and redside shiners. Macrophytes currently constitute a significant source of cover in the lower Snake River reservoirs and their loss would result in a reduction in rearing habitat, primarily for juvenile fishes. Loss of macrophytes would probably result in a significant reduction in yellow perch, the abundance of which is closely correlated with the presence of macrophytes (Bennett, 1991).

In the absence of a temperature model, the effect of the reservoir drawdown to near spillway crest on water temperatures is uncertain. Reduced water temperatures would probably result in slower growth for fishes that are currently temperature limited, including smallmouth and largemouth bass, sunfishes (bluegill, pumpkinseed and warmouth), crappies, channel catfish, and other non-game species. Juveniles of warm-water species produced during 1992 would probably exhibit reduced over-winter survival because of their smaller body size. Reductions in prey availability would tend to further reduce growth potential. Species that prefer lower water temperatures (mountain whitefish, occasional resident salmonid) might be benefitted by the cooler temperatures although reductions in prey might offset potential improvements in growth. However, increased water temperatures could accelerate the spawning period in the reservoir. Fish growth would also be enhanced. In addition, warmer temperatures would enhance plankton production and might partially offset reductions in productivity resulting from increased turbidity and reduced retention time.

Increased velocities, reductions in volume of standing water, reductions in zooplankton production, and the loss of larger substrate are all factors that would potentially affect resident fish. These factors would tend to result in reduced spawning success of shallow-water species, reduced prey availability, reduced feeding success, and reduced growth of warm-water species. Increased turbidity might further reduce feeding success and growth, but turbidity might also provide cover from predation. The worst-case scenario for turbidity increases predict 200 mg/l for 30 days. Investigation results of effects of suspended sediments on fish species are highly variable and depend on the species tested and the composition of the suspended materials. In some experiments suspended solid concentrations from 200 to several thousand mg/l have caused deaths among fish exposed for several weeks. Other experiments have indicated good survival of fish in the same range (Alabaster and Lloyd, 1982). Generally, studies indicate some mortality at concentrations greater than 200 mg/l and few mortalities at concentrations less than 100 mg/l (Alabaster and Lloyd, 1982). Turbidities in the Columbia/Snake River System are expected to range between 100 and 200 mg/l for about 1 month. Depending upon the composition of the suspended sediments, these levels are likely to cause some mortalities in the most sensitive species (whitefish, trout, kokanee, and walleye), and may also affect some moderately sensitive species. Increased turbidities generally have the greatest impact on sensitive spawning and incubation periods.

Operation of the lower Snake River reservoirs near spillway crest would require routing all river flow over the spillways. Increased flows over the dams might result in gas supersaturation levels in excess of 115 to 125 percent, which would likely cause mortalities in resident fishes in the tailrace area (Fickeisen and Montgomery, 1978; Montgomery and Becker, 1980). The extent of impact to resident fish resulting from elevated gas levels is unknown.

Operating the four lower Snake River reservoirs near spillway crest from April 15 to June 15 as opposed to operating through August 15 would be less damaging to the resident fishery because of the difference in duration. Under this option, similar changes in the physical habitat would occur, but water surface elevations would be returned to the normal operating range at an earlier date. Exposing the shorelines to desiccation at this time would result in loss of aquatic macrophytes, benthos, and spawning and rearing habitat. Increased turbidities and reduced water retention times in the reservoirs would reduce plankton production. Because of the shorter time, effects on plankton production would not be as great as anticipated over the longer drawdown period.

#### 4.3.2.3 Lower Granite to near Spillway Crest and Little Goose to elevation at which tailwater is equivalent to near spillway crest, March 1 to 31

Drawdown of Lower Granite and Little Goose reservoirs during the period from March 1 to 31 will avoid the spawning period of most reservoir species. The quality of the spawning habitat available in early April may be degraded relative to that present at normal pool, particularly for those species which require rocks or other structure for spawning (e.g., walleye).

The spring drawdown will also result in a general loss of shallow-water habitat used for foraging. Since the drawdown would occur prior to the juvenile rearing period, the effects of the loss of shallow habitat will not be as great as those described for later drawdown. However, fish present in the reservoir will be subjected to some level of stress, and will be pushed into open water where predation on these fish is likely to be greater due to the absence of cover. Foraging success is likely to be affected to a degree due to the loss of benthic organisms in the limited shallow water areas during the drawdown.

## 4.3.3 Lower Columbia River Reservoirs

### 4.3.3.1 All Reservoirs to MOP

Under this option, water surface elevations would be held near the lower elevation of the normal April-to-August operating range at all four lower Columbia River reservoirs. Although the average water levels would be reduced during this time, they would be held fairly constant relative to normal operations. The shorelines of these reservoirs are generally not as steep as the Snake River reservoirs. This is particularly true of John Day and McNary. As a result of the more gradual slopes of the shorelines, larger areas of temporarily available shallow-water habitat would be lost. Most of this area, however, is subjected to occasional desiccation under normal spring and summer reservoir operations (Appendix D).

The total amount of shallow-water (less than 10 feet deep) habitat available at MOP in McNary Reservoir is estimated to be 115 percent greater than at full pool (based on data from 67 HEC2 transects and assuming that data is representative of the entire reservoir). Taking into account fluctuating water surface elevations, the actual difference in the amount of shallow water available between operations at MOP and existing conditions is probably insubstantial.

Above MOP evelations, normal fluctuations of the reservoir would tend to expose developing eggs. Hence, the amount of viable spawning habitat at MOP is probably similar to that available under normal conditions. Under normal operations, water surface elevation variations are not as pronounced at John Day and The Dalles; therefore, reductions in available shallow-water habitat would tend to be greater and would tend to result in greater impacts on spawning and egg incubation. Reduced fluctuations in water surface elevation should result in greater hatching success of eggs spawned in shallow water in Bonneville and McNary pools. Therefore, the effect of operations at MOP at Columbia River dams would be very similar to the effects of operations at MOP for the lower Snake River reservoirs.

As is the case in the upper Snake River reservoirs, benthic and macrophytic production might be slightly improved in the Columbia River reservoirs because of stabilized water levels. Slight reductions in some areas might occur because of a loss of shallow-water habitat. Reductions in water retention times and increased turbidity might have some impact on plankton production. It is unknown whether these reductions would be sufficient to decrease feeding success of fish and other aquatic organisms.

### 4.3.3.2 John Day and McNary Above MOP

The second drawdown option for the lower Columbia River reservoirs would hold Bonneville and The Dalles pools near the lower elevation of the normal April to August operating range, while elevations of John Day and McNary pools would be near normal (262.5 and 337 feet, respectively). Although the average water levels would be reduced by up to 3 feet during this period, they would be held fairly constant relative to normal operations.

Effects on resident fish populations would be similar to those described under MOP conditions for all four lower Columbia River reservoirs. Shallow-water habitat in the John Day and McNary reservoirs would likely be more available than under MOP conditions. Production of benthic organisms and macrophytes might be enhanced as a result of stabilized water elevations. Spawning success might also be enhanced relative to conditions at MOP. Changes in water retention time are not expected to result in substantial changes in plankton production, but increased turbidity might reduce overall production levels. Overall, fish production should be slightly improved over operation at MOP and under existing conditions.

## 4.3.4 Augmentation

### 4.3.4.1 Dworshak

Alternatives include flow augmentation from Dworshak Reservoir at 600, 900, and 1,200 acre-feet. The final alternative includes water releases at whatever level is required to attain a target flow of 140,000 cfs at Lower Granite Dam in May. Under the first three alternatives, water surface elevations would be reduced from 0 to 36.3 feet below normal operating levels. Under the last alternative, elevations in the reservoir would be reduced by an average of 70.9 feet. Under normal conditions, the reservoir fluctuates approximately 45 to 150 feet annually, with average fluctuations in the range of 75 to 125 feet (Statler, 1990). The reservoir is typically filled from March 1 through July 1. Flow releases under the alternative operating plans would generally result in delayed refilling and possibly incomplete refilling of the dam rather than increased drawdown of the reservoir; however, some increased reduction in water surface elevation might also occur.

Generally, major effects to aquatic organisms are not anticipated because the reservoir is already a highly disturbed system because of the broad range of water level fluctuations that occur annually under normal conditions. Aquatic macrophytes and aquatic macroinvertebrates are virtually non-existent in Dworshak Reservoir; hence, drawdowns would not affect production of these organisms. It is unknown how delayed refilling of the reservoir would impact plankton production; however, studies conducted by the University of Idaho indicate that slight reductions in plankton production would occur at lower pool levels and that production would be best maintained through maximizing water surface elevations in summer and fall. There may also be a decrease in terrestrial insects present in the reservoir caused by decreases in the area of shoreline which is inundated in the spring and increases in the distance between terrestrial vegetation (a source of insects) and the shoreline.

Kokanee feeding success would not be significantly affected since kokanee feed primarily on plankton (Mauser et al., 1990) which are not anticipated to be affected significantly.

The principal food source for rainbow trout during the spring is terrestrial insects. A reduction in the abundance of terrestrial insects may constitute a moderate stress on the trout populations. Trout spawning is expected to be unaffected.

Kokanee, however, might be affected by additional mortality due to loss of fish over or through the dam. Currently, kokanee populations in Dworshak have extremely high mortality rates (> 80 percent) between year classes (personal communication, Melo Maiolie, Idaho Department of Fish and Game (IDFG), Coeur d'Alene, Idaho, August 23, 1991).

In recent years, studies have been conducted to assess factors contributing to this mortality. Preliminary results suggest that most of the entrainment occurs during the winter and early spring when the reservoir is drawn down to its lowest levels. It is difficult at this time to determine how the additional drawdown would affect the kokanee populations.

Smallmouth bass also depend upon terrestrial insects and might be adversely affected not only through the reduction of insects as a direct food item, but also through the impacts that the reduced terrestrial insect biomass would have on insectivorous fishes upon which the bass prey.

Smallmouth bass spawning might also be affected by the withdrawals. There are relatively few shallow-water areas suitable for smallmouth bass spawning in the reservoir and maximum habitat availability is at full pool. Water withdrawals would reduce the availability of spawning habitat during the spawning season. The effects that this would have on the bass population is unknown.

Numerous other species of fish have been documented in Dworshak Reservoir that have a variety of food and spawning requirements. It is likely that either the feeding or spawning success of many of these species would be affected by the withdrawals. The degree of effect is impossible to estimate.

Increased flow releases out of Dworshak Dam are not large enough to have a major impact on riverine species below the dam. However, water released from the dam would tend to cool the river, which might delay biological processes in the river including invertebrate production, spring spawning of river spawning species, and egg incubation.

#### 4.3.4.2 Brownlee Reservoir

**150,000 and 200,000 Acre-Feet Releases.** Current operations call for reservoir drawdown to elevation 2,034 feet by March 1 of each year. Attempts are made to refill the reservoir by July 1; however, a second dip in water surface elevations is predicted in May. Under the flow augmentation alternatives calling for the release of 150,000 and 200,00 acre-feet of water, the average annual fluctuation in water elevation is not appreciably different from existing conditions. Refilling of the reservoir, however, is delayed approximately 1 month under these alternatives.

Many of the species in the reservoir are primarily bottom feeders such as suckers, channel catfish, and carp and would not be affected by reservoir drawdowns. Black crappie and smallmouth bass, however, make extensive use of shallow water and, hence, would be the game species most affected by reservoir drawdowns.

Smallmouth bass typically spawn in April, May, and June in shallow-water areas. Because the shorelines are steep, suitable shallow-water area is believed to decrease as water level is reduced. Poor or no reproduction has been reported in years when water surface elevations are low (BPA, 1985). Since water levels are normally rising during the spawning and incubation period, the reduced reproductive success is more likely related to a lack of suitable spawning habitat than to desiccation of eggs.

Under all alternative flow releases calling for release of 150,000 and 200,000 acre-feet of water, some spawning habitat would likely be lost. The Idaho Department of Fish and Game has indicated that a stable or refilling pool in June can often result in great enough spawning success to offset losses caused by declining pools in April and May (letter from T. Morse, July 31, 1991). The various alternatives all call for an increasing pool in June. However, some loss of production is likely due to timing of drawdowns and the second dip in water surface elevations during egg incubation.

Some unquantified impacts to smallmouth bass spawning might therefore occur under the alternatives calling for limited flow releases.

It is anticipated that benthic and primary productivity would be unaffected by changes in reservoir elevations from April through June under these two alternatives.

Water releases might affect temperature in the reservoir. In the absence of a temperature model, it is impossible to predict the degree or direction of change. Minor changes in temperature are not expected to affect sport species in the reservoir (BPA, 1985).

Entrainment of fish into the turbines or over the spillway could potentially increase with increased flow releases. The potential for loss is related to the rate of drawdown and the depth of water released. Alternatives calling for limited releases are not likely to significantly affect entrainment because drawdown rates and resulting water surface elevations are not substantially different from existing conditions.

Flow augmentation releases from Brownlee Reservoir would result in increased flows in May and decreased flows in June in the river below the dam. Although most bass and resident trout in the river spawn before or during May, eggs incubate through June. Increased flows during May would reduce dewatering of redds. The increased flows, however, would also encourage fish to spawn higher along the banks of the river. Incubating eggs present at higher elevations in June might become dewatered as flows are reduced. It is unknown whether the advantages of increased flows in May would offset the impacts of the decreased flows in June (BPA, 1985).

**Unlimited Withdrawals to Meet 140,000 cfs at Lower Granite Dam.** The alternative calling for unlimited withdrawals to meet 140,000 cfs at Lower Granite Dam in May would require unusually low drawdowns during the spring and would essentially empty the reservoir in most years. This level of drawdown would have devastating impacts on the resident fish population. Benthic and planktonic production would be severely reduced. As a result, the availability of prey for resident fish species would be greatly diminished. Introduced lacustrine species would not be expected to spawn under these conditions. In addition, much of the existing rearing habitat for juveniles and adults would be lost. The reduced availability of rearing habitat together with the reduced forage base would likely result in high mortalities of all age groups. Native riverine species might spawn successfully in their normal spawning areas; however, the reduced volume of water and reduced prey availability would probably support fewer fish. Hence, riverine species might have high mortality rates.

Downstream of the reservoir, greatly increased flows in May followed by decreased flows in June would probably result in desiccation of incubating eggs present in the river in June. The increased flows in May could also flush larvae, which hatched in April and May, downstream. Finally, the reduced plankton production in the reservoir would also result in reduced prey availability in the river below the dam.

### 4.3.4.3 Transfer of Flood Control Storage

Transfer of flood control storage from Dworshak and/or Brownlee reservoirs to Grand Coulee to free up water for flow releases would result in greater than normal drawdowns at Grand Coulee and lesser drawdowns at the other two reservoirs. This alternative would provide a more stable pool level at Dworshak and Brownlee reservoirs, which would significantly reduce impacts of flow releases at those reservoirs and could benefit the fisheries.

Reductions in water surface elevations at Grand Coulee, however, could potentially affect fisheries of that reservoir. An increasing pool is anticipated during the walleye and yellow perch spawning and incubation which should minimize or prevent desiccation of eggs. Previous studies conducted on Lake Roosevelt have indicated that the provision of a constant or rising pool positively affects yellow perch production (Beckman et al., 1985). The proposed drawdown would be similar to that which occurred in 1989. Production of yellow perch was high in 1989 (Peone et al., 1990) suggesting that the proposed drawdown should not have a substantial impact on spawning success of spring spawners provided that an increasing pool is maintained. Decreased water retention time would likely cause zooplankton populations to develop later with some effect on developing young fish.

Stober et al. (1981), Beckman et al. (1985), and Peone et al. (1990) have all documented an increase in zooplankton populations with increasing water surface elevations (which generally correspond to water retention times). Zooplankton abundance, however, is also affected by numerous other factors such as photoperiod, water temperature, and predator density. The interaction of these factors can obscure the relationship between water retention time and zooplankton production. Production in 1989 when retention time was particularly low was higher than that measured in either 1980 or 1982 (Peone et al., 1990), suggesting other factors were controlling overall production. While some level of reduced zooplankton production is likely to occur, the amount is difficult, if not impossible, to predict. Generally, water retention time of less than 30 days in spring is considered to be deleterious to feeding resident fish populations. Water retention time may fall below 30 days for a period of time under this option. Reduced levels of zooplankton would tend to result in reduced feeding success and reduced growth of resident fish.

Little natural spawning of kokanee occurs in Lake Roosevelt which may be related to the decreasing water surface elevations that normally occur throughout the spawning and incubation period. The increased spring drawdown could potentially expose a larger number of redds and result in further reductions in natural reproduction of kokanee in 1992. The decreased water retention time and probable reduction in zooplankton production may substantially affect feeding success of kokanee although previous studies failed to document reduced growth (or zooplankton production) with decreased water elevations. The effect on feeding success may be minimal and insubstantial. The lower water surface elevation may also result in increased entrainment of juvenile kokanee, however, the relationship between entrainment and water surface elevation is unknown at this time.

Increased spring drawdown at Grand Coulee might also affect the net pen operation, causing operators to move their nets and possibly release fish earlier than normal (April versus May/June) (Peone et al., 1990). Because of their smaller size and the greater flows in the reservoir, these fish might be more prone to move downstream and be entrained through the turbines or spill tubes than fish released in May and June (Peone et al., 1990).

## 4.3.5 Temperature Control Release

The up to 20 feet drawdown of Dworshak Reservoir in August associated with the temperature control release will tend to reduce water retention time which will likely affect zooplankton production. Standing crops of zooplankton in the reservoir, however, have been documented at higher levels than required by the existing resident fish populations (Peone, 1990). Hence, reductions in zooplankton production is not expected to significantly affect feeding success of reservoir fish populations.

The drawdown of the reservoir in August will result in a decrease of terrestrial insects present in the reservoir due to the decrease in total shoreline area and the increase in the distance between terrestrial vegetation (a source of insects) and the shoreline. This reduction in the abundance of terrestrial insects will likely affect the foraging success of some fish species including smallmouth bass and rainbow trout.

The drawdown could potentially expose deltas at the mouths of tributaries and disturb upstream migration of kokanee and trout. The elevation of this drawdown, however, will be higher than that proposed for earlier in the season. Sediments accumulated at the mouths of the tributaries since the 1991 summer drawdown are most likely dominated by fines. These sediments are expected to rapidly erode away during the spring drawdown, creating a channel in the delta area. Accumulation of sediments between spring and August is not expected to be great enough to refill these channels. Hence, late summer and fall spawning runs up the tributaries are not expected to be affected by the drawdown.

Normal August temperatures in the Clearwater River below Dworshak Dam range from 16 to 19°C and discharge ranges from approximately 2,000 to 9,000 cfs during the period. During the temperature control release, water temperatures in the Clearwater River will be approximately 9 to 11°C lower than normal in August and flows will increased to approximately 10,000 cfs. The reduction in temperature will result in reduced productivity and reduced growth potential of resident fish during the month of August and could potentially cause temperature shock at the start of the release period. The increased flows are likely to reduce the amount of rearing habitat available, particularly for smaller fish (e.g. juvenile rainbow trout) which will result in increased competition among fish in the river and may result in increased mortality. Fish and fish habitat upstream of Dworshak Dam will not be affected.

Reservoir species in Lower Granite and Little Goose Reservoirs will also be affected by the temperature release. In these reservoirs, summer temperatures often approach critical levels where fish become stressed and may suffer mortality. The temperature control releases will reduce reservoir temperatures and subsequently will reduce temperature stress in the reservoir fish populations.

### 4.3.6 No Action

The no action alternative would result in no change in the resident fish populations.

### 4.3.7 Mitigation

The most significant impacts to resident fish, excepting some flow augmentation effects on Brownlee, occur as a result of the drawdown options for the lower Snake and Columbia Rivers. These actions dewater shallow-water areas and associated wetlands that are essential for resident fish in the Snake and Columbia rivers. Some mitigation actions could be achieved if an active planting program were to coincide with the expected drawdown. However, such actions would not likely be ready to be implemented in 1992. Should the option that calls for a flow of 140,000 cfs in the Snake River be implemented, some of the expected losses of resident fish in Brownlee could be mitigated by developing special harvest regulations. In the longer term, resident fish impacts might be mitigated by a resident fish hatchery restocking program.

## 4.4 TERRESTRIAL ECOLOGY

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown** | |
| ***Snake River*** | |
| All 4 projects to MOP (April 1 to July 31) | • Minimal impacts to (a) aquatic plants and invertebrates; (b) riparian communities; (c) wetlands; and (d) wildlife.<br>• Potential temporary increase in herbaceous vegetation in the drawdown zone. |
| All 4 projects to near spillway crest (April 15 to August 15) | • Substantial loss of aquatic plant and invertebrate communities associated with shallow-water habitat.<br>• Substantial changes to riparian communities; greatest at Lower Granite, Little Goose, and Lower Monumental.<br>• Wetlands would experience severe moisture stress.<br>• Islands used for goose nesting would be land-bridged, increasing predation. Nest platforms used by geese would become useless.<br>• Decrease in prey species upon which raptors depend for food; possible increase in vulnerability of raptor prey species; and possible increase snag abundance in riparian zones.<br>• Adverse impact to upland game birds, big game, furbearers, reptiles, amphibians, small mammals, bats, State and Federally listed species, and others from reduced riparian and wetland habitats. |
| All 4 projects to near spillway crest (April 15 to June 15) | • Similar to spillway drawdown above; decrease in duration/severity. |
| Lower Granite to near spillway crest (February 1993 or July 15 to August 15) | • Identical to near spillway crest drawdown at Lower Granite; decrease in duration and severity; MOP effects at remainder. |
| Lower Granite to 710 feet, others to MOP (April 15 to June 15) | • Effects similar to Lower Granite at spillway, others at MOP. |
| Lower Granite/Little Goose drawdown test (March) | • Impacts to vegetation and wildlife similar to those described for 4-month spillway crest option at Lower Granite and Little Goose pools, but considerably less severe except for nesting waterfowl. |
| ***Lower Columbia*** | |
| All 4 projects to MOP (April 1 to August 31) | • Exposure of over 10,000 acres of shallow-water habitat, most at Umatilla NWR, resulting in significant loss of shallow-water habitat.<br>• Significant impacts to riparian communities at John Day and McNary, and in the Umatilla and McNary NWRs. Significant impacts on wetland development at John Day and McNary.<br>• Impacts to waterfowl nesting and aquatic furbearers are expected to be most significant at John Day. |

Terrestrial Ecology (continued)

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown (continued)** | |
| *Lower Columbia (continued)* John Day at 262.5 feet, McNary at 337 feet, remainder at MOP (April 1 to August 31) | • Impacts to John Day and McNary will be similar, but less severe than those at MOP; MOP impacts at Bonneville and The Dalles are described above. |
| **Flow Augmentation** | • Minimal impacts to vegetation or wildlife expected on Brownlee, Dworshak, Grand Coulee, or downstream pools. |
| **Combination Alternatives** | • Effects additive; see drawdown and augmentation. |
| **Temperature Control Test (August)** | • Minimal impacts to vegetation expected on Dworshak pool. |

Effects to aquatic and riparian vegetation from reservoir drawdown would depend on a number of factors including project length; reservoir topography; duration, timing, and magnitude of drawdown in relation to normal operating conditions; and severity of summer droughts. In general, drawdown effects would be most severe for the Snake River projects at spillway crest and least significant at the storage reservoirs, which already experience extensive drawdowns. Furthermore, drawdown to MOP is not likely to differ from existing conditions for projects where the proposed drawdown is within the lower limits of normal operating conditions.

### 4.4.1 Shallow Water

The composition, nature, and extent of aquatic and invertebrate communities associated with shallow-water habitat throughout the project area are poorly documented. Thus, impacts of pool drawdown to resources cannot be assessed quantitatively. However, these resources are expected to be adversely affected to some degree by pool drawdown. Aquatic plant and invertebrate communities are expected to be most affected by the 4-month spillway crest option on the lower Snake River, and by the MOP option on the lower Columbia River particularly at John Day, which has extensive shallow-water habitat. A net loss is expected to occur in these aquatic plant and invertebrate communities that have become established over long periods under the existing reservoir conditions. Densities of aquatic plants and invertebrates might temporarily increase in newly established, shallow-water areas as a result of pool drawdown. Some shift downward along an elevation gradient for aquatic plants might also occur. However, eventual return to normal pool level would likely prevent establishment of plants in lower elevation zones.

Impacts of the 4-week (March 1 to March 31) drawdown of Lower Granite and Little Goose to spillway crest and near spillway crest, respectively, would be similar but less severe than the 4-month (April 15 to August 15) drawdown of both reservoirs to spillway crest due both to the timing and duration of the drawdown. The 4-week drawdown would occur 1 month earlier in the year than the 4-month drawdown, before the peak in the growing season. Thus, those plants and benthic organisms occupying areas that become exposed with drawdown will likely die, but most will probably re-establish once the pools are returned to normal levels.

Estimates of shallow-water habitat loss under the MOP option are available only for three pools on the lower Columbia River. The greatest changes to shallow-water habitat under the MOP option are anticipated at the John Day Pool; drawdown from maximum pool level to MOP at John Day is expected to expose about 8,400 acres of shallow-water habitat. The majority of this exposed acreage would likely occur at Umatilla NWR. Actual loss of shallow-water habitat caused by MOP drawdown at John Day would likely be significant, but less severe, since estimates were based on loss from full pool level to MOP and John Day is not normally operated at its maximum. Estimates of shallow-water habitat loss were not available for the McNary Pool. However, losses at McNary would be less than at John Day, since the MOP alternative would draw down McNary to within 1 foot of normal pool elevations (338 to 340 feet). Although an estimated 1,400 acres of shallow-water habitat is expected to be exposed in Bonneville Pool and 465 acres at The Dalles Pool under the MOP alternative, shallow-water habitat loss at these pools should be relatively insignificant. In addition to the lack of shallow-water habitat at these pools, neither pool normally operates at maximum pool level and both normally operate within a couple of feet from MOP (see Table 2-3).

The proposed drawdowns of Brownlee, Dworshak, and Lake Roosevelt pools and the 20-day drawdown of Dworshak in August (temperature control test) would have minimal effects on shallow-water habitat, since shallow-water habitat is extremely limited at these pools and the associated aquatic plant and invertebrate communities have developed under widely fluctuating pool levels since the dams were built.

### 4.4.2 Riparian Communities

Detailed information on the distribution and composition of riparian communities along the project reservoirs is limited. Thus, the assessment of impacts to riparian communities from the proposed drawdowns is qualitative. The primary impacts of the proposed drawdowns to riparian communities on the Columbia and Snake rivers would depend largely on the extent, duration, and location of drawdown. Although riparian vegetation associated with the project reservoirs is accustomed to 3- to 5-foot water fluctuations, negative effects are expected since the proposed drawdowns would occur during the growing season. Effects on riparian vegetation would likely be exacerbated during a drought year, when riparian communities would already be under moisture stress; moisture recharge is especially important during the growing season for riparian plants. Species in the riparian zones that would be particularly sensitive to drawdown include shallow rooting plants such as willows, Russian olive, false indigo, white alder, and mulberry. Although data on drought tolerance in these plants are limited, a dramatic removal of soil-water content for more than 30 days, as proposed under the 4-month spillway crest option, is probably the upper limit for most riparian vegetation in the area.

Effects of the 4-month spillway crest option would be considerably more severe than those under the MOP option on the lower Snake River reservoirs, since spillway crest water levels deviate dramatically from normal operating pool levels. Drawdowns to spillway crest on the lower Snake River could range from up to 49 feet at Ice Harbor to 57 feet on Lower Monumental, Little Goose, and Lower Granite reservoirs. Riparian communities associated with these pools would therefore experience significant losses due to drawdowns of this duration and magnitude. Impacts of the 4-week drawdown of Lower Granite and Little Goose to spillway crest and near spillway crest (respectively), however, are expected to be minimal because the drawdown would be relatively short in duration and would occur before the peak in the growing season.

Among the lower Snake and lower Columbia reservoirs, effects on riparian communities under the MOP option would be most significant at John Day. This project has extensive backwater areas, and riparian vegetation is considerably more abundant than at any of the other project reservoirs. Effects of the MOP option would extend into the Umatilla NWR and HMUs, which receive moisture from the reservoir. In contrast, effects of the MOP option and the 20-day drawdown of Dworshak Pool in August to riparian communities on the lower Snake River and the storage reservoirs should be relatively minimal. Development of riparian communities is extremely limited along the shorelines of these reservoirs (especially at the storage reservoirs) and is basically restricted to the relatively limited backwater areas.

### 4.4.3 Wetland

Detailed information on wetland communities is limited for the project area, precluding any quantitative assessment of effects on wetlands at this time. In general, effects of the proposed drawdowns on wetland communities in the project area would likely resemble those already discussed for riparian habitat (see Section 4.4.2).

If wetlands in the project area depend on existing pool levels for sufficient water, then wetland plants associated with the lower Snake River reservoirs would likely show severe signs of moisture stress under the 4-month spillway crest option. Moreover, in some cases they might be replaced entirely by more drought-resistant species. Among the lower Snake reservoirs, effects of spillway crest drawdown would probably be most dramatic at Lower Monumental. This reservoir supports the most extensive wetland communities of any of the lower Snake River projects. Upland plants (primarily annuals) and exotics (primarily purple loosestrife [*Lythrum salicaria*]) might invade newly exposed areas; however, it is unlikely that these plants would become fully established before refill of the reservoirs in the late summer. Invasion of emergent plants (such as cattails and bulrush) into lower elevation zones could also reduce the amount of open-water habitat available for waterfowl use in some areas. Establishment of wetland communities might also occur around backwater areas in the drawdown zone, although backwater areas are relatively limited on the lower Snake reservoirs.

Impacts of the 4-week drawdown of Lower Granite and Little Goose to spillway crest and near spillway crest (respectively), however, are expected to be minimal since the drawdown would be of relatively short duration and would occur before the peak in the growing season.

Similar to effects on riparian communities, effects on wetlands under the MOP option on the lower Snake River reservoirs should be considerably less severe than those under the spillway crest option. Among the lower Snake and lower Columbia River reservoirs, effects of the MOP option are expected to be most severe at the John Day. Extensive wetland areas have developed in associated backwater areas at this pool, particularly in the Patterson and McCormick Slough Units. Effects on wetland areas from the MOP option would extend into the Umatilla NWR and HMUs. Impacts to McNary are not expected to be as severe since drawdown to MOP would vary by only 1 foot from normal operating conditions.

The proposed drawdown of Brownlee, Dworshak, and Lake Roosevelt pools, and the 20-day drawdown of Dworshak Pool would have minimal impacts on wetlands; wetland development at the storage reservoirs is extremely limited, and reservoir levels would generally vary within the range of elevations under existing conditions.

### 4.4.4 Embayments, Ponds, and Associated Tributaries

The primary effects to embayments, ponds, and associated tributaries caused by the proposed drawdowns on the Columbia and Snake rivers would also be largely dependent on the extent and duration of drawdown. As the reservoirs are drawn down, embayments and associated habitats would lose their hydraulic connection to the main channel and begin to dry up. Associated plant communities would also experience moisture stress as discussed above. Some of these effects might be offset by the development of new backwater areas within the drawdown zone. However, the lack of adjacent, established shoreline vegetation coupled with greater exposure to wind would lessen their value to most wildlife currently inhabiting embayment areas.

A dramatic reduction in the number and size of embayments and associated habitats would probably occur under the 4-month spillway crest option. Most of the areas would also likely be affected at MOP and few areas would be impacted under the 4-week drawdown of Lower Granite and Little Goose. Information on the number or extent of embayments that would be affected by reservoir drawdown is currently unknown for the project area. However, it is likely that effects would be greatest under the 4-month spillway crest option on the lower Snake River. Effects of drawdown to MOP for the lower Columbia River projects are expected to be most significant at John Day because of the extensive development of embayments at this site. The proposed drawdown on Brownlee, Dworshak, and Lake Roosevelt pools and the 20-day August drawdown of Dworshak would have minimal impacts to embayments since reservoir levels would generally vary within the range of elevations under existing conditions, and limited embayment development has occurred at the storage reservoirs.

### 4.4.5 Waterfowl

The most significant impacts on terrestrial wildlife as a result of the proposed drawdowns would likely be to island-nesting waterfowl occurring in reservoirs of the Columbia and Snake rivers. Potential negative impacts of increased drawdowns at any of the project reservoirs may include the following:

- a decrease in the quantity of aquatic plant beds and benthic invertebrates as food sources for waterfowl in shallow-water areas;
- a decrease in the number of embayments and protected shallow-water areas for waterfowl nesting, roosting, loafing, feeding, and brood rearing;
- land-bridging of some islands used for goose nesting and increased access of these nest sites by mammalian predators;
- an increase in escape distance between shoreline foraging resources and the water; and
- a decrease in marsh vegetation used for nesting cover by ducks.

In addition, a number of positive effects to waterfowl populations could result from the proposed drawdowns:

- surface area of some islands currently used by geese for nesting might increase without a concomitant land-bridge forming;
- additional islands might be exposed that could be suitable for waterfowl nesting;
- the density and accessibility of invertebrate populations for waterfowl foraging might temporarily increase in certain shallow-water areas; and
- the accessibility of aquatic vegetation for waterfowl foraging may temporarily increase.

The degree of these effects to waterfowl populations would be site-specific and depend largely on the timing, duration, and level of drawdown. Effects of pool drawdown to nesting waterfowl would likely be greatest at John Day, where island-nesting waterfowl are most abundant, and at any of the lower Snake River pools if they were drawn down to spillway crest. Effects to waterfowl from drawdown of Lake Roosevelt, Dworshak Reservoir, and/or Brownlee Reservoir, where nesting geese are less numerous, should be minimal. However, the net effect of the proposed drawdowns cannot be definitely determined without more detailed, site-specific information regarding quantitative impacts on aquatic vegetation and invertebrate prey populations and the extent to which embayments and backwater areas would become desiccated.

Based on existing information, effects to waterfowl from lowering pools on the Columbia and Snake rivers would likely be significant. Drawdown of all four pools on the lower Snake River to spillway crest is expected to land-bridge every island used for goose nesting on this segment of river, increasing the accessibility of these islands to mammalian predators. In addition, all nest platforms used by geese at the four pools on the lower Snake River would likely become useless with drawdown to spillway crest. The increased distance from these platforms to water would likely reduce the potential for platform use by geese. Nest platforms are especially important goose production sites at the Ice Harbor and Lower Monumental pools. Approximately 90 percent and 95 percent of the goose nests on Ice Harbor and Lower Monumental pools, respectively, were located on nest platforms. In contrast, 50 percent and 5 percent of the Canada goose nests at Lower Granite and Little Goose pools, respectively, were located on nest platforms. In addition, cliff-nesting by Canada geese was relatively common on the lower Snake River projects. Drawdowns would increase the distance goslings must travel from these sites to the water, thus increasing their vulnerability to predation.

Drawdowns to spillway crest on the lower Snake River projects are also expected to desiccate all backwater ponds associated with the four lower Snake River pools. These areas are currently used for duck production. Influences of drawdown of the lower Snake River pools is also expected to negatively affect the associated HMUs. The relatively small number of Canada goose nests located in the HMUs are expected to be lost as a result of greater accessibility for mammalian predators if the associated pools are drawn down to spillway crest especially under the 4-month spillway crest drawdown option. Such a drawdown, therefore, could critically reduce the Canada goose production along the entire lower Snake River.

As stated previously, effects of drawdowns to MOP on waterfowl nesting would likely be significant, but less severe than those caused by drawdowns to spillway crest. On the lower Snake River, six nest islands at Lower Granite and two islands each at Ice Harbor, Little Goose, and Lower Monumental are considered vulnerable to land-bridging at MOP. In April 1991, a 2-week drawdown to MOP near Rufus, Oregon, resulted in 8 depredated nests on islands used for nesting by Canada geese.

It is expected that drawdown to MOP would result in the loss of up to 44 goose nests on Rufus Island and 50 nests on Three-Mile Island due primarily to predation effects. Chief Timothy Island on Lower Granite and New York Island, the primary goose production sites on the lower Snake River, however, are not expected to become land-bridged because of drawdown to MOP. Drawdown of McNary Pool to 337 feet is expected to land-bridge three islands used for Canada goose nesting. However, detailed water-depth information in the vicinity of the nest islands is necessary to accurately determine the potential for land-bridging of individual nest islands as a result of drawdown.

Effects of drawdowns to brood-rearing areas for Canada geese in the project areas are less clear. In areas where waterfowl and their broods are dependent upon shoreline forage resources, escape distance from these feeding sites to the water would increase and may result in greater mammalian predation. On the lower Snake River, drawdown to spillway crest is expected to increase the distance from shoreline vegetation to water by approximately 65 to 140 feet at Ice Harbor, Lower Monumental, Little Goose, and Lower Granite pools. Effects on distances between shoreline vegetation and water caused by drawdown to MOP would still be significant; these distances are expected to increase by approximately 20 feet.

Abundance and distribution of aquatic plant and benthic invertebrate communities near shore and in embayments are expected to shift in response to the proposed drawdowns. These communities would become desiccated in some areas; however, in other areas, these resources may become more concentrated and closer to the surface, resulting in temporary increase in availability to waterfowl. Consequently, concentrations of foraging waterfowl that use these resources may also shift. Both short- and long-term quantitative effects on the aquatic plant and benthic invertebrates communities, however, cannot be determined without site-specific information describing their distribution and abundance in the project area.

Effects to wintering Canada geese in the project area are expected to be negligible because winter wheat crops, which are not irrigated, should still be capable of supporting geese after drawdown. Similarly, impacts to wintering ducks are expected to be minimal, provided that irrigated crops are not significantly affected by the proposed drawdowns. Loss of irrigated crops, especially corn, would increase the severity of impacts, particularly to overwintering ducks.

### 4.4.6 Raptors

Negative effects to raptors caused by the proposed drawdowns on the Columbia and Snake rivers would depend primarily on: (1) loss of riparian habitat, embayments, and wetland habitat along affected reservoirs, and (2) reductions in prey densities associated with these habitat losses. In addition, some benefits to raptors may occur including: (1) an increase in distance prey species would have to travel from water to cover, (2) higher concentrations of prey (primarily fish) within remaining shallow-water areas, and (3) increased number of snags within the riparian zone. Although some inferences can be made based on anticipated changes in habitat, the net effect of these changes cannot be determined without more detailed information regarding: (1) abundance, distribution, and dependencies of various prey and raptor species on riparian and wetland communities, and (2) impacts of reservoir drawdown on riparian, wetland, and embayment areas in the drawdown zone.

Riparian, wetland, and embayment areas that become desiccated because of reservoir drawdown would influence local distribution and abundance of prey, particularly small mammals, fish (see Sections 4.2 and 4.3), and songbirds. Raptors dependent on these prey species may show concomitant shifts in population numbers and distribution. However, this effect may be partially offset by increases in distance between the water's edge and escape cover expected from drawdown, which could increase raptor prey captures as well. In addition, fish might become concentrated in portions of the remaining channel following drawdown, providing piscivorous raptors (bald eagles and ospreys) with additional foraging opportunities. However, the benefit to fish-eating raptors might be temporary because of overall reductions anticipated in resident fish populations due to drawdowns (see Section 4.3).

Under the 4-month spillway crest option, any desiccation of large trees within the river corridor might initially provide additional perch and nest opportunities for raptors, because tree death would contribute to snag recruitment rates. However, such tree death would be greatly limited if reservoirs are returned to normal pool levels in August and if drawdowns are not repeated the following year.

The degree of these effects to raptor populations would be site-specific and depend largely on the level of drawdown. Effects of pool drawdown would likely be greatest for the lower Snake River projects under the 4-month spillway crest option, because a drawdown of this duration and magnitude would substantially alter riparian, wetland, and embayment areas on which many prey species are dependent. Impacts to raptors from drawdown of the Lake Roosevelt, Dworshak, and Brownlee reservoirs and the 4-week drawdown of Lower Granite and Little Goose pools are expected to be minimal since impacts to their nesting habitat and prey species are expected to be minimal.

### 4.4.7 Upland Game Birds

Effects of the proposed drawdowns on upland gamebird populations would be largely dictated by the following: (1) changes in riparian vegetation along the affected reservoirs, and (2) increased distance between vegetated shorelines and the pool edge. The expected loss of riparian habitat caused by the proposed drawdowns would negatively affect those upland gamebird populations that are either partially or totally dependent on these riparian areas for their existence. The severity of these impacts, however, would depend somewhat upon the amount of rainfall during 1992. Wildlife that depend on riparian vegetation for nesting cover and winter food (e.g., wild turkey, ring-necked pheasant) would probably be more affected by drawdown than those that use riparian areas secondarily (e.g., chukar). However, even species that use riparian habitat secondarily might suffer increased losses to predation because of the need to travel greater distances from hiding/escape cover to reach drinking water. This is especially important during dry summer periods. In addition, loss of embayments along the lower Columbia River as a result of drawdown might result in more birds having to cross Interstate 84 at the John Day Pool to reach water on the other side. This would undoubtedly increase the number of road-killed upland gamebirds near John Day.

Four-month drawdown to spillway crest on the lower Snake River would have considerably more dramatic impacts on upland gamebird populations than the proposed 4-week drawdown to spillway crest or drawdown to MOP. Elevation changes at the Brownlee, Dworshak, and Lake Roosevelt pools from flow augmentation or temperature control releases (at Dworshak) would have minimal impacts on upland gamebird populations and would likely be restricted to those birds nesting on the narrow band of riparian vegetation that would be desiccated during the spring. Specific losses to upland gamebirds, however, are difficult to assess without more complete information regarding the composition, abundance, and distribution of species inhabiting riparian areas that would potentially be affected along the Columbia, Snake, and Clearwater rivers.

### 4.4.8 Furbearers

Negative impacts of the proposed drawdowns on furbearers would primarily include the following: (1) exposure of muskrat and beaver dens during the spring and summer when kits are present, (2) reduction in riparian areas used by foraging beavers, (3) reduction in wetlands used by muskrats, and (4) exposure of riprap used by otters as den sites. Impacts to mink and river otter might also occur if embayments and associated tributaries and ponds become desiccated. However, these losses might be partially offset if ponding occurs within the drawdown zone.

Losses to riparian, wetland, and embayment areas on which furbearers depend would be most significant on the lower Snake River if projects are drawn down to spillway crest for 4 months. Effects of drawdowns to MOP would likely have the most significant impact at John Day since this pool has the most extensive embayments and ponds. Drawdowns at Lake Roosevelt, Brownlee, and/or Dworshak are not likely to affect aquatic furbearers, since pool levels would generally vary within the range of elevations under existing conditions.

### 4.4.9 Big Game

Primary effects to big game would likely include the following: (1) reduction in riparian habitat and embayments that provide foraging and wintering areas for deer; (2) increase in distance from water's edge to cover; (3) increase in land bridges; and (4) increase in road kills. An increase in the distance to cover might decrease deer productivity because of higher predation losses. Desiccation of watering areas during the summer could also be particularly damaging to deer productivity because of potentially high losses to fawns. Drawdown, which results in loss of embayments or other water sources, might increase road kills as deer cross highways in search of replacement watering areas. This effect is most likely to occur on the Oregon side of Interstate 84 where the highway is closest to the river.

Reservoir drawdown to spillway crest for 4 months on the Snake River is likely to impact big game. Under this alternative, embayments and riparian areas would be greatly affected, resulting in a reduction in deer foraging and wintering areas. As the quality of deer range declines, deer productivity levels are expected to decrease along the Snake River. Along the Columbia River, minimal impacts to big game are expected at MOP since few deer occur in riparian habitats adjacent to the river. The highways and railroads abutting the river serve as barriers to big game and also fragment the existing habitat. Losses to riparian areas would, therefore, probably be minor since habitat fragmentation caused by highway and railroads is probably limiting deer use in this area.

It is also anticipated that deer losses due to drawdown of Dworshak, Lake Roosevelt, and Brownlee pools and the 4-week drawdown of Lower Granite and Little Goose pools would be minimal since the storage reservoirs would deviate only slightly from existing conditions and the 4-week drawdown is relatively short.

### 4.4.10 Other Wildlife

Information on site-specific impacts to the large number of wildlife species occurring in the project area is currently unavailable. However, some general inferences can be made based on predicted changes in habitat.

Concomitant changes in wildlife communities associated with the project reservoirs are likely to occur in response to habitat changes induced by reservoir drawdown. Species directly dependent on riparian and wetland communities and shallow-water areas for food, water, and cover would likely experience local population declines. This could potentially include up to 65 vertebrate species that depend on riparian habitat (see Lewke and Buss, 1977) including numerous reptiles, amphibians, small mammals, bats, colonial nesting birds, and songbirds. Colonial nesting birds might be affected if islands used for nesting become land-bridged or if trees used for nesting die. Drawdown might also expose substantial mudflats that might significantly affect freshwater clams, but could also provide additional foraging and nesting opportunities for shorebirds. Moreover, if fish are concentrated in the remaining channel within the drawdown, several piscivorous species might benefit. These species include belted kingfisher (*Ceryle alcyon*), herons, mergansers, mink, and river otter.

The degree of these impacts to wildlife communities would be site-specific and depend largely on the timing, duration, and level of reservoir drawdown. Consequently, it is anticipated the 4-month spillway crest option proposed for the lower Snake River and drawdown to MOP on John Day would have the greatest impacts on wildlife associated with riparian and wetland communities. Impacts to wildlife from drawdown of Lake Roosevelt and Dworshak and Brownlee reservoirs and the 4-week drawdown of Lower Granite and Little Goose are expected to be minimal.

### 4.4.11 Threatened and Endangered Species

#### 4.4.11.1 Peregrine Falcon

Peregrine falcons not associated with nest sites along the Lower Columbia would likely not be affected by the proposed pool lowerings; use of regions of the project area outside of Bonneville and The Dalles by peregrines appears to be low. Nesting peregrines using the Bonneville and The Dalles pools are also not expected to be affected by drawdown since drawdown to MOP is not likely to significantly alter wetlands or riparian areas on which associated prey species depend (see Sections 4.4.2 and 4.4.3). Thus, based on existing information, none of the proposed flow options is likely to affect peregrine falcon use of the project reservoirs.

#### 4.4.11.2 Bald Eagle

Bald eagles using the project area might be affected by the proposed pool lowerings if one or more of the following occurs:

- nesting bald eagle food sources (primarily fish and waterfowl) are significantly affected on the Bonneville Pool or Lake Roosevelt during the nesting season (mid-February through August);
- wintering bald eagle food sources (primarily waterfowl and upland gamebirds) are significantly affected in the project area between November and April; and
- occurrence of potential perching, roosting, or nesting trees in, the project area (primarily cottonwoods and Ponderosa pines) is significantly affected.

Temporarily lowering water levels at any of the project pools has the potential to both positively and negatively affect bald eagles using the Columbia, Snake, and Clearwater rivers. Bald eagles could benefit from pool drawdowns in the following ways:

- more adult fish might eventually return to the project area for spawning (see Section 4.2), providing more potential food for bald eagles foraging along the Columbia, Snake, and Clearwater rivers in the future;
- more fish could become stranded or concentrated in resultant shallow-water areas, thus temporarily increasing their availability to bald eagles (see Section 4.3);
- more nesting waterfowl might become vulnerable to predation during 1992 as a result of loss of nesting and escape cover caused by temporary drought and/or an increase in distance between shoreline escape cover and water's edge (see Section 4.4.5); and
- more large snags might become available for bald eagle perching and roosting as a result of project-related desiccation.

Likewise, the proposed pool lowering could negatively affect bald eagles inhabiting the Columbia, Snake, and Clearwater rivers in the following ways:

- overall numbers of resident fish might decline because reductions in shallow-water habitat at spillway crest (see Section 4.3);
- a decrease in 1992 waterfowl production might occur (see Section 4.4.5), thus decreasing bald eagle foraging opportunities;
- a decrease in waterfowl wintering in the project area might occur (see Section 4.4.5), thus decreasing winter food sources for bald eagles;
- a decrease in upland gamebirds might occur (see Section 4.4.7), thus decreasing bald eagle foraging opportunities; and
- a decrease in the recruitment of potential perching, roosting, or nesting trees because of project-related desiccation.

The extent to which these potential impacts might affect bald eagles would depend largely on the location, time of year, timing, and degree of pool lowering. Potential effects on bald eagles would be greatest where they are most concentrated and the degree of pool lowering is relatively high, and least significant where eagles are uncommon and pool lowering is minimal. Although nesting bald eagles occur only on Lake Roosevelt and Bonneville Reservoir, and wintering eagles are concentrated on Lake Roosevelt and Brownlee and Dworshak reservoirs, impacts of pool drawdown to the surrounding environment at these reservoirs are expected to be minimal (see Section 4.4). Impacts of lowering pools on the lower Snake River to spillway crest would be considerably greater to the surrounding environment than lowering the pools to MOP; however, bald eagle use of the lower Snake River is basically restricted to the winter and appears to be minimal. Although a more detailed assessment of the effects on bald eagles is not possible at this time, none of the proposed flow options is expected to affect bald eagle use of the project reservoirs. Site-specific information is needed regarding the abundance and distribution of waterfowl and upland gamebird species in the project area, and the impacts of pool lowering to waterfowl food supplies; waterfowl and upland gamebird nesting and escape cover; land-bridging of waterfowl nest islands; and bald eagle nest, roost, and perch trees.

### 4.4.12 State-Listed and Candidate Species

Site-specific impacts to the large number of state-listed and candidate species potentially occurring in the project area cannot be determined at this time without further study of local abundances, specific habitat associations, and species-specific responses to reservoir drawdown. However, some general inferences can be made based on predicted changes in habitat caused by reservoir drawdown under the different options.

Each of the listed plant species in the project area typically occurs in moist areas that have established under moisture recharge from existing reservoir conditions. Reservoir drawdown to spillway crest would at least temporarily eliminate many of these plants along the lower Snake River. It is also possible that some of the more vulnerable listed plants could be replaced by colonizing species (e.g., purple loosestrife) that are typical of disturbed areas. This may be especially important on the lower Snake River where grazing impacts have resulted in plant communities dominated by weedy species (see Tabor, 1976; Lewke and Buss, 1977). Drawdown to MOP on the lower Columbia and lower Snake rivers and drawdown of the storage reservoirs, however, would likely have only minor impacts to listed plants since both alternatives would deviate only slightly from existing reservoir conditions. Listed plant species might show signs of moisture stress particularly if drawdown occurs from April 15 to August 31 as proposed for the lower Columbia River projects. This might be especially important at the John Day and McNary pools where riparian and wetland areas that potentially support listed plants are most extensive. However, the MOP option is not expected to cause widespread shifts in vegetation communities that support listed plant species (see Section 4.4.2 and 4.4.3).

Response of listed wildlife to drawdowns would likely depend on site-specific changes in essential habitat components associated with the project reservoirs. Species with limited dispersal capabilities (e.g., many herpetofauna and insects) would be especially vulnerable to drawdown and would, therefore, at least temporarily experience local population declines due to potential reductions in breeding success and loss of habitat. Other wildlife could potentially experience impacts through loss of habitat or prey species associated with wetlands and riparian areas. This might be especially important for insectivorous species such as bats and martins and species dependent on the narrow fringe of riparian vegetation associated with the project reservoirs such as various herpetofauna and herons. Listed species associated with backwater areas such as herons, turtles, frogs, and ducks would also likely experience local population declines if backwater areas become desiccated. In contrast, some listed wildlife might temporarily benefit from changes in habitat that increase vulnerability of prey species (e.g., see raptor section) or from greater exposure of mudflats along shoreline areas (e.g., shorebirds).

As with other wildlife species in the project area, the severity of the above impacts to listed wildlife would depend on duration, timing, and extent of reservoir drawdown. Since the spillway crest alternative would likely have the most significant impacts to wetlands, riparian areas, embayments, and shallow-water habitats, listed wildlife species associated with these areas would probably at least temporarily experience local population declines. Drawdown to MOP on the lower Columbia or Snake river and drawdown of the storage reservoirs would likely have only minor impacts to listed wildlife because reservoir conditions would deviate only slightly from existing conditions.

### 4.4.13 Cumulative Impacts

Reservoir drawdown would likely contribute to cumulative impacts on terrestrial resources of the lower Columbia, lower Snake, and Clearwater rivers. Since the projects were built, riparian and wetland habitats have declined on regional and local levels primarily because of agriculture and urban expansion, hydroelectric development, and timber harvest (see Lewke and Buss, 1977; Swift, 1984; Kauffman, 1988). Habitat loss is the primary cumulative impact for most plant and wildlife species in the project area.

Reservoir drawdown would also likely increase livestock damage to riparian habitat, which has already been extensive throughout the Snake Columbia River Basin (see Lewke and Buss, 1977). Exposed shorelines would allow livestock access to HMUs that are currently fenced to prevent livestock damage under existing reservoir conditions.

Additional cumulative impacts caused by reservoir drawdown would include riparian and wetland losses associated with increased dredging for navigation and disposal of dredge materials, blasting of rocks to provide navigable waterways, and dredging to access causeways for irrigation pumps associated with the HMUs. It is likely that these impacts would be greater under the spillway crest option on the lower Snake River.

### 4.4.14 Summary

Impacts to aquatic and riparian vegetation and associated wildlife groups from reservoir drawdown would be most severe under the 4-month spillway crest option on the lower Snake River. The 4-week drawdown of Lower Granite and Little Goose reservoirs is expected to have considerably less severe impacts to wildlife and vegetation than the 4-month spillway crest drawdown, except for island-nesting waterfowl. Drawdown to MOP would be less dramatic than the 4-month spillway crest option, although considerable impacts would also occur at John Day where extensive shallow-water habitats and riparian vegetation have developed. Drawdown of the storage reservoirs is not expected to significantly affect vegetation and wildlife communities because the proposed drawdown would deviate only slightly from normal operating conditions.

Losses to wildlife habitat under the various options would include temporary reductions in shallow-water, riparian, and wetland habitats; embayments; and designated habitat management areas, including several wildlife refuges and HMUs that depend on moisture received from the project reservoirs. Numerous associated plants and wildlife, including state and federally listed species, have established in these areas over prolonged periods of reservoir operation. Loss of habitat for these species would be most significant under the 4-month spillway crest option. The most substantial impacts to wildlife, however, would include land-bridging goose nesting islands and reducing aquatic plant and benthic invertebrate food sources for waterfowl on the lower Snake River under the spillway crest option and at John Day at MOP. Associated mitigation for these losses and losses to HMUs would be greatest under this alternative. The proposed flow modifications would likely contribute to cumulative impacts on terrestrial resources of the lower Columbia, lower Snake, and Clearwater rivers. Since the projects were built, riparian and wetland habitats have declined primarily because of agriculture and urban expansion, hydroelectric development, and timber harvest. The proposed flow modifications would add to these impacts as stated above and would likely contribute additional losses as a result of increased dredging to keep waterways navigable.

Beneficial impacts are also anticipated from the proposed flow options and include temporary increases in foraging areas for shorebirds, temporary concentrations of raptor prey and waterfowl food sources into remaining shallow-water areas, and localized increases in snag densities along shoreline areas.

### 4.4.15 Mitigation

Extensive documentation, research, and monitoring have been conducted to determine the original habitat losses from construction of the project reservoirs. It is anticipated that under each of the reservoir drawdown options, additional monitoring and further research would be required to fully assess impacts and determine appropriate mitigation requirements for losses to shallow-water habitat, wetlands, embayments, riparian areas, and HMUs. Mitigation for habitat losses at HMUs would require, where possible, the use of irrigation pumps and new wells to deliver additional water to affected areas.

Since extensive vegetation has established both along the shoreline and in HMUs and other habitats associated with the reservoirs, replacement would be necessary to preserve wildlife values. Thus, additional mitigation for vegetation losses would have to be developed. Livestock watering corridors would also have to be replaced or eliminated. Additional fencing would also be needed to prevent grazing impacts to exposed areas at HMUs.

Loss of goose nesting areas because of reservoir drawdown would require additional study to document the extent of impacts and need for appropriate mitigation. Planting the exposed mud flats with annual food plants might be an appropriate action for waterfowl and deer, and could provide some aesthetic benefits.

## 4.5 Geology and Soils

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown** | |
| ***Snake River*** | |
| All 4 projects to MOP (April 1 to July 31) | • Slight increase in slope movement rates.<br>• Minimal shoreline erosion of beaches, recreation facilities, roads, and railroad grades. |
| All 4 projects to near spillway crest (April 15 to August 15) | • Increased beach erosion.<br>• Exposure of substantial portion of unprotected railroad and highway embankment.<br>• Wave erosion would likely affect dam embankments. |
| All 4 projects to near spillway crest (April 15 to June 15) | • Similar to near spillway crest drawdown but with decrease in duration. |
| Lower Granite to near spillway crest (February 1993 or July 15 to August 15) | • Effects proportional to near spillway and MOP alternatives noted above. |
| Lower Granite to 710 feet, others to MOP (April 15 to June 15) | • Effects proportional to near spillway and MOP alternatives noted above. |
| Lower Granite/Little Goose drawdown test (March) | • Same as spillway effects for Lower Granite and Little Goose but lesser potential because of reduced duration. |
| ***Lower Columbia*** | |
| All 4 projects to MOP (April 1 to August 31) | • Slight increase in slope movement rates.<br>• Minimal shoreline erosion of beaches, recreation facilities, roads, and railroad grades. |
| John Day at 262.5 feet, McNary at 337 feet, remainder at MOP (April 1 to August 31) | • Effects similar to MOP for The Dalles and Bonneville, minimal for John Day, McNary. |
| **Flow Augmentation** | • Increase in erosion and sedimentation.<br>• Variability among options. |
| **Combination** | • Effects additive; see drawdown and augmentation. |
| **Temperature Control Test (August)** | • No significant impacts because drawdown and discharge are within normal operating ranges. |

Reservoir drawdown and increased flow velocities would affect shorelines by decreasing slope stability and by increasing beach and river erosion. These processes would redistribute coarser sediment within the reservoirs while much of the fine sediment would pass through them. Railway and highway embankments would also be affected by wave erosion.

### 4.5.1 Slope Stability

Lowering reservoir levels lowers the factor of safety for slope stability (Lawson, 1985). This lower safety factor occurs because the slope load factor is increased by the increased slope height and the additional groundwater weight. When reservoir levels are lowered, groundwater from exposed materials begins to drain out of bedrock and surficial sediments. This groundwater drainage increases pore water pressure within the materials and seepage pressure where it exits from the deposit. The increased water pressures decrease slope stability. Regionally, soil moisture is highest in April, at the beginning of the drawdown period, from winter storms, spring snowmelt, and water draining into the bedrock and sediments during high reservoir levels.

Slope instability can be reduced by lowering reservoir levels at a rate that does not greatly exceed the groundwater drainage rate (Lawson, 1985). The estimated maximum tolerable drawdown rate is 2 feet per day in the Columbia-Snake River reservoirs. Renewed wave erosion also occurs at new pool levels which locally increases the slope angle and reduces the factor of safety (Lawson, 1985). Slope stability under the proposed two-reservoir drawdown would be locally reduced, but not markedly reduced overall. The levees at Lewiston and the dam embankments should be monitored carefully during these tests.

Fluctuating reservoir levels would result in increased movement of active landslides. Major active landslide problems are not reported at the Snake River projects (Miklancic, 1989c, 1989d, 1989e, 1989f), so substantial landslide activity is not expected. Numerous landslides are reported up- and downstream of Grand Coulee; however, an extensive stabilization program has been implemented (Hansen, 1989) and a large increase in movement is not expected. Lake Bonneville also has extensive landslides and two of these continue to move (Sagar, 1989a). Based on observations from 1960 to 1970 at Collins Point, a lobe of one landslide continues to move at a maximum rate of 1.5 feet per year (Sagar, 1989a). This movement, however, is correlated with precipitation and seems unaffected by fluctuations in pool levels (Sagar, 1989a). At Lake Celilo and Lake Umatilla, there are several slope failures whose movement might be increased at low reservoir levels. Overall, slope movement rates and slumping would increase slightly in all reservoirs on a small, localized basis. Dworshak and Brownlee reservoirs, however, are operated as storage reservoirs and experience wide elevational fluctuations every year. Consequently, they would not experience increased mass movement rates.

### 4.5.2 Beach Erosion

As waves affect a shoreline over time, the shoreline progressively becomes adjusted to the available wave energy. These shorelines develop equilibrium beaches that are minimally affected by wave energy (Lawson, 1985). Previously, the reservoirs have been operated at MOP for minimal periods and have not been operated below MOP, so equilibrium beaches are not developed at these low elevations. Consequently, beach erosion along shorelines would increase as waves attack these lower level positions.

MOP levels are generally 3 to 5 feet below full pool. The reservoirs have riprap protection down to MOP, in most locations where wave erosion has been a problem. Therefore, at MOP, shoreline erosion of beaches, recreation facilities, roads, and railroad grades would be minimal. Spillway elevations, however, are up to 50 feet lower in elevation than MOP.

Waves would have little impact on bedrock-dominated areas and there would be minimal to no wave erosion at these sites. Areas dominated by surficial sediments, however, would have no beach profiles developed and would experience accelerated erosion. This erosion would move sediment into deeper water. Beach erosion would also create steep slopes that would have the potential to produce small-scale mass movement.

At recreational facilities, roadways, and railway grades that are developed on surficial sediments, beach erosion might cause undercutting and local collapse of the structures if these surficial sediments are exposed. Dworshak and Brownlee reservoirs currently experience wide elevational fluctuations, so beach erosion rates would not increase.

### 4.5.3 Soil and Streambank Erosion

Reservoir drawdown would expose shoreline areas and areas of the normally drowned river channel, immediately downstream of the lower Snake River dams. Soil erosion results when rainfall exceeds the infiltration capacity of a soil, resulting in water flow over the soil's surface. This surface flow, along with raindrop impact, detaches soil particles and transports them to stream channels and then into the reservoir. Soil erosion is minimized by the high infiltration capacities of coarse-grained sediments, by vegetation cover, and by low rainfall. The exposed materials would be dominated by gravel or sand with a high infiltration capacity. They would have no vegetation cover to minimize overland flow velocity. Rainfall will be highest in April and May and minimal during the June through August period.

During free-flow conditions (with reservoir drawn down near spillway crest), sediments in the upper part of each Snake River reservoir would be exposed. The rivers would experience normal streamflow along these exposed reaches. The amount of soil erosion under the proposed two-reservoir drawdown will depend on the amount of rainfall that occurs during the drawdown tests. The lower Columbia River reservoirs would not be below MOP under any proposed actions and would not create free-flowing river reaches. With normal river flow, the environment in the exposed reaches would change from depositional to normal river sediment transport as the lower pool elevation displaces the reservoir downstream. The exposed sediment would be eroded from the riverbanks and the river bed and transported downstream until it enters the lower pool elevation of the reservoir. Tributaries that enter the reservoirs have also deposited sediment either as alluvial fans or as bottom sediments in drowned embayments. Reservoir drawdown would cause these tributary creeks and rivers to erode through their own deposits in order to reach the lower reservoir level. During drawdown, erosion into sediments deposited previously by the Columbia, Snake, Tucannon, and Asotin rivers might produce braided stream patterns. These braided segments would have sufficient water discharge and depth so that fish passage would not be affected.

In the lower Snake River reservoirs, maximum drawdown would expose between 6 and 11 miles of river. With flow augmentation, discharges in these channels would be between 20,000 cfs and 140,000 cfs, which would be sufficient to erode and transport available gravels, sands, and finer materials downstream to the reservoir. Gravels and sands would settle to the bottom of the reservoir. Water velocities through the reservoirs would vary between 0.6 to 1.25 feet per second (fps). These velocities are sufficient to keep most silts and clays in suspension and to transport them through the reservoir. The deposited gravels and sands would be drowned by subsequent reservoir rise. The streams draining into tributary alluvial fans would similarly erode and redistribute the heavy sediments to the lower reservoir levels. These materials would also be drowned by reservoir rise to normal operating levels. This redistribution might deepen some channels and locally alleviate the need for dredging.

During free-flow conditions, some channel erosion would occur in the exposed reaches. At these sites any utilities that cross the reservoir could be exposed or damaged. Sewer, natural gas, and water lines could be affected at Lewiston. Under the two-reservoir drawdown, bank erosion might occur locally depending on wind conditions. If no major storms occur, it should be minor except at the most unstable sites.

### 4.5.4 Sedimentation

Sedimentation, or particle settling, occurs when water velocity falls below that necessary to keep the particle rolling along the bottom or in suspension. Sediment is transported by the mainstem rivers, tributaries, and by wave action. The sediment load delivered to the reservoirs is high as shown in Table 4.5-1. Gravels and sand cannot bypass dams and are trapped within each reservoir. Silt and clay can bypass dams and only small percentages are trapped in quiet water areas of each reservoir.

The remobilization of sediment downstream from the Snake River dams and from tributary alluvial fans and embayments would result in sediment

**Table 4.5-1.** Sediment delivery in the Columbia River Basin.

| | Suspended Load | | Total Load | |
|---|---|---|---|---|
| Location | Acre feet/year | Tons/year | Acre-feet/Year | Tons/Year |
| Lower Columbia River | 3,609 | 5,501,761[a/] | | |
| | 8,988 | 13,702,500[b/] | | |
| | 15,156 | 23,107,394[a/] | | |
| Walla Walla River/ McNary Dam | 7,674 | 11,700,000[c/] | | |
| Yakima River | 184 | 280,000[d/] | | |
| Snake River/ Lower Granite Dam | | | 1,535 | 2,340,000[e/] |
| Palouse River | 1,036 | 1,580,000[f/] | | |

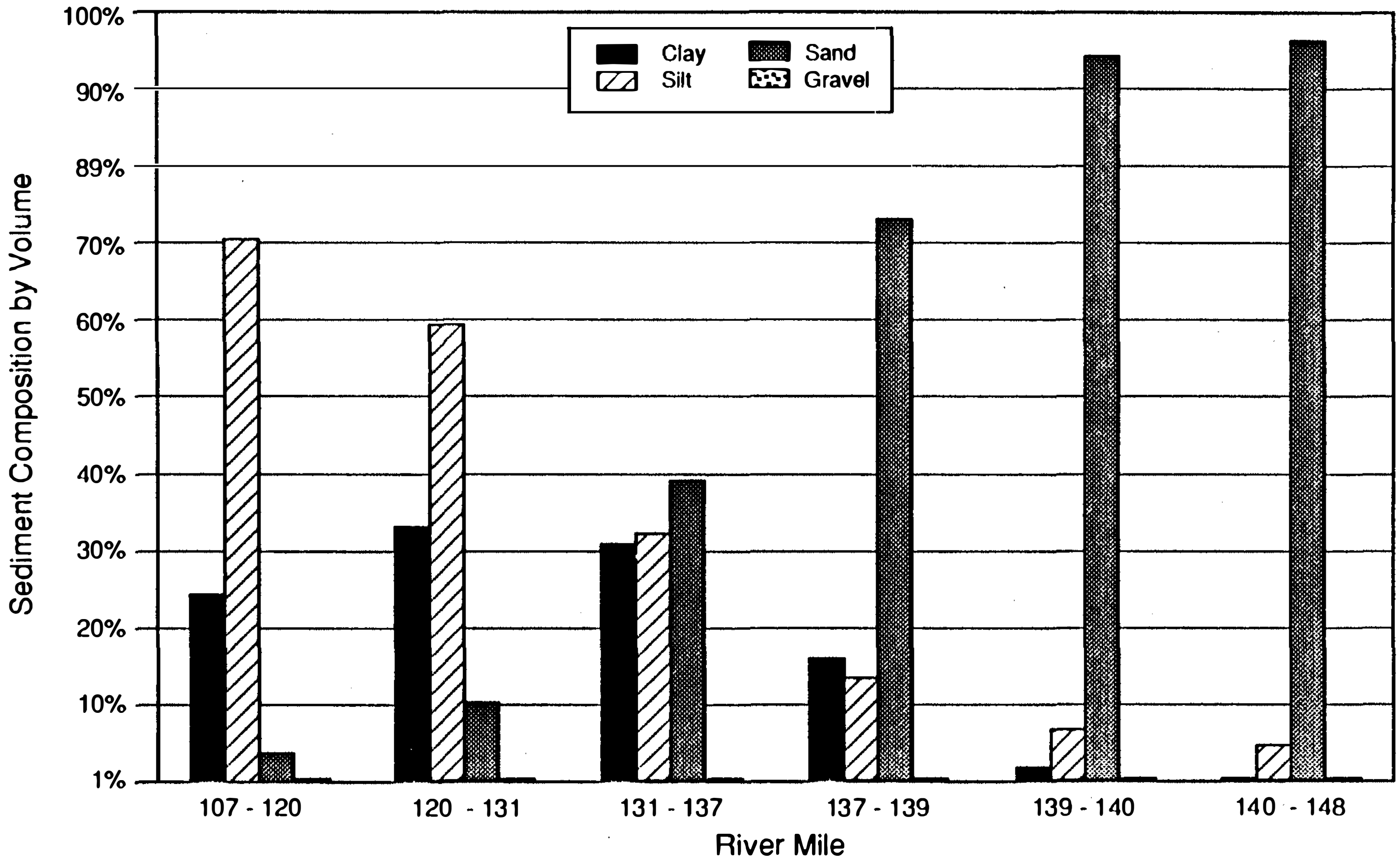
a/ Sternberg, 1986
b/ Corps, 1962
c/ Mapes, 1969
d/ Nelson, 1974
e/ USGS, 1980
f/ Boucher, 1970

erosion, transport, and sedimentation. The majority of this sediment would have already been part of the reservoir bottom and most of it would be drowned by subsequent reservoir rise. There would also be increased rates of landslide activity, beach erosion, and soil erosion that would slightly increase sedimentation rates. Gravels, sands, and some silt would settle out in the reservoir. Most of this sediment would be deposited in deeper water where it would not affect flood height or navigation (Corps, 1987). Some embayments would experience slightly increased sedimentation rates. Decreased reservoir travel times, however, would increase the amounts of silts and clays that would pass through the reservoirs during drawdown and flow augmentation. This results in a loss of nutrients from the system.

The Lower Granite Reservoir is discussed here as an example of the types of sedimentation impacts that could be expected during reservoir drawdown. Drawdown to MOP exposes about 220 acres of reservoir shoreline. Drawdown to the spillway exposes about 2,700 acres.

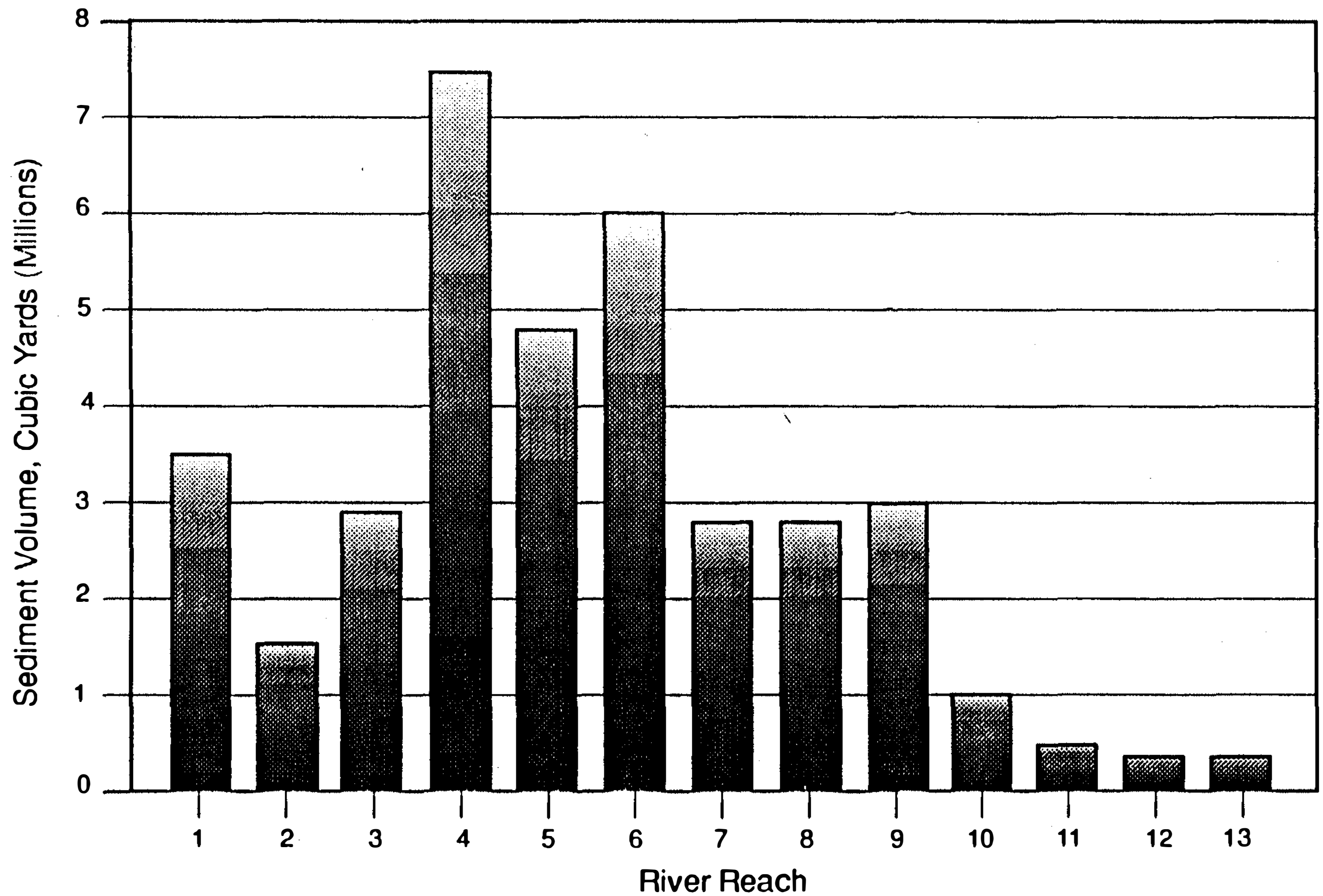
The Lower Granite Reservoir traps about 85 percent of the incoming upstream sediment supply which averages 2.3 million tons per year (Table 4.5-1). Sediment in the upper reservoir consists primarily of sand (Figure 4.5-1) while silts and clays dominate farther down the reservoir. The greatest volume of sediment is stored in reaches 4 through 6 (Figure 4.5-2) which are predominantly silt (Figure 4.5-1). Typically the thickest sediment deposits are toward the centerline of the reservoir with the sediment depth tapering towards the reservoir margins. In the active drawdown, portions of the upper reservoir, native materials, and sediment deposited during full pool are eroded and redistributed deeper in the reservoir.

Historical reservoir operations, with drawdowns to MOP at elevation 733, promote movement of sediment from reaches 10 through 13 to farther down the reservoir. With drawdowns to the spillway elevation 681, the sandy delta deposits in reaches 8 through 13 would be eroded further down the reservoir by free-flowing river conditions. A total of about 10.5 million tons of sediment, primarily sand (Figure 4.5-1), would be redistributed from reaches 8 through 13 to reaches




Reach 1, 2, 3 and 4 are RM 107.43 to 120.46
Reach 5 and 6 are RM 120.46 to 130.93
Reach 7 and 8 are RM 130.93 to 137.17
Reach 10 is RM 137.17 to 139.29
Reach 11 is RM 139.29 to 140.51
Reach 12 and 13 are RM 140.51 to 148.83

**Figure 4.5-1.** Bed material composition of the Snake River.




Reach 1 is RM 107.43 to 110.50
Reach 2 is RM 110.50 to 111.70
Reach 3 is RM 111.70 to 115.70
Reach 4 is RM 115.70 to 120.46
Reach 5 is RM 120.46 to 126.07
Reach 6 is RM 126.07 to 130.93
Reach 7 is RM 130.93 to 134.58
Reach 8 is RM 134.58 to 137.17
Reach 9 is RM 137.17 to 138.94
Reach 10 is RM 138.94 to 139.43
Reach 11 is RM 139.43 to 141.21
Reach 12 is RM 141.21 to 143.69
Reach 13 is RM 143.69 to 146.87

**Figure 4.5-2.** Volume of sediment by reach in the Snake River.

6 and 7. All of the sand, about 9.5 million tons, would be deposited in reaches 6 and 7. Much of the silt and clay (about 1.1 million tons) would flush through the reservoir downstream. The need for further dredging in the area of the Snake and Clearwater confluence would be greatly reduced or eliminated by the redistribution of sediment downstream at spillway elevation.

To estimate the kinds of sediment production that could be expected from sheetwash and rilling deposits in the drawdown zone, the Universal Soil Loss Equation (USLE) was used (Goldman et al., 1986) assuming that half the shoreline is composed of erodible materials. The USLE indicated that drawdown to MOP for 5 months per year would erode 2,500 to 3,000 tons of sediment from one half of the 220 acres of exposed reservoir. With drawdown to the spillway, the USLE indicated about 45,000 tons of sediment production would result. This amount would include approximately 22,500 tons of sand which would be redeposited lower in the reservoir each year. It would also include about 15,000 tons of silt; some of which would be redeposited in the reservoir with part flushing downstream. The clay portion would amount to about 8,000 tons that would mostly flush downstream. Since much of the reservoir margin is composed of bedrock and gravel, these values should be the maximum sediment production from surface erosion. Wave erosion would also be active on parts of the shoreline.

To estimate the additional input from wave erosion, it is assumed that the total shoreline erosion is four times the USLE value. This amounts to 180,000 tons of sediment production. Combining this value with the sediment redistribution by the free-flowing river sections amounts to about four times the average natural upstream sediment supply to the Lower Granite Reservoir (Table 4.5-1). Most of this quantity, however, consists of sand with only about 1 million tons being silts and clays. The 1 million tons of silts and clay are about 45 percent of the average annual total load (2.3 million tons) delivered to the Lower Granite Reservoir.

An estimate of maximum sediment concentration from the addition of 1 million tons of silt and clay to Lower Granite Reservoir yielded a value of 200 mg/l. This value is based on the assumption that: (1) erosion of the available sediment load in the free-flowing river reach is distributed evenly over the approximately 27 days it would take to reach spillway crest; (2) the sediment is distributed evenly over the entire reservoir volume at the given reservoir level; (3) sediment flushing from the reservoir occurs at the same rate as water particle travel time for various reservoir levels; and (4) no deposition of silt and clay occurs during the drawdown interval. The values rise to the maximum at spillway crest and then decline. These concentrations are not high enough for a long enough time to have adverse effects on fish (Alabaster and Lloyd, 1982).

The sediments in the upper part of the Lower Granite and Little Goose reservoirs would be mobilized during the two-reservoir drawdown tests. This sediment transport would contribute to higher sediment concentrations and turbidity. These levels should be less than indicated above since soil and beach erosion would be less. Additionally, the tests would be conducted for short periods, reducing the volume of sediment mobilized. These reservoirs should have their sediment concentrations and turbidity monitored during the drawdown tests.

### 4.5.5 Conclusions

Overall, slope movement and beach erosion would increase slightly, and soil and streambank erosion would increase moderately. Slope movement and beach erosion would influence structures and would add sediment to the reservoirs. Soil erosion would redistribute sediment that is already deposited in the reservoirs. Streambank erosion would redistribute sediment that is already deposited in the reservoirs but might also erode embankments and undermine levees in the Lewiston area. High river levels and streambank erosion downstream from Bonneville Dam would inundate river banks and would cause some bank erosion. Coarser sediment that is eroded would be redistributed into lower parts of reservoir. In the upper pools, and at tributary entrances to reservoirs, the redistribution of sediment might reduce the need for dredging. Finer sediment that is eroded would predominantly remain in suspension and would be transported downstream to the ocean. The increase in suspended sediment, compared to known inputs, would be within the range of typical turbidity historically occurring in the system.

At elevations below MOP, however, slope stability, beach erosion, and streambank erosion would cause significant undermining of railroad and highway embankments, levees, and of some bridge piers. This instability could produce life threatening situations and would require a significant expenditure of time and money for observation and maintenance.

### 4.5.6 Mitigation

Mitigation for erosion caused by one of the options could vary from a simple replacement of material lost to extensive reconstruction of embankments with riprap protection. Due to scope and timing considerations, the Corps does not propose to add this protection before implementation for measures for 1992. However, emergency actions to repair damage could occur as needed in 1992.

## 4.6 AIR QUALITY

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown** | |
| ***Snake River*** | |
| All 4 projects to MOP (April 1 to July 31) | • A slightly but no significant change from present air quality. |
| All 4 projects to near spillway crest (April 15 to August 15) | • Most exposed shoreline and bottom areas, therefore most widespread fugitive dust and odors. No significant air quality impact. |
| All 4 projects to near spillway crest (April 15 to June 15) | • Similar to near spillway crest drawdown from April 15 to August 15 except with decreased duration. |
| Lower Granite to near spillway crest (February 1993 or July 15 to August 15) | • See spillway and MOP effects above. |
| Lower Granite to 710 feet, others to MOP (April 15 to June 15) | • See spillway and MOP effects above. |
| Lower Granite/Little Goose drawdown test (March) | • See spillway and John Day at 262.5 feet. |
| ***Lower Columbia*** | |
| All 4 projects to MOP (April 1 to August 31) | • Slightly more exposed reservoir shoreline and bottom areas but no significant change from present air quality. |
| John Day at 262.5 feet, McNary at 337 feet, remainder at MOP (April 1 to August 31) | • See spillway and MOP effects above. |
| **Flow Augmentation** | • Incremental increases from present in extent and duration of exposed bottom areas with some resulting fugitive dust, particularly at Dworshak and to lesser extent at Brownlee. |
| **Combination** | • Effects additive; see drawdown and augmentation. |
| **Temperature Control Test (August)** | • See effects of flow augmentation. |

Flow measures that change the river and reservoir levels might have some localized impact on fugitive dust levels because more silt and sand would be exposed. Blowing silt and sand might alter the emissions from coal-fired and nuclear powerplants in the region. This section considers potential air quality impacts in a general sense. For any given year, the effects of meteorology, local precipitation, and topography on air quality are likely to overwhelm any variation in flows as a factor for influencing air quality.

### 4.6.1 Fugitive Dust

Reservoir drawdowns would expose reservoir shoreline and bottom areas that are normally not available to wind action. Similarly, flow augmentation could change the drawdown and refill patterns of the affected storage reservoirs and marginally increase the extent of exposed bottom area in these locations. In both cases, exposed areas covered with fine sediments (silts and clays) would dry out and begin contributing dust to the atmosphere.

The primary effect of flow measures that expose fine sediments to wind erosion would be some loss of enjoyment for recreationists and nearby residents of the rivers and reservoirs. Blowing dust is not likely to be a health effects concern for short duration exposures experienced by the general public, and EPA has reason to believe that rural fugitive dust is less harmful than urban fugitive dust (52 CR 24716).

Fugitive dust emission rates based on wind erosion from agricultural lands can be used to estimate the amount of material that is entrained from exposed sediments (Midwest Research Institute, 1974). Up to 1.75 pound per acre per day can be eroded from exposed dry sediments, which contain substantial silt. This emission rate assumes no crust has formed on the sediments, which would reduce the emissions considerably. However, recreational vehicle traffic during windy conditions could create substantial increases in emissions, such as experienced on rural unpaved roads. Emission rates for fugitive dust increase with wind speed (Winges, 1991).

Flow measures that decrease reservoir storage and expose more sediments during the late summer would lead to higher levels of fugitive dust generation, all other factors remaining equal. If the exposed area of a representative reservoir changes by 1,000 acres and the effect of crust formation on erosion rates is about 80 percent (BPA, 1985), then 0.35 pound per acre per day would be generated, or 350 pounds per day per reservoir. The effect of this wind-blown dust would be highly localized in the river valley and would not likely affect public health. Blowing dust and sand could annoy recreationists using the facilities. The most likely places where this might occur are shallow embayments such as Welty Bay near Kettle Falls. In the vicinity of Wallula, Washington, any increased fugitive dust generation could be construed to affect air quality in an area not now attaining the ambient air quality standard for PM-10.

### 4.6.2 Odors

Odors would be generated by newly exposed sediments containing substantial organic material. Once dry and crusted, the sediment odor generation would likely be substantially diminished. The duration of odor generation would be strongly influenced by local precipitation, which could keep sediments damp, and by local winds, which could increase the rate of drying. As with fugitive dust, the impact of odors is localized and not a significant public health concern. There are no factors available to quantify the rate of odor emission generation or the degree to which the public might be affected. The extent of odor would be somewhat dependent on the extent of the sediments exposed; therefore, flow measures which decrease impoundments would increase the exposure of potentially odorous sediments.

### 4.6.3 Chemical Emissions

Reservoir drawdown and flow augmentation could adversely affect both the amount of hydroelectric generating capacity on the river system and the amount of non-firm electricity produced (see Section 4.9). BPA would need to obtain varying amounts of replacement power, depending upon the specific flow measures implemented and the eventual water and load conditions in 1992. Replacement power could be imported from outside the region, or it could conceivably be obtained from Pacific Northwest thermal powerplants.

The air pollution releases at thermal powerplants that could be associated with decreased generating capacity at hydroelectric plants can be generically estimated based on emission limits established by EPA. However, it cannot be determined which of the several powerplants would be used to make up for the lost capacity. Thus, the impact on local air quality can be assumed to be acceptable in all cases. Every thermal powerplant in the region (including several plants in Wyoming owned by local utilities) is licensed to operate at its maximum capacity and still maintain air quality standards. This is accomplished by limiting the amount of pollutants in fuels, or by requiring a degree of pollution control necessary to maintain standards.

EPA has administered a program of ever increasing stringency for large new sources of air pollution, which applies in part to utility powerplants burning coal, oil, or gas (40 CFR 60). The standards, which are least stringent, allow emissions summarized below:

| | |
|---|---|
| Particulate matter | 0.1 lb/MMBtu |
| Sulfur dioxide | 1.2 lb/MMBtu |
| Nitrogen oxides | 0.2 - 0.7 lb/MMBtu |

(Pounds per million (MM) British thermal unit of heat input.)

Making certain engineering assumptions regarding typical thermal efficiencies and emission rates for large utility coal-fired powerplants (i.e., 10 Btu heat input for each watt output, and 10,000 Btu per pound of coal) results in the following maximum estimates for additional emissions which could result from the generation of a megawatt-hour of electricity:

| | |
|---|---|
| Particulate matter | 1 pound |
| Sulfur dioxide | 12 pound |
| Nitrogen oxide | 7 pound |

If several hundred megawatts of peaking capacity were shifted from hydroelectric generation to thermal powerplants, the emission of air pollutants would be increased by several hundred pounds of particulate matter and oxides of sulfur and nitrogen. This increase is assumed to be consistent with permit conditions imposed on the thermal powerplants in the region to protect ambient air quality. The impact on air quality at nuclear powerplants in the region would likely be negligible since those units do not normally supply peaking capacity power.

### 4.6.4 Mitigation

Most air quality impacts would occur as a result of exposing large expanses of previously submerged land. Air quality impacts could be mitigated by any actions taken to seed these areas for wildlife or the protection of exposed embankments with riprap. Additional air quality impacts might occur with the use of fossil fuels for power generation. This might be mitigated by reducing the extent higher polluting facilities are used.

## 4.7 TRANSPORTATION

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown** | |
| *Snake River* | |
| All 4 projects to MOP (April 1 to July 31) | • Potential adverse impacts negated by dredging in early 1992. |
| All 4 projects to near spillway crest (April 15 to August 15) | • Barge transportation on lower Snake River closed for 5 months.<br>• Potential barge rate increase from 25 to 40 percent to compensate for revenue loss.<br>• Total transportation costs for all commodities increased by $5.7 million.<br>• Refill could reduce water depths below Bonneville by 1 to 2 feet, with potential added shipping cost of up to $0.6 million. |
| All 4 projects to near spillway crest (April 15 to June 15) | • Barge transportation on lower Snake River closed for 3 months.<br>• Total transportation costs for all commodities increased by $2.8 million.<br>• Potential barge rate increase of 20 percent to recover lost revenues. |
| Lower Granite to near spillway crest (February 1993 or July 15 to August 15) | • Barge service on Lower Granite interrupted for 1 month.<br>• Total transportation costs increased by nearly $0.4 million. |
| Lower Granite to 710 feet, others to MOP (April 15 to June 15) | • Barge service on Lower Granite closed for 3 months.<br>• Total transportation costs increased by $0.9 million. |
| Lower Granite/Little Goose drawdown test (March) | • Barge service on Lower Granite and Little Goose closed for up to 6 weeks.<br>• Total transportation costs increased by $0.5 million. |
| *Lower Columbia* | |
| All 4 projects to MOP (April 1 to August 31) | • Potential adverse impacts negated by dredging in early 1992. |
| John Day at 262.5 feet, McNary at 337 feet, remainder at MOP (April 1 to August 31) | • Similar to MOP effects above. |

Transportation (continued)

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Flow Augmentation** | • Dworshak log transport costs increased by $0.3 million for Options B through F. |
| **Combination** | • Effects additive; see drawdown and augmentation. |
| **Temperature Control Test (August)** | • Possible late-season interruption of log transportation on Dworshak. |

The proposed flow improvements under consideration could affect several different modes of transportation. A primary concern is the disruption of barge navigation on the river system. Additional navigation issues include potential impairment of deep-draft shipping on the lower Columbia River and use of Dworshak Reservoir for log rafting. Proposed actions could also result in direct physical impacts to railroads and highways, as well as indirect effects on those facilities through diversion of barge traffic.

## 4.7.1 Navigation

The key impact issue for navigation is the potential disruption of barge traffic on the Columbia-Snake Inland Waterway above Bonneville. Wheat and barley producers in eastern Washington, northern Idaho, and northeast Oregon rely on barge transportation on the waterway to move grain to export facilities. Barge shipping and transfer operations are designed around MOP elevations, the water level at which there is an authorized 14-foot minimum channel. Pool elevations have typically been held above MOP and navigation interests have become accustomed to depths greater than 14 feet. Reservoir drawdown would reduce water depths in the navigation channel. Depending upon the degree of drawdown, this could result in insufficient depths at the navigation locks, in the shallower portions of the reservoirs, and at port facilities along the affected reservoirs. The consequences of minor changes in water levels would generally be an inconvenience to shipping operations and increased costs. Alteratively, significant drawdowns would completely interrupt barge transportation on the affected pools for the duration of drawdown and refill. This would have direct impacts on the barging and transfer operations and indirect impacts on producers and alternative modes of transportation.

Reservoir drawdown and flow augmentation could also affect navigation on the Columbia River below Bonneville. Specifically, river levels could be raised somewhat during the spring compared to normal conditions. Conversely, reductions in downstream flows to accomplish refill of reservoirs after major drawdowns could temporarily decrease river levels and channel depths. This could have consequences for deep-draft shipping in the lower Columbia.

A final issue concerns the effects of flow augmentation on Dworshak Reservoir, where commercial navigation is an authorized project function. Logs are dumped into the reservoir at ramps built for that purpose and rafted down to a log handling facility at the dam. The ability to put logs into the reservoir is sensitive to pool elevation.

#### 4.7.1.1 Physical Effects of Reservoir Drawdown

Two levels of response to the physical changes of reservoir drawdown have been identified. At one level, barge transportation would be able to continue, with perhaps some localized navigation difficulties. Beyond a certain level of drawdown, barge transportation would be completely interrupted for the duration of the drawdown.

**Drawdown to MOP.** Existing project operations generally maintain the level of the mainstem reservoirs approximately 1 to 3 feet above minimum pool. Under these conditions, barge navigation within the channel and to port facilities is generally unimpeded.

Lowering the pools to MOP could have a limited impact on terminals that currently have a draft limitation, such as grain elevators at Clarkston and Lewiston, unless dredging were conducted to maintain navigation clearances at MOP. The Corps, in conjunction with towboat operators and ports, used existing information to identify 17 port facilities where access might be constrained if the system were drawn down to MOP. The Corps subsequently conducted a bathymetric survey of the waterway and port areas to pinpoint terminal and channel problem areas.

Based on this information, the Corps developed a proposed dredging program for potential problem locations on the lower Columbia and Snake rivers. The dredging was authorized and funded under Public Law 102-104, the Energy and Water Development Appropriations Act passed by Congress on August 17, 1991. Dredging activity will be conducted between January 1992 and late February 1992. Presently, dredging is planned for 28 sites, listed as follows, by pool:

**Bonneville Pool**

- Stevenson Co-Ply, RM 149
- Cascade Locks Marina and Access Channel, RM 149.2
- Port of Skamania County Dock Facility, RM 150
- Herman Creek, RM 151
- Stevenson In-Lieu, RM 151
- Government Cove, RM 151.9
- Rock Creek Cove and Access Channel, RM 150
- Wind River Boat Ramp, Access Channel, Log Storage Pond and Access Channel, RM 154.8
- Little White Salmon River Hatchery, RM 162
- Port of Hood River Industrial Park and Access Channel, RM 169
- Underwood In-Lieu, RM 169; Hood River Inn, RM 169.8; Area D SD&S, RM 171.5
- Bingen Boat Basin and Access Channel, RM 171.7
- SD&S Lumber Dock, Access Channel and Log Storage Area, RM 170.6
- Mayer State Park Boat Ramp and Access Channel, RM 181
- Mt. Fir Dock Facility and Access Channel, RM 187
- Joe Bernert Dock Facility, RM 188.5
- Cargill Grain (Kelly) Dock Facility and Access Channel, RM 188.6
- The Dalles Boat Basin and Marina, RM 189.7

**The Dalles Pool**

- Biggs Grain Dock Facility and Access Channel, RM 208

**John Day Pool**

- Rock Creek Park Boat Ramp, RM 229
- Roosevelt Grain Dock Facility and Access Channel, RM 243.5
- Port of Morrow Dock Facility and Access Channel, RM 270

**McNary Pool**

- Boise Cascade Port Facility, RM 316
- Port of Walla Walla at Burbank, Snake RM 0

**Little Goose Pool**

- Port of Almota, RM 104

**Lower Granite Pool**

- Port of Lewiston, Clearwater RM 1

NEPA implementation for the dredging activity has been accomplished through separate environmental assessments prepared by the Portland and Walla

Walla Districts of the Corps (1991c, d), which are hereby incorporated by reference.

In addition to required dredging at port facilities, there is a general concern that increased velocity in the channel could result in more dredging required to keep the channel at 14 feet.

In absence of dredging, a likely response to access limitations from drawdown to MOP would be light loading of barges using the affected terminals. Tug and barge industry representatives report that the typical draft of vessels operating in the shallow sections of the Columbia and Snake River is as follows:

| Vessel Type | Draft (feet) |
|---|---|
| Grain Barges (Jumbo) | 13.6 |
| Container Barges | 10 |
| Log/Chip Barges | 11 |
| Tugs | 11 to 12 |

There is a mandatory Corps requirement of 1 foot of clearance from all vessels at the navigation lock sills. Because the sills are located at a design depth of 15 feet, or 1 foot below MOP, there would be sufficient lock clearance with operation at MOP, although transit times could increase.

Consequently, the controlling factor would be the depth of the river bottom in the channel and terminal approaches. Within reasonable limits, primarily determined by the draft of the tugs, barges could carry less than full loads to access terminals that have less than a 14-foot water depth.

**Drawdown Significantly Below MOP.** At some reservoir level slightly below MOP, barge traffic would cease. As the reservoir elevation decreases below MOP, the depth at the navigation lock sills would become the controlling factor. Based on the 15-foot design depth of the sills, typical tug drafts, and required clearances, the critical elevation would appear to be about 2 feet below MOP.

Options with deep drawdowns would significantly affect the Pacific Northwest grain industry and other major shippers of commodities on the Snake River portion of the waterway. The degree of effect would vary with the duration and extent of the drawdown.

Cargo statistics for April, May, and June 1990 are presented in Tables 4.7-1 through 4.7-3. Assuming 1990 is a representative year, these data provide a reasonable approximation of the grain tonnage that would be affected by drawdown to near spillway crest from April 15 to June 15. Grain loadings in April, May, and June were approximately 22 percent of wheat tonnage and 11 percent of barley tonnage for the year. By pool, wheat loadings in the Snake River section ranged from 11 percent to 25 percent of the annual total.

Corresponding percentage figures for other commodities are indicated in Table 4.7-4. Wood chips and manufactured forest products originate in both the Lower Granite and McNary pools. (These McNary Pool data are presented primarily for comparison purposes, as drawdown below MOP is not under consideration for McNary.) Shipments originating in these pools in April, May, and June represented 20 to 25 percent of annual shipments of these products. About 21 percent of annual pea and lentil shipments, which originate in the Lower Granite Pool, occurred in April, May, and June. The corresponding proportion of upbound petroleum products bound for the transfer facilities in the Tri-Cities area was 13 percent.

Temporary closure of barge transportation would force shippers to evaluate one of four basic responses:

- store the commodities over the period of the closure;
- accelerate shipment or preposition product downstream before closure;
- divert shipments to rail; and
- divert shipments to truck.

All four alternatives might be constrained and would result in substantial cost increases that would be borne by producers or shippers. The viability and likelihood of these responses are examined below for the key commodities.

Operating the lower Snake River projects near spillway crest elevations from April 15 through June 15 would result in a 3-month closure of the waterway, including drawdown and refill time. Likely responses by shippers are reviewed below for each commodity group.

Table 4.7-1. Total tonnage of grain moved by pool, 1990.[a/]

| Pool | Wheat | Barley | Total Grain | Percentage Barley | Percentage Wheat |
|---|---|---|---|---|---|
| Lower Granite | 1,259,007 | 128,230 | 1,387,237 | 9.2 | 90.8 |
| Little Goose | 923,559 | 260,138 | 1,183,697 | 22.0 | 78.0 |
| Lower Monumental | 128,502 | 10,090 | 138,592 | 7.3 | 92.7 |
| Ice Harbor | 447,834 | 53,013 | 500,847 | 10.6 | 89.4 |
| Total | 2,758,902 | 451,471 | 3,210,373 | 14.1 | 85.9 |

Source: Corps, Walla Walla District, unpublished data.
a/ 1990 is considered a representative year by the Corps for measuring potential system impacts.

Table 4.7-2. Tonnage of grain moved by pool in April, May, and June 1990.[a/]

| Pool | Wheat A/M/J | Barley A/M/J | Total A/M/J | Percentage Barley | Percentage Wheat |
|---|---|---|---|---|---|
| Lower Granite | 316,272 | 16,142 | 332,414 | 4.9 | 95.1 |
| Little Goose | 213,065 | 30,552 | 243,617 | 12.5 | 87.5 |
| Lower Monumental | 13,846 | 2,800 | 16,646 | 16.8 | 83.2 |
| Ice Harbor | 66,636 | 1,780 | 68,416 | 2.6 | 97.4 |
| Total | 609,819 | 51,274 | 661,093 | 7.8 | 92.2 |

Source: Corps, Walla Walla District, unpublished data.
a/ 1990 is considered a representative year by the Corps for measuring potential system impacts.

Table 4.7-3. Percentage of annual wheat and barley shipments in April, May, and June 1990, by pool.[a/]

| Pool | Wheat | Barley | Total |
|---|---|---|---|
| Lower Granite | 25.1 | 12.6 | 24.0 |
| Little Goose | 23.1 | 11.7 | 20.6 |
| Lower Monumental | 10.8 | 27.8 | 12.0 |
| Ice Harbor | 14.9 | 3.4 | 13.7 |
| Total | 22.1 | 11.4 | 20.6 |

Source: Corps, Walla Walla District, unpublished data.
a/ 1990 is considered a representative year by the Corps for measuring potential system impacts.

Table 4.7-4. Non-grain commodity shipments moved by pool, April, May, and June 1990.

| | Lower Granite | | | McNary | | |
|---|---|---|---|---|---|---|
| | Total | A/M/J | A/M/J Percent | Total | A/M/J | A/M/J Percent |
| Downbound Products | | | | | | |
| Wood Chips | 285,296 | 72,840 | 25.5 | 92,218 | 20,690 | 22.4 |
| Pulp, Paper and Other Manufactured Forest Items | 98,104 | 24,108 | 24.6 | 74,044 | 14,830 | 20.0 |
| Vegetables (i.e., peas and lentils) | 46,452 | 9,627 | 20.7 | -- | -- | -- |
| Upbound Products | | | | | | |
| Petroleum | -- | -- | -- | 74,567 | 9,507 | 12.7 |

*Effects on Grain Traffic* - The ability to store grain over a 3-month closure varies widely by facility (see Table 4.7-5). Some elevators have space for 3 or 4 million bushels of grain and annual turnover of 4 times. These facilities would be the most likely to hold grain over a closure without requiring new storage facilities or a shift to alternate transportation modes. Other elevators, primarily on the Ice Harbor Pool, have storage for less than 1 million bushels and turn this inventory over 20 times a year. These facilities would not be able to store grain over a closure and would have to find alternate transportation. If barge traffic were not resumed by harvest time in July and August, owners of all elevators would be searching for means to move product.

Accelerated shipment or pre-positioning of wheat and barley to downriver elevators would be constrained by lack of storage for surge exports (large, unanticipated volumes) and the nature of grain export transactions. This option was mentioned by some grain elevator operators contacted, but its potential was assessed as limited under existing conditions. The sale of grain requires substantial coordination between the farmer, the sellers, and the ultimate purchasing country. The importing country typically purchases grain for delivery within 30 to 60 days of sale. The farmer owns the grain until it is sold to the merchandiser or trading company. This company is responsible for delivering the grain to the downriver terminals.

The merchandiser or trading company only buys the grain after a sale has been made. Therefore, delivery downstream would only occur after a sale has been made. The price of grain paid to the farmer is the free-on-board (FOB) downstream elevator price, less the cost to transport the grain. The additional cost to transport the grain would therefore ultimately fall onto the shoulders of the farmer. The merchandisers would be reluctant to move grain downstream to pre-position until after the sale has been finalized. Hence, pre-positioning is not a likely option for grain sales.
However, there is an idle grain elevator located at the Port of Longview. This facility, which has a storage capacity of 200,000 bushels, could be used for downriver storage in the event of problems with upriver storage.

Barley, which is primarily used for animal feed, can be stored outside at the expense of shrinkage of 1 to 4 percent of volume, as well as additional handling costs. Wheat cannot be stored outside (unprotected) without significantly reducing its market value.

Table 4.7-5. Grain traffic/storage comparison, 1990.

| Pool | Wheat Tonnage | Barley Tonnage | Total Grain Tonnage | Inside Storage Tonnage | Annual Turnover |
|---|---|---|---|---|---|
| Lower Granite | 1,259,007 | 128,230 | 1,387,237 | 316,257 | 4.39 |
| Little Goose | 923,559 | 260,138 | 1,183,697 | 238,879 | 4.96 |
| Lower Monumental | 128,502 | 10,090 | 138,592 | 36,363 | 3.81 |
| Ice Harbor | 447,834 | 53,013 | 500,847 | 24,545 | 20.40 |
| McNary | 1,162,094 | 32,540 | 1,194,634 | 499,242 | 2.39 |

Sources: Corps, Walla Walla District, unpublished data.
BST Associates.

Construction of additional storage facilities for a test drawdown would not be a viable response. The impact would only occur for 3 months of 1 year and would not allow an adequate return on investment.

Existing storage in the elevators in the Lower Granite and Little Goose pools is probably adequate to handle the grain that typically moves during April, May, and June. However, additional inventory carrying and storage costs would occur (addressed below), and the ability of grain producers to sell their crops if a surge demand occurred during the drawdown would be constrained.

Assessment of the prospects for diverting grain shipments to rail or truck must account for the relative capacities of the equipment units. The volume of grain loaded by pool in April, May, and June 1990 is translated into equivalent numbers of barges, railcars, and trucks in Figure 4.7-1. The total of 218 barge loads of grain would require nearly 6,610 railcars or 22,034 truck loads if diverted to these modes. The next least expensive mode of transportation after barge is rail, which is approximately twice as expensive. Other constraints would prevent railroads from carrying more than a fraction of the grain that now moves by water. These include lack of rail access, inadequate loading capability, and relative shortage of grain cars.

Lack of rail access is a problem for nearly all of the elevators on the river. Of the 19 facilities handling grain from McNary upriver, only 5 have rail access. Three of 7 facilities on the McNary Pool have rail access, with capacities ranging from 10 to 26 cars. There is no rail capacity in the Ice Harbor, Lower Monumental or Little Goose pools. Two of the four grain elevators on Lower Granite have rail access; they can accommodate 8 cars and 6 cars, respectively. All ports with the exception of one on the Lower Granite Pool and one on the Little Goose Pool have rail access nearby. However, it could be expensive to provide rail access in some cases.

Most of the grain terminals were designed to offload grain from trucks and load it onto barges, and are not located on rail spurs. Once the product is in these elevators, transfer to rail is not currently possible. The river elevators are typically fed by 10 or 20 inland elevators, some of which are on rail spurs. It is possible that some product may be able to move through these inland facilities. Two railheads located near Pullman and the Oregon Unit Train Facility south of Walla Walla can load rail cars and might be able to handle some of the load.

Those elevators on the river with the ability to load railcars can load at a rate of 4 or 5 cars per shift, compared with 30 carloads per barge loaded in four hours. These elevators neither have the conveyor system in place to load cars quickly nor the track

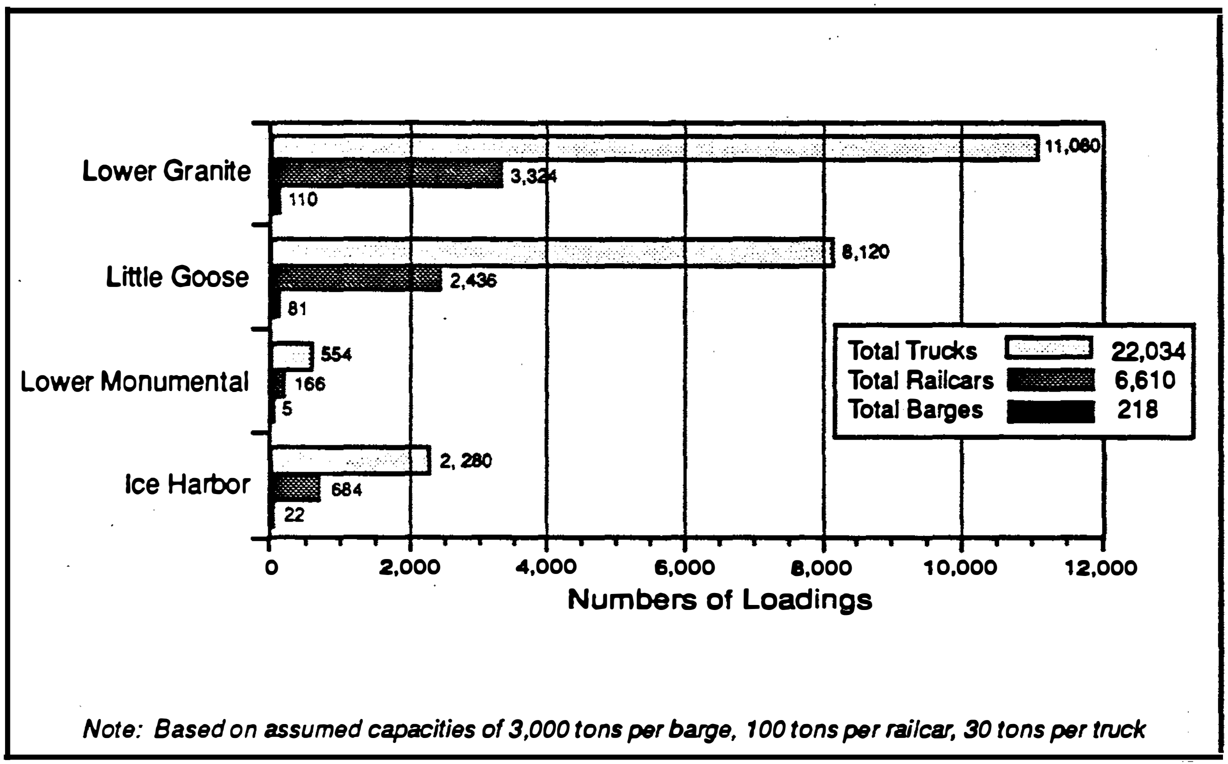



**Figure 4.7-1.** Equivalent number of loadings (roundtrips) for wheat and barley, April to June 1990 shipments (Source: BST Associates).

for a 26-car-unit train. One operator reported it would cost more than $500,000 to add the track, conveyors, and other infrastructure necessary to efficiently load to rail in the volumes required, if the necessary land were available.

Lack of rail cars could make rail access a moot point. There is seldom a surplus of grain hopper cars in the United States fleet, and these cars are not positioned where they could easily haul Pacific Northwest grain. In May and June, the Pacific Northwest would be competing for hopper cars with California, Texas, and other areas with earlier harvests. In July and August, there would be an extreme shortage of cars as the rest of the country harvests grain. Railroads would require 120-days notice to position hopper cars in the Northwest, and would charge a significant premium for this. In addition, rail rates would likely increase as competition from water transportation decreased.

A recent Interstate Commerce Commission (ICC) (1990) report addressed the issue of the adequacy of grain hopper supplies. The primary problem is unanticipated surges in grain export demand. For example, the Soviet Union recently purchased 318 million bushels of corn for short-term delivery between October and December 1990. This was the equivalent of 94,000 jumbo covered hopper carloads. Events such as this cannot be met with the existing supply of hoppers because railroads will purchase hoppers only to meet normal loading requirements. The existing hopper car fleets are estimated at 24,458 cars (19,600 owned and 4,858 leased) for UPRR and 26,100 cars for BNRR. In January 1990, BNRR ordered 1,000 new jumbo hoppers at a cost of $44 million.

BNRR and UPRR would probably attempt to serve grain shippers during a barge shutdown. However, grain industry operators question the railroads' ability to provide the cars. They noted the lack of proximate loading facilities and substantially higher than normal rates for cars as obstacles to diverting grain to rail.

Trucking is by far the most expensive means of moving grain from Lower Granite to Portland, costing as much as $1.00 per bushel versus $0.16 for barge and $0.32 for rail. The grain trucking industry in the upper Columbia-Snake River region is an integral but limited part of the transportation system. It is efficient at moving small amounts of grain for short distances from many points to a central destination, the elevator. To move large amounts of grain for long distances would require more trucks and more drivers than are available. For a closure in April, May, and June, it is very unlikely that grain would move far downriver by truck. Grain would only be likely to move all the way downriver if the closure lasted well into the harvest season. At this point, producers might be willing to pay the high transportation cost and absorb a loss rather than not move the grain at all and have no place to store it. Again, however, the capacity of the truck fleet is nowhere near that needed to meet demand if this situation were to occur.

*Effects on Other Traffic* - Wood chips can be stored in outside storage facilities at downstream facilities, on barges, or in piles at the upriver port terminals.

Three sources supply the wood chips loaded on Lower Granite, and all of these sources are currently on rail lines (Henry, 1991). However, none currently use rail service. These producers could shift to rail if rates were attractive enough. If not, storage is probably the optimum alternative.

Wood chips from the Lower Granite Pool serve several mills in the lower Columbia River. Three sources supply the wood chips loaded at Lower Granite, and all of these sources are currently on rail lines (Henry, 1991). None currently use rail service. These producers could shift to rail if rates were attractive enough. However, the availability of chip cars is very limited at present. One mill operator indicated that rail cars were not available.

If railcars are not available, storage is probably the next best alternative. Downriver storage is extremely tight. Chips would most likely be stored at downriver and upriver sites. However, the cost of carrying additional inventories must be included in the impact assessment.

Typically, a ton of green chips moving on a barge will produce one-half bone dry unit (BDU). Based on prime rate plus 1/2 percent (i.e., 9 percent per year as used in the grain inventory cost analysis), and an average rate of $120 per BDU), the inventory cost of carrying chips either upriver or downriver is $65,556 for the 3-month drawdown. Over a 5-month period, the inventory cost is $183,924.

The Potlatch Corporation is the primary generator of pulp and paper moving downstream from Lower Granite. In addition, Potlatch receives pulp, supplies, and empty containers upriver by barge. Barge service is extremely important to Potlatch. During the scoping process, the company noted that it currently ships about 30 percent of its paperboard and pulp production downriver and to the export market (personal communication, T. Maddock, Potlatch Corporation, June 14, 1990). Potlatch has identified the next best alternative to barge service as being boxrail service with transloading to container in Portland. However, Potlatch also questions whether sufficient rail cars (about 200 per month) would be available.

The American Dry Pea and Lentil Association exported approximately 179,000 tons of product in 1990. Of this total, 46,500 tons (75 percent) were moved by barge. A few major shippers located near the Snake River in the Washington and Idaho Palouse region account for this barge traffic. Competition for this product in world markets is particularly intense, and shipping rates are extremely important in the product's marketability. If barge traffic were not available to shippers, the next best alternative would be to ship the product by rail to lower Columbia River or Puget Sound ports. This would be done at a rate two times the current barge rates.

Petroleum products move from lower Columbia transfer facilities to Tri-Cities distribution facilities. Approximately 13 percent of these products moved by barge in 1990 from April through June. Shipper alternatives include receipt of product by pipeline and use of additional storage.

### 4.7.1.2 Economic Effects on Barge Transportation

**Drawdown to MOP.** As discussed above, the impacts to navigation from reservoir drawdown to minimum pool include additional dredging in the channels and at the terminals to ensure that navigation is possible. The costs of this activity cannot be fully estimated with data currently available. The Corps recently completed a bathymetric study of the Snake and Columbia rivers that will enable an estimate of the costs associated with this alternative.

Reducing pools to a level at which barges would need to operate at reduced load would result in an increase in transportation costs. Barge shippers pay on a per-ton basis, with a guaranteed minimum amount. If they ship less than the minimum, the fee per barge is the same regardless of weight shipped, and therefore the unit cost will increase as the amount shipped decreases.

Operating at minimum pool would also increase the time and cost of loading barges at depth-limited facilities. As a result of the dredging program described in Section 4.7.1.1, these costs would be avoided for 1992 options involving drawdown to MOP. There could also be additional cost associated with increased time to navigate the locks as a result of increased velocity. This has not been quantified.

**April 15 to June 15 Drawdown Below MOP.** For grain, the best option (i.e., lowest cost) in response to a 3-month shutdown would be storage at the elevators. Upriver grain elevator operators can provide storage for shippers during the months of the shutdown depending upon the size of their storage facilities. Generally, with the exception of the Ice Harbor Pool, upriver storage is adequate to meet the needs of a 3-month shutdown.

However, in order to store the grain, upriver elevator operators would require an additional storage and inventory carrying cost. The storage cost covers physical use of the silos. The inventory carrying costs cover the elevator operators buying the grain and holding before it can be sold.

Typical storage charges are approximately $0.025 per bushel per month. Typical inventory carrying costs are based upon a monthly charge calculated at 9 percent per year interest rate (i.e., prime plus 0.5 percent to 1 percent) and a price per bushel of $3.45 for grain.

Additional storage charges and inventory costs would be incurred during a 3-month closure. This would amount to $2.2 million for shipments from the lower Snake River (see Table 4.7-6).

Diversion to rail or especially truck for delivery downstream would be very unlikely because of the relative costs involved. Rail transportation is approximately twice as expensive as barging, while trucking is approximately 5 times as expensive (Table 4.7-7). Rail diversions would further depend upon availability of cars (which is questionable) and freight rates that might be higher than normal.

A comparison of additional storage/inventory carrying costs with rail costs (escalated by 20 percent to simulate the expected rate response) reveals that storage charges are approximately 70 percent of additional rail costs using existing rail rates. Storage would therefore be used unless it is not available (e.g., as at Ice Harbor pool) (Table 4.7-8).

The only likely diversion to trucks would occur with options where Lower Granite Pool were drafted to elevation 710 or near spillway crest and other pools were held at MOP. In this case, trucks normally bound for Lower Granite elevators would be diverted to the Little Goose Pool and possibly to the Lower Monumental Pool. The extent of this response might be limited by the capacity of roads to Almota to accept the additional traffic.

During the shutdown, shippers would look for the next least expensive alternative. Grain shippers at all pools except Ice Harbor would store grain for the 3-month shutdown. As mentioned above, Ice Harbor storage is inadequate to meet the demand. Therefore, shippers would move their product by rail, which is the next best option.

The net expected cost effects for grain shippers therefore are the estimated existing rail costs for Ice Harbor Pool and the storage and inventory costs for the other pools. In aggregate, grain shippers

Table 4.7-6. Estimated grain storage and inventory carrying costs for April-June barge closure.

| Pool | Storage Costs ($)[a/] | Inventory Costs ($)[b/] | Total Costs ($) |
|---|---|---|---|
| Lower Granite | 548,483 | 567,680 | 1,116,163 |
| Little Goose | 401,968 | 416,036 | 818,004 |
| Lower Monumental | 27,465 | 28,427 | 55,893 |
| Ice Harbor | 112,886 | 116,837 | 229,723 |
| **Total** | 1,090,803 | 1,128,982 | 2,219,785 |

Source: Local grain industry specialists, BST Associates.

a/ Additional storage costs of $0.025 per bushel per month are typical in the regional grain industry. Average time of storage is 2 months.

b/ Inventory carrying costs are calculated based upon a grain price of $3.45 per bushel and an interest rate of 9 percent per year during the 3-month storage time.

will experience an increase of $2.3 million dollars due to additional storage, inventory and rail costs as shown in Table 4.7-9.

Pea and lentil shippers would probably ship their products to the lower Columbia River by rail. This would at a minimum double their cost of transportation during the closure. Potlatch officials estimate that their cost increases could run $140,000 per month or $420,000 for a 3-month shutdown, assuming that rail cars were available.

The total increase in transportation costs for all shippers during a 3-month shutdown from April through June is estimated at nearly $2.8 million (Table 4.7-10). The additional costs to grain shippers represent about 81 percent of this total.

Shippers worry about the potential effect of drawdowns on the long-term viability of the barge industry. The potential financial impact of a 3-month closure in 1992 on individual barge companies is unknown. Barge traffic provides the lowest-cost transportation for these shippers and keeps rail rates competitive within the sphere of influence. Rail rates could increase if barge service is lost or curtailed. This would be especially important if a surge export demand occurred during the shutdown months. Under these circumstances, the higher cost of Northwest wheat might force the importer to consider sources of grain other than the U.S.

**April 15 to August 15 Drawdown Below MOP.** The consequences of operating the four lower Snake River projects near spillway crest for a 5-month period from April 15 to August 15 would be significantly different from the effects of a 3-month closure. This is largely because the longer drawdown would overlap with the harvest season, which would drastically reduce the ability of producers or shippers to store grain until barge service resumed.

Traffic movements by pool and product for the April-August period of 1990 are summarized in Table 4.7-11. Grain accounted for about 87 percent of the total tonnage during this period. By commodity, the April-August proportion ranged from 35 to 44 percent of the annual total. The tonnage of grain shipped from April through August 1990 translates into approximately 382 barges, 11,466 railcars, and 38,222 trucks (Figure 4.7-2).

The options available to producers and shippers for an April through August navigation closure are more constrained than is the case for an April through June shutdown. If all the grain shipped during the longer period were stored temporarily, the storage and inventory costs would equal $5.8 million (Table 4.7-12). However, storage in the

**Table 4.7-7.** Wheat shipping rate differentials for representative movements.

| Movement/Mode | Cost/Ton ($) | Difference to Barge($) | Difference to Rail($) |
|---|---|---|---|
| From Lower Granite to Lower Columbia Elevators | | | |
| Barge[a/] | 5.55 | | |
| Rail[b/] | 10.15 | 4.60 | |
| Truck Only[c/] | 28.50 | 22.95 | 18.35 |
| From Little Goose to Lower Columbia Elevators | | | |
| Barge[a/] | 5.33 | | |
| Rail[b/] | 10.37 | 5.04 | |
| Truck Only[c/] | 27.17 | 21.84 | 16.80 |
| From Lower Monumental to Lower Columbia Elevators | | | |
| Barge[a/] | 5.02 | | |
| Rail[b/] | 10.00 | 4.98 | |
| Truck Only[c/] | 22.67 | 17.65 | 12.67 |
| From Ice Harbor to Lower Columbia Elevators | | | |
| Barge[a/] | 4.70 | | |
| Rail[b/] | 9.72 | 5.02 | |
| Truck Only[c/] | 21.17 | 16.47 | 11.45 |
| From McNary to Lower Columbia Elevators | | | |
| Barge[a/] | 4.32 | | |
| Rail[b/] | 8.89 | 4.57 | |
| Truck Only[c/] | 18.75 | 14.43 | 9.86 |

Assumptions/Sources:
a/ Tidewater Barge Lines - Rate Schedule.
b/ UPRR/BNRR 3 car rates.
c/ Truck costs determined at $1.25 per mile for round trips based upon 1-way mileage below from Rand McNally; trucks carry a 30-ton payload.

Note:

Highway Mileage to Vancouver/Portland

| | |
|---|---|
| Lewiston | 342 |
| Almota | 326 |
| Kahlotus | 272 |
| Walla Walla | 254 |
| Pasco | 225 |

upriver elevators is barely adequate to handle the amount of grain shipped in April, May, and June. It is inadequate to handle the additional volumes shipped in July and August, due to the volume of newly harvested grain.

Diversion of grain to transportation by rail or truck would require shippers to pay a substantial premium to make hoppers and trucks available. Even with such a premium, it is very doubtful that the equipment would be forthcoming in view of the hopper car fleet conditions noted previously. If three equipment were available, additional rail costs would be $5.5 million if all of the grain were diverted to rail at existing rail rates. Total diversion to truck would produce additional truck costs of $24.6 million (Table 4.7-13).

The likely response of shippers in this case would be to store as much grain as possible at existing facilities and then switch to rail for overflow volumes. The total estimated storage, inventory,

Table 4.7-8. Cost comparison of grain alternatives for April-June barge closure.

| Pool | Storage & Inventory Costs ($)[a/] | Existing Rail Costs ($)[b/] | Existing Truck Costs ($)[b/] | 20% Higher Rail Costs ($)[c/] | 20% Higher Truck Costs ($)[c/] |
|---|---|---|---|---|---|
| Lower Granite | 1,116,163 | 1,529,104 | 7,628,901 | 1,834,925 | 9,154,681 |
| Little Goose | 818,004 | 1,227,829 | 5,320,595 | 1,473,395 | 6,384,714 |
| Lower Monumental | 55.903 | 82,897 | 293,801 | 99,476 | 352,562 |
| Ice Harbor | 229,723 | 343,448 | 1,126,811 | 412.138 | 1,352,173 |
| Total | 2,219,785 | 3,183,279 | 14,370,110 | 3,819,935 | 17,244,132 |

a/ Based on Table 4.7-7.
b/ Based on Table 4.7-8.
c/ Due to short-term nature of the closure, a surcharge for rail and trucks may be 20% or higher.

Table 4.7-9. Summary of cost impacts for grain with April-June barge closure.

| Pool | Cost |
|---|---|
| Lower Granite[a/] | 1,116,163 |
| Little Goose[a/] | 818,004 |
| Lower Monumental[a/] | 55,893 |
| Ice Harbor[b/] | 343,448 |
| TOTAL | 2,333,510 |

Assumptions:
a/ Storage and inventory costs
b/ Rail costs above barge costs

4.7-10. Increased total transportation costs for April to June barge closure.

| Commodity | Impacts ($) |
|---|---|
| Grain | |
| Stored | 1,990,061 |
| Railed | 343,448 |
| Total | 2,333,510 |
| Wood Chips | 65,556 |
| Pulp & Paper | 350,000 |
| Peas & Lentils | 95,000 |
| Total Impact | 2,844,066 |

Source: BST Associates.

Table 4.7-11. April through August traffic movements, 1990.

| | Total Annual Tonnage | April-August Tonnage | April-August Percent |
|---|---|---|---|
| **Wheat/Barley** | | | |
| Lower Granite | 1,387,237 | 529,845 | 38.2 |
| Little Goose | 1,183,697 | 415,786 | 35.1 |
| Lower Monumental | 138,592 | 17,716 | 12.8 |
| Ice Harbor | 500,847 | 183,294 | 36.6 |
| McNary | 1,194,634 | 510,414 | 42.7 |
| Total | 4,405,007 | 1,657,054 | 37.6 |
| **Wood Chips** | | | |
| Lower Granite | 285,296 | 136,240 | 47.8 |
| McNary | 92,218 | 28,705 | 31.1 |
| Total | 377,514 | 164,945 | 43.7 |
| **Pulp, Paper, etc.** | | | |
| Lower Granite | 98,104 | 41,129 | 41.9 |
| McNary | 74,044 | 32,825 | 44.3 |
| Total | 172,148 | 73,414 | 42.6 |
| **Peas, Lentils** | | | |
| Lower Granite | 46,452 | 16,108 | 34.7 |

Source: Corps, Walla Walla District, unpublished data.

and rail costs for grain shippers are estimated at $4.7 million (Table 4.7-14). Total estimated transportation costs for all commodity groups during a 5-month closure are indicated in Table 4.7-15. Methods for assessing responses and costs for non-grain products were as used previously for the 3-month closure. The total costs in this case are estimated at $5.7 million, with the grain share at 84 percent of the total.

**Lower Granite/Little Goose Test Drawdown** - The proposed test drawdown of the Lower Granite and Little Goose reservoirs in March 1992 would interrupt barge service on these two pools for up to approximately 6 weeks. The test itself is scheduled to occur from March 1 to March 31. Navigation service would not be possible from about February 20 through April 10, due to the need to remove and reinstall the navigation lock guidewalls before and after the test. The annual 2-week lock maintenance period will be scheduled for the test period to reduce the net duration of the navigation closure.

The barge traffic movements that would likely be affected by this closure are summarized in Table 4.7-16. Traffic during the period March 1 through April 15 has been used to approximate the traffic volume expected to be affected by this closure. The proportions of annual traffic affected range from about 3 percent for wood chips to 15 percent for pulp and paper. About 12 percent of annual grain shipments on these two pools move during this period.

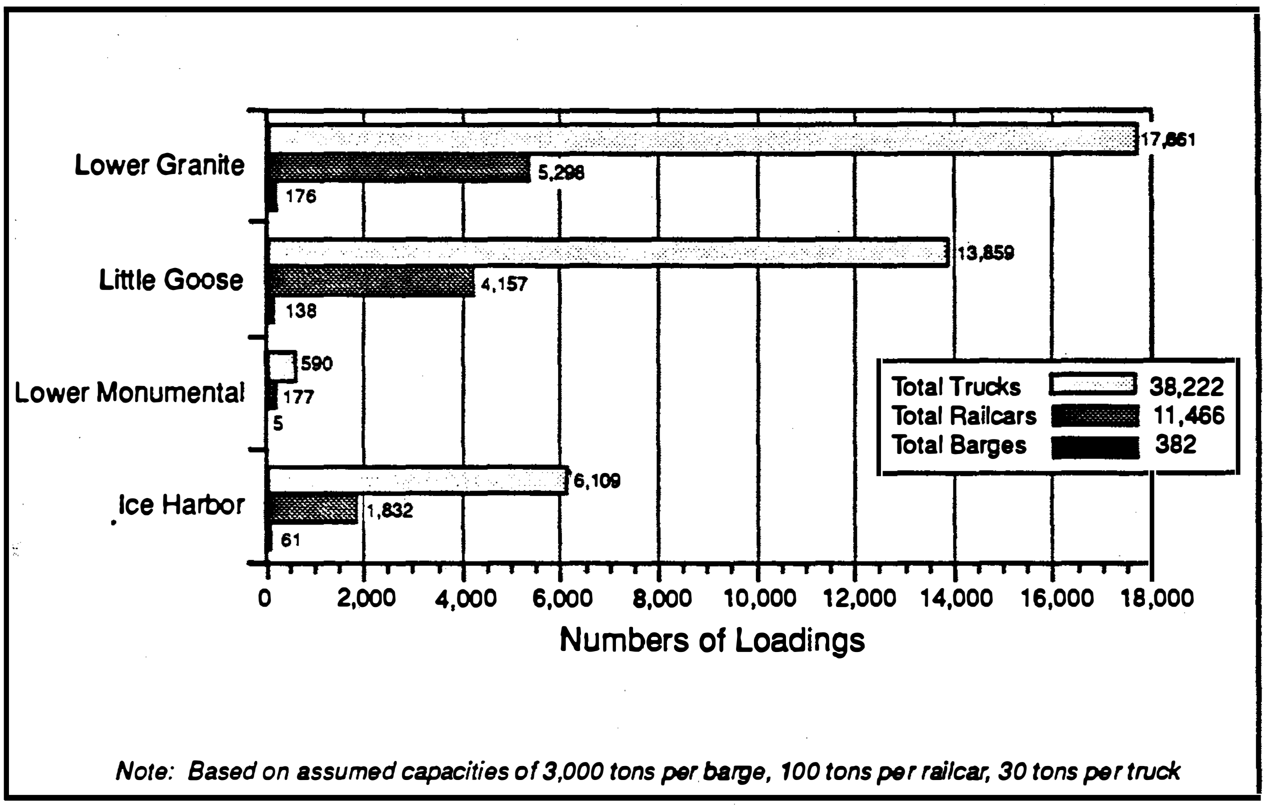



**Figure 4.7-2.** Equivalent number of loadings (roundtrips) for wheat and barley, April to August 1990 shipments (Source: BST Associates).

Table 4.7-12. Estimated grain storage and inventory carrying costs for April to August barge closure.[a/]

| Pool | Storage Costs ($) | Inventory Costs ($) | Total Costs ($) |
|---|---|---|---|
| Lower Granite | 1,311,366 | 1,357,264 | 2,668,630 |
| Little Goose | 1,029,070 | 1,065,087 | 2,094,158 |
| Lower Monumental | 43,847 | 45,381 | 89,228 |
| Ice Harbor | 453,650 | 469,527 | 923,178 |
| Total | 2,837,934 | 2,937,262 | 5,775,196 |

Source: Local grain industry specialists, BST Associates.

a/ Additional storage costs of $0.025 per bushel per month are typical in the regional grain industry. Average time of storage is 3 months.

Table 4.7-13. Cost comparison of grain transportation alternatives for April to August barge closure.

| Pool | Storage & Inventory Costs ($) | Rail Cost at Existing Rates ($) | Truck Costs at Existing Rates ($) | Rail Costs at 20 Percent Higher Rates ($) | Truck Costs at 20 Percent Higher Rates |
|---|---|---|---|---|---|
| Lower Granite | 2,668,630 | 2,437,287 | 12,159,942 | 2,924,744 | 14,591,931 |
| Little Goose | 2,094,158 | 2,095,561 | 9,080,766 | 2,514,673 | 11,450,746 |
| Lower Monumental | 89,228 | 88,225 | 312,687 | 105,870 | 487,898 |
| Ice Harbor | 923,178 | 920,130 | 3,018,835 | 1,104,157 | 5,047,889 |
| Total | 5,775,196 | 5,541,205 | 24,572,232 | 6,649,446 | 29,486,679 |

Table 4.7-14. Summary of cost impacts for grain with April to August barge closure.

| Pool | Storage/Inventory Cost ($) | Rail Cost ($) | Total Cost ($) |
|---|---|---|---|
| Lower Granite[a/] | 1,116,163 | 908,182 | 2,024,345 |
| Little Goose [a/] | 818,004 | 867,731 | 1,685,736 |
| Lower Monumental[a/] | 55,893 | 5,328 | 61,221 |
| Ice Harbor [a/] | | 920,130 | 920,130 |
| Total | 1,990,061 | 2,701,374 | 4,691,345 |

a/ The likely response of shippers would be to store as much grain as possible at existing facilities and then switch to rail for additional overflow volumes. Approximately 592,677 tons of grain would be stored (51.7 percent of total) and 533,963 tons railed (48.3 percent). The entire cost of additional storage, inventory, and rail costs is estimated to be $4.7 million for grain shippers.

Table 4.7-15. Increased total transportation costs for April to August barge closure.

| Commodity | Impact ($) |
|---|---|
| Grain | |
| Stored | 1,990,061 |
| Railed | 2,701,374 |
| Total | 4,691,435 |
| Wood Chips | 183,924 |
| Pulp & Paper | 630,000 |
| Peas & Lentils | 171,000 |
| **Total Impact** | 5,676,359 |

Source: BST Associates.

Tables 4.7-17 through 4.7-19 provide the basic data supporting estimation of increased transportation costs for this option. The grain tonnage shipped from March 1 to April 15 corresponds to approximately 99 barge loads, 2,981 railcars or 9,936 truckloads. Storage in upriver elevators would be the most economical option for grain shippers, as with prior cases, and the storage capacity in upriver elevators is more than adequate to handle this amount of grain. Additional storage and inventory carrying costs for this closure are estimated at approximately $333,600 (Table 4.7-18). Including the additional transportation costs for pulp and pea and lentil shippers, the total transportation cost impact is estimated at approximately $511,600. No increased costs are expected for wood chips as the small volume affected could probably be accommodated within the downriver storage capacity.

*Effects on Barge Industry* - The grain trade on the Snake River accounts for approximately one-half or more of the revenues of the barge companies operating on the waterway. There would be limited opportunity to use this equipment in other trades during a barge closure. The barges were designed for the Columbia/Snake River System and are not seaworthy outside this waterway. The cargo base on the system is also not great enough to make up for the loss of hauls from the Snake River. Consequently, the equipment now used to haul grain from the Snake River elevators would not likely be redeployed elsewhere on the waterway.

Without a cargo base during the shutdown period, barge companies might be forced to try to raise their rates during the remainder of the year to compensate for the loss of revenue during the shutdown. This would apply if grain were diverted to a competitive transportation mode. The revenue increase would be approximately 25 percent in order to compensate for a loss of 3 months, and 42 percent for a loss of 5 months.

However, it was concluded that storage at the upriver elevators is adequate to handle the load from an April to June shutdown. Under this scenario, the barge industry would have to carry 12 months of grain in 9 months. This could entail adding new equipment, which would be at an increased cost. Barge rates would probably increase less than 25 percent in this case.

If the shutdown were more than the 3 months of April, May, and June, the harvest traffic would need to be moved. The upriver storage would be inadequate and the grain would move to alternative transportation modes (i.e., rail). The barge industry would need a rate increase of 25 percent to 40 percent to compensate for the revenue loss, depending upon the size of the diversion.

Table 4.7-16. March 1 through April 15 traffic movements, 1990.

| | Total Annual Tonnage | Mar 1-Apr 15 Tonnage | Mar 1-Apr 15 Percent |
|---|---|---|---|
| **Wheat/Barley** | | | |
| Lower Granite | 1,387,237 | 174,705 | 12.6 |
| Little Goose | 1,183,697 | 123,386 | 10.4 |
| Total | 4,405,007 | 298,091 | 11.6 |
| **Wood Chips** | | | |
| Lower Granite | 285,296 | 9,750 | 3.4 |
| **Pulp, Paper, etc.** | | | |
| Lower Granite | 98,104 | 14,780 | 15.1 |
| **Peas, Lentils** | | | |
| Lower Granite | 46,452 | 6,727 | 14.5 |

Source: Corps, Walla Walla District, unpublished data.

Since barge rates are approximately 50 percent of the rail rates, an increase of 25 percent to 42 percent would keep barges competitive relative to the railroads. However, barge rates also serve to keep railroad rates low. The increase to barge rates could therefore result in an increase to rail rates throughout the region. The size of such a potential increase is not known at this time. No rate increases are included in the costs shown in the summary impact table.

*Surge Exports* - A key factor in the overall impact on grain farmers is the potential for surge exports when barging may be curtailed. Some grain importers buy fairly evenly throughout the year while others buy in surges when financing is available. There is an approximately even split between these types of buyers.

Temporary closure of barge transportation would result in additional costs to move grain to the down river elevators. Industry representatives have indicated a concern that these additional costs might require the grain merchandisers to place a premium on Northwest wheat, which could make it uncompetitive in comparison with grain from other countries.

To test this hypothesis, grain exports by quarter through Northwest elevators (i.e., Puget Sound and Columbia River export terminals) were examined. As shown in Table 4.7-20, wheat exports experience some seasonality in accordance with the harvest periods in the third and fourth quarters, which account for nearly 54 percent of total annual sales. Export movements in the first and second quarters are surprisingly strong, accounting for 23.9 percent and 22.4 percent of annual movements, respectively. While exports in general were lowest from April to June, specific countries such as Taiwan and Bangladesh made large volume purchases during the second quarter. These surge buyers require grain when credit terms are arranged. Since arrangement of credit and subsequent grain purchases are random for these countries, additional costs for Northwest grain

Table 4.7-17. Equivalent number of loadings (roundtrips) for wheat and barley, March 1 to April 15, 1990.

| Pool | Barges | Railcars | Trucks |
|---|---|---|---|
| Lower Granite | 58 | 1,747 | 5,824 |
| Little Goose | 41 | 1,234 | 4,112 |
| Total | 99 | 2,981 | 9,936 |

Assumes:
1) 3,000 tons per barge
2) 100 tons per railcar
3) 30 tons per truck

Table 4.7-18. Storage and inventory carrying cost calculations for March 1 to April 15 closure.

| Pool | Storage Costs ($) | Inventory Costs ($) | Total Costs ($) |
|---|---|---|---|
| Storage and Inventory Carrying Cost Calculations | | | |
| Lower Granite | 96,088 | 99,451 | 195,539 |
| Little Goose | 67,862 | 70,237 | 138,100 |
| Total | 163,950 | 169,688 | 333,638 |

Table 4.7-19. Increased total transportation costs for March 1 to April 15 closure.

| Commodity | Impact ($) |
|---|---|
| Grain | |
| Stored | 333,638 |
| Rail | 0 |
| Total | 333,638 |
| Wood Chips | -- [a] |
| Pulp & Paper | 140,000 |
| Peas & Lentils | 38,000 |
| Total | 511,638 |

a/ Likely to be negligible due to small volume and short duration of closure.

Table 4.7-20. Northwest wheat and barley exports by quarter, 1990.

| Product | Q1 | Q2 | Q3 | Q4 | Total |
|---|---|---|---|---|---|
| Wheat | 2,408,503 | 2,256,727 | 2,942,313 | 2,482,120 | 10,089,663 |
| Percent | 23.9 | 22.4 | 29.2 | 24.6 | |
| Barley | 205,512 | 82,560 | 2,268 | 370,698 | 661,038 |
| Percent | 31.1 | 12.5 | 0.3 | 56.1 | |

could negatively affect sales. The potential change has not been quantified, but is a concern to Northwest producers.

### 4.7.1.3 Effects on Deep-Draft Shipping

Hydraulic analysis indicates that water depths at the deep-draft lower Columbia River ports could be reduced in extreme cases. The degree of change would depend on how quickly the upper river pools were refilled and whether they were refilled from river flows at that time or from upstream storage. If the lower Snake River pools were drafted to near spillway crest through August 15, water depths below Bonneville could be reduced by about 2 feet if refill were accomplished in 1 month. The reduction would be about 1 foot if refill were extended over 2 months. Other reservoir drawdown options would not produce this depth effect.

This reduction of depth would hamper port access by vessels currently calling in the lower Columbia River. Decreased water depths would force operators of larger vessels to forego loading their vessels to their optimal weights. Over a 2-month period, loss of 1 foot in draft for vessels could affect 19 vessel calls and approximately 50,000 tons of cargo. The estimated dollar impact of this potential event would be about $630,000 in additional transportation costs. If 2 feet of draft were lost over a 1-month period, approximately 12 vessels and 44,000 tons of cargo would be affected. The estimated dollar impact of this potential event would be nearly $574,000 in additional transportation costs.

Conversely, the actions that would create this type of depth reduction in late summer would also increase channel depths in spring at the start of the drawdown period. During this period deep-draft ships would be allowed to draft more and experience shipping cost savings. It is possible that such savings would at least partially offset any increase in costs due to reduced depths during the refill period.

### 4.7.1.4 Dworshak Logging Operations

The three primary Dworshak log dump sites are operable to elevation 1570 or 1580 feet. Use of the three sites is currently constrained during annual drawdown periods. The lower ends of the log ramps have been constructed or extended as far as possible log bundles now begin to incur damage (bands break or logs are damaged) before they reach the ends of the ramps. The reservoir typically reaches elevation 1570 about June 15 and remains above that level until late September.

The proposed flow augmentation measures would result in shifts in the drawdown/refill pattern that would decrease the period in which these sites were usable. The likelihood and degree of such a change would be highly variable in any given year, as it would depend both on annual water conditions and timber harvest scheduling. With the fixed or unlimited draft options, under average water conditions the log dumps would remain inoperable throughout the 1992 season. Augmentation options involving variable drafts and/or changes in flood control operations would, on average, allow use of the log dumps by mid-June as at present.

Loss of use of the dumps for additional time would require hauling of logs by truck over longer routes to mills. In scoping input provided to the Corps, Potlatch Corporation referenced a cost of $750,000 per season for transporting 30 million board feet of logs 200 miles round trip by truck (personal communication, T. Maddock, Potlatch Corporation, June 14, 1991). Subsequent input provided in review comments on the Draft OA/EIS indicates that Potlatch believes logging operations at the Dworshak log dumps would be interrupted during an average water year with flow augmentation Options B through F (personal communication, T. Maddock, Potlatch Corporation, November 14, 1991). The increased transportation and storage costs in these cases were estimated at $290,000 per year. This estimate has not been independently confirmed, but appears to be reasonable.

The proposed temperature control test release from Dworshak in August could have similar effects on log transportation. The test could lower the reservoir by up to 20 feet in August, depending upon the rate of inflow. Assuming Dworshak were full or nearly so at the end of July, this suggests that the reservoir elevation would drop below the useable level by early September, or possibly 2 to 4 weeks before this normally occurs. Given the variability in log storage and shipping patterns, it is not known whether this change would have a measurable impact on the log handling operations.

### 4.7.2 Railroads

Two potential impact issues relate to railroads serving the study area. Rail lines that are adjacent to the affected reservoirs could suffer physical damage due to erosion and failure of the railway embankments. Railroads throughout the study area could also experience indirect effects through potential diversion of cargo now carried by barge.

Lowering Snake River elevations to spillway crest would expose a substantial portion of unprotected railroad and roadway embankment. The embankments are armored with riprap for protection against wave action and excessive scour, but the riprap only extends a little below minimal pool elevation. With a lower reservoir, wave action would erode the embankments and result in an unstable fill. With time, sloughing off of the fill would occur. As the erosion progressed, the design safety factor for the embankment would be diminished and the fill would fail.

If the damaged fill interfered with the passage of railroad or highway traffic, use of the area would be restricted until the repairs are implemented. Because of the magnitude for installing protection of the embankments prior to lowering the reservoirs, the option of repairing the fills as they fail is probably more practical. Under this scenario, however, the public would be exposed to life-threatening events.

Protection of the embankments would require placement of additional riprap or geotextile fabric and grout, or the repair of the embankments as they are damaged. Approximately 1.2 million square feet of riprap would be required for protection. The quantity accounts for only the protection of 5 feet above and below the proposed drawdown pool elevation. During drawdown and when refilling the reservoirs, additional surface area on the embankments would be subjected to erosion. If lowering of the reservoirs became an annual event, eventually the entire slope of the embankment would need to be protected.

The Joso Bridge across the Snake River at Lyons Ferry appears to be founded on bedrock. Because the bridge was built before the raising of the pool, potential scour of the footings should not be a problem. The other Snake River railroad crossing is upstream of Lyons Ferry approximately 2.5 river miles. The Riparia Branch Bridge was designed and built by the Corps as part of the relocation of the Camas Prairie Railroad in 1965. The design drawings show piers to be excavated 12 inches into the bedrock. Therefore, increased flows should not cause scour or undermining of the footings.

The bridge located at Lewiston near the mouth of the Clearwater River was retrofitted in the 1970s for the raising of the Lower Granite reservoir. Original piers were founded on bedrock. Piers 3, 4, and 5 were modified and are supported on H-pile driven to bedrock. The H-pile for Pier 5 appears to have been enclosed within a sheet pile cofferdam, but Piers 3 and 4 are not confined and undermining is a possibility. The bottom of the concrete cap elevation for Pier 4 is approximately 696.5. Protection for this bridge could be accomplished with placement of cofferdams around Piers 3 and 4 and sealing between the pile cap and bedrock with concrete.

Indirect effects on area railroads are expected to be minimal under any of the proposed actions. Based on analysis of rail rates and service capability, the navigation analysis concluded that a temporary loss of barge serve from reservoir drawdown would result in approximately 10 percent of the affected tonnage being diverted to rail. This would represent approximately 900 railcar loads of grain, plus significantly smaller amounts of other commodities. Such a diversion would constitute a minor benefit to one or more railroads serving the area.

### 4.7.3 Highways

The impact assessment framework for highways parallels that for railroads. Highways cross the lower Snake River reservoirs in several locations, and some highway segments parallel the reservoirs on embankments. These embankments would suffer an elevated risk of failure from physical processes triggered by deep reservoir drawdowns. Highways could also be indirectly affected by diversion of commodities now transported by barge.

#### 4.7.3.1 Physical Effects

Six highway bridges cross the Snake and Clearwater rivers. Three of the bridges cross the Snake River in Washington. Two bridges connect Clarkston, Washington with Lewiston, Idaho and are also across the Snake River. The remaining bridge crosses the Clearwater River in Idaho on the east end of Lewiston. Depending on site conditions, these bridges could be subject to damage and potential failure due to the reservoir drawdown.

The Lyons Ferry Bridge on State Highway 261 was constructed in 1968 during the relocation process for raising the Lower Monumental Reservoir. The piers are founded on bedrock so increased river velocities and a lower pool elevation should have minimal impact. The Central Ferry Bridge on State Highway 127 across the Little Goose Reservoir was also built in 1968 for the relocation of highways in preparation for filling the pool. The piers extend to bedrock, which should decrease any potential impact when operating the pool at a lower elevation.

The remainder of the highway bridges are located in the Lewiston-Clarkston area. The Someday Bridge, also referred to as the Red Wolfe Bridge, crosses the Snake River and connects Clarkston, Washington to the Port of Wilma on State Highway 193. The bridge was designed and built in 1977. Three of the four piers are founded on bedrock or dense gravels and are below elevation 680. The last pier is on a foundation of gravel at elevation 712. Lowering the reservoir to near spillway crest height of 681 would cause an estimated low river at approximately the 706 elevation. Potential scour could be a problem, based on velocities from 7 to 10 feet per second and existing river topography.

The other bridges in the Lewiston-Clarkston vicinity were constructed before the raising of Lower Granite Reservoir. The piers are founded on bedrock or otherwise have construction histories that should not make them susceptible to scour from higher flow velocities.

For bridges, which might present a problem, protection for the supporting piers could be the placement of riprap, sheet pile and grout, or geotextile fabrics and grout. The choice, type and complexity of protection must be evaluated to a higher degree before the drawdown occurs to guarantee the public's safety.

#### 4.7.3.2 Redistribution of Traffic

The primary impact from this redistribution of trucking patterns would be increased truck traffic on well-maintained roads. Any increased truck traffic would generate additional tax revenues that would at least partially offset increased costs to maintain and repair the highway systems. The economic consequence of such events would be a transfer of costs among jurisdictions, locations, and transportation sectors. Overall, any impact on roadways would be minimal because the highway system and taxing structure appear adequate to handle the volume and associated costs of a relatively minor increase in traffic.

The potential indirect effects on the highway network in each state are assessed below:

**Idaho**

None of the drawdown options would significantly affect the Idaho highway system. Imports and exports currently using the Port of Lewiston are already traveling to and from the port by trucks on the existing Idaho highway system for transfer to/from barges. The level of truck traffic on this portion of the Idaho system would not be increased due to a lack of barge transfer in the Lewiston/Lower Granite Pool.

The most likely highway impact of a temporary navigation closure on the lower Snake River would be to slightly decrease truck traffic on the access routes to the Lewiston-Clarkston area. The decrease would be due to some shift of wheat and barley exports to rail facilities in Idaho, where rail can be used as a direct connection to Portland, Oregon. Some truck shipments from origins/destinations on the edge of the Columbia/Snake River service area might also shift to other routes and connections.

**Oregon**

None of the drawdown options would significantly affect the Oregon highway system. There could be some shift of truck traffic from the Lewiston-Clarkston area to the Pendleton area for railroad shipping or the Umatilla area for barge shipping. Truck traffic would shift from one highway to another, so no increased traffic-related impacts would occur. Additionally, the state of Oregon's taxing system for trucks is based on the tonnage of commodity moved, so the industry would pay additional taxes to compensate for any increased weight loading.

**Washington**

Any highway impacts would be concentrated on the Washington State highway system, as drawdowns would preclude navigation only on the lower Snake River pools. The Columbia River pools would maintain navigation during the drawdown periods. Thus, there could be diversion to downstream pools with appropriate port facilities and to rail facilities with appropriate loading capacity depending upon shipper response to the barge closure (see Section 4.7.1). This could extend existing truck traffic bound for Lewiston-Clarkston and other lower Snake River ports to other pools that could accommodate the diverted tonnage of commodities. Some truck traffic could also be diverted to rail terminals with appropriate loading/unloading facilities.

For drawdown to near spillway crest at all four pools on the lower Snake River, the primary highway system identified in Section 3.7.3 could conceivably receive increased traffic. However, the navigation analysis concluded there would generally be little tendency for shippers to divert cargoes from barge to truck transportation in the event of a 3-month (or less) navigation closure from reservoir drawdown. This was because of the large cost differential between truck and barge transportation, and the availability of other options. With all four lower Snake River pools near spillway crest, temporary storage with minor diversion to rail transportation was the expected response. In this case, the same volume of truck traffic would continue to haul grain (primarily) from farms to storage and rail loading facilities, with only a minor redistribution on destinations. Temporary storage in upstream elevators is also the expected shipper response to a four-week drawdown test of Lower Granite and Little Goose in March 1992.

Drawdown options for which only Lower Granite Pool would be out of service for navigation could present exceptions to this general case. Truck traffic currently headed for port facilities in the Lewiston-Clarkston area might instead be diverted downstream to the Little Goose Pool, or possibly the Lower Monumental Pool. This type of response would greatly increase the level of truck traffic, congestion and road damage at or near Almota and comparable downstream loading points.

Although this would create some traffic-related impacts on the existing state and county road systems, these would not be significant. Most segments of the highway system in eastern Washington carry low average daily traffic (ADT) volumes. The truck volumes require to move grain diverted from the Lower Granite Pool generally would not represent a significant increase in traffic on the highway system. A potential exception is the segment of U.S. 395 from Interstate 90 in Adams County to just north of Interstate 182 in Franklin County. This route is a 2-lane highway that currently carries a high proportion (approximately up to 30 to 35 percent) of truck traffic. Additional truck volume on this road from grain hauls would slightly increase the truck percentage. This would result in a slight reduction in the level of service for the travelling public on this portion of U.S. 395.

## 4.7.4 Mitigation

The most significant transportation impacts would be to bulk commodities that are transported by barge if drawdown to spillway crest is implemented. Because of the large cost differential between modes of transportation and the current low profit margin of grain commodities, there are few mitigation actions that may be taken to offset the effects of losing the opportunity to transport by barge. Some losses may be mitigated by temporary storage, but these gains may be offset by an oversupply of grain at a later date.

## 4.8 AGRICULTURE

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown** | |
| ***Snake River*** | |
| All 4 projects to MOP (April 1 to July 31) | • No effect on irrigation. |
| All 4 projects to near spillway crest (April 15 to August 15) | • No production from 56,000 irrigated acres in 1992, all on Ice Harbor.<br>• Lost net crop value and reestablishment costs of $83 million. |
| All 4 projects to near spillway crest (April 15 to June 15) | • Same as April 15 to August 15. |
| Lower Granite to near spillway crest (February 1993 or July 15 to August 15) | • No effects on irrigation. |
| Lower Granite to 710 feet, others to MOP (April 15 to June 15) | • No effects on irrigation. |
| Lower Granite/Little Goose drawdown test (March) | • No effect on irrigation. |
| ***Lower Columbia*** | |
| All 4 projects to MOP (April 1 to August 31) | • No production from 226,000 irrigated acres in 1992, most at John Day.<br>• $197 million in lost net agricultural production and reestablishment costs. |
| John Day at 262.5 feet, McNary at 337 feet, remainder at MOP (April 1 to August 31) | • No production from 13,000 irrigated acres in 1992, mostly at Bonneville.<br>• $52 million in lost net agricultural production and reestablishment costs. |
| **Flow Augmentation** | • Increased probability of no production from 460 acres and crop losses valued at $220,000. |
| **Combination** | • Effects additive; see drawdown and augmentation. |
| **Temperature Control Test (August)** | • No effects on irrigation. |

Altering reservoir elevations on the Columbia-Snake River pools would have serious economic consequences for many irrigators drawing water from those pools. The number of irrigators affected and the extent of the impact varies between pools and between options. Important economic issues associated with 1992 options include the following:

- Direct economic effects are assumed to include the loss of agricultural production and income for the 1992 season. This could, in turn, result in possible bankruptcy for some land owners and farm operators.

- Loss of production and income could have a variety of indirect economic consequences that cannot be predicted. Some of these consequences would be longer-term effects that could be triggered by a significant change in irrigated production in 1992, while others might not be evident without several years of modified river operations. Land values for non-irrigated land are much lower than the value of irrigated land, suggesting a lower tax base and a negative impact on local government revenues, schools, and other services (if actions taken in 1992 were perceived to indicate long-term changes to irrigation). Agricultural processing firms, elevator operators, ports, and shippers would be adversely affected by the loss of crops. Other secondary economic effects would be felt throughout the regional economy.

- Under normal circumstances, the possible responses to disruption of irrigation from the affected pools might be to obtain water from alternative sources or convert to non-irrigated production. These options do not appear feasible for most irrigators either in 1992. Regardless of the ability to implement or afford modifications, the lead time required would preclude making such modifications for the 1992 irrigation season in virtually all cases.

Although the focus of this EIS is the analysis of actions that could be implemented in 1992, other economic issues that would be relevant only for longer term actions were prominently mentioned in scoping meetings and are therefore addressed in this section. Issues that would apply to long-term reservoir drawdowns include the following:

- Some existing pump stations would have to be redesigned and modifications would have to be made. Modifications could be both expensive and time-consuming for those irrigators who would be affected. New Section 10 and Section 404 permits would be required for most modifications, and additional easements might be required for some.

- Virtually all irrigation pumps would be more expensive to operate because of the additional power needed to provide additional lift and maintain adequate system pressure, and because electricity rates could be higher.

- Some farms would not be able to afford pump modifications or increased operating costs and might cease operation.

- Nevertheless, the least-cost response to reservoir drawdown in most instances would be to modify pumping plants. This would be the expected response, given sufficient time.

- Economic losses within the region would be at least partially offset at the state or national level by benefits to other farmers, processors, and shippers who would increase production and sales to fill the void left by decreased production in the Columbia-Snake River region.

The perceptions and expectations of the irrigators would strongly influence their actual responses to disruption of irrigation supply and the eventual economic consequences. These responses are clouded by the peculiar timing of the proposed actions currently under review. This EIS addresses short-term actions that would be implemented in 1992, while possible longer term modifications are being evaluated under a separate decision process. In contrast, irrigators would likely be basing their responses to 1992 actions largely on their expectations of longer term conditions. For example, at least some irrigators would likely commit to pumping plant modifications if they expected that lowered reservoir levels would recur annually. They would also evaluate alternative water sources or cropping strategies differently depending on whether they expected long-term modification of reservoir operations. Alternative water sources and cropping strategies are not feasible alternatives for many irrigators, however.

Because of the influence of perceptions and the shortage of applicable data existing in the public domain, the following analysis is heavily dependent upon information obtained directly from the potentially affected irrigators. Staff from the cooperating agencies contacted many representatives of the irrigation community, including individual irrigators, irrigators' associations, and consultants hired by the irrigators to assess and plan pump station modifications. The agencies' objectives were to develop primary data concerning as much of the affected acreage as possible, and to have an information base representative of water users on each pool.

As noted in Section 2.10, 65 irrigators representing 255,512 acres of irrigated land were interviewed by the agencies. They represent about 71 percent of the acreage irrigated with water drawn from the Bonneville, The Dalles, John Day, McNary, Ice Harbor, and Brownlee pools. For this analysis, it is assumed that the interviewed irrigators are representative of those not interviewed. Therefore, as cost estimates for the interviewed irrigators are presented throughout this analysis, the estimates are increased by 41 percent to represent estimated costs to all irrigators (71 percent times 1.41 equals 100 percent).

## 4.8.1 Value of Lost Agricultural Production

There would be insufficient time for operators to make necessary pump station modifications by the 1992 irrigation season, and most irrigators indicated that their only option would be to cease operation entirely for the year. Because of the limited rainfall and relatively low elevation of these farmlands compared to some upland sites, the land is not suitable for most non-irrigated crops. Most irrigators do not appear to have a readily available alternative source of irrigation water. (It is conceivable or even likely that some operators would be able to find a means of getting water to crops during the 1992 season, assuming such measures were physically feasible and less costly than the income that would otherwise be lost. In the absence of any reasonable basis to predict the extent and effect of such a response, it must be assumed that all affected production would be lost.) Crops that require irrigation, such as potatoes, corn, vegetable row crops, and orchards, could not be grown at all on non-irrigated acres. The loss of water for even a short period of time would mean loss of the crop for the year. In the case of younger orchards, vineyards, and crops such as asparagus, plants could die and would have to be replaced.

The total value of lost agricultural production presented here has two components (Table 4.8-1). The first component is net crop value, equal to the price the farmer would receive for selling the crop less the variable costs of producing the crop. The second component is the net present value of reestablishment costs for those crops such as orchards and vineyards that would take several years to replace once the plants had died. The net value of crop losses was estimated using Washington State University (WSU) Cooperative Extension Service Farm Business Management Reports for most crops (WSU, 1985; 1988; 1989; 1990a; 1990b; undated a; undated b). Reestablishment costs for orchards and vineyards were based on some of the same sources (WSU, 1985; 1990a). Reestablishment costs were not estimated for any crops other than orchards and vineyards, because survey data did not differentiate between crops requiring reestablishment (such as asparagus) and other crops.

The total value of lost agricultural production was estimated for two cases. First, the loss associated with 1992 options was estimated, assuming all irrigated acres would yield no crop for the year (Table 4.8-2). Estimates of crop losses were made first for those irrigators who were actually interviewed and then the estimate was expanded to account for all potential irrigators affected. The estimated net value of crop losses and reestablishment costs on each pool shown in Table 4.8-2 is the best available estimate of losses, but the estimates differ from expected costs in at least three respects: (1) some variable costs associated with a 1992 crop have already been incurred or will be incurred before a decision is made on 1992 actions. Any variable expenditures made before the decision point is reached would add to the net loss of irrigators; (2) reestablishment costs for some crops such as asparagus have not been included,

Table 4.8-1. Per acre value of crops and reestablishment costs.

| Crop | Gross Value Used in DEIS | Net Value and Reestablishment Costs | | | | |
|---|---|---|---|---|---|---|
| | | Gross Value | Variable Cost | Net Value | Reestablishment Cost | Total Cost/Acre |
| Pasture | $ 200 | $ 120 | $ 78 | $ 42 | $ 0 | $ 42 |
| Unspecified Crops | 1,251 | | | 616[a/] | 0 | 616 |
| Grass Seed | 435 | 630[b/] | 256 | 374 | 0 | 374 |
| Alfalfa | 426 | 455 | 249 | 205 | 0 | 205 |
| Sweet Corn | 1,692 | 495[c/] | 280 | 215 | 0 | 215 |
| Field Corn | 540 | 500 | 420 | 80 | 0 | 80 |
| Winter Wheat | 236 | 420[d/] | 211 | 209 | 0 | 209 |
| Potatoes | 3,004 | 2,732 | 1,248 | 1,484 | 0 | 1,484 |
| Misc. Vegetables | 1,550 | | | 742[e/] | 0 | 742 |
| Grapes | 2,620 | 3,000 | 1,100 | 1,900 | 4,888 | 6,788 |
| Mixed Orchard | 2,000 | | | 1,698[f/] | 4,617 | 6,315 |
| Apples | 3,198 | 5,400[g/] | 2,928 | 2,472 | 4,617 | 7,089 |

Sources: WSU, 1985; 1988; 1989; 1990a; 1990b; undated a; undated b.

a/ Unspecified crop value equals weighted average net value of all other crops.
b/ Higher net value of grass seed than that shown in DEIS reflects change from DEIS use of all grass seed average value to more appropriate bluegrass seed value.
c/ Significantly lower net value of sweet corn than that shown in DEIS reflects change from DEIS use of fresh market corn value to more appropriate corn for processing value.
d/ Higher gross value of winter wheat than that shown in DEIS reflects change from DEIS use of Washington average wheat yields to higher Columbia Basin yields on irrigated land.
e/ Miscellaneous vegetables value equals one-half potato value.
f/ Mixed orchard value equals two-thirds red delicious apple value.
g/ Significantly higher gross value of apples than that shown in DEIS reflects change from DEIS use of Washington average yields to higher Columbia Basin yields.

and would add to the cost of irrigators; and (3) at least some irrigators would be able to grow other, non-irrigated crops or would be able to get water from an alternative source. Although these options are not available to many, they would reduce the losses of irrigators who took advantage of them.

To respond to issues raised at scoping meetings concerning the losses associated with longer term drawdowns, a second estimate was made for agricultural losses associated with actions that could be taken in 1993 and beyond. Some irrigators indicated that they would not modify their pumps to accommodate long-term reservoir drawdowns but would instead cease farming. The net value of agricultural losses associated with those farms is indicated in Table 4.8-3. Crop losses were estimated first for those irrigators actually interviewed, and then the estimate was expanded to account for other irrigators who might make the same choice. If the long-term drawdowns were actually implemented, the associated costs could differ significantly from the estimates shown here. Operators would make decisions at that time whether to modify pumping stations, go out of business, or follow some other course of action.

## Table 4.8-2. Value of lost agricultural production in 1992, with no pump modifications.

| Pool (level) | | Apples a/ | Mixed Orchard a/ | Grapes a/ | Misc. Veg | Potatoes | Winter Wheat | Field Corn | Sweet Corn | Alfalfa | Grass & Seed | Unspec Crop | Fallow | Pasture | Total Interviewed Irrigators | Total All Irrigators |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bonneville (70 msl) | Acres | 500 | 4,977 | 26 | 76 | 0 | 0 | 0 | 0 | 205 | 0 | 0 | 0 | 251 | 6,035 | 8,509 |
| | Crop Value | $3,544,500 | $31,429,755 | $176,488 | $56,392 | $0 | $0 | $0 | $0 | $42,025 | $0 | $0 | $0 | $10,542 | $35,259,702 | $49,716,180 |
| The Dalles (155 msl) | Acres | 0 | 21 | 0 | 105 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 126 | 178 |
| | Crop Value | $0 | $132,615 | $0 | $77,910 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $210,525 | $296,840 |
| John Day (262.5 msl) | Acres | 0 | 0 | 0 | 0 | 725 | 575 | 1,250 | 200 | 0 | 0 | 0 | 0 | 0 | 2,750 | 3,878 |
| | Crop Value | $0 | $0 | $0 | $0 | $1,075,900 | $120,175 | $100,000 | $43,000 | $0 | $0 | $0 | $0 | $0 | $1,339,075 | $1,888,096 |
| John Day (257 msl) | Acres | 1,522 | 0 | 2,825 | 12,421 | 25,943 | 10,149 | 32,614 | 5,115 | 30,298 | 3,473 | 1,037 | 5,776 | 7,360 | 138,533 | 195,332 |
| | Crop Value | $10,789,458 | $0 | $19,176,100 | $9,216,382 | $38,499,412 | $2,121,141 | $2,609,120 | $1,099,725 | $6,211,090 | $1,298,902 | $638,792 | $0 | $309,120 | $91,969,242 | $129,676,631 |
| McNary (337 msl) | Acres | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Crop Value | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| McNary (335 msl) | Acres | 300 | 55 | 0 | 1,660 | 4,767 | 3,400 | 2,231 | 200 | 906 | 450 | 750 | 566 | 0 | 15,305 | 21,980 |
| | Crop Value | $2,126,700 | $347,325 | $0 | $1,231,720 | $7,074,228 | $710,600 | $180,090 | $43,000 | $185,730 | $168,300 | $462,000 | $0 | $0 | $12,529,683 | $17,666,853 |
| Ice Harbor (437 msl) | Acres | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Crop Value | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Ice Harbor (<409.5 msl) | Acres | 2,986 | 70 | 2,410 | 3,405 | 7,832 | 3,156 | 7,320 | 1,005 | 2,125 | 223 | 7,844 | 1,690 | 0 | 40,066 | 56,493 |
| | Crop Value | $21,167,754 | $442,050 | $16,359,080 | $2,526,510 | $11,622,688 | $659,604 | $585,600 | $216,075 | $435,625 | $83,402 | $4,831,904 | $0 | $0 | $58,930,292 | $83,091,712 |
| Brownlee | Acres | 0 | 0 | 0 | 53 | 54 | 105 | 11 | 0 | 66 | 0 | 0 | 35 | 0 | 324 | 457 |
| | Crop Value | $0 | $0 | $0 | $39,326 | $80,136 | $21,945 | $880 | $0 | $13,530 | $0 | $0 | $0 | $0 | $155,817 | $219,702 |

a/ Lost crop value includes present value of reestablishment costs.

Operators who cease farming could sell or lease their land to others who would continue producing crops, thus reducing the net agriculture loss to the region. Further analysis of such actions is beyond the scope of this OA/EIS.

The value of one year's lost production plus orchard and vineyard reestablishment costs is estimated at $49,720,000 for the Bonneville Pool and $300,000 for The Dalles Pool (Table 4.8-2) when drawn to MOP. It is possible that reestablishment costs from a 1992 action would not be incurred at Bonneville, due to the slightly wetter climate here compared to the remainder of the pools. If so, the total costs would be reduced by about $25.4 million. However, because drawdown to MOP would be maintained from April 1 through the warmest and driest part of the summer, the higher potential costs have been included in the table.

At 262.5 msl on the John Day Pool, the loss of the year's crop is estimated at $1,890,000 (Table 4.8-2). More than one-half of the lost value would be associated with the potato crop.

At MOP (257 msl) on the John Day Pool, 195,332 acres of crops would be lost, with a value of $130 million (Table 4.8-2). Much of that loss would be from potatoes and other vegetables, as well as reestablishment costs of orchards and vineyards.

At 337 msl on the McNary Pool, none of the irrigators indicated that they would be affected. At MOP (335 msl) on the McNary Pool, the value of lost agricultural production and reestablishment costs would equal $17,670,000 (Table 4.8-2).

None of the irrigators on the Ice Harbor Pool would be affected at MOP (437 msl). At near spillway elevations of 409.5 and lower, production valued at $83,100,000 would be lost from the 56,493 affected acres. Much of the lost crop value would be from apples, grapes, and potatoes, and would include the cost of reestablishing the orchards and vineyards.

Flow augmentation from Brownlee Reservoir would increase the probability that irrigators would be affected, especially in low water years. This would occur if flow augmentation caused the reservoir level to fall below elevation 2,034 during the irrigation season. Based on Table 3.4-3 this would be likely only with the unrestricted draft option. If all irrigators were affected, the value of crop losses would be about $220,000.

In total, the value of agricultural losses and reestablishment costs from drawing all the Columbia River pools to MOP would equal about $197 million. An additional $83 million in net crop value and reestablishment costs would be lost if Ice Harbor were drawn to near spillway crest, and up to $220,000 in net crop value could be lost if flow augmentation from Brownlee Reservoir affected irrigators. A 4- to 6-week test drawdown on Lower Granite and Little Goose pools would not affect irrigators.

### 4.8.2 Secondary Economic Effects

Secondary effects of the loss of agricultural production would include adverse effects on local agricultural processing plants, elevator operators, ports, and other agribusinesses; direct and indirect job losses; and possibly a lower tax base with associated local government fiscal effects (depending upon perceptions and real estate market responses).

Some of these effects would constitute net economic losses to the region and possibly the nation, while some would represent transfers of wealth from affected farms and businesses to other farms and businesses that would increase production and sales to fill the void. Additionally, farmers in other regions could benefit from higher crop prices brought about by the reduced supply of the products from the Columbia-Snake River region.

### 4.8.3 Pump Station Operating Ability

Many irrigation pumps on the Columbia-Snake River pools are designed to operate at normal pool elevations with short-term deviations to MOP. At MOP, some pumps cannot operate or operate at less than design capacity because of the increased lift and other problems. At levels below MOP, most pump stations would be left out of the water. Because of the existing pump station configurations and the effect of reservoir drawdowns on the size of the pools, most pumps could not simply remain in the same place and be set deeper in the pools. Most would require new intake systems that would extend both vertically and horizontally beyond the

**Table 4.8-3. Value of lost agricultural production associated with post-1992 actions if some irrigators modify pumps and others cease farming.**

| Pool (level) | | Apples[a] | Mixed Orchard[a] | Grapes[a] | Misc. Veg | Potatoes | Winter Wheat | Field Corn | Sweet Corn | Alfalfa | Grass & Seed | Unspec Crop | Fallow | Pasture | Total Interviewed Irrigators | Total All Irrigators |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bonneville (70 msl) | | | | | | | | | | | | | | | | |
| | Acres | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Crop Value | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| The Dalles (155 msl) | | | | | | | | | | | | | | | | |
| | Acres | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Crop Value | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| John Day (262.5 msl) | | | | | | | | | | | | | | | | |
| | Acres | 0 | 0 | 0 | 0 | 425 | 575 | 750 | 0 | 0 | 0 | 0 | 0 | 0 | 1,750 | 2,468 |
| | Crop Value | $0 | $0 | $0 | $0 | $630,700 | $120,175 | $60,000 | $0 | $0 | $0 | $0 | $0 | $0 | $810,875 | $1,143,334 |
| John Day (257 msl) | | | | | | | | | | | | | | | | |
| | Acres | 750 | 0 | 355 | 795 | 2,675 | 1,155 | 4,652 | 65 | 1,510 | 0 | 107 | 31 | 6,735 | 18,830 | 26,550 |
| | Crop Value | $5,316,750 | $0 | $2,409,740 | $589,890 | $3,969,700 | $241,395 | $372,160 | $13,975 | $309,550 | $0 | $65,912 | $0 | $282,870 | $13,571,942 | $19,136,438 |
| McNary (337 msl) | | | | | | | | | | | | | | | | |
| | Acres | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Crop Value | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | 0 |
| McNary (335 msl) | | | | | | | | | | | | | | | | |
| | Acres | 0 | 0 | 0 | 181 | 304 | 0 | 409 | 0 | 76 | 0 | 0 | 116 | 0 | 1,086 | 1,531 |
| | Crop Value | 0 | 0 | 0 | $134,302 | $451,136 | $0 | $32,720 | $0 | $15,580 | 0 | 0 | 0 | 0 | $633,738 | $893,571 |
| Ice Harbor (437 msl) | | | | | | | | | | | | | | | | |
| | Acres | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Crop Value | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Ice Harbor (<409.5 msl) | | | | | | | | | | | | | | | | |
| | Acres | 426 | 0 | 2,330 | 1,000 | 1,400 | 600 | 0 | 770 | 0 | 0 | 0 | 0 | 0 | 6,526 | 9,202 |
| | Crop Value | $3,019,914 | $0 | $15,816,040 | $742,000 | $2,077,600 | $125,400 | $0 | $165,550 | $0 | $0 | $0 | $0 | $0 | $21,946,504 | $30,944,571 |

a/ Includes present value of reestablishment costs.

current pump station placement. In extreme cases, such as where pump stations are located in coves that would be completely dewatered during a drawdown, pumps could be left as far as 10,000 feet from the new shoreline.

Many irrigators, especially the larger irrigators on the John Day and McNary pools, have consultants preparing conceptual designs for the required pump station modifications. The results of these studies indicate that the required modifications would have to be designed specifically for each site, based on the existing pump station configuration and the vertical and horizontal distance that would have to be covered by the new system (IRZ Consulting and PACAM Engineering, 1991). One concept that appears to be feasible at many sites involves keeping the existing station and adding an additional pumping facility in deeper water. The two facilities would be connected by new piping, and the new pumping plant would lift to the existing plant when the reservoir is drawn down. When the reservoir is at normal operating elevation, the existing plant would work as it currently does.

In addition to the cost of making pump station modifications, several months of lead time would be required to design the modifications, custom manufacture equipment, wait for equipment delivery, and install the new equipment. Estimates of the required lead time range from 10 to 14 months and even longer, including 2 to 4 months to complete the design and 4 to 10 months for equipment delivery, depending on whether standard or specialized equipment is needed. Most station modifications would require new or modified Section 10 and Section 404 permits from the Corps, adding another 2 to 4 months to the schedule. The construction schedule would also have to fit within the seasonal restrictions of the Washington Department of Fisheries. Work in the pools would be confined to a 3-month period between December 1 and the end of February. Depending on the extent of modifications, additional or modified easements would be required by some irrigators, adding to both the expense and time required to accomplish the modifications.

Because of the long lead time required to make pump station modifications, it is not a feasible option for the 1992 irrigation season. Nonetheless, many irrigators expressed concern about modification costs during the scoping process for this OA/EIS. For that reason, some assessment of modification costs is included here.

Several pre-engineering, reconnaissance level studies sponsored by the Umatilla Electric Cooperative Association, Benton County Public Utility District, and individual irrigators have reported modification cost estimates ranging from about $126,000 to nearly $4.8 million for each of the 17 stations evaluated on the John Day, McNary, and Ice Harbor pools (IRZ Consulting and PACAM Engineering, 1991). Excluding the single highest cost station ($4.8 million), the average cost per station is estimated at $400,000 on the John Day and McNary pools and $2 million on Ice Harbor. Although the reports feature only reconnaissance level estimates and are taken from a small sample of irrigators, they cover a wide range of operations from small (550 acres) to large (28,000 acres), and are the most comprehensive studies made to date.

To roughly estimate station modification costs that would be incurred if post-1992, long-term drawdowns are put into action, we reviewed information provided in the IRZ Consulting and PACAM Engineering reports (1991), as well as information provided by engineering firms consulting for other irrigators. Using that engineering data, we calculated the weighted average modification cost expressed as dollars per acre irrigated. The resulting estimates of $100 per acre on the John Day and McNary pools and $250 per acre on Ice Harbor are representative of those irrigators included in the studies, but are not known to be representative of other irrigators. Nonetheless, they offer a reasonable starting point for estimating modification costs for various reservoir levels. As noted earlier, more definitive estimates would require site-specific designs for each pumping station affected, and such an undertaking is beyond the scope, and outside the time limitations, of this OA/EIS.

On the Bonneville Pool, both of the interviewed irrigators would be affected by dropping the reservoir to MOP (70 msl). On average, just 3 feet of additional lift would be required, plus pipe extensions. The cost for these modifications, at $100 per acre, would be about $603,000 for the interviewed irrigators or about $850,000 for all irrigators on the Bonneville Pool.

On The Dalles Pool, two of the three interviewed irrigators would be affected by drafting the reservoir to MOP (155 msl), and the third would possibly be affected as well. Like modifications on the Bonneville Pool, a short additional lift and the extension of pipes would be required to continue irrigating. The cost of these modifications has not been determined.

Two of the 27 interviewed irrigators on the John Day Pool would be affected by dropping the pool elevation to 262.5 msl. One of these operators indicated an intent to make any needed modifications, at a cost of about $135,000. The other operator indicated that he would probably quit farming. Expanding on this estimate to represent all irrigators on the pool yields an estimate of $190,000 to make modifications and 1 or 2 operators who would quit farming.

Twenty-two of the 27 interviewed irrigators on the John Day Pool would be affected by dropping the pool to MOP (257 msl). At 257 msl, three irrigators could operate as they currently do. Two operators did not supply sufficient information to determine whether they would be affected. Of the 22 irrigators (representing 138,533 acres) affected at 257 msl, 11 irrigators (102,756 acres) indicated an intent to make any needed modifications and 4 irrigators (16,947 acres) indicated a willingness to consider making modifications, generally depending on how much it would cost to do so. Seven of those interviewed (18,830 acres) indicated that they would not be able to afford modifications and would go out of business. In general, those who indicated that they would make modifications are larger landholders, and some have already made estimates of the cost of modifications. Their current estimated costs ranged from $100,000 to $1.4 million each, and from $20 to $200 per acre. The cost for making modifications to the pumps of all interviewed irrigators considering modifications is estimated at about $11,970,000. Expanding on this estimate to represent all irrigators on the John Day pool yields estimates of $16,880,000 to make needed pump station modifications for those who choose to do so, and about 10 irrigators who would quit farming.

None of the 16 interviewed irrigators on the McNary Pool would be affected by dropping the pool elevation to 337 msl, while 6 (15,305 acres) would be affected by dropping to MOP (335 msl). Of those affected at 335 msl, four (13,299 acres) indicated an intent to make any needed modifications and one (1,086 acres) indicated that he would go out of business. The cost for making modifications to the pumps of all interviewed irrigators considering modifications and the others with no specific plans is estimated at about $1,420,000. Expanding this estimate to represent all irrigators on the McNary Pool indicates that modification costs would equal $2,005,000, and 1 or 2 irrigators would quit farming.

At Ice Harbor, none of the 14 interviewed irrigators would be affected at 437 msl but 11 (35,215 acres) would definitely be affected at 409.5 msl or lower. Three other irrigators (4,851 acres) draw water from wells, and they would probably be affected at 409.5 msl or below. Four of the affected irrigators (19,906 acres) indicated that they would consider making needed modifications. Two irrigators (6,526 acres) said they would go out of business, and eight did not indicate their plans. The cost of making modification to the pumps of all interviewed irrigators considering modifications and those with no specific plans is estimated at about $8,390,000. Expanding that estimate to include all irrigators on the Ice Harbor Pool yields an estimate of $11,820,000 to make needed modifications, while perhaps 3 irrigators would go out of business.

Cost estimates for any needed pump station modifications on Brownlee Reservoir have not been made.

In total, the cost of pump modifications is estimated at $19,740,000 if all pools were drawn to MOP, and an additional $11,820,000 if Ice Harbor were drawn below MOP to near spillway crest. If the John Day and McNary pools were kept above MOP at elevation 262.5 and 337, respectively, modification costs would drop to $1,040,000.

### 4.8.4 Increased Operating Costs

Operating costs would rise for the modified pumping stations. As noted in Section 3.8, irrigators currently report spending an average $75 per acre per year for electricity to run irrigation equipment. For the largest irrigators, electricity costs exceed $1 million per year. Electricity costs for each irrigator would increase, with the magnitude of the increase dependent on the additional lift required from the new water surface elevation, the additional horizontal distance to be covered, and the additional pressure needed to maintain pressure throughout a larger system.

Pump operating costs would also increase somewhat at existing stations that would still be able to operate at lower reservoir levels. This would be caused by the increased lift required, and possibly increased maintenance needs from strain on the pumps. Based on site-specific studies in Oregon and Washington made by IRZ Consulting and PACAM Engineering (1991) and unpublished engineering estimates made for several Washington irrigators, increased costs of electricity associated with lowering pools to MOP have been estimated at 3.6 percent above current costs. Based on current electricity cost estimates made by interviewed irrigators and expanded to account for other irrigators, this 3.6 percent increase would equal a total of $900 per year for Bonneville irrigators, $700 per year at The Dalles, $500,000 per year at John Day, $215,000 per year at McNary and $110,000 annually at Ice Harbor. With all pools drawn to MOP, the total increase in electricity costs would be about $825,000 for all irrigators combined. Insufficient data were available to make similar estimates for John Day at 262.5 msl and McNary at 337 msl, but the increased power costs associated with those pool elevations would be less than the costs indicated for the pools at MOP. The best current estimate of increased electricity costs at Ice Harbor if that pool is drawn to elevation 409.5 or lower is $545,000, a 17 percent increase over current costs.

### 4.8.5 Summary

As described in the foregoing sections, reservoir drawdowns in 1992 would have serious economic consequences for irrigators. These consequences include lost agricultural production from acreage that loses irrigation water and possible bankruptcy for some farmers. With all of the lower Columbia-Snake River pools drawn to MOP, one year's agricultural losses plus reestablishment costs for orchards and vineyards would equal about $197 million. If action were taken in later years and there were sufficient time to make pump modifications, the annual net value of agricultural losses would drop to $20,000,000, modification costs would equal $19,740,000, and increased operating costs would equal $825,000 a year.

When pump modification costs are amortized over the life of the modification, it becomes obvious that annual cost of long-term drawdown plans are much less than the drawdown cost in 1992.

### 4.8.6 Mitigation

The most significant agricultural impacts would occur when pool elevations drop to an elevation at which the irrigation pumps are affected. The only short-term mitigative actions available for 1992 are converting to dry land farming or developing alternative water sources. Neither action would be feasible for many irrigators.

## 4.9 ELECTRIC POWER

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown** | |
| ***Snake River*** | |
| All 4 projects to MOP[a/] (April 1 to July 31) | • Capacity loss would range from 550 MW to 1,400 depending on month (cost of $11 million).<br>• Minimal effect on firm energy availability.<br>• 800 to 1,200 MW-months lost in non-firm energy (cost of $9 to $13 million). |
| All 4 projects to near spillway crest (April 15 to August 15) | • Capacity loss of 300 MW to 3,200 MW depending on month (cost of $42 million).<br>• Firm energy loss of 300 average megawatts (aMW) (cost of $90 million).<br>• 2,500 to 5,500 MW-months lost in non-firm energy (cost of $27 million to $60 million). |
| All 4 projects to near spillway crest (April 15 to June 15) | • Capacity loss of 1,600 to 3,200 MW (cost of $32 million).<br>• Firm energy loss of 240 aMW (cost of $72 million).<br>• 2,000 to 5,000 MW-months lost in non-firm energy (cost of $21 to $55 million). |
| Lower Granite to near spillway crest (February 1993 or July 15 to August 15) | • Capacity loss of 800 MW (cost of $3 million to $8 million).<br>• Energy losses of 300 to 650 MW-months (cost of $3 million to $12 million; might be firm or non-firm energy, depending on water year). |
| Lower Granite to 710 feet, others to MOP (April 15 to June 15) | • 1,100 to 1,800 MW capacity loss (cost of $11 million).<br>• Firm energy loss of 60 aMW (cost of $18 million).<br>• Non-firm energy loss of 1,000 to 1,800 MW-months (cost of $11 million to $20 million). |
| Lower Granite/Little Goose drawdown test (March) | • Capacity loss of less than 600 MW.<br>• Firm or non-firm energy loss of 125 MW-months (cost of $1.5 million to $3 million). |
| ***Lower Columbia*** | |
| All 4 projects to MOP[b/] (April 1 to August 31) | • Capacity loss of 1,500 to 2,400 MW (cost of $33 million).<br>• Minimal firm energy loss.<br>• Non-firm energy loss of 850 to 1,600 MW-months (cost of $9 million to $17 million). |
| John Day at 262.5 feet, McNary at 337 feet, remainder at MOP (April 1 to August 31)[b/] | • 1,500 to 2,400 MW capacity loss (cost of $33 million).<br>• Minimal firm energy loss.<br>• Non-firm energy loss of 750 to 1,500 MW-months (cost of $8 million to $16 million). |

Power (continued)

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| Flow Augmentation | *Snake River:*<br>• Firm energy losses range from 40 aMW with Option J, to 450 to 500 aMW with unrestricted releases from Dworshak and Brownlee (cost $12 million to $146 million).<br>• In cases of unrestricted draft, there would be large capacity impacts in fall and winter (unquantified).<br>• Corresponding net gain in non-firm of $1 million to $27 million.<br>• Corresponding total costs ranging from $9 million to $130+ million.<br><br>*Columbia River:*<br>• Increase in total system costs ranging from $20 million to $75 million for Target 200 options. |
| Combination | • Effects additive; see drawdown and augmentation. |

a/ In 1991, projects were not allowed to refill until November. If this is necessary, costs indicated are too low.
b/ If MOP operations in the lower Columbia River are in addition to drawdown or MOP operations in the lower Snake River, costs could be significantly higher. Allowing a range near MOP significantly reduced power impacts.

The proposed actions could have a variety of consequences for the power production operations at the affected projects and for the regional power system as a whole. Both the reservoir drawdown and flow augmentation options would result in lost power generation, either through forced shutdowns of powerhouses or manipulation of stream flows and reservoir elevations. This could require production of replacement power by other sources either within or outside of the region. Lost hydroelectric generation would represent an economic cost to the region, which could translate into increased power rates. It could also result in an economic cost to the Pacific Southwest, because lost non-firm power normally exported to the Southwest would require replacement, likely by oil- and gas-fired generation.

Aside from the loss of power supply to the regional power grid, removal of hydro plants from service would entail some cost to replace station service power that is normally obtained from on-site generation. Finally, it is possible that the generation effects of the proposed flow measures could have adverse consequences for the stability of the regional power transmission system.

### 4.9.1 Power Losses

Identification of power losses associated with the proposed options requires separate assessment of several different elements of power production. These include changes to the overall generating capability of the system as a result of plant shutdown, loss of peaking capacity from operating specified reservoirs at static levels and transfer of this peaking operation to other projects, efficiency losses from reduced operating head, and reshaping of storage releases. In addition to capacity effects, generation levels and values would be affected by changes in the distribution of firm and non-firm energy generation.

The most important power impacts are estimated in the following sections.

#### 4.9.1.1 Capacity

The eight lower Snake and Columbia mainstem dams fluctuate regularly within their normal operating ranges as a result of system peaking operations. Reservoir levels at these projects can vary 2 to 5 feet on a daily or weekly basis as generation from these plants is shaped to follow load patterns. Electricity demands typically peak during daylight hours and are higher on weekdays than on weekends. If the reservoirs were held relatively constant at minimum pool levels, as would occur with several of the proposed drawdown options, the ability to cycle the plants to meet peak loads would be eliminated. This would result in a significant loss of instantaneous peaking capacity on the system. In addition, part or all of the load-shaping operation might be transferred to other projects, which would in turn experience greater pool and tailwater fluctuations.

Capacity losses from the proposed reservoir drawdown options are summarized in Table 4.9-1. The capacity losses shown are 50-hour sustained peaking values. This assumes that the generation available during a week is shaped to meet a 10-hour peak load each weekday, while still meeting minimum outflow and forebay restrictions. The various options in this OA/EIS limit how much the generation can be shaped and thus result in a reduced ability to generate sustained peaking capacity. The lost capacity is the difference between the maximum 50-hour peak load that can be met and the 50-hour peak load that can be met under each option. The critical period monthly average flow was calculated and used in a spreadsheet model to determine the amount of generation that could be shaped each month in each option.

It is important to note that currently the Northwest power system is not capacity-constrained. Thus, these capacity losses may not affect the system's ability to serve Northwest peak loads. In other words, this capacity might need to be replaced under certain situations, but under others it would have been surplus to the system's needs. Therefore, the costs of these capacity losses vary (see Section 4.9.2.2 for further discussion).

**Drawdown to MOP.** Drafting all four lower Snake River projects to MOP from April 1 to July 31 would result in capacity losses ranging from 550 MW in May to 1,400 MW in the second half of April. Capacity losses from the two drawdown options for the lower Columbia projects would range from 1,500 MW in May to 2,400 MW in the second half of April. These losses would occur primarily at John Day and The Dalles because of their larger turbine capacities compared to Bonneville and McNary.

**Lower Granite Drawdown to 710.** In analyzing the effects of operating Lower Granite at elevation 710 and the other three lower Snake projects near MOP from April 15 through June 15, it was assumed that the lower three plants could not load factor and could only generate the streamflow. Under these conditions, the capacity losses range from 1,100 MW in May to 1,800 MW occurring in the second half of April and in June.

**Drawdown to Near Spillway Crest.** The most significant capacity effect that could occur from the proposed measures would be a complete shutdown of one or more lower Snake River plants as a result of pool lowering below minimum operating levels. Operating the turbines at elevations below MOP would reduce turbine efficiency and increase the mortality rate for fish passing through the turbines, as well as possibly damaging the turbines. The juvenile fish collection and bypass facilities at these projects are designed to operate within the normal elevation range for the respective projects. These fish facilities will not operate properly at elevations of even a few feet below MOP because there would not be sufficient head in the gatewells to move fish into the orifices to the bypass conduits. Consequently, under these conditions juvenile fish that would normally be bypassed or transported downstream would instead pass through the turbines. Passing through turbines normally is considerably worse for fish than passing over spillways or through collection or bypass systems. In short, turbine mortality would presumably be so high at reservoir elevations below MOP as to defeat the purpose of pool lowering, requiring that power generation cease during the drawdown period for these options.

Drawdown to near spillway crest would produce peaking losses as high as 3,200 MW in May. Assuming a 1-month refill period, these losses would extend through either about July 15 or September 15 for the two drawdown duration options for near spillway crest.

**Table 4.9-1.** Estimated 50-hour sustained capacity losses from selected reservoir drawdown options, in megawatts (MW).[a]

| Period | Lower Snake Projects to MOP Apr 1- Jul 31 | Lower Snake Projects to Near Spillway Apr 15 - Jun 15[b] | Lower Snake Projects to Near Spillway Apr 15 - Aug 15 | Lower Granite to 710, Others to MOP Apr 15 - Jun 15 | Lower Columbia Projects to MOP Apr 1 - Aug 31 | John Day 262.5 McNary 337 Others to MOP Apr 1 - Aug 31 |
|---|---|---|---|---|---|---|
| April 1-15 | 1,300 | 2,600 | 2,600 | 1,600 | 2,300 | 2,300 |
| April 16-30 | 1,400 | 2,900 | 2,900 | 1,800 | 2,400 | 2,400 |
| May | 550 | 3,200 | 3,200 | 1,100 | 1,500 | 1,500 |
| June | 1,350 | 2,900 | 2,900 | 1,800 | 2,300 | 2,300 |
| July | 860 | 1,600 | 1,600 | | 2,100 | 2,100 |
| August | | | 1,000 | | 2,000 | 2,000 |
| September | | | 300 | | | |

a/ Based on critical water conditions.
b/ Assumes 1-month refill.

**Flow Augmentation.** Capacity losses resulting from flow augmentation options tend to be minor, with the exception of the option calling for unrestricted flows from Dworshak and Brownlee to meet a 140 kcfs target at Lower Granite in May. In this option, there are large capacity impacts in the fall and winter; however, these are very difficult to quantify and could not be estimated here.

### 4.9.1.2 Firm Energy

A key aspect of any evaluation of hydropower operational changes in the Northwest is the impact on the FELCC of the regional system. FELCC is the level of energy that could be produced by the existing regional hydro-thermal system if the region's worst historical water conditions (the 42 months from September 1928 through February 1932) were to reoccur. Energy produced within the FELCC limit is firm energy that can be guaranteed at all times and therefore sold at higher rates, while generation in excess of FELCC due to better streamflows is surplus or non-firm power that is sold at lower rates because its availability cannot be guaranteed.

The potential effect on FELCC from the proposed actions would result from changing the timing of water storage releases and associated generation in the flow augmentation options, and from spill in the reservoir drawdown options. The flow augmentation options would shift flows into the migration period, thereby increasing generation in the spring to levels higher than firm loads and reducing it in other periods of the year to below that required for firm loads. The net effect would be to transfer water from firm energy generation to providing flows for fish, which would effectively convert firm energy generation to non-firm energy, thereby reducing the system's FELCC.

**Reservoir Drawdown.** FELCC losses were estimated for some of the options and are shown in Table 4.9-2. Drafting all four lower Snake River plants to near spillway crest from April 15 through June 15 would reduce the FELCC of the system by about 240 aMW. In this option, the FELCC would be lost throughout the year. None of the lost FELCC would be converted to non-firm, because the water would be spilled due to shutdown of the plants. The other reservoir drawdown options that result in FELCC losses are those involving significant drafting of Lower Granite. For example, the FELCC loss from operating Lower Granite at elevation 710 from April 15 through June 15 would be 60 aMW.

**Flow Augmentation.** Increasing the water budget on the Snake River from 0.6 MAF to 1.7 MAF (1.2 MAF from Dworshak and 0.5 MAF from Brownlee and above) would reduce the FELCC of the system by about 140 aMW. Again, the FELCC would be lost throughout the year. However, in

Table 4.9-2. Estimated FELCC losses from selected options, in average megawatts (aMW).

**Reservoir Drawdown Options**

| Lower Snake Projects to MOP Apr 1-July 31 | Lower Snake Projects to Near Spillway Apr 15- June 15 | Lower Snake Projects to Near Spillway Apr 15- Aug 15 | Lower Granite to 710, Others MOP Apr 15- June 15 | Lower Columbia Projects to MOP Apr 1- Aug 31 | John Day 262.5 McNary 337, Others MOP Apr 1-Aug 31 |
|---|---|---|---|---|---|
| Minor | 240 | 300 | 60 | Minor | Minor |

**Flow Augmentation Options**

| 1,200 KAF Dwr 200 KAF Brn 300 Up Snake May (Option B) | Target flow of 140 kcfs Lower Grn May (Option F) | 900 KAF Dwr 50-200 KAF Brn 100 KAF Up Snake Trgt 100 kcfs Lwr Grn May (Option G) | 1,200 KAF Dwr Trgt 85 kcfs Lwr Grn April 15- May 31 (Option H) | 900 KAF Dwr Trgt 100 kcfs Lwr Grn April 15- May 31 (Option J) | Snake River Flow Portion of NPPC Plan |
|---|---|---|---|---|---|
| 140 | 450-500 | 60-70 | 70 | 40 | 80 |

this case there would be additional non-firm energy produced in the spring, which would have some value. Targeting a flow of 140 kcfs at Lower Granite in May through unrestricted releases from Dworshak and Brownlee would have the largest FELCC impact of the flow augmentation options. The FELCC impact of this option is estimated to be between 450 and 500 aMW. The new options added for the final OA/EIS, Option J and the NPPC plan, have estimated FELCC impacts of 40 aMW and 80 aMW, respectively.

The costs of FELCC losses are discussed in Section 4.9.2.1.

### 4.9.1.3 Non-Firm Energy

In addition to capacity and FELCC losses discussed above, there would be significant non-firm energy losses with some options because of water spilled rather than used to generate energy. This lost energy would translate into reduction in revenues from non-firm sales (see Section 4.9.2.3).

In the drawdown options, non-firm losses are due to spill since the turbines would be either out of service or unable to shape energy to follow load. The losses would be greatest for drafts below MOP, where all the water past a plant would be spilled. Significant losses would also occur when operating at MOP. Projects at MOP would be unable to generate energy in excess of streamflow in the daytime, and might well spill water at night due to lack of a market for energy or lack of sufficient forebay space to store unneeded water. The amount spilled under these conditions is difficult to determine as it depends on system-wide and on-site generation, plus the market for energy.

Flow augmentation options could result in spill of energy when either an upstream reservoir released water at a rate in excess of its turbine capacity, or the resulting flows at downstream plants produced energy in excess of the available market. However, these options generally produce net gains in non-firm energy, as FELCC losses are converted into non-firm gains.

Estimated non-firm losses and gains from selected options are shown in Table 4.9-3. In the case of the drawdown options, the amounts in the table assume that FELCC would be converted to non-firm energy, and that this and additional non-firm energy would be lost due to spill. Hence, all amounts shown for the reservoir drawdown options are total losses from spilled water. These non-firm losses range from 800 to 1,200 MW-months for operating the lower Snake River projects at MOP to 2,000 to 5,000 MW-months for operating the lower Snake River projects near spillway crest from April 15 to June 15.

For the flow augmentation options, it was assumed that FELCC losses would be converted to non-firm energy, and that a portion of this non-firm energy would be sold as non-firm; some of it, however, would be spilled. The amounts reported in Table 4.9-3 from the flow augmentation options show the net gain in non-firm energy due to conversion of firm to non-firm.

### 4.9.2 Replacement Power Costs

This section roughly estimates the costs of FELCC, capacity, and non-firm losses. It is important to note that these estimates are best used for comparing the costs of one option with the costs of another. They are not as useful as estimates of the actual increase in costs that the power system would face given implementation of any one of these options, although they give an indication of the magnitude of those increases. Determining these actual costs would require more detailed description and analysis of each option.

This analysis estimates the effect on power system costs of a 1-year implementation of the options, given a longer term perspective. This requires some explanation. Only one future year, 1992, was examined. In other words, a 20-year analysis of the effects on power system costs was not performed. Losses in the ability of the power system to produce energy would likely become more costly over time, since Pacific Northwest loads are growing and resources that will be added will become increasingly more expensive. If any of the options were implemented on a long-term basis, the impacts on power system costs could be higher than the 1-year numbers shown here.

However, a longer term perspective was taken in one respect. Losses in the ability to generate firm energy were calculated assuming those losses would be replaced through acquisition of new resources. Clearly, new resources will not be acquired and put on-line in time for the 1992 operating year. Losses in 1992 will need to be made up through purchases from existing sources. Should these purchases be substantially less expensive than new resource acquisition, the numbers shown here overstate the costs for 1992 somewhat. However, they give a good idea, again for comparison, of the yearly costs for firm energy replacement of a longer term implementation of these measures.

#### 4.9.2.1 Cost of FELCC Losses

As discussed above, some of the options have the effect of reducing the hydro system's FELCC. Because the Northwest power system is in energy load resource balance (just enough resources are available to meet current energy load requirements), a loss of FELCC would mean an inability to meet regional energy loads under the worst, or critical water conditions.

Therefore, this loss of FELCC would need to be replaced by whichever regional party suffers the loss. In most cases, the loss would be borne by the Federal portion of the hydro system, which would give BPA responsibility for securing replacement power. BPA is currently undertaking several processes for acquiring resources to meet future growth in its energy loads. One of these is competitive bidding.

In response to a solicitation, BPA recently received proposals for over 5,000 MW of both conservation and generation resources. The resource types varied, from gas-fired combustion turbines and cogeneration to wind turbines and biomass. BPA is currently evaluating these proposals and will begin deciding which resources to acquire in the near future.

It is likely that loss of FELCC on the Federal system would be made up by resources acquired through BPA's various acquisition processes. It is clear that these resources would be more expensive than the hydro resources that they would replace. However, it is difficult to predict the exact cost of acquiring replacement power since it is not known which resources or types of resources would be

Table 4.9-3. Estimated non-firm losses and gains from selected options, in MW-months.

**Reservoir Drawdown Options (losses)[a/]**

| Lower Snake to MOP Apr 1-Jul 31 | Lower Snake to Near Spillway Apr 15-June 15 | Lower Snake to Near Spillway Apr 15-Aug 15 | Lower Granite to 710, Others MOP Apr 15-Jun 15 | Lower Columbia to MOP Apr 1-Aug 31 | John Day 262.5 McNary 337 Others MOP April 1-Aug 31 |
|---|---|---|---|---|---|
| 800-1,200 | 2,000-5,000 | 2,500-5,500 | 1,000-1,800 | 850-1,600 | 750-1,500 |

**Flow Augmentation Options (gains)[b/]**

| 1200 KAF Dwr 200 KAF Brn 300 Up Snake May (Option B) | Target flow of 140 kcfs Lower Grn May (Option F) | 900 KAF Dwr 50-200 KAF Brn 100 KAF Up Snake Trgt 100 kcfs Lwr Grn May (Option G) | 1200 KAF Dwr Trgt 85 kcfs Lwr Grn Apr 15 - May 31 (Option H) | 900 KAF Dwr Trgt 100 kcfs Lwr Grn April 15-May 31 (Option J) | Snake River Flow Portion of NPPC Plan |
|---|---|---|---|---|---|
| 300-700 | 1,500-2,500 | 100-250 | 200-350 | 150-300 | 300-600 |

a/ Non-firm losses due to spill.
b/ Non-firm gains due to conversion of firm to non-firm (net of amount spilled).

acquired to cover FELCC losses. However, a good ballpark number may be used. Most firm resources that BPA can be expected to acquire in the near future to replace FELCC losses are likely to cost around 35 mills/kwh, in levelized real-dollar terms. Real levelization is a technique for comparing resources with different cost streams. In this context, it means a resource that will cost 35 mills the first year of operation, with costs rising by the rate of inflation over time. Hence, this number may be used to estimate the cost of FELCC losses.

The types of resources that BPA might acquire to replace hydro system losses could have environmental consequences of their own. This is difficult to assess for the purposes of this document. However, BPA is in the process of completing a draft Resource Programs Environmental Impact Statement that discusses the environmental consequences of acquisition of various resource types (draft to be issued in January 1992). The reader interested in this issue should consult that document.

### 4.9.2.2 Costs of Capacity Losses

Estimating the costs of capacity losses is rather difficult. If the regional power system were in capacity load/resource balance, the cost of capacity losses could be based on the cost of a new resource purchased to replace these losses (for example, a combustion turbine). However, it is generally assumed that the regional power system has a capacity surplus. Under most conditions, there is enough capacity to satisfy Northwest needs. Therefore, the capacity losses shown in Table 4.9-1 may not affect the system's ability to serve Northwest peak loads, but may affect its ability to market capacity. A number of assumptions, therefore, were necessary to estimate the cost of capacity losses. The first 1,000 MW of lost capacity in May and June (high non-firm months) was assumed to be useful only for shaping non-firm from light load hours into heavy load hours, and was therefore given a value of zero. Since most thermal plants are out of service in May and June, it was assumed that capacity losses in excess of 3,000 MW would need to be replaced at a cost of $10/kw/month. For losses of 1,000 to 3,000 MW in May and June, and for all capacity in all other months, the lost capacity was valued at $4/kw/month, the rate that BPA charges for capacity. Again, these values are not intended to represent the actual monetary loss to the power system, but should provide an estimate of the relative size of the losses because of implementation of the various options.

#### 4.9.2.3 Costs of Non-Firm Energy Losses

Reduction in the ability to produce non-firm energy would represent a loss in revenues because there would be less non-firm energy to sell to regional utilities for displacement of thermal resources, or on the export market to the Pacific Southwest. The price received from non-firm energy sales generally depends on the quantity sold and the season in which the sale is made. This can range from roughly 10 to 20 mills/kwh. A value of 15 mills/kwh was used here.

The costs of some of the options resulting from changes in capacity, FELCC, and non-firm energy production are shown in Table 4.9-4. These numbers are extremely approximate; they should not be regarded as precise quantitative expressions, but rather as rough estimates of what some options might cost.

### 4.9.3 Target 200 Results

In addition to the economic results presented above, three Target 200 options were analyzed to determine their impact on the cost of serving load in the Northwest. In these options, water was stored in Grand Coulee and Arrow through operational flexibility, either by foregoing non-firm sales or by purchasing energy from outside the region. A target flow of 200 kcfs at The Dalles from May through June was combined with various Snake River contributions. Results and alternative descriptions are shown in Table 4.9-5. These results only account for the costs of operational flexibility—no FELCC changes were assumed due to Target 200 operations on the Columbia River. (FELCC impacts from the various Snake River contributions were previously estimated in Table 4.9-2, with dollar losses from these shown in Table 4.9-4.)

The model used for the Target 200 analysis was the SAM. This model simulates the operation of the Northwest's power system over a given period, providing output on generation from individual projects, reservoir elevations, flows, and spill and the total cost of serving load.

A number of simplifying assumptions were made in the SAM analysis:

- SAM handles energy only—no capacity impacts were modeled.
- Only one contract year was analyzed, SAM year 1991 (September 1990 through August 1991). Thus, this is a short-term analysis, and results generated may not hold for the long term.
- Results are averages over the 50 water years of historical record.
- FELCC was assumed not to change across the alternatives—in other words, replacement resources were not acquired to cover potential losses in FELCC due to operations on the Columbia River.

Total system costs are shown for each option, as well as the increase in system costs from the base case. For example, the base case system costs are $523 million in 1991 dollars. It would cost approximately this much to operate the Northwest power system for 1 year, including production costs and capital costs for new resources, net of secondary revenues. This does not include costs for debt retirement on existing resources. The three Target 200 cases show increases over the base case of between $20 million and $30 million.

These increases in costs would arise from a number of sources: increases in production costs for Northwest thermal plants for serving Northwest load, increases in costs of purchasing power from outside the Northwest, and decreases in revenues

Table 4.9-4. Approximate economic costs of selected options for operating year 1992, in millions of 1991 dollars.

**Reservoir Drawdown Options**

| | Lower Snake to MOP Apr 1-Jul 31 | Lower Snake to Near Spillway Apr 15-Jun 15 | Lower Snake to Near Spillway Apr 15-Aug 15 | Lower Granite to 710, Others MOP Apr 15-Jun 15 | Lower Columbia to MOP Apr 1-Aug 31 | John Day 262.5 McNary 337 Others MOP Apr 1-Aug 31 |
|---|---|---|---|---|---|---|
| Capacity | 11 | 32 | 42 | 11 | 33 | 33 |
| FELCC | 0 | 72 | 90 | 18 | 0 | 0 |
| Non-firm | 9-13 | 21-55 | 27-60 | 11-20 | 9-17 | 8-16 |
| **Total** | 20-24 | 125-159 | 159-192 | 40-49 | 42-50 | 41-49 |

**Flow Augmentation Options**

| | 1,200 KAF Dwr 200 KAF Brn 300 Up Snake May (Option B) | Target flow of 140 kcfs Lower Granite May (Option F) | 900 KAF Dwr 50-200 KAF Brn 100 KAF Up Snake Trgt 100 kcfs Lwr Lower Granite May (Option G) | 1,200 KAF Dwr Trgt 85 kcfs Lower Granite April 15-May 31 (Option H) | 900 KAF Dwr Trgt 100 kcfs Lwr Grn April 15-May 31 (Option J) | Snake River Flow Portion of NPPC Plan |
|---|---|---|---|---|---|---|
| Capacity | minor | major | minor | minor | minor | minor |
| FELCC | 43 | 146 | 21 | 21 | 12 | 25 |
| Non-firm | gain 3-8 | gain 16-27 | gain 1-3 | gain 2-4 | gain 2-3 | gain 3-7 |
| **Total** | 35-40 | 119-130+ | 18-20 | 17-19 | 9-10 | 18-22 |

from reduced sales of non-firm power outside the Northwest. The analysis is particularly sensitive to the purchase costs assumed. Purchase costs depend primarily on the time of year and quantity purchased. Approximately half of the energy was purchased for around 35 mills/kwh and half for under 20 mills/kwh.

Because of the FELCC assumption stated above, the SAM results shown here may be considered a low estimate of the costs associated with the Target 200 alternatives. A longer term analysis might show higher costs when FELCC impacts were factored in. Other organizations (specifically PNUCC) have estimated the costs of Target 200 to be as high as $75 million per year.

### 4.9.4 Effects on Rates

At this time, BPA has set its rates for fiscal years 1992 and 1993. Consequently, the costs associated with implementation of any of these options during FY 1992 would not be recovered through increased rates. Rather, it is likely that BPA's operating reserves would be reduced. Assuming BPA's financial goals remained the same, this might lead to a rate increase in the FY 1994-1995 rate period; however, this is difficult to predict. As discussed above, the costs shown here are best used to compare options rather than to predict the actual increases in cost that the power system might face. Hence, no future rate impacts were estimated.

Table 4.9-5. Results from Target 200 SAM runs.[a]

| Case | Total System Costs (millions 91$) | Change from Base (millions 91$) |
|---|---|---|
| Base | 523 | — |
| Option S | 543 | 20 |
| Option T | 548 | 25 |
| Option U | 547 | 24 |

Definitions

Base: Base case for SAM runs

Option S: Target flow of 200 kcfs at The Dalles from May through June with 600 KAF from Dworshak, and 85 kcfs target at Lower Granite during May.

Option T: Target flow of 200 kcfs at The Dalles from May through June with 900 KAF from Dworshak, 50-200 from Brownlee, 100 from Upper Snake, and 100 kcfs target at Lower Granite during May.

Option U: Target flow of 200 kcfs at The Dalles from May through June with 1,200 KAF from Dworshak, 85 kcfs target at Lower Granite from April 15 through May 15.

TOTAL SYSTEM COSTS: The total cost of operating the Northwest power system (not including costs for debt retirement). Includes production costs and capital costs, net of secondary revenues.

CHANGE FROM BASE: The change from the base shows each case's increase in cost compared to the base case.

a/ All costs are for 1 year of operation only. Operating additional years under these cases would likely result in significantly increased differences due to varying refill probabilities.

### 4.9.5 Station Service Costs

Powerhouses and associated project facilities require electric power for station service needs, even when the plants are not generating. Under normal operations, station service needs are met from on-site generation. Replacement station service power would need to be purchased from local utilities or BPA with reservoir drawdown options that require that the lower Snake River project powerhouses not operate. A 4-week test with Lower Granite drawn down to near spillway during the summer would require purchase of nearly 1,400 MWH at a cost of approximately $33,600. The maximum station service cost would result from drawing all four reservoirs to near spillway crest from April 15 to August 15. This would require purchase of nearly 17,300 MWH of outside power during that 4-month period, at a cost of over $427,000. The total cost would be more, as the units would also be shut down while the reservoirs were being drafted and refilled.

### 4.9.6 Transmission System Effects

Without power from the lower Snake River projects, an outage of the Hanford-Vantage 500 kV line while the mid-Columbia generation was heavy would cause several lines to sag below minimum safe levels. Most of these lines could be raised to be made safe for the new operating condition. In addition to the sag problem, two lines (34 km each) between the Benton and Franklin substations would operate at temperatures that would cause permanent damage. Simply raising these lines would not be an option. An interim emergency option would be to open the Franklin end of these lines. This would result in no loss of load or generation. Currently, however, if another transmission link failed, cascading failures could result in loss of undetermined amounts of load and generation. Long-term solutions that would be considered are series inductors to reduce line currents, reconductoring using the existing structures, rebuilding, or adding a third line to parallel the lines. The lead times required for these options vary, as would their impact on existing projects. An EIS on major transmission modifications could take as much as 3 years to prepare and 2 years could be required for design and construction. A rough estimate of the costs of such actions might range up to $8 million.

### 4.9.7 Mitigation

Losses in the ability of the system to generate firm energy resulting from implementation of any of the options would need to be replaced. This replacement was discussed in Section 4.9.2. It would likely come from acquisition of new resources, or possibly from increasing generating capacity at existing projects or by purchasing firm energy from outside the region. Losses in the ability of the system to generate capacity might need to be replaced with new resources in some situations; in others, it would reduce the system's ability to market capacity. Non-firm losses result primarily in revenue losses and would not need to be replaced, as such.

## 4.10 RECREATION

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown** | |
| ***Snake River*** | |
| All 4 projects to MOP (April 1 to July 31) | • Of 28 boat ramps, 14 would be of marginal use.<br>• Of 5 moorage facilities, 4 would be of marginal use.<br>• Of 11 swimming areas, 5 would be marginally usable, and 4 would be unusable.<br>• No displaced visitation expected. |
| All 4 projects to near spillway crest (April 15 to August 15) | • All boat ramps, moorage facilities, and swimming areas in project areas would be unusable.<br>• Up to 733,000 recreation days would be displaced. |
| All 4 projects to near spillway crest (April 15 to June 15) | • Same effects as 4-month drawdown but for shorter duration.<br>• Up to 132,000 recreation days displaced. |
| Lower Granite to near spillway crest (February 1993 or July 15 to August 15) | • Lower Granite boat ramps unusable and 12 of 17 ramps at the other projects of marginal use.<br>• Lower Granite moorage facilities unusable; 2 of 3 moorage facilities at the other projects marginally usable.<br>• All swimming areas at Lower Granite and Little Goose unusable.<br>• Up to 158,000 recreation days displaced with summer test, 20,000 winter. |
| Lower Granite to 710 feet, others to MOP (April 15 to June 15) | • Same effects as drawing down Lower Granite to near spillway crest.<br>• Estimated 132,000 recreation days displaced. |
| Lower Granite/Little Goose drawdown test (March) | • All boat ramps and moorage facilities would be unusable at Lower Granite and Little Goose for up to 1 month.<br>• Estimated displacement of up to 33,000 recreation days in March; about one-third of total devoted to fishing. |
| ***Lower Columbia*** | |
| All 4 projects to MOP (April 1 to August 31) | • 13 of 39 boat ramps of marginal use, 13 unusable (with dredging program).<br>• 8 of 17 moorage facilities of marginal use (with dredging program).<br>• 15 of 20 swimming areas unusable.<br>• Visitation displaced, not quantified. |

Recreation (continued)

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown (continued)** | |
| John Day at 262.5 feet, McNary at 337 feet, remainder at MOP (April 1 to August 31) | • 11 boat ramps of marginal use, 11 unusable (with dredging)..<br>• 3 moorage facilities of marginal use (with dredging).<br>• 11 swimming areas unusable.<br>• Visitation displaced, not quantified. |
| John Day to approximately 262.5 (May 1 to August 31) | • 9 of 12 ramps usable, 5 fully functional.<br>• 5 of 7 moorage facilities fully functional, other 2 marginally usable.<br>• 4 of 7 swimming areas not functional. |
| **Flow Augmentation** | • Displaced recreation days at Dworshak range from 1,300 for fixed draft of 600 KAF in May/flood control/MRC to 268,000 for unlimited draft to meet 140 kcfs target.<br>• Very low probability of access or visitation changes at Grand Coulee.<br>• Minimal access or visitation effects at Brownlee, except with unrestricted draft. |
| **Combination** | • Effects additive; see drawdown and augmentation. |
| **Temperature Control Test (August)** | • By mid-August, Dworshak Reservoir may be approximately 10 feet below normal, swimming areas unusable or marginally usable, moorage and gas docks marginally usable.<br>• By end of August, pool may be 20 feet below normal, swimming areas unusable, moorage and gas docks marginally usable, 1 of 6 boat ramps marginally usable—the rest fully usable, difficulty accessing some mini-camp sites.<br>• Estimated potential displacement of up to 6,500 recreation days in August and 2,500 in September. Hunting access by boat constrained.<br>• Beaches on Clearwater River reduced in area to varying degrees and fly fishing more difficult. |

The 11 projects under evaluation in this OA/EIS are all significant recreation resources and support many recreational facilities. These facilities are dependent to varying degrees on adequate water levels. The proposed flow improvements would result in varying changes to water levels. Initially, this would have direct physical effects on the ability of the public to use these facilities. These physical changes would result in changes in visitation levels, which in turn could have consequences for some sectors of the local economies.

## 4.10.1 Physical Effects on Facilities

Reservoir fluctuations can adversely affect both water- and land-based recreational facilities. Fixed water-based facilities, such as boat ramps, swimming beaches and moorage facilities, have very specific ranges of elevation in which they can function. The options being examined in this OA/EIS would have different effects on recreational facilities. Some floating facilities, such as docks, log booms, and swimming area markers, can be relocated as pool elevations drop. In many cases, however, it is not practical to move them because pool elevations fluctuate frequently or rapidly and moving facilities can be difficult. Floating facilities can also be damaged by drawdowns. If drawdowns leave these facilities lying on the lake bottom, they may be punctured by rocks or twisted by uneven terrain, and can be difficult to refloat (NPS, 1989).

Also, land-based facilities at recreational sites can be affected by drawdowns. The primary physical impact would be to vegetation at sites that use river water for irrigation. Most of the developed recreational sites in the study area have extensive lawn areas and numerous shade trees that require irrigation. Irrigation water is generally taken from the adjacent pools. If pool elevations dropped below the intakes, irrigation systems would either have to be shut down or modified, if possible. Without modifications or alternative water sources, vegetation could be damaged or killed if irrigation were unavailable for several weeks or months. A discussion of general effects on run-of-river and storage facilities follows.

### Run-of-River Projects

Pool levels at lower Columbia-Snake Rivers run-of-river projects fluctuate on a weekly basis by as much as 5 feet. Project recreational facilities have generally been designed to function over the normal operating range. However, use of some facilities at virtually all projects is currently impaired at the low-pool elevations. Because pool elevations change so frequently, the negative effects in most cases are not long-lasting (although there are continuing problems with erosion and shoaling at some sites).

Operating these projects at relatively static levels near MOP would generally change these intermittent effects to continuous effects over the 3½- to 4½-month period of modified operation. In addition, the lowered pool levels might increase exposure to shoaling at moorage facilities and entrance channels, and wind and wave erosion on banks and the toes of ramps. Higher water velocities associated with either reservoir drawdown or flow augmentation could also increase facility damage from erosion.

Deep drawdowns, such as those contemplated for the lower Snake River projects, would have more acute effects on recreational facilities. Pool elevations more than a few feet below MOP would render virtually all developed facilities unusable for the period of the drawdown.

The proposed actions could diminish user safety. Low pool elevations, particularly with deep drawdowns, would expose rocks, tree stumps, shoals, and other objects that could pose hazards to boaters, wind surfers, water skiers, and other water users. Most users are aware of existing hazards at current operating levels, and markers are displayed to help navigate safely. Lower pool elevations might render some navigation aids unusable to guide vessels over a body of water that has significantly changed. Increased water velocity could increase the risks to swimmers and water craft operators. For example, boaters familiar with existing conditions would be confronted with new water depths and shoreline contours, plus more difficult navigation with faster currents.

### Storage Reservoirs

For recreational facilities to be used at storage reservoirs, pool elevations must be sufficiently high when there is a demand for the facilities. Each project has recreational facilities that function over a specific range of pool elevations. Some facilities such as developed swimming areas can only be used over a fairly narrow range at high pool elevations. Others, like some moorage facilities and boat ramps, are designed to be used over a greater range of elevations so they can be functional for longer periods of time. Most facilities at the three storage projects operate over different ranges, so there is not a threshold elevation that, when reached, will allow all facilities to be usable.

#### 4.10.1.1 Lower Columbia River

Recreational facilities at all of the lower Columbia River projects would experience some degree of physical effects from reservoir drawdown. Based on the options developed for this reach, these effects would occur throughout most of the primary recreation season.

**Lower River.** Reservoir drawdown on the lower Columbia and lower Snake Rivers and/or flow augmentation could alter water depths below Bonneville Dam, which might have some subtle effects on recreational sites in the lower reach of the Columbia River. Particularly with drawdown to near spillway crest on the lower Snake River, water levels below Bonneville would be somewhat elevated over typical existing conditions in the spring. Significant changes would probably lead to erosion problems at some facilities. Compared to typically high late spring flows, however, additional flows from augmentation would not likely have much noticeable effect on river levels. Moreover, flow augmentation would not be done if 1992 were a high runoff year, so there would not be a risk of elevating flows above already high levels.

Refill of drawn down reservoirs, particularly if begun in mid-August, could reduce water levels to a noticeable effect. Depending on the length of the refill period and whether refill were accomplished from storage or inflows, water levels below Bonneville in late summer could be reduced by up to 1 to 2 feet. In some locations, this might diminish the ability to use developed facilities. For example, low late-summer flows currently create shallow water and shoaling problems at the boat basins at Rooster Rock and Beacon Rock state parks. In other locations, however, lower river levels would further expose natural beach areas that are popular for informal recreation.

**Bonneville.** At the Bonneville project, the difference between the current low normal operating elevation (71.5 feet) and MOP (70.0 feet) is 1.5 feet. (see Appendix H). Seven ramps that are marginally usable at the existing operating low elevation would not be usable at MOP, unless dredging were conducted, and the number of fully usable ramps would decrease from 20 to 7. Out of a total of 27 ramps on Bonneville, 19 would be marginally or fully usable. Ramps at The Dalles Boat Basin and Marina and at the Cascade Locks Marine Park would only be usable for launching smaller boats. Launching larger or fixed-keel boats would not be possible because of the shallow water (approximately 3 feet). All the project's moorage facilities would be usable, but the use of four would be only marginal. The Hood River Boat Basin would have an estimated entrance channel depth of four feet, which would preclude larger boats, particularly fixed-keel sailboats, from entering the basin. The basin would still be able to accommodate moorage, but the courtesy and gas docks would be out of the water. As of December, 1991, however, all three of these key facilities at The Dalles, Hood River and Cascade Locks are included in the dredging program to be implemented during the winter 1992. Therefore, these impacts would be avoided.

Developed swimming areas would be the most affected of the three types of facilities at Bonneville, with four of six not functional as designed at MOP. Determining expected physical effects on swimming beaches is difficult. Much of the activity at these facilities is sunbathing, which could still occur at reduced pool levels. Access to the water would be less comfortable and convenient but some level of swimming and wading would likely still occur. For reporting purposes, however, swimming beaches are considered unusable at water levels below their design elevation.

**The Dalles.** The normal low operating pool elevation at The Dalles (elevation 155) is the same as the MOP elevation. At existing low-pool elevations, many of the recreational facilities are marginally usable. All seven boat ramps are usable at elevation 155, although several ramps have been damaged by erosion. At MOP, one boat ramp would be fully usable, four would be marginally usable, and two would not function. Erosion would continue or perhaps increase at ramps already suffering from that problem as a result of having the pool at low elevations for extended periods of time. Swimming beaches are also usable to varying degrees at current low pool elevations. Three of the four beaches that are usable at existing low pool elevations would not be usable at MOP.

**John Day.** The John Day project would be the lower Columbia River project most affected by operation at MOP. Existing low normal operating elevation at John Day is 260 feet during winter and the last 2 weeks of May, 262 feet from March 1 to May 15, and 265 feet from July 1 to October 1. Under existing operations, ramps at Alderdale, Roosevelt, and Quensel parks are marginally usable at normal summer low operating pool due to erosion at the ramp toes. At MOP, these ramps and two more would not be usable; continued erosion could cause further damage. However, ramps at most (7 of 12) of the major parks and moorage facilities would remain at least marginally usable at MOP. Six of seven swimming areas would be unusable at MOP.

Operating John Day at elevation 262.5 would affect fewer facilities than operating at MOP. Nine of 12 ramps would be usable; 5 of these would be fully functional. Five of the seven John Day project moorage facilities would be fully functional and the other two would still be marginally usable. Four of seven developed swimming areas would not be functional at elevation 262.5 feet.

**McNary.** The normal low operating pool elevation at McNary is 337 feet. In general, all existing recreation facilities are usable at this elevation. Although pool elevations at McNary fluctuate frequently, the elevation is maintained at full pool elevation (340) the last week in July for the annual Tri-Cities Water Follies that feature hydroplane races.

At MOP, 5 of the project's 9 boat ramps would not be usable and 4 would be marginally usable (see Appendix H). Popular ramps that would not be usable include one of three ramps at Columbia Park, plus those at Sacajawea State Park, McNary Yacht Club, Wye Park, and the Pasco Boat Basin. Three moorage facilities would be marginally usable and two would remain fully functional. Moorage facilities that would be affected include the McNary Yacht Club, the Walla Walla Yacht Club, and the Metz Marina. Of the six developed swimming areas, three would remain usable, and two would be unusable. The popular Two Rivers Park swimming lagoon would be landlocked.

### 4.10.1.2 Lower Snake River

Lowering pool elevations to MOP for 3½ months would affect most facilities at lower Snake River projects, but most would remain at least marginally usable (see Appendix H). Operation near spillway crest would essentially eliminate the use of all water-oriented facilities. All swimming areas at developed beaches would be unusable. Natural beaches that are unsupervised would be exposed and could pose safety hazards to users. The increased velocity of the river could also be a safety hazard to swimmers and beach users. Some marina facilities would be dewatered and would require the removal or shoring up of much of their facilities. Boats and facilities such as the Clarkston Resource Office boathouse would have to be relocated or removed (several boats moored on Lower Granite are too large to be trailered).

**Ice Harbor.** Drawdown to MOP would affect all Ice Harbor recreational facilities to various degrees, but all would remain at least marginally usable (see Appendix H). The six boat ramps would be marginally usable as would the four developed beaches. A sand bar at the entrance of Charbonneau Park would restrict access to the marina and moorage facilities. The primary impacts on facilities as a result of an extended drawdown result from access problems associated with shoaling. Dredging near some ramps and Charbonneau would be required. Drawdown to near spillway crest would make all recreational facilities unusable from early April through June or August.

**Lower Monumental.** Lower Monumental facilities would be the least affected of any of the lower Snake facilities by drawdown to MOP. The most affected facilities would be at Lyons Ferry State Park, where the swimming area would be marginally usable and the beach would need new sand. Boat ramps would also be marginally affected. All water-based facilities would be unusable at reservoir elevations near spillway crest.

**Little Goose.** Drawdown to MOP would allow access and use of all project facilities, although use would be marginal for most (see Appendix H). At

Central Ferry State Park and the Boyer Marina, swimming areas would become very shallow and would need dredging and additional sand to cover exposed rough lake bottom. Sand bars at the entrances of the boat launching and moorage facilities would affect access (Central Ferry is only 3 feet deep at MOP) and require dredging to be more than marginally usable. Operation near spillway crest, or at elevations 15 to 20 feet below MOP for the proposed two-reservoir March, test would temporarily eliminate use of all water-based facilities.

**Lower Granite.** At MOP, 9 of the 11 boat ramps would still be fully functional and use of the other 2 would be marginal (see Appendix H). Moorage facilities at the Red Wolf Marina and the Hells Canyon State Park Marina would be affected by shoaling and shallow water and would be marginally usable. The Chief Looking Glass boat basin and ramp would be only marginally usable as a result of shallow water. Dredging would be required at all three facilities. Half of the swimming areas at developed beaches would be non-functional. The near spillway crest, elevation 710, and the March two-reservoir test options would eliminate use of all water-oriented facilities at Lower Granite. In addition, these options would lower pool elevations so that eight irrigation intakes at project recreation areas would be above water and irrigation from the reservoir would not be available. The extended loss of irrigation water could cause the loss of plants at these areas.

### 4.10.1.3 Dworshak

Recreational facilities are currently affected by the extensive reservoir fluctuations at Dworshak and are only usable during part of the year. Under current operations, these recreational facilities become usable at various elevations and times during the current refill period. The minimum operating elevations of the six boat ramps range from elevation 1,577 (23 feet below full pool) to 1,445 feet (minimum pool). The Big Eddy ramp is functional over the entire range of drawdown. Ramps serving Dworshak State Park (Freeman Creek) and Dent Acres, two other major developments are usable down to elevations 1,535 and 1,520 feet, respectively. Moorage and gas docks become marginally usable above elevation 1,505, which typically occurs at the end of April, but are only fully functional above elevation 1,590 (usually reached near the end of June under existing operations). Swimming beaches also become usable at approximately elevation 1,590 to 1,595.

More than three quarters of all use at Dworshak occurs from June through September. With existing operations, the median reservoir elevation at the end of May is 1,557 feet (Table 3.4-1). Five of the eight flow augmentation options involving Dworshak would produce corresponding elevations of 1,545 or higher. End-of-May elevations in this range would diminish or preclude early-season utility of some of the facilities on the reservoir, primarily at Canyon Creek and the mini-camps. However, the major facilities at Big Eddy, Freeman Creek, and Dent Acres would still be functional.

The other three Dworshak options, involving either an unrestricted draft or fixed drafts of 1,200 KAF, would result in median elevations of 1,445 to 1,512 feet at the end of May. If normal runoff conditions occurred in 1992, implementation of the two 1,200 KAF fixed-draft options would render most facilities on the lake unusable or highly unattractive until about the end of June. However, with these options there would be a 10 percent chance of end-of-May elevations of about 1,550 feet in 1992. Conversely, the reservoir would be empty (elevation 1,445) at the end of May with normal runoff and the unrestricted option, with a 10 percent chance of reaching only elevation 1,512.

### 4.10.1.4 Brownlee

The six boat ramps at developed recreational sites become unusable at Brownlee at pool elevations ranging from 2,026 to 2,073 feet (BPA, 1985). The project's three developed swimming beaches are usable to pool elevations of 2,027; 2,069; and 2,073. Existing operating conditions include an average low point of 2,037 feet in April and full pool of 2,077 feet by the end of June. The April elevation allows anglers to use the ramps at Spring and Woodhead parks when the most popular fishing period (April to June) begins. Typically, three of the boat ramps are usable by May (elevation 2,058), and all ramp and beach facilities are functional by June. Drawdowns to serve irrigation loads begin in July and affect the use of two beaches and several boat ramps.

Elevation changes at Brownlee resulting from the flow augmentation options would generally be limited to May, June, and July. Access conditions for April fishing would remain as at present. Refill probabilities by the end of July would also be unchanged, with the exception of the unrestricted draft option. Because drafts would be made in May or May and June, median elevations at the end of May would be either 2,046 feet or 2,055 feet, again except for an unrestricted draft. These elevations compare to a typical level of 2,063 feet at the end of May, which allows use of three of six ramps. The three augmentation options with typical May elevations of 2,046 feet would only allow use of the Spring and Woodhead ramps. Reservoir elevations with these options would typically return to existing condition levels by the end of July.

An unrestricted draft from Brownlee is the only option that would have severe effects on the utility of recreational sites. If implemented, this case would hold a probability of greater than 50 percent that Brownlee would be empty (elevation 1,976) at the end of May in 1992. Access for early-season fishing would be precluded in that event, and use of facilities in general would be delayed considerably into the season.

#### 4.10.1.5 Grand Coulee

Many recreational facilities at Grand Coulee are designed to operate near full pool, elevation 1,290. When pool elevations drop below about elevation 1,285, some facilities and concessions start to be affected (NPS, 1989). However, 7 of the 14 boat ramps are used at lower reservoir elevations, including 5 that are usable at least to elevation 1,240. Use limitations at higher elevations primarily apply to facilities such as docks and swimming beaches. Some of these facilities can be as much as 800 feet from the water at elevations as high as 1,270 feet. Current operations typically result in the reservoir elevations near full from early July through December.

Generally, expected impacts to recreational facilities at Grand Coulee would be insignificant because additional normal drafts below the drafts for power and system flood control would be small and would have a low probability of occurring in 1992. Most of the additional drafts modeled would be 4 feet or less. Only in the 3 or 4 driest years of the 50 years modeled would there be significant additional drafts during the recreation season. The potential effects to recreation in 1992 are further limited by the fact that 1992 could not be a critical water year, because of near-normal runoff in 1991; most of the significant additional drafts from the model runs were in critical water years.

Flow augmentation options involving flood control shifts from Dworshak or Brownlee would generally have produced noticeable recreation impacts in up to 2 years of the 50 modeled. In these cases, most of the large additional drafts would have occurred in January and February, and would not have been so low that access for early fishing would have been restricted in those months. Additional drafts in May and June typically would be 2 to 5 feet deeper than existing conditions and would probably only affect swimming beaches. Even with the unrestricted draft option, recreational facilities at Grand Coulee would have been impaired in only 2 of the modeled years (discounting critical period years) in which flood control shifts would have been possible. In both years, the base-case elevations were below swimming beaches and some boating facilities.

None of the Target 200 options, as modeled, would adversely affect recreational facilities. These options tend to increase simulated water surface elevations in Lake Roosevelt from January through April, and then pass some of the spring runoff during May and part of June. May end-of-month elevations for these measures were higher than the elevations simulated for existing conditions, while June elevations were equal for existing and Target 200 conditions.

### 4.10.2 Visitation Effects

A number of factors determine if and to what extent reservoir drawdowns influence recreational participation. One important factor is the sensitivity to water levels held by various user groups. Different levels of sensitivity can influence which user groups use a recreational resource, the level of participation, and how the resource is used. Some groups are not particularly sensitive to lake levels. A study of Hungry Horse Reservoir in northwest Montana found that 43 percent of the recreational users surveyed had no preference as to lake level and displayed a willingness to adjust their activities correspondingly (Ben-Zvi, 1990). Many recreationists participate in more than one activity, and some no doubt would switch activities when lake levels would preclude participating in certain activities. Low water levels would influence the number of participants at various activities and the ways people would choose to recreate. As drawdowns become more severe, there would be an expected increase in participation in land-based activities.

Abt Associates (1978) found that on most reservoirs in the Columbia River Basin, most recreationists remain fairly insensitive to moderate reductions in elevation as long as water facilities are still available. Ben-Zvi's research at Hungry Horse reservoir confirmed that premise when it was found that the most common reason recreationists decided not to visit the reservoir was because they could not launch their boats (Ben-Zvi, 1990).

At a some point, water levels and resource quality may decline to a point where demand for specific activities may drop to zero. As reservoir quality declines, recreationists initially have three choices. They can: (1) accept the lower quality of the resource and continue to use it, (2) decide to recreate less frequently or not at all, or (3) travel to an alternative site (Corps, 1980). If the change in resource quality is temporary, users also may have the option of shifting their use in time by scheduling a trip to a reservoir earlier or later than they would under normal circumstances. Within the limits of resource capacity and individual schedules, a portion of the use that is displaced from a given reservoir by low water levels in May could be shifted to later months when elevations have returned to more favorable levels.

Changes in visitation associated with changes in reservoir levels would be concentrated among activities that are most dependent on developed facilities with specific operating ranges. The physical effects on these facilities would be expected to displace activities such as boating, boat fishing, water skiing, swimming, and windsurfing. Limited utility of these developed facilities would also produce corresponding effects on related uses at different locations. Camping from a boat, for example, is a popular activity throughout the study area that would be indirectly affected by reduced ability to launch boats from developed ramps.

Apart from the reduced utility of developed access facilities, visitation could be shifted or decreased by physical changes in the reservoir itself that would alter user patterns. Sport fishing is a likely example of this type of effect. As pools are lowered, fish will be confined to smaller areas and the number of fish caught might actually increase for a period of time. On the other hand, lower pools could increase turbidity, which would lower visibility, and reduce fishing success. Low pool elevations might change the areas where fish and anglers congregate. For example, on the Bonneville project fishing for spring chinook is currently limited to several areas near river mouths. These areas can be difficult to access by boat at low pool elevations because of sand bars. If pool elevations are reduced further, boat access for fishing would be more difficult and the amount of prime fishing area near the river mouths reduced. Bank fishing might be reduced if lower pool elevation makes access to the water more difficult. Finally, lower pool elevations could reduce the area of embayments and seep lakes and their rate of water exchange with the reservoirs. Fish present in these water bodies could suffer from poorer water quality or confinement in a smaller area, ultimately decreasing the quality of the fishery.

The physical changes discussed above would displace some or all of the existing use at the affected developed sites and dispersed areas. Within the limits of available data, the expected levels of displaced visitation are described below for the major geographic components of the study area. These estimates generally are based on the level of existing use of sites that would no longer be usable under a specific reservoir condition for the duration of that condition. They do not account for most of the visitation changes that would occur at developed sites that remain marginally usable or dispersed areas affected by changed water conditions, and therefore may understate actual visitation effects. Conversely, it is possible that some recreationists would continue to use sites that are considered unusable in this analysis.

The estimates of visitation changes are only indicators of the amount of use that would be initially displaced from the locations and times where it currently occurs. These figures should not be interpreted as net losses of recreational activity from the region, local areas, or even specific projects. The cooperating agencies do not have applicable data on user preferences and responses that would permit allocation of the displaced use quantities to the various possible responses.

Particularly for relatively small quantities of displaced use on reservoirs where other facilities would remain in operation, it is reasonable to expect that most displaced users would try to shift to other sites on the same reservoir. Even in more extreme cases where virtually all resources at a given project would be inoperable or unattractive, a likely response would be to use alternative sites or engage in alternative activities. Much of the use displaced at a given project or area might therefore shift to different local areas, but would likely remain within the larger region in one form or another. These kinds of shifts would produce some net loss of satisfaction for the users, which again cannot be quantified with the available information.

### 4.10.2.1 Lower Columbia River

Existing visitation on the lower Columbia River is greatest during the summer and appears to be related to weather. Water-oriented activities are very popular at project facilities and use increases during the summer. Although MOP levels would allow most ramp and moorage facilities to remain usable to various degrees, the use of a significant number would be impaired or eliminated. Most developed swimming areas would not be usable at MOP. The reduction in quality and/or number of water-based recreational facilities would affect the visitation at those facilities. Because most facility users participate in more than one activity, a negative effect on one type of facility could induce reductions in other activities. Land-based activities such as picnicking and camping could be expected to decline in use because of changing visitation patterns among water-oriented users. Land-based visitation could also decrease somewhat if pool levels dropped low enough to create irrigation problems. If the extensive lawns and shade trees found at many project recreational sites withered or dried from lack of irrigation, the change in attractiveness might cause a drop in visitation.

It is difficult to quantify effects of different drawdown options on use and visitation patterns. Most likely, some users of impaired facilities would shift their activity to usable facilities at the same project, to other Lower Columbia projects, or to other nearby recreational sites. Other users of project facilities would likely change their activity type or cease participating altogether. The cooperating agencies have no basis for estimating the frequency of these responses among affected users.

The Bonneville project receives the greatest number of visitors of all the projects examined in this OA/EIS and would have the greatest number of visitors potentially affected by a change in reservoir level. The Bonneville Pool would be 1.5 feet below the existing normal low elevation between April 1 and August 31 or through most of the primary recreation season. Use of project facilities affected at MOP would most likely shift to remaining usable facilities (see Section 3.10.1.1), to facilities on the Columbia River below Bonneville Dam, or to other reservoirs in southern Washington and northern Oregon. Increased water levels below Bonneville could improve conditions at downstream facilities at sites like Rooster Rock and Beacon Rock state parks and might lead to increased use at these locations.

At MOP, The Dalles project would lose or have the use of several boat ramps and beaches diminished. There are no major moorage facilities at the project that would be affected. Land-based use of project waterfront parks would likely decrease. Visitation by both visitors and residents would diminish.

Both elevations considered at the John Day project would allow all or most of the boat-launching and moorage facilities to be fully or marginally functional. Six of the seven swimming beaches would not be functional at MOP. Overall, existing use would primarily be shifted and concentrated somewhat at the remaining facilities in both cases, with some additional displacement away from the project with operation at MOP.

Visitation at the McNary project would probably be reduced at MOP because of facilities affected by shallow water and siltation. All boat ramps would be affected to some extent and five of the nine would not be usable at MOP. All five moorage facilities would still be usable, although use at the McNary and Walla Walla Yacht Clubs and Metz Marina would be restricted. A total of five boat ramps at McNary would not be usable at MOP, resulting in potential boating use displacement of up to 79,000 recreation days. Affected ramps at Columbia Park and the Pasco Boat Basin account for most of this boating use. The swimming lagoon at Two Rivers Park (50,000 estimated recreation days in 1990) would be unusable at

MOP, as would the beach at Sacajawea State Park (2,000 recreation days). Overall, it is estimated that approximately 142,000 recreation days would be displaced at McNary as a result of pool reduction to MOP.

The second option for McNary would establish a low pool elevation of 337, which is within the current normal operation range. Recreational facilities would continue to be used as they currently are. Users at the Tri-Cities Follies and hydro races in late July would be inconvenienced by low water at a pool of elevation 337, unless the reservoir were raised to full pool (elevation 340), as is customary for this event.

### 4.10.2.2 Lower Snake River

Visitation patterns at lower Snake project facilities also reach a peak during the summer. Weather is apparently a strong influence on the use of project facilities and water-based activities are especially popular during warm weather.

**Drawdown to MOP.** Operation at MOP would allow most of the boat ramps and moorage facilities at lower Snake projects to remain marginally or fully usable. Developed swimming areas that currently experience problems at low pool elevations would be further affected by the drawdown during most of the swimming season. Visitation of marginally affected facilities would be expected to decrease. For instance, difficult access to a facility for 3½ months might cause traditional users of the facility to move to other facilities. However, none of the facilities at these four projects would be rendered totally unusable, and dredging at selected boat basins and additional sand at some swimming areas could improve use conditions at MOP. Therefore, no displacement of recreational use was specifically estimated.

**Deep Drawdown Options.** Drafting the lower Snake projects to near spillway crest would essentially make all water-oriented facilities unusable for the period of the drawdown. Private and commercial boat activity would be eliminated or greatly restricted. The two excursion boat companies that take up to 2,300 passengers from Portland to Clarkston between April and June would be unable to operate under these conditions. Tour boats that take passengers from Clarkston or Hells Gate State Park to Hells Canyon would need to shift operations to another location. Use of land-based facilities would decrease as fewer people would visit recreational sites with no usable water facilities and diminished visual appeal.

Drawdown to near spillway crest from April 15 through August 15 would largely coincide with the most popular time of the year for recreational activity at project facilities (June through August). As a result, an estimated 732,900 recreation days would be displaced at the four projects.

Drawdown to near spillway crest between April 15 and June 15 would have a less severe effect on visitation because it would occur before most of the primary recreation season. Most of the users affected would be boaters, as little swimming and beach activity would occur at this time of year. The April 15 to June 15 near-spillway crest option would cause displacement of approximately 132,000 recreation days at the lower Snake River projects.

Operating Lower Granite at 710 feet and the other three lower Snake River projects to MOP between April 15 and June 15 would primarily affect visitation at Lower Granite. Water-oriented recreation at Lower Granite essentially would be eliminated and day-use visitation would likewise be reduced. Visitation at the other three projects would not be greatly affected. There might be a slight increase in visitation at the downstream projects from users who would not be able to use Lower Granite facilities. The implementation of this option would result in an estimated 132,000 displaced recreation days at Lower Granite and 14,000 at Little Goose, for a total of 146,000 days displaced.

Visitation effects from a four-week drawdown test at Lower Granite would depend on the time of year selected for the test. A drawdown to near spillway crest from July 15 to August 15 would displace most use from about July 1 through sometime in late August. Displaced use from this option is estimated at approximately 120,000 recreation days at Lower Granite and 38,000 recreation days at Little Goose, for a total of 158,000. Conducting this test in February would displace an estimated 20,000 recreation days, all of which would be boating activity.

The four-week drawdown test of Lower Granite and Little Goose in March would have visitation effects similar to the above options. Potentially displaced use with this option is estimated at approximately 33,000 recreation days, of which about one-third would be fishing activity.

### 4.10.2.3 Dworshak

Changes in Dworshak Reservoir elevations compared to existing conditions as a result of flow augmentation could shorten, and in some cases eliminate, the operable season of virtually all of the recreational facilities at the project. Displaced use resulting from these elevation changes was estimated on the basis of proportional changes in the number of available days from June through September at each water-based facility, as measured by median reservoir elevations throughout the season. This approach does not directly account for effects on the small proportion of use that occurs before and after the primary recreation season, but it also overstates the displacement of land-based use at facilities associated with boat ramps and other water-based facilities. The results should therefore represent a reasonable approximation of likely visitation effects.

The results of this procedure are summarized by option and facility in Appendix H. The estimated displaced recreation days range from about 1,300 to 268,000. The lower number corresponds to a fixed draft of 600 KAF from Dworshak in May with a flood control shift to Grand Coulee. The maximum displacement, which would represent a decrease of 76 percent compared to estimated use in 1990, would occur with an unrestricted draft to meet a 140 kcfs target flow. Fixed drafts of 1,200 KAF would result in estimated use displacement with typical water conditions ranging from about 15,000 to 76,000 recreation days. The three remaining options, including the new Option J, would displace modest totals of 2,000 or about 7,000 recreation days. The estimated displacement for most of the options would be concentrated at the Big Eddy Marina, Canyon Creek, Grandad Creek, and the mini-camps.

The temperature control releases would draft Dworshak by up to 20 feet in August and would displace some use during the peak of the summer recreation season and in September. The primary reductions in use would be at beaches and some of the mini-camps. Potential displacement from this option is estimated at 6,500 recreation days in August and 2,500 in September, for a total of 9,000. Hunting access by boat would also be more difficult in the fall, although specific displacement of use has not been attributed to this effect.

Temperature control releases would also have some effect on recreational activities downstream on the mainstem Clearwater River. Higher flows on the river would reduce the area of natural beaches, although use would still be possible. Fly fishing would be more difficult and less productive. Use in both activities might well decrease during the 20-day release, but a specific estimate of displaced recreation days is not possible.

### 4.10.2.4 Brownlee

The effects of the flow augmentation options on use at Brownlee would generally not be great. Approximately 77 percent of all recreation days (215,000 out of a total of 279,000) are spent at Farewell Bend State Park by day-users, and many of those are travellers using the park as a rest stop. However, there could be significant effects on other specific user groups, particularly anglers. Angler surveys indicate that use of Brownlee starts to increase in April, and that April and May are the most popular months to fish. Currently, boat anglers can access the reservoir in April from two ramps at either end of the project. Access conditions for April fishing would remain as at present, because reservoir elevations would only be changed from May, June, and possibly July. Some boating and fishing in May could be displaced due to loss of use of one of the three ramps that is typically usable at this time, but this activity might also just be shifted to the two remaining facilities. A similar situation would apply to boating and swimming facilities at typical June and July elevations. Bank fishing use should not be affected, as this activity currently increases in April when the project is at its lowest elevation.

On balance, the unrestricted draft option is the only flow augmentation case where it appears likely there would be significant displacement of existing visitation. An empty reservoir at the end of May, the most likely condition for this case, would probably eliminate most water-based use during May and a portion of June. Lack of data on the seasonal distribution of use at Brownlee prevents a quantitative estimate of displaced recreation days. However, it is likely that a significant minority of total use for the year would be displaced under these conditions.

### 4.10.2.5 Grand Coulee

The flow augmentation options would produce elevations very similar to existing operations during the recreation season, and would have little or no effect on recreational facilities at Grand Coulee. The probability of reservoir levels below existing conditions in any one year is generally 5 percent or less, so no quantitative changes in use have been estimated for these options. In the few years in which elevation differences were simulated, these changes were generally confined to February or May and June. Twenty-two percent of annual fishing activity occurs from March through May, and from 8 to 20 percent of annual use occurs in June for activities such as camping, boating, and swimming. Some portion of this activity could be displaced in the event of water conditions that would reduce elevations in Lake Roosevelt.

## 4.10.3 Economic Aspects

Recreationists spend varying amounts of money to participate in their selected activities. They purchase durable and non-durable goods and services for equipment, supplies, travel, shelter and other needs. A recent study of recreationists at Hungry Horse Reservoir in Montana estimated average expenditures per person per day at approximately $11 for non-travel items and $17 for travel costs, or $27 total (Ben-Zvi, 1990). The study population in this case no doubt has some differences with typical users at the projects addressed in this OA/EIS, but the expenditure figures among the different populations are not likely to be large. In both cases, a large majority of total use is by residents living within 50 to 100 miles of the respective reservoirs.

Multiplying this expenditure level by expected changes in visitation provides a rough approximation of the magnitude of expenditure shifts that could happen as a result of the proposed actions. For example, displaced use at the lower Snake River projects resulting from reservoir drawdown to near spillway crest from April 15 through August 15 was estimated at approximately 733,000 recreation days. At $27 per day, the gross recreation expenditures associated with this level of use would be nearly $20 million. Under normal conditions, these expenditures would circulate through the local economies of southeastern Washington and adjacent areas, directly and indirectly supporting businesses, jobs, and local income.

Because of the variable and uncertain responses of displaced recreational users, the gross expenditure level associated with visitation changes from a given option should not be interpreted as a net loss to local and regional economies. Expenditure patterns would shift in a number of possible ways, but at a broad level there probably would not be much of a change in total expenditure levels. Displaced recreationists would shift their preferred activity to a different time or location, or to another activity. Because the natural response would be to find some acceptable substitute for the displaced activity, some form of activity and expenditure would continue. The greatest potential for economic effects resulting from displaced recreation use would be for geographic shifts in expenditures from one area to another as displaced users sought alternate locations for their preferred activities. These types of effects would generally be felt at the community or county level.

A more direct economic consequence of displaced recreational use would be felt by concession operations and other businesses that would suffer lost revenue. Several concessionaires operating at the lower Snake River projects and at Dworshak would be particularly susceptible to such revenue losses. Lower Snake River operators would lose some revenue if the projects were operated at MOP, and would lose most of an entire season's revenue if the projects were lowered to near spillway crest through August 15. The operating season could also be shortened significantly at Dworshak with some of the flow augmentation options, resulting in large potential revenue losses. A key factor concerning the consequences for the Dworshak marina concession would be the probability of a significantly deeper draft in 1992 compared to existing operations. Options that would result in the seasonal loss of the marina operating would have a significant economic impact at Dworshak.

Similarly, commercial operations that are not directly on the affected reservoirs but are dependent on reservoir-related recreation activities could experience loss of business. For example, the fish and wildlife resources of the refuge areas on the McNary and John Day pools attract considerable recreation activity, which supports local outfitters, guides, recreational equipment suppliers, and related businesses. Significant adverse effects on these fish and wildlife resources from operation at MOP (see Sections 4.3 and 4.4) could result in decreased recreational use and lost revenues for these businesses. These types of impacts cannot be quantified with the limited information available.

Apart from their direct expenditures for goods and services associated with their activities, recreationists derive intrinsic value from the recreation experience. When use is precluded or diminished at the users' preferred site, the users suffer a loss in the value of their experience. The extent of the net loss depends on their level of reduced enjoyment at the original site or at an alternative site, or the lower value they may place on an alternate activity. These losses in user value represent potential direct costs of the flow measures under consideration. They are evaluated in the cost-effectiveness analysis presented in Section 5.5.

### 4.10.4 Mitigation

The actions that will measurably affect recreation would be pool drawdown below the point that access could be gained to ramps, marinas, and developed beaches. Mitigative measures that may be implemented vary from temporary extensions to existing ramps to permanent extensions. If justified, temporary extensions could be developed for some areas in time for the 1992 season.

## 4.11 AESTHETICS

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown** | |
| ***Snake River*** | |
| All 4 projects to MOP (April 1 to July 31) | • Little change from existing, some exposed shallows. |
| All 4 projects to near spillway crest (April 15 to August 15) | • Large areas of lake bottom exposed including debris (tree stumps, rocks, etc.)<br>• Some reservoir-dependent-seep lakes and embayments would decrease in size or disappear.<br>• Negative impact on water clarity and color. |
| All 4 projects to near spillway crest (April 15 to June 15) | • Same effects as 4-month drawdown to near spillway crest, but for shorter duration. |
| Lower Granite to near spillway crest (February 1993 or July 15 to August 15) | • Same effects for Lower Granite as near spillway. |
| Lower Granite to 710 feet, others to MOP (April 15 to June 15) | • Same effects for Lower Granite as near spillway but to slightly less degree. |
| Lower Granite/Little Goose drawdown test (March) | • Similar impacts as spillway crest alternative at Lower Granite and Little Goose, but for shorter duration with fewer viewers present. |
| ***Lower Columbia*** | |
| All 4 projects to MOP (April 1 to August 31) | • Significant exposed shallows at John Day and McNary. |
| John Day at 262.5 feet, McNary at 337 feet, remainder at MOP (April 1 to August 31) | • Little change from existing conditions. |
| **Flow Augmentation** | |
| ***Dworshak*** | • Insignificant increase in lake bottom exposure with some drafts up to 1,200 KAF.<br>• Significant increase in vertical exposure of 30+ feet in summer with four fixed-draft, 1,200 KAF options.<br>• Severe increase in vertical exposure of 90+ feet with unrestricted draft. |
| ***Brownlee*** | • Minor May–June departure from existing conditions for most options. |

Aesthetics (continued)

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Flow Augmentation (cont.)** | |
| *Grand Coulee* | • Insignificant changes from existing conditions.<br>• Empty reservoir in May in most years with unrestricted draft. |
| **Combination** | • Effects additive; see drawdown and augmentation. |
| **Temperature Control Test (August)** | • By end of August, Dworshak pool may be 20 feet below normal, exposing shoreline area during period of highest visitation. |

Reservoir drawdowns could have significant aesthetic impacts on adjacent lands. Impacts could result from a number of factors, including increased shoreline visibility and contrast, reduction in the size of embayments and seep lakes, changes in recreational facilities, changes in water characteristics, and erosion problems. A negative change in the aesthetic quality of the projects being examined in this OA/EIS could affect the use of project recreational facilities and have social and economic consequences. If visitors and residents find project areas aesthetically unpleasing as a result of drawdowns, they may choose not to visit them or may go elsewhere.

### 4.11.1 Factors Of Visual Change

Changes in the aesthetic qualities of projects covered in this OA/EIS can be attributed to changes in specific physical factors. The factors responsible for aesthetic quality are discussed generically below. The options being examined would have different effects on those factors.

#### 4.11.1.1 Shoreline Contrast

Drawdowns have the greatest aesthetic impacts on project areas where: (1) the greatest amount of shoreline is exposed, (2) there is greatest color and textural contrast between shoreline and adjacent uplands, and (3) significant numbers of people can view affected shorelines. As reservoir levels decrease, the demarcation between the water and land becomes more distinct. Shorelines can contrast greatly in color and texture with adjacent water, vegetation, and land. Thus, in areas where exposed shorelines create a great deal of color or textural contrast, drawdowns would be most noticeable. The greater the vertical and horizontal distances are between the high water level and current reservoir level, the greater the shoreline contrast tends to be. As reservoir levels decrease, floating debris (such as logs) can be left on the shoreline, and mudflats, stumps, and rocks that would normally be underwater can be exposed. Dried algae left on adjacent rocks and shoreline can create a "bathtub ring."

As reservoir levels fluctuate, the risk of landslides and erosion can increase along reservoir shores. If landslides and erosion occur, visual contrast between the shoreline zone and adjacent land might be increased. Areas such as recreational facilities that are built on surficial sediments may be subject to undercutting and even collapse with fluctuating reservoir levels.

#### 4.11.1.2 Seep Lakes and Embayments

Seep lakes separated from reservoirs by railroad and highway embankments, or embayments connected to reservoirs by open channels, may be affected by lowering reservoir elevations. Both are connected to the reservoirs hydrologically and, without water replenishment, could be reduced in size, experience reductions in water quality, experience effects to wetlands contained within them, and have bottom material exposed.

#### 4.11.1.3 Facility Impacts

Drawdowns can have significant aesthetic impacts on waterside facilities such as beaches, swimming areas, boat ramps, docks, and marinas. The positive aesthetic qualities that facilities such as beaches and marinas may have may be diminished by drawdowns that render them unusable and unsightly. Reservoir drawdowns can reduce or eliminate the ability to irrigate lawns and plantings associated with parks and recreational facilities. As a result, plants may be affected or even die and the aesthetic quality of the facilities diminished.

#### 4.11.1.4 Water Characteristics

Changes in reservoir levels can affect water characteristics in several ways. By lowering water levels in reservoirs, the remaining water flows at a higher velocity and picks up additional sediment, which in turn leads to increased turbidity. The increase in turbidity could cause a decrease in water clarity and change in color. Reservoir drawdowns also increase the amount of slack water. As the reservoir recedes, shallow areas and the far reaches of the reservoir become exposed and the amount of slack water is reduced. Reduction in reservoir size increases water velocity and gives areas in a reservoir a more riverine character. As slack water recedes, streams and rivers entering it that had been inundated reestablish channels in the exposed lake bed. As a result, decreased reservoir size is accompanied by a corresponding increase in rivers and streams with a free-flowing character.

#### 4.11.1.5 Dust and Odors

As a result of reservoir drawdown, exposed shoreline and lake bottom are subject to effects of wind. Fine sediments are subject to wind erosion and could affect recreationists. The options that would reduce reservoir levels the most or for the longest periods of time have the greatest potential for increasing dust. Odors can be created in areas of reservoirs where organic material is exposed as a result of drawdowns. The extent of odor impacts would depend upon the amount of organic material exposed, the amount of shoreline exposed, the wind direction, and the proximity to areas frequented by people.

### 4.11.2 Aesthetic Effects by Project Area

#### 4.11.2.1 Lower Columbia River

The options that call for operating lower Columbia-Snake River projects at MOP would, in general, have the same aesthetic impacts as current operating schedules. The primary difference would be a lack of project pool elevation fluctuations that currently occur on a daily or weekly basis. Instead, the pools would stay at a constant MOP elevation for several months, and the aesthetic impacts that currently occur for limited periods of time would last longer.

Areas of projects that would be most affected aesthetically by extended MOP elevations include embayments and seep lakes that could be reduced in size, and shallow shorelines that would be exposed. At MOP, the John Day project would be 8 feet lower (elevation 257) than normal summer low pool (elevation 265). As a result, it would be the project with the most aesthetic impacts at MOP. John Day also has extensive shallow areas that would be dewatered at elevation 257. Low lying shoreline and lake bottom areas that could be exposed at MOP include the shoreline and islands near Quensel; the shore near Roosevelt, Heppner Junction, and Crow Butte State Park; the river channel and shore in the Blaylock Islands area; the back bay area; and shoreline near Plymouth Park and Umatilla.

#### 4.11.2.2 Lower Snake River

Operating the lower Snake River projects near spillway crest would have significant impacts on aesthetics. As Table 3.2-3 illustrates, lowering pool elevations to near spillway crest would result in lower Snake River project pools from 34 feet to 42 feet lower than MOP conditions. At these elevations, large areas of lake bottom would be exposed as would debris such as tree stumps, rocks, etc. Based on interpretation of general depth information (Evergreen Pacific, 1991), areas that would have significant amounts of reservoir shoreline exposed at pool elevations near spillway crest include:

| Project | Area Exposed |
|---|---|
| Ice Harbor | Shoreline and mid-river shoals between Walker and Lower Monumental Dam. |
| Lower Monumental | South shore for several miles up and down river from Ayers; shoreline and mid-river at Lyons Ferry State Park where Palouse and Snake rivers converge. |
| Little Goose | Mid-river between New York Island and the eastern shoreline; the north shore near Central Ferry State Park; most of reservoir between Illia and Lower Granite Dam. |
| Lower Granite | South shore near Silcott Island and Chief Timothy State Park; east shoreline near Wilma; most of reservoir upstream of the confluence of the Clearwater and Snake River as it flows through Lewiston and Clarkston to points upstream. |

Some seep lakes and embayments that depend upon water replenishment from reservoirs would be reduced in size or disappear altogether, as a result of projects at near spillway crest. Water characteristics would change at project pools as slack water at reservoirs would be reduced in area and replaced in some places with faster moving water confined to narrower channels that would be more riverine in character. Water clarity and color would be negatively affected as the turbidity of the water increased as a result of increased sediment transport in faster moving water. Many recreational facilities would be completely dewatered and would be damaged if not removed. The unused, and possibly damaged, facilities would most likely be considered aesthetically detrimental to the reservoir environment by most viewers.

Drafting Lower Granite to 710 feet would have aesthetic effects similar to, but somewhat less than operating the project at spillway crest. At elevation 710, the reservoir would be 23 feet lower than MOP and about 25 feet lower than the average normal elevation, as opposed to more than 40 feet lower with drawdown near spillway crest. All of the areas mentioned above that would be affected at the spillway crest level would also be affected at the elevation 710 option, although to a lesser degree. The section of the project that would be most affected would be the stretch near Lewiston and Clarkston because of the shallow depth of that stretch. Near Lewiston and Clarkston, the reservoir would recede into the former channel and take on a riverine character, and the old reservoir bottom adjacent to the river would be exposed. The two-reservoir drawdown test would result in the same aesthetic impacts as operating the project at spillway crest.

### 4.11.2.3 Dworshak

The current annual fluctuation at Dworshak averages 100 feet, which creates a significant aesthetic effect. However, the current average low elevation of 1,488 feet is reached in March when there are few project viewers. The reservoir is rapidly refilled beginning in April and reaches an average elevation of 1,555 feet in May and 1,585 feet in June, when visitation has increased. The pool will typically refill by the end of July, when visitation has hit its peak.

Most of the flow augmentation options would produce lower pool elevations during the summer. In June, elevations with fixed-draft options vary from approximately 30 to 40 feet below the current average elevation. The unlimited draft option would typically be approximately 100 feet lower in June. The three less drastic augmentation options would result in June reservoir elevations at essentially the same level as existing operations. This general pattern would continue through September, although the differences would be reduced and two options would result in higher elevations than the current conditions. The unlimited drawdown option would be approximately 54 feet lower than the current average September elevation. The temperature control test would result in the pool being 20 feet below normal by the end of August and exposing more shoreline than normal.

In summary, flow augmentation with up to 1,200 KAF could be accomplished at Dworshak without significant adverse aesthetic effects, based on comparative reservoir elevations during the year. Conversely, four options for fixed drafts of 1,200 KAF would result in pool elevations 30 or more feet below typical summer conditions with existing operations. Changes of this magnitude would be considered significant aesthetic impacts. The unrestricted draft option would leave the reservoir more than 90 feet below full throughout a typical water year, creating an even more severe aesthetic loss.

#### 4.11.2.4 Brownlee

Pool drawdowns at Brownlee currently average approximately 40 feet and create a significant visual impact in the late winter and spring by exposing mudflats, tree stumps, lake bottom, and reservoir sides devoid of vegetation. The visual contrast in color at Brownlee between the steep adjacent grass-covered slopes and the exposed lake bed is significant. The average end-of-month elevations for most of the options are close to the existing month-end averages with May and June the only months that differ much from the existing month-end averages. In May, the average elevation differences are from approximately 8 to 11 feet below the existing condition for all but the unlimited draft option. The total drawdown at this time would increase from the current typical level of 14 feet to up to 31 feet. This would expose significant additional areas of lake bottom but would not be considered a major departure from existing impacts. The unlimited drawdown option would have a high chance of draining the reservoir during May, creating a major negative aesthetic effect. In June, when visitation at project facilities increases, the differences between options and the existing condition would be less than in May, except with unlimited drafts. During the rest of the summer when the greatest number of viewers see the project, monthly elevations of most of the options would be the same as the existing averages. With the exception of the unlimited drawdown option, the options being examined would not significantly change the existing aesthetic qualities at Brownlee.

#### 4.11.2.5 Grand Coulee

The typical drawdown at Grand Coulee ranges from 30 to 82 feet from January through June. Drawdowns of such magnitudes create significant aesthetic impacts. However, Lake Roosevelt is, on average, refilled by the busy summer season when the project receives most of its visitors. The month-end average pool elevations at Grand Coulee under the various options do not differ significantly from the existing average month-end elevations. In some simulation years where month and pool elevation differ, the additional drafts are generally 5 feet or less. The timing of the drawdowns would be very close to the existing timing, generally occurring from February through May or June. As a result, aesthetic impacts created by the options are not expected to be significantly different from those created by current operations.

### 4.11.3 Effects On Viewers

The various options being examined would have different effects on viewers. Some of the options would vary little from current operations in terms of physical changes brought about by drawdowns. Others would cause significant changes in the physical and aesthetic environment of some projects. Most of the options would be implemented during the spring or summer. These are generally the times of year when recreational use and highway travel are greatest.

Aesthetic effects from drawdown of the lower Columbia River projects would be greatest in duration, lasting from April 1 through August 31. Based on seasonal patterns of travel and recreational use (see Sections 2.12 and 2.13), more than half of all potential viewers in this area would be exposed to views of these reservoirs at MOP. These people would be viewing relatively minor aesthetic changes at most locations.

Viewer exposure at other locations would be somewhat dependent upon the recreational effects of each option. Deep drawdowns on the lower Snake River projects would be expected to displace over 730,000 recreational users who would otherwise be potential viewers. It is possible that these drawdown conditions would actually initially draw many local area residents to look at the projects because of curiosity over a condition that has not occurred before. In general and over the longer term, however, viewer numbers would likely be considerably less than with normal operations. This would also hold true where flow augmentation significantly reduced reservoir elevations at Dworshak and Brownlee, where recreationists are the dominant component of the viewer population.

### 4.11.4 Secondary and Cumulative Impacts

Although sections of some of the projects being studied are remote, virtually none of the areas can be considered pristine. Even in the farthest sections of the most remote reservoirs, evidence of human activity is present. The most noticeable evidence of human activity in remote project areas is the presence of slack water from reservoirs in a river valley setting. Other human-initiated impacts in evidence include grazing, logging, roads, train tracks, residences, and transmission lines. In short, the aesthetic impacts of the alternatives would not greatly add to the cumulative impacts from human activity already apparent in virtually all parts of the study area.

The greatest potential secondary impact (as a result of a decrease in aesthetic quality) would be a decline in the quality of developed recreational facilities. Drawdowns diminish the aesthetic character of facilities and can contribute to a decline in use. Features such as dewatered beaches and marinas or lawn areas that die would not only be unusable, they would also be considered aesthetically unappealing. In addition to users who would stay away when they cannot use particular facilities, other visitors who find the atmosphere of recreational sites unappealing may also choose to stay away.

### 4.11.5 Mitigation

The major aesthetic impacts would result from pool drawdowns that leave large expanses of mud flats exposed. These impacts could be mitigated if actions are taken to seed these areas. Such plantings would likely be part of a wildlife mitigation plan developed for that area.

## 4.12 CULTURAL RESOURCES

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown** | |
| ***Snake River*** | |
| All 4 projects to MOP (April 1 to July 31) | • Possible reduction in wave erosion because reservoirs would remain static rather than fluctuate weekly. |
| All 4 projects to near spillway crest (April 15 to August 15) | • Larger areas of cultural sites would be exposed to erosion, vandalism, vehicle traffic, abrasion, breakdown, and movement of material. |
| All 4 projects to near spillway crest (April 15 to June 15) | • Less anticipated damage from shorter period of drawdown. |
| Lower Granite to near spillway crest (February 1993 or July 15 to August 15) | • See effects of near spillway and MOP. |
| Lower Granite to 710 feet, others to MOP (April 15 to June 15) | • See effects of near spillway and MOP. Four-week duration of this test would result in shorter exposure of cultural sites and, therefore, less anticipated impact. |
| Lower Granite/Little Goose drawdown test (March) | • See effects of near spillway. |
| ***Lower Columbia*** | |
| All 4 projects to MOP (April 1 to August 31) | • See drawdown of lower Snake reservoirs to MOP. |
| John Day at 262.5 feet, McNary at 337 feet, remainder at MOP (April 1 to August 31) | • No change anticipated at John Day and McNary; MOP effects to The Dalles and Bonneville. |

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Flow Augmentation** | |
| *Dworshak* | • Negative impacts would occur with unlimited withdrawals to meet flows of 140 kcfs during May. |
| *Brownlee* | • Increased damage of cultural sites from erosion, livestock, vandalism, primarily with unrestricted draft. |
| *Grand Coulee* | • Typically, no change in ongoing effects upon cultural resources is anticipated. In some years, drawdown might occur earlier than the historical norm, which could cause incremental increases in ongoing adverse effects from vandalism or erosion. |
| **Combination** | • Effects additive; see drawdown and augmentation. |
| **Temperature Control Test (August)** | • Potential increased exposure of cultural sites from drawdown of Dworshak to 20 feet below normal in August, increasing erosion and human-caused damage. |

Currently, cultural resource sites within the affected reservoirs are subject to damage from several significant sources. Erosion from wave action continues to be a major source of site disturbance. Human activities (vandalism, vehicle traffic, farming, recreation) also contribute to the loss of cultural resources. It is not possible to determine which specific cultural resources might be affected by actions resulting from this study. The ability to evaluate project impacts on cultural resources is site-specific. For the purpose of this study, each archaeological or historic property will require some form of cultural resource evaluation. But, for this discussion, broad conclusions can be made about general effects. In general, the effects of virtually all the options would be to exacerbate current impacts, although there would be considerable differences in degree.

## 4.12.1 Lower Snake River

### 4.12.1.1 Draft Lower Snake River Projects to MOP

The current impacts to cultural resources can be expected to continue with drawdown to MOP. There is the possibility of a slight positive benefit because reservoir elevations would remain relatively static from April 1 to July 31 rather than fluctuating 3 to 5 feet on a weekly basis as is currently the case. This condition might help to reduce erosion from wave action.

### 4.12.1.2 Draft Lower Snake River Projects to Near Spillway Crest

Generally, this would require a 30- to 40-foot drawdown (from April 15 to either June 15 or August 15), which would expose larger portions of reservoir cultural sites to erosion, vandalism, vehicle traffic, abrasion, breakdown, movement of cultural material resulting from wet and dry cycles (repeated raising and lowering of reservoir levels), and livestock damage. Damage likely would be more extensive with the longer period of drawdown to spillway crest.

### 4.12.1.3 Draft Lower Granite to Near Spillway Crest, Remaining Projects to MOP

Effects at Lower Granite would parallel effects noted above for dropping all four reservoirs to near spillway crest. Effects on the other three Snake River projects would be the same as noted above for drawing down reservoirs to MOP. The 4-week duration of this option, however, as opposed to the 4-month drawdown to MOP and the 2- to 4-month drawdown to spillway crest noted above, would result in a shorter exposure of cultural sites and, therefore, anticipated less impact.

#### 4.12.1.4 Draft Lower Granite to 710 Feet, Remaining Projects to MOP

The effects of this option would be similar to dropping Lower Granite to near spillway crest and the other Snake River projects to MOP. Less exposure than at spillway would result from dropping Lower Granite to 710 feet, and the duration of drawdown for the others to MOP would be 2 months rather than 4. These variations might result in greater erosion, breakdown, movement, and damage from human effects than under current operating conditions, but possibly less damage than dropping reservoirs to spillway crest and MOP for extended periods.

#### 4.12.1.5 Lower Granite-Little Goose Test Drawdown

The effects of this option would parallel effects of dropping lower Snake River reservoirs to near spillway. Effects, however, would be limited to Lower Granite and Little Goose, and would result in a shorter exposure of cultural sites (4 weeks) and, therefore, anticipated less impact.

### 4.12.2 Lower Columbia River

#### 4.12.2.1 Draft Lower Columbia River Projects to MOP

As with dropping lower Snake River projects to MOP, the impacts to cultural resources could be expected to continue as under current conditions. A slight positive benefit might result because reservoir elevations would remain relatively static from April 1 to August 31 rather than fluctuating 3 to 5 feet on a weekly basis as is currently the case. This might help to reduce erosion from wave action.

#### 4.12.2.2 Hold McNary to 337 Feet and John Day to 262.5 Feet, Draft Bonneville and The Dalles to MOP

This option would have the least impact on lower Columbia River cultural resources because it most closely parallels current operating condition. Operating Bonneville and The Dalles at MOP over an extended period of time would increase exposure of cultural sites to vandalism and human-created damage.

### 4.12.3 Flow Augmentation

#### 4.12.3.1 Dworshak

Some of the flow augmentation options at Dworshak could result in reservoir elevations significantly lower than under normal operating conditions for several months out of the year. Simulations undertaken to estimate resulting reservoir fluctuations indicate that all drawdowns under flow augmentation options would exceed those currently undertaken for flood control purposes. This would increase exposure of cultural sites and likely increase current negative impacts (erosion and human-caused damage). The greatest exposure would occur with unlimited withdrawals to meet downstream target flows of 140 kcfs during May. A shift of flood control space to Grand Coulee, thus allowing greater storage at Dworshak, would result in reservoir elevations an average of 6 to 13 feet higher, which could alter the current effects from vandalism, vehicle traffic, and wind and wave erosion.

#### 4.12.3.2 Grand Coulee

Operations for the reservoir drawdown alternatives would not involve Grand Coulee Dam. Therefore, no effect would occur to cultural resource sites around Lake Roosevelt from use of this alternative. Options D through J of the Snake River flow augmentation alternatives and all Columbia River flow augmentation alternatives could involve Grand Coulee Dam in some years to accommodate the flood shift or to augment flows. However, since the operation associated with the flow augmentation would never draft below 1,220.2 feet (12.2 feet above the historic springtime minimum operational elevation for Grand Coulee), it is anticipated that little or no effect would occur to cultural resources as a result of these modified operations. Existing impacts associated with the normal spring drawdown for flood and power operation (erosion, vandalism, recreational use, and off-road vehicle operation) would continue, but are not attributable to the proposed actions. The impacts from these normal operations are being addressed by BoR and BPA under other programs. These programs, to be implemented under a Memorandum of Agreement signed on October 27, 1991, will result in a reservoir-wide site inventory followed by site evaluation, excavation, or stabilization in accordance with a site management plan that will be approved by the Colville Confederated Tribes, the Spokane Tribe of Indians, the Washington State Historic Preservation Office (SHPO), and the Advisory Council on Historic Preservation. BoR will also continue the annual spring monitoring of sites that contain human burials. The only anticipated potential impact upon cultural resources at Lake Roosevelt from the modified operations to augment flows would occur if the reservoir was drafted earlier than normal to ensure room for the Lower Snake flood shift. Then, an incremental increase in ongoing effects could occur because of prolonged access to the sites by vandals or recreators, or from prolonged exposure to wind erosion.

#### 4.12.3.3 Brownlee

Flow augmentation options would result in the reservoir level at Brownlee being significantly below normal operating range (from 20 feet to empty) for up to 5 months. Near-shore wave action likely would increase, resulting in erosion and siltation of sites and site deposits. Cattle might severely compact the top 8 to 10 inches of topsoil in bands several feet wide for most of the extent of the reservoir when taking advantage of newly exposed beaches (USDI, 1981). Vandalism would likely increase.

### 4.12.4 Cultural Resources Evaluation

Proposed cultural resource actions will be coordinated with the State Historic Preservation Offices of Washington, Oregon, and Idaho along with the Advisory Council on Historic Preservation, appropriate Indian tribes, and other interested agencies and parties. Key components of the evaluation process will be the preparation of a comprehensive overview of all identified cultural resources sites located within the project area and development of a monitoring program for assessing project impacts to sites. This information will be used, in turn, to develop long-range management plans and strategies for project sites.

### 4.12.5 Mitigation

Mitigation requirements for project impacts to cultural resources may range from simple in situ documentation to detailed data recovery and preservation plans. Potential vandalism of sites might be prevented by use of additional enforcement. There would be no constraint on when these actions could begin.

## 4.13 SOCIOECONOMICS

The dollar and employment figures listed below reflect the impacts (direct and indirect) of the options on local and regional economic activity in the areas of transportation, agriculture, and recreation.

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown** | |
| ***Snake River*** | |
| All 4 projects to MOP (April 1 to July 31) | • No identifiable employment or income effects. |
| All 4 projects to near spillway crest (April 15 to August 15) | • Transportation: Temporary layoffs in barge industry.<br>• Agriculture: Near-term gross direct and indirect impact of $146 million from lost production, 2,500 jobs.<br>• Recreation: Potential shifts in $19.8 million in gross user expenditures; lost season revenues for concessionaires. |
| All 4 projects to near spillway crest (April 15 to June 15) | • Same industries affected as under 4-month drawdown to near spillway, but less effect on transportation.<br>• Recreation: Potential shifts in $3.6 million in displaced gross expenditures; lost concession revenues for about one-third of peak season. |
| Lower Granite to near spillway crest (February 1993 or July 15 to August 15) | • Recreation: Potential shifts in $0.5 million (winter test) or $4.3 million (summer test) in displaced gross user expenditures; lost concessionaire revenues. |
| Lower Granite to 710 feet, others to MOP (April 15 to June 15) | • Effects similar to Lower Granite at near spillway and others to MOP. |
| Lower Granite/Little Goose drawdown test (March) | • No effect on agriculture likely; no or minimal effect on barge industry.<br>• Recreation: Potential shift in $0.9 million in displaced gross user expenditures; lost concessionaire revenues. |
| ***Lower Columbia*** | |
| All 4 projects to MOP (April 1 to August 31) | • Agriculture: Near-term gross impact of $586 million from lost production; 10,000 jobs lost.<br>• Recreation: Potential shifts in minimum of $4 million in gross user expenditures. |

Socioeconomics (continued)

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservation Drawdown (continued)** | |
| John Day at 262.5 feet, McNary at 337 feet, remainder at MOP (April 1 to August 31) | • Agriculture: Near-term gross impact of $43.5 million from lost production; 740 jobs lost. |
| **Flow Augmentation** (effects to recreation only) | |
| ***Dworshak*** | • Recreation: Potential shifts in Dworshak user expenditures ranging from $35,000 to $7.6 million.<br>• Recreation: Insignificant to major loss of revenue for recreation business. |
| **Combination** | • Effects additive; see drawdown and augmentation. |
| **Temperature Control Test (August)** | • No effects on agriculture. No employment effects expected involving Dworshak log transportation.<br>• Potential shifts in Dworshak recreation user expenditures of $0.2 million; lost concessionaire revenues. |

The socioeconomic impacts of the proposed actions would affect the various river interests of the study area's surrounding communities. Those interests of particular concern include transportation, agriculture, logging, recreation, power, and water supply. The potential reservoir drawdowns and flow augmentation may have the effect of impeding navigation and the transport of agricultural products and lumber, restricting the availability and accessibility of water for irrigation, and reducing or eliminating the recreational activities that the river system provides at normal operating levels. These effects and the related impacts on employment in each industry are discussed in the following paragraphs.

## 4.13.1 Employment and Related Effects

Potential employment and related economic effects are presented below for each resource use. In most cases, these assessments are based on results derived in the corresponding resource sections of the OA/EIS.

The draft OA/EIS discussed gross economic and employment near-term (1992) impacts to navigation, crop production, power, and water supply, and the longer-term (1993 and later) impacts as a result of implementing pump station and other project-related modifications. This final OA/EIS excludes discussion of longer-term impacts and focuses on the near-term gross impacts because the agricultural analysis was calculated to evaluate net impacts (versus gross) and to include orchard/crop replacement values. As a result, this section analyzes the majority of the economic impacts deriving from the alternatives and the long-term and net agricultural impacts are discussed in Section 4.8. The remaining resource areas are not likely to be or will not be affected over the long term under the proposed 1992 actions.

The total impacts presented in the following paragraphs include both direct and indirect impacts. Direct impacts include employment, income, and production impacts associated with the affected industries. Indirect impacts were calculated by applying a multiplier of 2.0 for recreation and 1.0 for the remaining resource areas to the direct impacts throughout related industries and the rest of the regional economy. Thus, direct impacts equal indirect impacts for all but recreation and are added to obtain the total impacts.

#### 4.13.1.1 Transportation

The impacts on transportation in the study area would vary depending on the action taken. Operating the Columbia-Snake River reservoirs at or above MOP levels would not curtail barge traffic and should not cause any employment-related effects in the barge industry.

Alternatively, if four reservoirs on the lower Snake River are drawn down to near spillway crest, the entire reach would be unnavigable. Temporary layoffs of barge company employees would occur until alternative job opportunities could be found or navigation were restored. The number of potential layoffs is unknown, but it would be some fraction of the total industry employment (including administrative) of 600 people. Some shifting might also occur within shipping and farming employment as farm producers attempt to transport their products to market before the proposed actions take place, or stored agricultural products at elevators or terminals. Loss of barging capabilities at spillway crest would also significantly affect Potlatch Corporation shipping pulp and paper products from the Lower Granite Pool, peas and lentils from throughout the Snake River region in Washington and Idaho, and possibly upriver shipments of petroleum products from the Tri-Cities distribution facilities on the Columbia River. Wood chips from three sources use the Lower Granite Pool to serve several mills in the lower Columbia River. None of these currently use rail service, although they are on rail lines and could shift to rail shipment if rates made it economically feasible and if cars were available.

#### 4.13.1.2 Agriculture

The primary consequence of most of the reservoir drawdown options for the agricultural sector would be the loss of crop production in 1992 from irrigated acres served by pumps with intakes above the respective drawdown elevations. The net agricultural costs associated with these effects were reported in Section 4.8. However, the lost crop production would have several secondary impacts, including potential lost employment in the farming and food processing sectors and a reduction of total economic activity in the affected local economies. The levels of these indirect impacts would be determined by the gross crop value of the lost production.

Direct impacts include lost value of crops, additional operating costs, and increased employment costs. The indirect impacts include those economic impacts resulting from a multiplier effect of lost related economic activity and the opportunity cost of redirected resources.

Employment changes were estimated on the basis of 34 jobs lost per $1 million of lost near-term direct gross crop value (personal communication, Jim Barron, Washington State University Cooperative Extension, Pullman, Washington, July 1991). Total direct and indirect economic activity (output) associated with the lost gross crop value was estimated by applying an assumed multiplier of 2.0.

Based on these multipliers, drawing down the lower Snake River projects to MOP would not result in a loss of gross crop values in the near-term because pumping stations in the Ice Harbor Pool are designed to operate at MOP. The two-reservoir test drawdown also would not affect irrigation withdrawals for agriculture.

Drafting all four lower Snake River projects to near spillway crest, for either 2 months or 4 months, would have the effect of eliminating most agricultural production dependent on the Ice Harbor Pool. Based on a gross crop value of $73.1 million, the total near-term direct and indirect economic impact would be over $146.1 million. Approximately 2,500 jobs would be associated with the lost production.

Drawing all of the Lower Columbia projects down to MOP would result in about $586.1 million in gross lost near-term economic activity and up to 10,000 jobs. This would result in a gross loss of $33.5 million and 570 jobs in the Bonneville Pool, $0.6 million and 10 jobs in The Dalles Pool, $471.9 million and 8,000 jobs in the John Day Pool, and $80.1 million and 1,400 jobs in the McNary Pool. Only drawing John Day down to 262.5 feet, McNary to 337 feet, and the remainder to MOP would result in a gross loss of $9.4 million and 160 jobs for John Day and no gross losses for McNary, plus the previous impacts for Bonneville and the Dalles at MOP. This would produce a total gross loss of $43.5 million and 740 jobs.

Flow augmentation options would generally not affect agricultural use of water for irrigation.

#### 4.13.1.3 Logging

The impact on the logging industry would be localized primarily in the region surrounding the Dworshak project. If significant drawdowns occur at this site, transport of timber on the lake would no longer be possible and timber companies would have to convert to transporting by truck, or truck/rail. The potential increase in operating costs ($290,000 for Options B through F) were previously addressed in Section 4.7. It does not appear that there would be any direct effect on logging and related employment as a result of any change in the ability to use the log dumps, due to the existence of other shipping options.

#### 4.13.14 Power Supply

Changes in hydroelectric generation would not result in any direct effects on employment in the study area or elsewhere in the region. However, the costs of generation losses associated with flow improvements could eventually have some indirect effects on employment and overall economic activity through potential effects on wholesale power rates. Rate effects from a 1992 action have not been identified and are highly uncertain. If the proposed action did lead to a future rate increase, the additional power cost to the regional economy could exert a slight downward influence on regional output and employment. No estimates of potential positive employment and income impacts arising from the use of alternative electric power sources.

#### 4.13.1.5 Recreation

An unknown but presumably significant portion of jobs in the retail and services industries of the study area are devoted to recreation-related employment. Reduced levels of use or actual closure of facilities because of changed water levels could directly and indirectly affect employment. Direct employment impacts would occur at concessions and marinas located on the pools, campsites, and other private businesses directly adjacent to the pools. Secondary job effects would occur at lodging, restaurants, and other service establishments that depend partially on recreational users for business.

Direct employment impacts resulting from disruption of recreation activities have not been estimated. There are relatively few of these businesses, and they tend to be small, family-operated ventures. Employment losses would be small in number and might be limited to seasonal jobs. In addition, some positive employment and income impacts may arise from use of alternative recreation activities. Some of the drawdown and flow augmentation options would cause the loss of revenue for these businesses over most or all of a recreation season. It is possible that some of these operations would not be able to sustain such losses and would fail. While the number of affected proprietors would again be small, for the individual this would likely represent the loss of a major personal investment and commitment.

Changes in secondary employment and income effects would be driven by any shifts in recreation expenditures by displaced users. Gross expenditure levels that would be subject to redistribution would range as high as $21.5 million ($7.2 million direct and $14.3 million indirect), with drawdown of the lower Snake River reservoirs to near spillway crest. Based on research indicating that 69 jobs could be supported by each $1 million of direct recreational expenditures (Ben-Zvi, 1990), the maximum level of affected expenditures could be associated with up to about 495 jobs. Some of these jobs could be lost as a result of shifting activity patterns from displaced users, or the geographical distribution of jobs supported by recreation could shift.

### 4.13.1.6 Water Supply

Although municipal and industrial water supply users do not consume a significant amount of water from the river system, various users do rely upon the system to meet their water needs. Municipal and industrial users could incur additional capital and operational (i.e., labor, electricity, etc.) costs from modifying intakes and pumping facilities as a result of lowered water levels. An alternative to modifying existing facilities could be the much more costly option of drilling wells. Industrial users which could be affected include food processing plants and timber-related industries.

For instance, in addition to the impacts to farmers and the resulting secondary impacts to food processors, those food processors could also be more directly affected by capital and operational costs for modifying pumping facilities, or a lack of water to meet water quality requirements.

Municipal and Industrial water supply intakes in the Lewiston area are on the Clearwater River above Lower Granite Reservoir. Elevations and water depths at these intakes are such that there should be no adverse impacts if Lower Granite is drawn down to near spillway crest. The Tri-Cities of Richland, Kennewick, and Pasco all derive a portion of their water supplies from the McNary Pool. These intakes are designed to be able to operate at the minimum pool level periodically, but not for long periods of time. Drawdown to MOP could increase pumping costs an estimated 18 percent in at least one case, and could create mechanical problems. The city of Kennewick expressed concern during scoping over potential effects of drawdown on the city water supply and other utilities (personal Communication, R. Hammond, City of Kennewick, July 8, 1991).

A number of municipalities and individual water consumers also derive water supplies from shallow wells that are near and hydrologically connected to the Snake and Columbia rivers. The ground water table in the vicinity of the rivers is essentially the river elevation. When the dams were constructed, the water table near the river rose accordingly. Numerous shallow wells have been installed that are dependent on the current water elevation. Lowering reservoirs would also lower the water table, thereby affecting water supplies from these shallow wells.

The extent and magnitude of these effects cannot be predicted from the limited data on water supplies that are currently available. In general, however, it appears that minor drawdowns (such as drawdown to MOP) would have minor incremental effects on operating costs and well yields, while deep drawdowns could leave wells dry. Comments on the draft OA/EIS from the City of Boardman, Oregon likely illustrate a typical situation with respect to minor drawdowns (see letter L1, Appendix N). Boardman uses a Ranney well system on the banks of the John Day Pool. The potential well yield at a pool elevation of 265 feet is 9,000 gallons per minute (gpm), which is 50 percent higher than the design capacity of 6,000 gpm. Lowering the John Day Pool to elevation 257 feet (MOP, the lowest elevation for John Day considered in this OA/EIS) would reduce the potential yield to 5,630 gpm, which is 6 percent below design capacity. Because current peak usage appears to be well below this level, there would apparently not be any adverse effects if John Day were operated at MOP. In other locations, however, it is possible that minor drawdowns would result in actual decreases in well yields and increases in pumping costs. While these changes might be noticeable in individual cases, they would not likely be significant given the small changes in reservoir elevations being considered (excluding drawdowns to near spillway crest in the lower Snake River).

## 4.13.2 Social Effects

The greatest expected economic and employment impacts are associated with impacts to the agricultural sector; however, many categories of users of the Columbia-Snake River System would be negatively affected in some way. The potential cessation of farming by some farmers would likely mean the loss of their farms and moving their families elsewhere, either within or outside the study area. In addition, other non-seasonal and seasonal workers losing jobs probably would have to relocate themselves and their families. In addition to the loss of jobs and income, displaced workers might have to obtain employment in another sector, which would represent an altered lifestyle. Although the effects could have significant social effects on these workers and families, they would represent a small proportion of the total population in the study area (1,215,938).

Implementation of flow improvements that cause significant dislocations to resource users could be expected to provoke strong negative social reactions. Based on the type and distribution of all expected impacts, adverse reaction would be particularly strong in agricultural communities if there were barge production losses from reservoir drawdown options. The recent and ongoing controversy over logging restrictions to protect spotted owl habitat provides a likely parallel of some potential social effects. Popular accounts of reaction in timber-dependent communities report widespread anger at the imposition of controls by outside agencies that are having immediate effects on individual livelihoods. They also indicate that the ensuing social and personal stress has increased demands on providers of various social services.

### 4.13.3 Indian Fishing Rights

Improvements to the in-lieu sites and development of the Section 401 sites are scheduled to occur during 1993. The Site 401 developments will be designed to function at MOP levels. Therefore, options proposed for 1992 would not affect the Section 401 sites. Effects on in-lieu sites from alternatives proposed for 1992 are discussed below.

Of the five in-lieu sites, the three located in Washington were developed to accommodate MOP conditions. However, MOP conditions could make boat launching more difficult at the Wind River, Underwood, and Cooks Landing sites. The Wind River site is currently too shallow for boat launching and is in need of dredging. The Indians staying at this site have been using a county public launch site a short distance downstream on the Wind River. This county site would become shallow with MOP, making boat launching more difficult. The condition of the ramps at the Underwood and Cooks Landing sites at MOP has not been verified. It is possible that at MOP the ramp ends would be exposed and/or deteriorate. If this situation occurred, some mitigation might be required to extend the ramps or remove sediment accumulations.

The two sites in Oregon (Cascade Locks and Lone Pine) do not have boat ramps or docks. Indians fishing at these sites use platforms or bank fishing, or use the public launch site at Cascade Locks County Park, which is not expected to be affected. Minimum pool levels would require some adjustment from those fishing from platforms or banks, and would probably necessitate modifying fishing equipment and/or relocating/rebuilding platforms. The extent of this impact is not known. Impacts to Native Americans using public boat ramps would be similar to those expected to occur to other members of the public (see Recreation Impacts, Section 4.10).

At present, no assessment has been made regarding impacts that would be caused by lowering reservoirs to spillway crest. Most likely, impacts from such an alternative would generally make boat launching more difficult at sites with boat launches.

## 4.14 STRUCTURAL IMPACTS

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Reservoir Drawdown** | |
| ***Snake River*** | |
| All 4 projects to MOP (April 1 to July 31) | • No significant adverse effects. |
| All 4 projects to near spillway crest (April 15 to August 15) | • Increased turbulence at dam stilling basins could cause scour and undermine stilling basins, lock walls, and locks.<br>• Could cause unstable dam embankments.<br>• Lewiston and Marmes levees could be undermined by waves.<br>• Reduced soil bearing capacity and possible settlement, resulting in damage to facilities.<br>• Railroad and highway embankments exposed; wave erosion could result in unstable fill and ultimately failure.<br>• Potential scour could undermine Red Wolf Bridge piers.<br>• Elimination of buoyancy from reservoir water could cause failure of Lyons Ferry water supply pipeline. |
| All 4 projects to near spillway crest (April 15 to June 15) | • Same above except with decrease in duration. |
| Lower Granite to near spillway crest (February 1993 or July 15 to August 15) | • Same effects for Lower Granite as for drawdown to near spillway crest. |
| Lower Granite to 710 feet, others to MOP (April 15 to June 15) | • Similar to drawdown to near spillway crest. |
| Lower Granite/Little Goose drawdown test (March) | • Same as spillway effect for Lower Granite and Little Goose but lesser potential because of reduced duration. |
| ***Lower Columbia*** | |
| All 4 projects to MOP (April 1 to August 31) | • No adverse effects to stilling basins. |
| John Day at 262.5 feet, McNary at 337 feet, remainder at MOP (April 1 to August 31) | • Effects to Bonneville and The Dalles similar to MOP. No adverse effects to John Day and McNary. |
| **Flow Augmentation** | • No significant effects, as augmentation would not be needed in high-flow years. |

Structural Impacts (continued)

| Alternative/Option | Potential Significant Impacts (Positive and Adverse) |
|---|---|
| **Combination** | • Effects additive; see drawdown and augmentation. |
| **Temperature Control Test (August)** | • No significant impacts because drawdown and discharge are within normal operating ranges. |

Drawdown below MOP would lower tailwaters and allow greater downstream turbulence at dam stilling basins. This turbulence may cause scour that could undermine stilling basins, lock walls, and locks. Wind waves could cause erosion of dam embankments, levees, and railroad and highway embankments. Increased flow velocities would also affect these latter structures. During natural high flow years, however, the flow augmentation alternative would not pose additional risk to structures because no additional releases would occur at these high discharges.

## 4.14.1 Dam Safety

### 4.14.1.1 Spillways

As water passes over the spillway, the elevation difference between the upstream pool and the downstream tailwater is converted into high velocity flow. This flow has a large amount of energy that must be dissipated before being passed into the downstream river. This can be accomplished using a number of different types of energy dissipaters. The majority of dams on the mainstem Columbia-Snake River System use a hydraulic jump type stilling basin for this purpose. The basins are designed so that the highly turbulent hydraulic jump would occur within the confines of the basin, thus minimizing the potential downstream erosion. The Little Goose project on the lower Snake River uses a submerged roller bucket type energy dissipater. This type uses the roller action caused by the bucket to dissipate the high energy before passing into the downstream channel.

A critical design parameter in determining the effectiveness of an energy dissipater is the downstream tailwater depth. If the tailwater elevation drops below that which was used to design the energy dissipater, the hydraulic jump will tend to move downstream, causing extremely turbulent flow outside the basin. This could cause severe erosion damage to the downstream channel, undermine the stilling basin and even the dam itself. The Little Goose roller bucket is particularly susceptible to large fluctuations in tailwater depth. This energy dissipater requires tailwater depths within narrowly defined limits for adequate energy dissipation to occur. Insufficient tailwater depth would result in the flow sweeping out of the bucket and forming a jet. A still more undesirable condition could occur just prior to sweepout, when an instability develops that could result in excessive erosion and undesirable wave conditions in the tailrace and downstream channel. In addition, the Little Goose project has already (under normal conditions) experienced erosion in the area downstream and adjacent to the concrete spillway. Lower tailwaters would also increase the roller bucket's tendency to move loose material from the downstream channel into the bucket itself, which would damage the bucket and further reduce its ability to dissipate energy.

The options that require taking the lower Snake River pools below MOP are of particular interest in regards to effects on energy dissipation below the dams. The option that would require spillway free-flow conditions at the four lower Snake River dams would cause a substantial lowering of tailwater elevations for Lower Monumental, Little Goose, and Lower Granite when compared to original design (Table 4.14-1). As an example, for a river flow of 100,000 cfs, the tailwater elevations at Lower Monumental, Little Goose, and Lower Granite would drop 6 feet, 13 feet, and 11 feet, respectively. This magnitude of change would substantially increase the risk of damage to the downstream channel, the energy dissipater, and the dam itself. This is especially critical for the Little Goose project with its history of problems and the added complications associated with the roller bucket design. Additional technical analysis, including extensive physical modeling, would be necessary to precisely define the extent of damage that would occur during extended operation at the lower tailwater levels. Another problem associated with this option would affect all four of the lower Snake projects. Because of other constraints, the powerhouse would not be operational whenever the pool levels are below MOP. This would allow the spillway flows to expand toward the powerhouse leaving the basin out the side. The turbulence at this point would be even higher than that exiting out the end of the basin. This would further increase the potential for severe erosion downstream of the powerhouse. This option is not acceptable because of increased risk to dam safety.

The other options that would require operation of projects below MOP include operating Lower Granite near spillway crest or at elevation 710 while the other lower Snake River projects remained at MOP. For these options, the reduction in tailwater elevation at Lower Granite for a river flow of 100,000 cfs would be 5 feet below original design. With additional technical analysis, it may be possible to more clearly define the risk associated with this magnitude of tailwater lowering. A physical test that examined similar conditions was videotaped in June 1991. Using this information, as well as theoretical computations, a better assessment of the effects would be possible. Lowering the pool to spillway crest or elevation 710 is considered marginal in regards to dam safety and additional technical analysis is necessary before a final decision is made.

Operation of the lower Snake projects at MOP would fall within existing operating parameters and no adverse effects in regards to dam safety are anticipated.

### 4.14.1.2 Dam Embankments

Lowering Snake River pools to near spillway crest would expose the unprotected rockfill embankment. With time and wave action, the unprotected rockfill would begin to erode. The loss of material would result in an unstable earth embankment with the potential for failing.

Each of the lower Snake River projects has a rock fill dam embankment section. These embankments have riprap erosion protection down to MOP, with the exception of Lower Granite, which has protection down to 9 feet below MOP.

To protect the rockfill, additional riprap must be placed. The quantities of riprap that would be required are:

(1) Ice Harbor - 14,700 square yards

(2) Lower Monumental - 16,650 square yards

(3) Little Goose - 12,800 square yards

(4) Lower Granite - 14,000 square yards

Riprap could be placed prior to the reservoirs being drawn down or during the drawdown. Another option could be the placement of geotextile grout blankets prior to drawdown.

For the option of operating Lower Granite at elevation 710, the exposed embankment that would need protection is approximately 5,000 square yards. The 5,000 square yards of protection could be provided by placing riprap prior to lowering the pool or while the drawdown is taking place. Another option for protection is the placement of geotextile fabric filled with a cement-like grout.

Maintaining dam embankment stability is critical to the integrity and safety of the lower Snake River projects. Regular observation of embankments to detect erosion or stability problems is a key feature of the monitoring program that will be implemented as part of the 1992 actions. Implementation plans also include appropriate measures for emergency repairs to embankments, if needed.

**Table 4.14-1.** Tailwater elevation comparisons for lower Snake River projects operated at spillway free-flow conditions.

| | Tailwater Elevation at 100 kcfs flow | | Tailwater Elevation at 200 kcfs flow | |
|---|---|---|---|---|
| | Design Condition[a/] | Spillway Freeflow | Design Condition[a/] | Spillway Freeflow |
| Lower Granite | 639 | 628 | 641 | 637 |
| Little Goose | 541 | 528 | 542 | 536 |
| Lower Monumental | 442 | 436 | 445 | 443 |
| Ice Harbor | NA | >345 | NA | >345 |

NA Not available.
a/ Based on original project model studies for spillway and stilling basin design.

## 4.14.2 Levees

The city of Lewiston is protected by levees that are protected by riprap to elevation 730. These levees could be undermined by wave action or high flow velocities and would have to be protected by placement of riprap or geotextile fabric and grout. If a levee were damaged, repair would have to take place before raising the pool. If levee damage were extensive, repairs could take many months.

The Lewiston levees were constructed with a downstream (city side of levee) filter between the cohesive core and the gravel shell of the embankment. This performs well according to its design purpose. However, there is no such filter on the river side of the core. In the reverse flow situation, which will be realized during the drawdown, there is the potential for piping of fine, graded, core material through the more porous granular shell. The extent and magnitude of the problems that could be realized by the reverse flow situation are uncertain. The relatively short drawdown time might not produce any significant particle migration problems; however, the possibility of sink holes, seeps, and sliding should not be discounted.

Near Lyons Ferry on Lower Monumental Pool, the Marmes levee was constructed to protect an historical area. This levee is not protected by riprap below elevation 540. It would need the placement of riprap or geotextile fabric and grout. Shoreward of these levees are ponds. The primary source of water for these ponds is storm drainage runoff. Siphons are used to introduce freshwater (from the river) into the ponds to keep them from becoming stagnant. The siphons would be inoperable when the river elevation dropped below approximately elevation 731. The ponds would therefore be subjected to wetting and drying with all drawdown options that would operate Lower Granite below MOP. To maintain a constant water elevation in the levee ponds, pumps could be installed and water pumped from the river into the ponds.

## 4.14.3 Soli Bearing Capacity

Lowering of pool levels would reduce the groundwater level in the adjacent surficial sediments. This drop in water level would alter the soil bearing capacity. Design criteria for facilities in this area were done with the assumption of a high water table. Most detrimental is the potential for settlement that could result in damage to facilities. Pre- and post-drawdown surveys of affected structures will be needed to assess impacts.

## 4.14.4 Railroad and Highway Embankments

Lowering the pool elevations to near spillway crest would expose a substantial portion of unprotected railroad and roadway embankment. The embankments are armored with riprap for protection against wave action and excessive scour, but the riprap only extends slightly below MOP levels. With all reservoirs drawn down below MOP, wave action would erode the embankments and result in an unstable fill. With time, sloughing of fill would occur. As erosion progressed, the embankment's design safety factor would be diminished and failure would occur. Protection would require additional riprap, the placement of a geotextile fabric and grout, or repair of embankments as they are damaged.

Culverts are an additional hazard to embankment stability. Embankments block surface water movement from the valley sides to the reservoir. Consequently, culverts were installed at many locations to allow drainage through the embankments. Water spilling out of culverts has a high potential for eroding embankments and eventually undermining them. This is especially so during rainstorms. Consequently, the culverts have large rocks placed at their outlets to prevent erosion. Lowering pool levels would allow this water to accelerate below the existing rocks, reinitiating the erosion process. New rocks would have to be placed below the culverts to prevent this process.

Structure protection prior to reservoir lowering would be a major construction project. Consequently, the option of repairing the fills as they are damaged is probably more practical. Under this scenario, the public could be exposed to potential life-threatening situations. Alternatively, damage to embankments could force road or railway closure, restricting area usage until repairs were completed.

Approximately 1.2 million square feet of riprap would be required for rail and roadway embankment protection along the Snake and Clearwater rivers. This quantity only accounts for the protection of a band 5 feet above and below the proposed drawdown pool elevation. During drawdown and when refilling the reservoirs, additional surface area of the embankments would be subjected to erosion. If reservoir lowering becomes an annual procedure, the entire embankment slope would have to be protected.

### 4.14.5 Bridges

The Snake and Clearwater rivers' railroad bridge piers are generally placed in bedrock and would not require reinforcement to protect against scour from increased flow velocity and wave action. At Bridge No. 69.87, located at Lewiston near the mouth of the Clearwater River, Piers 3 and 4 are supported on H-piles, which are not enclosed within a sheet pile cofferdam. These piers would require cofferdam placement and sealing with concrete between the pile cap and bedrock.

Red Wolf Bridge in the Lewiston-Clarkston area is the only roadway bridge with potential problems. The piers are founded on dense gravels, three at elevation 712 and one at elevation 706. Lowering the reservoir to near spillway crest height of elevation 681 would cause an estimated low river at approximately elevation 706 in the vicinity of the bridge. Potential scour could occur with estimated river velocities of 7 to 10 feet per second. Protection for the supporting piers could be the placement of riprap, sheet pile, and grout, or geotextile fabrics and grout. The choice, type, and complexity of protection must be evaluated before drawdown occurs to guarantee safety. At a minimum, the bridge piers in question would need river soundings taken to establish the current river channel. A model could then be used to determine flow characteristics around the piers and the needed protection level.

### 4.14.6 Lyons Ferry Water Supply Pipeline

The 5-foot supply pipe is submerged and supported on bents spaced 64 feet on center. The design incorporated the buoyancy force of the reservoir water to aid in the support of the pipe. Drawdown of Lower Monumental Reservoir to near spillway crest would expose this pipeline and remove the support. Without the support from the buoyancy force, the pipe would quickly go through excessive deformations in mid span and over the bent supports until failure occurs. Modifications would require an embankment fill to be placed under the pipe to give additional support before the pipe can be filled with water. Without modification, loss of the pipeline would severely reduce the production capacity of the hatchery.

### 4.14.7 Summary

Preliminary assessment of the dam safety issue resulted in the following conclusions relative to the flow measures under consideration:

- UNACCEPTABLE / Operating all four lower Snake River projects near spillway crest would pose an unacceptable risk to dam safety.

- ACCEPTABLE / Operating lower Snake and Columbia River projects at MOP would pose acceptable risks to the integrity of stilling basins and dam embankments.

- MARGINAL / Operating Lower Granite at elevation 710 or near spillway crest, while the other lower Snake River projects were operated at MOP, would be a marginal dam safety condition. Hydraulic modeling/studies are currently being conducted. This work will be completed by January or February 1992 and the results of this work used to determine acceptability.

Reservoir drawdown below MOP would also represent some risks for the integrity of levees, railroad and highway embankments, and bridges. The degree of risk to these structures is unknown. The Corps has sought to limit the risk by constraining the rate of drawdown to no more than 2 feet per day. For limited locations, such as bridge abutments, the risk could be minimized or eliminated by adding protection prior to or during drawdown. Where protection would not be practical because of the extent of the structures, reservoir drawdown could only be implemented with recognition that structural damage could occur and require considerable time and expense to repair.

# 5.0

# Plan Selection and Implementation

1992 COLUMBIA RIVER SALMON FLOW MEASURES
OA/EIS

CONTENTS

CONTENTS (Continued)

## TABLES



## FIGURES

# 5.0 PLAN SELECTION AND IMPLEMENTATION

## 5.1 INTRODUCTION

The objective of this section is to describe the process of developing an operational plan for 1992 that will lead to improved flow conditions for adult and juvenile salmon in the Columbia River Basin. Flow condition improvements will be based on reducing in-river water particle travel time for migrating juvenile salmon stocks, or developing test data that will support future actions to meet this objective, and reducing late summertime water temperatures for adult migrating salmon.

## 5.2 EVALUATION CRITERIA

Typically, the Corps bases plan selection on the Federal objective established in the Water Resource Council's *Economic and Environmental Principles for Water and Related Land Resources* (February 3, 1983). The Federal objective is to select the plan that maximizes contributions to national economic development (NED) consistent with protecting the nation's environment. Contributions to NED are increases in the net value of the national output of goods and services, expressed in monetary units. The evaluation of alternatives under this Federal objective requires thorough assessments of all the costs and benefits associated with each alternative. Unfortunately, the extremely short timeframe of this study does not allow for basic data collection to determine all the costs and benefits. Nor is sufficient biological data available to establish biological outputs of the alternatives. Furthermore, the Snake River sockeye has now been listed as endangered and several other stocks of salmon are proposed for listing under the ESA. This document is analyzing temporary measures designed to test proposed methods that water management agencies feel should contribute to improved survival of the key salmon stocks at issue. Given these conditions, strict adherence to maximizing NED is not appropriate, so the NED plan selection criteria cannot be completely implemented in this study and alternative selection criteria are necessary.

The evaluation process used for this study is similar to the mitigative evaluations undertaken by the Corps when assessing the effects of construction and operation of multipurpose water development projects. The Corps' process for selecting mitigation plans consist of several steps. The basic procedures can be summarized as: (1) establishing a mitigation goal in terms of biological outputs (e.g., number of returning adult salmon or number of smolts surviving past Bonneville Dam); (2) identifying incremental measures that provide the intended biological output; (3) ranking the measures in terms of costs per unit of biological output from the most cost effective to least cost effective; (4) combining alternatives to define the most cost-effective combinations to meet the mitigation goal; (5) justifying each increment of the combined alternatives by showing that the incremental benefits (monetary and non-monetary) exceed the incremental costs (monetary and non-monetary); (6) considering implementability, which includes whether the alternatives physically can be accomplished and whether sufficient statutory authority exists for the action to be initiated; and (7) determining the acceptability of the alternatives by State and local entities and the public.

Given the state of scientific debate and the uncertainty surrounding flow proposals, universally accepted biological data are not available to determine the biological output of the numerous measures or alternatives; therefore, this procedure cannot be completely followed. However, by replacing the biological goal with a physical goal, the spirit of the procedures discussed above can be used to help guide the plan selection process.

The Salmon Summit identified two physical objectives for consideration by the Corps and other reservoir operating agencies. The objective for juvenile salmon is the reduction of water particle travel time. For adult migration, the measurable objective is to reduce water temperatures in the lower Snake River downstream to the confluence of the Snake and Columbia rivers during the warmest period of the summer (generally sometime between mid-August and September).

These physical objectives became the starting point for the evaluation procedures established for this document. Plan formulation and plan selection criteria are based on a screening process as depicted in the decision chart shown in Figure 5.2-1.

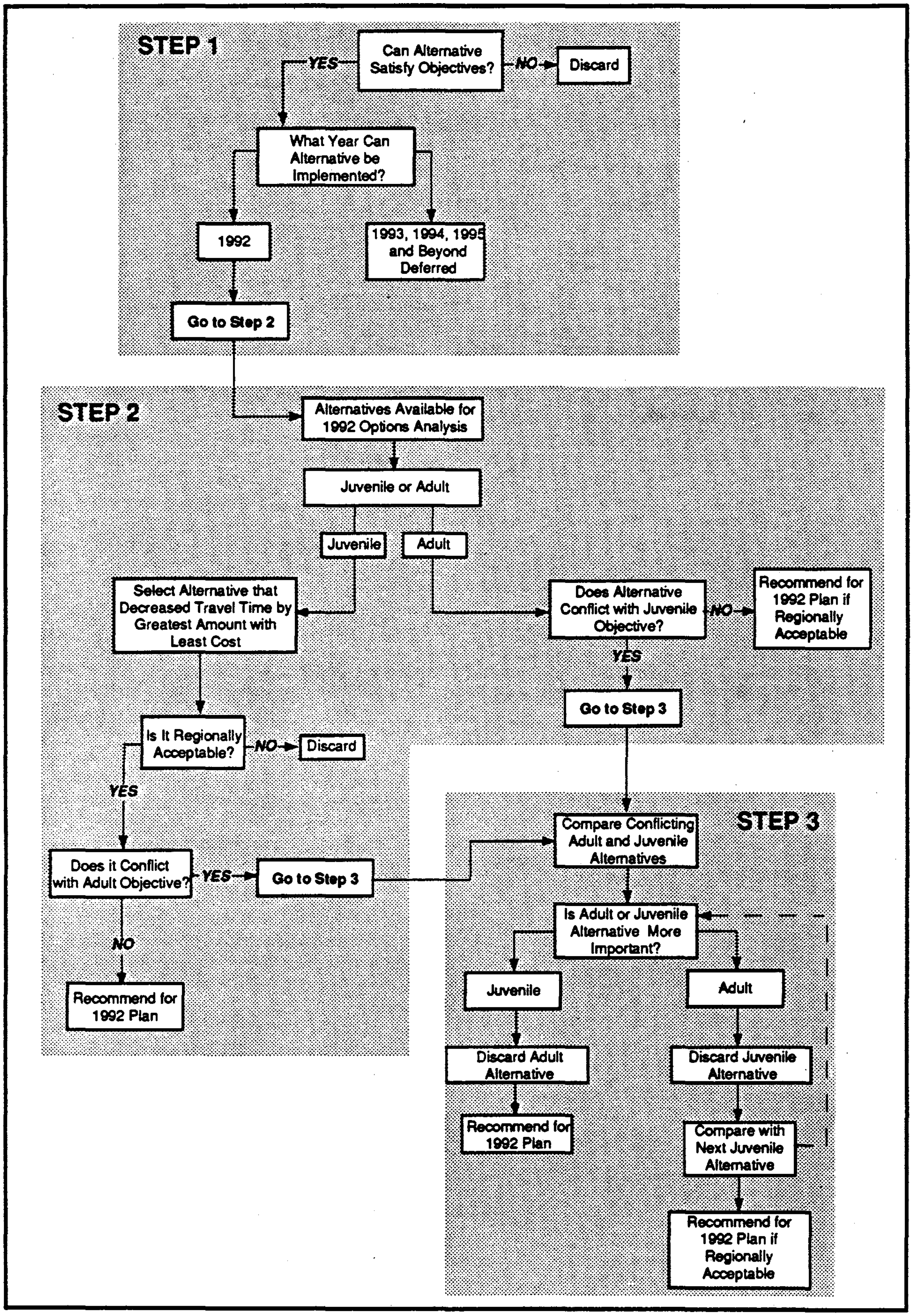



**Figure 5.2-1.** Decision chart.

Individual options were screened to determine whether they satisfied (to some degree) one or more of the physical objectives (Step 1 of the decision chart). Those that did not meet this test were discarded from further consideration. The next step was to screen remaining measures into categories of implementability. Category one are those options that can be physically implemented by March 1992 within existing authorities. The remaining category is a deferred status for consideration in later years.

Options that were determined to be implementable in March 1992 and within existing authorities were then evaluated under Step 2 of the decision chart. Criteria used for this step are that the option: (1) will not have significant negative effects on fish and wildlife; (2) will provide information beneficial to future fish activities and will not foreclose future flow alternatives; (3) will not present unreasonable safety hazards to the physical structures or to the operation of the projects; (4) will maintain the water quality of the Columbia River Basin; and (5) will address project operations in a manner that recognizes a balance of the uses served by the Columbia River Basin while providing biological benefits to fish. These options are presented for review by the public in this document.

Cost effectiveness and acceptability served as major considerations in the plan selection process. The cost-effectiveness criteria, in terms of relative costs to achieve a decrease in water particle travel time and water temperature goals, were used to rank the options. However, some options are purely tests intended to provide information needed for potential future flow improvements, and would not provide travel time reductions during 1992 juvenile outmigration periods. The benefits of these measures are not adequately addressed through this cost-effectiveness approach. The costs included all implementation costs and foregone costs in terms of reduced output of project benefits, such as hydropower or navigation benefits from the current conditions. The benefits foregone component of costs are presented in terms of reduction in the physical outputs and, to the extent possible given the limited time frame, the economic costs. The presentation of impacts may contain numerous estimates of possible losses or gains in dollars for the different alternatives. The limitations of these monetary values must be recognized. In general, the monetary values were taken from available data, were quantified over a range of possible values, and were based on informed professional judgement.

The monetary values do not, in all cases, measure directly comparable economic values. For example, the estimates may represent net income changes, gross income changes, expenditures, or transfers from one economic region to another. Since these represent different types of values (e.g., regional versus national), they cannot be traded off on a one-to-one basis. In all cases, the bases for the monetary estimates are clearly stated so that the reader can differentiate between the estimates. By combining the economic costs with the known losses in outputs associated with each alternative, a ranking of alternatives from least to most costly was possible. This information was used in the plan selection process.

Acceptability of these alternatives by State and local entities and the public was assessed for each alternative. The public had 50 days to review this draft document and participate in public meetings on its content.

From this process a preferred alternative that most closely meets regionally established objectives with acceptable costs, minimal environmental damage, and public acceptability was selected for the 1992 juvenile fish action plan. This plan is presented in Sections 3 and 5 of this document. There will be a 15-day public review period on the FEIS, after which a decision on the 1992 plan will be announced in a Record of Decision to be released on or around February 14, 1992.

The decision chart lays out a similar process (Step 3) for meeting the adult fish objective. The plan resulting from the adult decision chart was subjected to the same final test of acceptability discussed above and then added to the plan for juvenile fish. This final combination plan became the recommended action water management plan for 1992.

It should be recognized that the alternative selected for implementation in 1992 might require adjustment depending on hydrologic conditions. To identify what adjustment might be required, the selected plan will be evaluated against low and high basin runoff volumes.

Actions implemented in 1992 may be considered for implementation after 1992 depending on the results of the 1992 monitoring actions and any future project modifications that may be in place.

## 5.3 INITIAL SCREENING OF ALTERNATIVES

All measures in Section 3.0 to some degree satisfy the objective of reducing travel time for migrating salmon. Thus, to satisfy Step 1 of the screening criteria, measures must be implementable in 1992. To evaluate implementability in 1992, three questions were asked:

1. Will the measure negatively affect fish?
2. Will the measure present unreasonable safety hazards to physical structures or the operation of the projects?
3. Will the measure foreclose future actions (i.e., result in irreversible effects)?

If the answer to any of these questions is yes, the measure was determined to be non-implementable in 1992 and eliminated from further consideration in this document. Two of the options that were determined to be non-implementable in 1992 are discussed below.

### 5.3.1 Draft Snake River Projects to Near Spillway

Although producing the greatest reduction in practical travel time, the alternative that operates all lower Snake River projects at near spillway was determined not to be implementable in 1992. This alternative would have significant negative impacts to salmon stocks. Adult passage facilities would be inoperable and could not be modified in time for the 1992 upstream migration period. Thus, all adult passage from Ice Harbor Dam upstream would be eliminated. A trap and haul program to provide adult passage when ladders are inoperable is not feasible. A trap requires certain flow conditions for attraction and collection similar to those required at ladders. These conditions would not exist under this alternative. In addition, the sheer number of adults that would require handling makes this approach impractical. For example, at Ice Harbor approximately 34,000 chinook and 95,000 steelhead would require handling. Furthermore, the destination of these adults would not be known and the effect of such handling may be detrimental (i.e., increased injury/mortality). Also, increased spill would increase dissolved gas levels to levels considered lethal to fish (125 to 150 percent).

Finally, this option results in significant impacts to navigation, power, irrigation, recreation, resident fish, wildlife and presents an unreasonable safety hazard to the projects. Without adequate tailwater elevations, unacceptable scour and severe erosion could occur at the downstream toe of each project. Project modifications to accommodate upstream fish passage and structural protection would require extensive hydraulic modeling before effective designs could be completed. Implementation would, therefore, be sometime after 1992.

### 5.3.2 Upper Snake River Flow Augmentation

Flow augmentation alternatives that include water volumes greater than 100 KAF from the upper Snake River System (above Brownlee) are not implementable in 1992. Negotiations for this water are very complex and cannot be completed in time for the water to be available in the spring of 1992.

## 5.4 COMPARISON OF ALTERNATIVES FOR 1992

Seven reservoir drawdown alternatives and 11 flow augmentation alternatives have potential for implementation in 1992. In addition, three combination measures were evaluated. These combinations do not represent all possibilities, but are discussed to illustrate how various alternatives can be combined and the impacts displayed. However, all impacts resulting from individual alternatives have been outlined and further combinations will not present new information on impacts. Tables 5.4-1 and 5.4-2, at the end of Section 5, present a comparison of these alternatives.

The data presented for comparison are a summary of information outlined in Section 4. For a complete description of the individual alternatives, refer to Section 3. The performance of all the alternatives, including those eliminated in the initial screening, against the plan selection criteria, is described below.

### 5.4.1 Performance Against Physical Objectives

The objectives of the 1992 options with respect to juvenile salmon are the reduction of water particle travel time in the 1992 outmigration season, or collection of test data that can be used in the development of long-term proposals to improve migration conditions. The reservoir drawdown, flow augmentation, and combination alternatives were therefore evaluated against the calculated water particle travel time that would result in each case. This was done from two perspectives. Absolute and percentage changes from existing travel times at different flow rates were calculated and used to evaluate the potential benefits to fish. Alternatives and options were also evaluated on the basis of the probability in any one year that a specific flow or water particle travel time objective could be met. This approach is particularly valuable in comparing and selecting temporary measures to be implemented for the 1992 migration.

The physical objective for 1992 for adult migration was to reduce late summer water temperatures at the confluence of the Snake and Columbia rivers. Multiple options for temperature control releases were evaluated against their ability to reduce temperatures at this location, particularly to a target level of 68°F.

#### 5.4.1.1 Existing Conditions

Existing flow/travel time conditions for juvenile salmon migration in the Columbia-Snake River System are widely considered to be unsatisfactory in many years as indicated by the need for the proposed action. Water particle travel times vary with flow. Under existing conditions with the mainstem dams at normal operating levels, water particle travel times from the head of Lower Granite Reservoir to the Columbia River range from about 20 days at flows of 40 kcfs to 6 days at flows of 140 kcfs. Snake River flows at Lower Granite during the April 15 to June 15 peak outmigration period are typically in the range of 80 to 100 kcfs. Flows have been considerably below these levels in several recent dry years. Water particle travel times on the Columbia River from the mouth of the Snake River to Bonneville Dam range from about 22 days at flows of 100 kcfs to 5 days at flows of 450 kcfs. Typical flows at The Dalles from April 15 to June 15 are in the range of 250 to 300 kcfs.

CBFWA, an umbrella organization comprised of the regional fisheries and wildlife agencies and tribes, has proposed a program emphasizing enhanced river flows in the lower Columbia and Snake rivers to increase juvenile salmon survival. The proposal recommended specific flow targets of 140 kcfs for the lower Snake River and 300 kcfs for the lower Columbia River from April 15 through June 15. These flows correspond to water particle travel times of about 6 days and 9 days, respectively, for a combined total of 15 days. The probability of meeting these targets in any given year under existing conditions is about 17 percent for the lower Snake and 33 percent for the combined reach.

#### 5.4.1.2 Reservoir Drawdown

Over the range of possible flow conditions, drawing the four lower Snake River reservoirs to MOP levels would reduce water particle travel time by a range of 3 days to less than 1/2 day. This absolute change would represent a relative improvement of at most about 7 percent, and 3 to 4 percent compared to typical operating elevations.

In contrast, lowering the pools to near spillway crest would provide a 100 percent probability of meeting the target, based on simulations over a 50-year period of historical water conditions. Deep drawdowns would reduce water particle travel time in this reach by a range of 28 to 3 days, representing reductions of about 50 percent over the range of flows.

Other drawdown options for the lower Snake River are intermediate between the above cases, involving deep drawdowns at Lower Granite while keeping the other three pools at normal or minimum levels. These options would yield water particle travel time changes ranging from about 7 to 10 days at low flows to 1/2 to 1 day at high flows. The relative improvements in water particle travel time would generally be about 15 to 20 percent for these cases.

The drawdown options for the lower Columbia River involve relatively modest changes in elevation from existing operations. Correspondingly, reductions in water particle travel time for this reach alone would be about 10 percent or less compared to the existing condition.

### 5.4.1.3 Flow Augmentation

The flow augmentation options were generally developed with the intention of meeting a specific target flow at Lower Granite or The Dalles. The targets for the Snake River options varied from 85 to 140 kcfs in flow, generally for the month of May. Long-term simulations indicate a 68 percent chance that flows will be 85 kcfs in May with existing conditions. The Snake River flow augmentation options would increase this probability to 74 to 98 percent. The probability of meeting a 100 kcfs target ranges from 44 to 96 percent for these options. In contrast, the highest probability of meeting a 140 kcfs target is 46 percent, which could only be accomplished with an unrestricted draft from Brownlee and Dworshak.

A flow of 200 kcfs was the only target specified for lower Columbia River flow augmentation options. The annual probability of meeting this target ranged as high as 98 percent in May and 70 percent in June. These results reflect additional flow contributions from both the Snake River and the upper Columbia.

In terms of water particle travel time, the flow augmentation options would be capable of achieving modest reductions. The maximum reduction for the lower Snake River would be about 2 to 4 days with the unlimited draft option, representing relative improvements of up to about 30 percent. Changes produced with the other options would generally be about half of this level or less. Options for the lower Columbia could reduce water particle travel time by up to 2 to 3 days at low flows and 1 to 2 days at medium flows.

### 5.4.1.4 Combinations of Drawdown and Augmentation

Three specific combination options (Options X, Y and Z) were identified and evaluated in the OA/EIS. All three included some type of drawdown measure for the lower Snake and the lower Columbia and some level of flow augmentation from each river. The combined effects resulted in water particle travel times from Lewiston to Bonneville of approximately 19, 17 and 18 days, respectively. These times represent reductions of from 1 to 3 days over existing conditions, or up to a 15 percent improvement.

Several additional conclusions can be drawn from the analysis of the respective components and combinations. The first is that drawing all eight run-of-river projects down from current pool elevations (midway between maximum and MOP) to MOP would reduce water particle travel time by only about 1 day. On the other hand, operating the four lower Snake projects at spillway free flow, in combination with the lower Columbia projects at MOP, would result in a travel time of less than 15 days in all 50 simulated years without any additional flow augmentation measures.

Using the flow augmentation options alone, only the most extreme measure—unlimited storage drafts from Dworshak and Brownlee augmented with 300 KAF from the upper Snake (Option F)—reduces travel time to almost 6 days. Option G, which involves a draft of 900 KAF from Dworshak and 50 to 200 KAF from Brownlee, would reduce travel time by only about 1 day.

Unfortunately, the two measures that produce the greatest water particle travel time reductions, operation of the lower Snake projects at spillway free flow and unlimited draft of Dworshak and Brownlee, also would have the greatest impacts on other project uses, and also fish. It would appear that the approach that would produce the greatest likelihood of achieving a significant reduction in water particle travel time with the least impact on other project uses would be a combination of flow augmentation and reservoir drawdown.

One strategy might be to use one of the more moderate flow augmentation proposals (such as Option G) in combination with operation of all eight run-of-river projects at MOP as a normal operation. A travel time of 15 days or less would be achieved by this combination in about 56 percent of the years (compared to about 30 percent in 3 under current operations). In low flow years, the lower Snake projects could also be lowered below MOP to meet this goal. Under most flow conditions, however, lowering the projects to spillway free flow would reduce water particle travel time even further. To reduce impact on other river uses, the water particle travel time goal could be met in moderately low flow years by partial drawdown of all four projects or drawdown of only certain projects. The success of such a plan would be dependent on accurate runoff forecasts, so that drawdown of the lower Snake projects could be scheduled if needed.

Other combinations could also produce a high probability of meeting a goal of 15 days travel time. One such combination is heavier flow augmentation options in combination with operating Lower Granite at elevation 710.

#### 5.4.1.5 Storage Releases for Temperature Control

One alternative addresses the need to improve the temperature in the lower Snake River in late summer. Currently, temperatures in the Ice Harbor Pool reach levels up to 72°F or greater in late August to early September. High temperatures create unfavorable environmental conditions for adult salmon. Preliminary results of models addressing the use of the cooler waters from Dworshak to cool the Snake River show some opportunity for temperature control at Ice Harbor. The data and results of these studies remain somewhat inconclusive, and research is continuing. In August 1991, the Corps released water from Dworshak in a test of the ability to reduce Snake River water temperatures. The information gained from this action was used to conduct further modeling studies.

### 5.4.2 Environmental Effects of Alternatives

The results of the environmental evaluation reflect expected impacts to an extensive and complex water resources system that is managed for a variety of uses, including conservation of fishery resources. As would be expected, some of the potential modifications to this system would produce substantial negative impacts to existing users who have made decisions based on a 20-year history of system operation.

The following material is an abbreviated summary of those impacts, as presented in detail in Section 4 of the OA/EIS. The objective of this summary is to aggregate the details of the evaluation with respect to individual options and present broad conclusions that focus on the most significant environmental impact issues.

#### 5.4.2.1 Existing Conditions (No Action Alternative)

The no action alternative is to continue to manage the Federal projects in the Columbia River System as was done during the operational years of 1984 through 1990. Water conditions and flows in the Snake River Subbasin may improve relative to recent dry years. If so, the Snake River salmon stocks may show an improvement, remain at their present levels, or continue to decline. This is because flow conditions alone may not be the dominant factor affecting stock survival and numbers.

#### 5.4.2.2 Reservoir Drawdown

**Lower Snake River.** Drawing the lower Snake River projects down to MOP would result in insignificant and often offsetting impacts in most resource areas. Anadromous fish, for example, would likely benefit slightly from minor reductions in water particle travel time, but there would also be a minor reduction in rearing habitat for subyearling chinook. Similarly, spawning and rearing habitat for resident fish would be reduced somewhat, but spawning success might be increased by stabilized water surface elevations. The most significant impacts would be to power generation. Operation at relatively static levels near MOP would eliminate the opportunity to shape generation to match the variation in daily and weekly load demands, and could result in spilling of flows above turbine capacity at night. Capacity losses ranging from 550 to 1,400 MW during the drawdown period would have an estimated cost of $11 million, while non-firm energy losses are estimated at an additional $9 to $13 million.

The two options for drafting the lower Snake River projects to near spillway crest would significantly reduce water particle travel time throughout this reach of the river. However, without prior modification of the projects, there would be significant impacts to reservoir aquatic habitat, navigation, irrigation, energy production, and recreation. In addition, upstream passage for adult migrants would be blocked because fish ladders would no longer be operable. Because of these unacceptable impacts, without prior structural modification of the projects, drafting the lower Snake River projects to near spillway crest was eliminated from further consideration (Section 5.3).

Three of the remaining Snake River drawdown options combine deep drawdowns at Lower Granite with MOP or normal operation at the other three projects. Environmental impacts from these options would be similar in type to those with all Snake River projects at run-of-river spillway crest, but would generally be localized to Lower Granite. Agricultural losses would not be associated with these options. The impact magnitude would be significantly less for several resource areas. Additional transportation costs from disruption of barge service would range from about $0.4 million to $0.9 million. The costs of lost peaking capacity, firm energy and non-firm energy would range from about $17 million to over $130 million for the lower Snake River System. Recreation effects would be measured by up to 158,000 recreation days of displaced use.

Two distinguishing characteristics among the options focused on Lower Granite should be noted. The option of operating Lower Granite at elevation 710 and the other three projects at MOP would theoretically maintain upstream fish passage, thereby eliminating one of the major adverse impacts associated with drawdown to near spillway crest. Similarly, scheduling a test drawdown to near spillway crest at Lower Granite during winter would greatly reduce or eliminate adverse effects on anadromous and resident fish, recreation, and aesthetics compared to a summer drawdown.

Partially in response to public and agency review of the draft OA/EIS, a new reservoir test drawdown option has been investigated in the final OA/EIS. This test involves drafting Lower Granite to near spillway crest and drafting Little Goose by up to 15 feet below MOP to simulate spillway-freeflow tailwater conditions, if possible, during March 1992. This option would avoid most of the potential adverse impacts to migrating adult and juvenile fish described above for other Snake River drawdown options, as few upstream or downstream migrants would be present. The 4-week duration of this test and its timing (in late winter) would work to minimize adverse impacts to navigation, irrigation and recreation. The primary environmental concern with this option is the potential for adverse impacts to fall chinook salmon, either though dewatering of spawning redds in the upper reaches of Little Goose Pool or dissolved gas supersaturation effects on alevins or fry.

**Lower Columbia River.** The differences between the two drawdown options for the Columbia River dams relate to whether John Day and McNary pools are lowered to MOP or are maintained at somewhat higher elevations; Bonneville and The Dalles pools would be lowered to MOP in either case. The elevation differences for John Day and McNary produce major differences in environmental effects between the options.

The John Day and McNary projects encompass large areas of shallow water. Drawdown of these projects to MOP would result in dewatering much of this area. At John Day, for example, drawdown to MOP would expose over 10,000 acres of shallow-water habitat. One immediate effect would be the loss of invertebrates and aquatic plants that had established in these areas. The lower water levels and flat slopes could result in a change in the extent and diversity of the existing riparian vegetation, and elimination of the more sensitive species. These changes would result in immediate adverse impacts to resident fish, migrating and resting juvenile salmon, waterfowl, and terrestrial wildlife. Terrestrial impacts would be concentrated on wetland and riparian communities that have developed in the Umatilla and McNary National Wildlife Refuges.

Other resources that would be most affected by drawdown to MOP on the lower Columbia River would be agriculture, recreation, aesthetics, cultural resources, power, and municipal and industrial water uses. Impacts that are measurable in dollars would be greatest for agriculture. Lowering of pools below irrigation intake levels would eliminate production from approximately 226,000 acres of irrigated land in 1992, with most of the acreage dependent on the John Day Pool. The net loss in agricultural production and reestablishment costs is estimated at $197 million. Minimal firm energy would be lost with this option, but capacity losses would range from 1,500 to 2,400 MW. Including lost non-firm energy, power generation effects are estimated at $42 to $50 million in value. Lower water levels would impair or preclude the use of most of the boat ramps and swimming beaches at the four projects, resulting in significant shifts or declines in recreational use during most of the summer season. Aesthetics would be degraded by exposure of large areas of reservoir bottom, again largely concentrated at John Day and McNary. Cultural resource sites are also most numerous at these two projects and would be subject to increased exposure and potential damage.

Drawdown of McNary to elevation 337, John Day to 262.5, and the others to MOP would result in much lesser impacts to most of these affected resources. One exception would be power generation, where the loss of operational flexibility would produce similar capacity and non-firm energy losses. Affected agricultural acreage would be reduced to 13,000 acres and the net lost production and replacement costs to $52 million. Without the large losses of shallow-water habitat, resident fish could benefit from enhanced spawning and rearing conditions because of more stable water levels. Municipal and industrial water supply intakes at McNary would continue to function as at present.

Adverse impacts in the lower Columbia reach could be further reduced by only drawing down John Day to elevation 262.5 from May 1 to August 31. The net cost of the agricultural impacts from this option would be about $1.9 million, while the power costs would likely range from about $20 to $25 million (approximately half the level of the other two lower Columbia drawdown options).

### 5.4.2.3 Flow Augmentation

The environmental consequences of the various flow augmentation options would generally be limited to the storage reservoirs. Storage releases to meet a target flow would most likely be varied so as to maintain that target flow until the allocated storage was exhausted. This would result in relatively stable flows and elevations at the run-of-river pools. Effects on wildlife, resident fish, plant communities, navigation, irrigation, recreation, and cultural resources at these projects would be limited to changes in velocity that would not be great.

Effects at the storage projects (Dworshak, Brownlee, and Grand Coulee) would depend on the magnitude and timing of the elevation change (draft). These, in turn, are determined by the size of the release and the way in which operations are changed to accomplish the release. Options involving transfer of system flood control storage from Dworshak and Brownlee to Grand Coulee, for example, would generally maintain higher elevations at the former projects for the same volume of release.

The size and structure of the flow augmentation options result in a pattern of greatest changes in elevation from base conditions at Dworshak, lesser effects at Brownlee, and minor to minimal changes at Grand Coulee. One option, intended primarily to test how much stored water would be required to meet the CBFWA target flow of 140 kcfs, allowed unrestricted drafts of both Dworshak and Brownlee. Simulation model runs indicate that this option would draft Dworshak and Brownlee to the bottom of each pool in May of most years. Less significant or drastic options would result in much more modest elevation changes. These changes are summarized below by project:

**Dworshak.** Aside from the unrestricted draft, the options would produce two general levels of elevation changes. One group of options, generally fixed drafts of 1,200 KAF (double the existing water budget), would result in typical May elevations that are up to 50 feet lower than expected with existing operations. These options also have a much lower chance of refill by the end of July, indicating that the lower elevations could persist through the summer and from year to year. A second group of options, incorporating drafts of from 600 to 1,200 KAF and various operational modifications, would typically result in May elevation differences from existing operations of 10 to 12 feet or less. These options would not drastically affect refill probability, and in one case would actually result in a higher chance of refill.

**Brownlee.** Major changes in elevations from existing conditions would only occur with the unrestricted draft option. In all other cases, elevation differences are confined to May, June and July, and refill patterns would not be greatly altered. Drafts made in May produce elevations about 20 feet lower than base conditions. Drafts divided between May and June would result in May elevation differences of less than 10 feet, but extend refill into August under some water conditions.

Grand Coulee. Due in part to operational constraints incorporated in the analysis, the probability and significance of elevation changes at Grand Coulee are not large. Flood control shifts from Dworshak or Brownlee would be possible in about 1 in 3 years of simulated water conditions. Differences in elevation were generally 5 feet or less in the few simulated cases where changes would occur, and none of the options would have an effect on the probability of refill in July.

The effects of these elevation differences would primarily apply to resident fisheries, recreation, aesthetics, and power production. The unrestricted draft option would significantly affect spawning, feeding, and survival of resident fish, particularly at Brownlee. Other options with significant elevation differences would raise concerns over reduced production of food sources and transfer of fish downstream through entrainment.

Effects on recreation and aesthetics at Dworshak could range from severe to minor. The unrestricted draft option would virtually eliminate use at most recreation sites on the reservoir in a typical water year. This would result in displacement of an estimated 268,000 recreation days, or more than 75 percent of the existing use level. However, impacts to recreation would be much less drastic with other options. Four options with relatively small elevation changes would displace visitation of 2,000 recreation days or less. Access for recreation at Brownlee in May and June would not be significantly reduced except with an unrestricted draft, so minimal changes in visitation would be expected with the other options. The size and probability of elevation changes at Grand Coulee are such that no visitation changes were projected.

Flow augmentation options for the Snake River would result in firm energy losses ranging from 60 to 70 average MW to 450 to 500 average MW with unrestricted drafts. The associated value of these losses would range from $12 million to $146 million. Despite gains in non-firm energy production, total power costs would range from about $9 million to over $130 million. The Target 200 options for the Columbia River would result in power costs ranging from $20 million to $75 million.

### 5.4.2.4 Combinations of Drawdown and Augmentation

The effects of the three combination options evaluated amount to the additive impacts of the various components. Two of the combination options incorporate drawdown of all four Snake River projects to MOP, with no unresolvable adverse impacts to anadromous fish or other resources. One option would include drawdown of Lower Granite to elevation 710 feet, requiring 100 percent of the flow to be passed over the spillway. This could limit upstream passage by disorienting adult salmon, and would result in elevated dissolved gas levels.

With respect to the lower Columbia River, all three combination options incorporate the higher elevations for John Day and McNary. Consequently, the major adverse impacts to multiple resources that would be associated with operating all four lower Columbia projects at MOP would generally be avoided.

Two of the combination options include the existing level of flow augmentation for the Snake River, while the third involves additional storage releases that would likely lead to only minor elevation changes at Dworshak and Brownlee. All three combination options also include the Target 200 flow strategy for the Columbia River, which would have minimal effect on Lake Roosevelt elevations. The environmental impact contribution from the flow augmentation components of these options should therefore be minor.

### 5.4.2.5 Storage Releases for Temperature Control

Releasing cool water from Dworshak to attempt to reduce temperatures downstream in the Snake River would raise several potential issues concerning anadromous and resident fish. Aside from providing needed test data, the proposed August release of cool water from Dworshak would have a measurable positive effect on temperature at Lower Granite, and to a lesser extent downstream. This would potentially enhance upstream migration success of some early fall chinook and steelhead. Growth rates for a portion of the Dworshak hatchery steelhead production would be reduced. Use of some elevation-sensitive recreational facilities at Dworshak would be curtailed or eliminated during a peak use month, resulting in potential displacement of 9,000 recreation days. Recreationists continuing to use the reservoir would experience loss of aesthetic quality from a drawdown of up to 20 feet.

### 5.4.3 Cost Effectiveness

Typically, the Corps bases plan selection on the Federal objective to maximize contributions to NED consistent with protecting the environment. The evaluation of alternatives under this objective requires thorough assessments of all the costs and benefits associated with each alternative. Unfortunately, the extremely short timeframe of this study does not allow for basic data collection to determine all the costs and benefits. In addition, insufficient biological data are available to establish biological outputs of the alternatives; therefore, the biological goal is replaced with a physical goal. As a result of these limitations, the evaluation tool used in comparing the alternatives is a measure of cost-effectiveness, calculated in terms of relative costs to achieve a unit of the physical objective.

#### 5.4.3.1 Approach and Methods

The physical objective used in this analysis is the reduction in water particle travel time achieved by each option. The reduction in water particle travel time (expressed in days) is then weighted by the percentage of the juvenile fish run passing during the implementation period to determine the effective reduction in water particle travel time. In other words, a reduction in water particle travel time of ten days that would benefit 50 percent of the run would represent a weighted water particle travel time reduction of 5 days. A thorough discussion of water particle travel time and the potential reductions achieved by the alternative actions can be found in Section 4.2.1.2.

In determining the costs for this analysis, only the NED, also referred to as direct net, costs and benefits were considered. In addition, the options investigated in this analysis will occur in 1992 only; therefore, only short-term impacts were estimated. The costs include implementation costs and foregone benefits in terms of reduced output of project benefits from the current conditions.

Total direct costs by option are then divided by the reduced weighted water particle travel time to arrive at a measure of the cost per day of reduced weighted water particle travel time. This figure is calculated for each option, and then the options are ranked according to cost-effectiveness.

The cost-effectiveness analysis has several shortcomings and this was recognized when the process was used for plan selection. The limited time period for this OA/EIS and the lack of data led to the following simplifications:

- The cost-effectiveness analysis does not cover all the possible options and does not contain the same level of detailed analysis for each alternative.

- The end result of the cost-effectiveness analysis is a measure of the cost required per day of water particle travel time reduction for each option. Some of the options are purely tests that would be conducted in non-migratory periods, and as such, would not yield benefits that are measurable in this manner.

- The analysis was limited to the average water conditions. To provide a complete picture it would be appropriate to investigate the cost-effectiveness under relatively dry and wet water years, but time did not allow this.

- Ideally the cost-effectiveness would be based on the number of wild salmon surviving under each option, instead of the weighted water particle travel time reductions.

- Numerous assumptions were made to estimate values of impacts.

For these reasons the cost-effectiveness analysis was used primarily to rank alternatives from the most cost-effectiveness to the least cost-effectiveness and to discard those alternatives that were clearly most costly for the amount of reduced water particle travel time. For example, the drawdown of the John Day Reservoir to MOP in 1992 was found to be extremely costly primarily because of the impacts to irrigated agriculture and, hence, this action was not considered in the final plan selection.

The cost-effectiveness analysis does not fully represent the Northwest Power Planning Council's most recent fish and wildlife amendments. The selection of the final amendments occurred too late to allow for complete investigation in this document. However, due to the similarity of the amendments to several of the options studies in this OA/EIS and limited cost data available on the NPPC Plan (Snake River Flow Augmentation), preliminary approximations of the relative cost-effectiveness of the NPPC Plan were possible.

### 5.4.3.2 Travel Time Improvements

Water particle travel time improvements for most of the options are presented in Table 5.4-3. For the lower Snake River drawdown options, the improvements in weighted water particle travel time range from 0.60 days for the option of lowering the Snake River projects to MOP, to 4.48 days for drafting the Snake River projects to near spillway crest. It should be noted that improvements in weighted water particle travel time relate to both positive and negative impacts to migrating fish. The advantage is improved smolt travel time with increased flow. However, under these conditions (four reservoirs to near spillway crest) neither upstream nor downstream fish passage facilities would be operational, and increased spill would produce dissolved gas levels considered lethal to fish.

Weighted water particle travel time reductions range up to 2 days for lower Columbia River drawdown options, and are generally less than 1 day for Snake River flow augmentation options.

### 5.4.3.3 Cost of Options

The direct costs associated with the various options are presented in Table 5.4-4. The costs are tabulated in the four categories of navigation, irrigation, recreation, and hydropower. A discussion of the assumptions made in evaluating these costs is presented in the following paragraphs. Impacts that would occur in other resource areas are not suitably quantifiable in monetary terms.

**Navigation.** Impacts to navigation will be experienced primarily on the Columbia-Snake Inland Waterway and are associated with the drawdown options which lower pools below MOP. Impacts on log movement at Dworshak could occur with some of the flow augmentation options. A detailed discussion of transportation costs is presented in Section 4.7.

Increased costs for a 3-month (April to June with refill) closure were computed based on increased storage costs on all Snake reservoirs except Ice Harbor, where storage capacity was judged inadequate. For Ice Harbor, the rail costs were used. For the longer drawdowns from April through August, the storage facilities would be full when newly harvested grain starts arriving. The analysis assumes added storage costs up to capacity and then diversion to rail for the balance.

The analysis did not attempt to quantify several potential or speculative impacts including changes in the price of commodities due to modification of deliveries, increased rail and barge rates from shifts in movements, impacts on deep-draft navigation below Bonneville, and increased highway and railbed operations and maintenance costs due to increased traffic. All of these changes could occur to some extent, but they are extremely difficult to quantify for short-term impact. These items, however, would represent additional economic costs; therefore, it must be recognized that the existing analysis somewhat understates total transportation costs.

The navigation-related direct costs of the various options range from no impacts for several of the options to $5.7 million for the option of drafting the Snake River projects to near spillway crest from April 15 through August 15.

**Irrigation.** It was assumed that the implementation of options would occur in the spring and summer of 1992 and this would not allow irrigators to modify pumps and piping. It was assumed this would result in no crop production for 1992 on the affected acreage. This assumption was supported by the complexity and high costs of modifying the pumping systems. In addition, with the very arid situations along John Day, McNary, and Ice Harbor pools, it is very unlikely that alternative crops could be established and economically grown under dry-land conditions.

For the purposes of this analysis, the impacts were computed as the loss of net income plus continued fixed cost (gross crop value less variable cost) plus re-establishment costs in some circumstances as

**Table 5.4-3.** Reduced weighted water particle travel time (WWPTT), average water year.

| Alternative/Option | Period | Number of Weeks Effective | Reduction in WPTT c/ (days) | Percent of Run Passing (Average Year, All Anad. Fish) | Weighted Reduction WPTT |
|---|---|---|---|---|---|
| RESERVOIR DRAWDOWN | | | | | |
| Snake River | | | | | |
| All 4 Projects to MOP | 4/1 to 7/31 | 16 | 0.6 | 99.6 | 0.60 |
| All 4 Projects to Near Spillway | 4/15 to 8/15 | 16 | 4.5 | 99.6 | 4.48 |
| All 4 Projects to Near Spillway | 4/15 to 6/15 | 8 | 4.5 | 65.9 | 2.97 |
| LWG to Near Spillway, Others to MOP a/ | 2/1 to 2/28 | 4 | NA | 0 | NA |
| LWG to Near Spillway, Others to MOP a/ | 7/15 to 8/15 | 4 | NA | 2.4 | NA |
| LWG to 710', Others to MOP | 4/15 to 6/15 | 8 | 1.2 | 65.9 | 0.79 |
| LWG to Near Spillway, LGS to MOP −20' a/ | 3/1 to 3/31 | 4 | NA | 0 | NA |
| Lower Columbia | | | | | |
| All 4 Projects to MOP | 4/1 to 8/31 | 20 | 2.1 | 98.8 | 2.07 |
| JDA to 262.5'; MCN at 337'; TDA, BON to MOP | 4/1 to 8/31 | 20 | 1.6 | 98.8 | 1.58 |
| JDA to 262.5' | 5/1 to 8/31 | 16 | 0.9 | 81.7 | 0.74 |
| MCN to 337', BON and TDA to MOP | 5/1 to 8/31 | 16 | 0.6 | 81.7 | 0.49 |
| FLOW AUGMENTATION | | | | | |
| Snake River | | | | | |
| Option A (Base Case) | 5/1 to 5/31 | 4 | -- | -- | -- |
| Option B Snake River | 5/1 to 5/31 | 4 | 1.2 | 39.5 | 0.47 |
| Columbia River | | 4 | 0.7 | 31.4 | 0.37 b/ |
| Total | | | | | 0.84 |
| Option C Snake River | 5/1 to 6/30 | 8 | 0.6 | 68.9 | 0.41 |
| Columbia River | | 8 | 0.3 | 64.2 | 0.33 b/ |
| Total | | | | | 0.74 |
| Option D Snake River | 5/1 to 5/31 | 4 | 1.2 | 39.5 | 0.47 |
| Columbia River | | 4 | 0.7 | 31.4 | 0.37 b/ |
| Total | | | | | 0.84 |
| Option E Snake River | 5/1 to 6/30 | 8 | 0.6 | 68.9 | 0.41 |
| Columbia River | | 8 | 0.3 | 64.2 | 0.33 b/ |
| Total | | | | | 0.74 |
| Option F Snake River | 5/1 to 5/31 | 4 | 2.3 | 39.5 | 0.91 |
| Columbia River | | 4 | 1.4 | 31.4 | 0.75 b/ |
| Total | | | | | 1.66 |
| Option G Snake River | 5/1 to 5/31 | 4 | 0.5 | 39.5 | 0.24 |
| Columbia River | | 4 | 0.3 | 31.4 | 0.16 b/ |
| Total | | | | | 0.40 |
| Option H Snake River | 4/15 to 5/31 | 6 | 0.5 | 52.7 | 0.26 |
| Columbia River | | 6 | 0.3 | 40.0 | 0.20 b/ |
| Total | | | | | 0.46 |
| Option I Snake River | 5/1 to 5/31 | 4 | 0.2 | 39.5 | 0.08 |
| Columbia River | | 4 | 0.1 | 31.4 | 0.05 b/ |
| Total | | | | | 0.13 |
| Option J Snake River | 4/15 to 5/31 | 6 | 0.4 | 52.7 | 0.21 |
| Columbia River | | 6 | 0.3 | 40.0 | 0.20 b/ |
| Total | | | | | 0.41 |
| NPPC Plan Snake River | 4/16 to 6/15 | 8 | 0.3 | 67.4 | 0.20 |
| Columbia River | | 8 | 0.2 | 56.4 | 0.19 b/ |
| Total | | | | | 0.39 |
| Columbia River | | | | | |
| Target 200 kcfs | 5/1 to 6/30 | 8 | 1.5 | 64.2 | 1.64 b/ |
| Non-Treaty Storage | 7/1 to 8/31 | 8 | 1.1 | 17.5 | 0.19 |

a/ Physical Test Only
b/ Also weighted by greater number of smolts originating in mid and lower Columbia than Snake; Approx. 1.7
c/ WPTT reductions for flow augmentation are based on a constant distribution of releases over the entire period. Actual releases will be shaped by the Fish Passage Center to provide the optimum benefit for the downstream migrants.

**Table 5.4-4.** Cost and effectiveness of options, average water year.

| Alternative/Option | Period | Weighted Reduction WPTT | Direct Costs ($ Millions) Navigation 1/ | Irrigation | Recreation | Power (low) | Power (high) | Total (low) | Total (high) | Cost/Reduced Wt. Travel Time ($ mil/day reduced) (low) | (high) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RESERVOIR DRAWDOWN | | | | | | | | | | | |
| Snake River | | | | | | | | | | | |
| All 4 Projects to MOP | 4/1 to 7/31 | 0.60 | 0.0 | 0.1 | 0.0 | 20.0 | 24.0 | 20.1 | 24.1 | 33.5 | 40.2 |
| All 4 Projects to Near Spillway | 4/15 to 6/15 | 4.46 | 5.7 | 63.0 | 3.7 | 159.0 | 192.0 | 245.7 | 278.7 | 54.6 | 62.2 |
| All 4 Projects to Near Spillway | 4/15to6/15 | 2.97 | 2.8 | 63.0 | 0.7 | 125.0 | 159.0 | 208.7 | 242.7 | 70.3 | 81.7 |
| LWG to 710', Others at MOP | 4/15to6/15 | 0.79 | 0.9 | 0.1 | 0.7 | 40.0 | 49.0 | 40.6 | 49.6 | 51.6 | 63.0 |
| LWG to Spillway, LGS to MOP -20' | 3/1 to3/31 | NA | 0.5 | 0.0 | 0.2 | 3.5 | 9.0 | 4.2 | 9.2 | NA | NA |
| LWG to Near Spillway | 2/1 to2/28 | NA | 0.3 | 0.0 | 0.1 | 6.0 | 20.0 | 6.4 | 20.4 | NA | NA |
| LWG to Near Spillway | 7/15 to 6/15 | NA | 0.5 | 0.0 | 0.8 | 6.0 | 20.0 | 7.3 | 21.3 | NA | NA |
| Lower Columbia | | | | | | | | | | | |
| All 4 Projects to MOP 2/ | 4/1 to 8/31 | 2.07 | 0.0 | 197.0 | 2.0 | 42.0 | 50.0 | 241.0 | 249.0 | 116.4 | 120.3 |
| JDA to 262.5'; MCN to 337'; Others to MOP 2/ | 4/1 to 8/31 | 1.58 | 0.0 | 52.0 | 1.0 | 41.0 | 49.0 | 94.0 | 102.0 | 59.5 | 64.6 |
| JDA to 262.5' 3/,4/ | 5/1 to 8/31 | 0.96 | 0.0 | 1.9 | 0.1 | 20.5 | 24.5 | 22.5 | 26.5 | 23.4 | 27.6 |
| MCN to 337', BON and JDA to MOP 3/ | 5/1 to 8/31 | 0.62 | 0.0 | 50.0 | 0.9 | 20.5 | 24.5 | 71.4 | 75.4 | 115.2 | 121.6 |
| Flow Augmentation | | | | | | | | | | | |
| Option A | 5/1 to 5/31 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Option B 5/ | 5/1 to 5/31 | 0.84 | 0.3 | 0.0 | 0.4 | 35.0 | 40.0 | 35.4 | 40.4 | 42.1 | 48.1 |
| Option C 5/ | 5/1 to 6/30 | 0.74 | 0.3 | 0.0 | 0.1 | 35.0 | 40.0 | 35.1 | 40.1 | 47.4 | 54.2 |
| Option D 5/ | 5/1 to 5/31 | 0.84 | 0.3 | 0.0 | 0.3 | 35.0 | 40.0 | 35.3 | 40.3 | 42.0 | 48.0 |
| Option E 5/ | 5/1 to 6/30 | 0.72 | 0.3 | 0.0 | 0.1 | 35.0 | 40.0 | 35.1 | 40.1 | 48.6 | 55.7 |
| Option F 5/ | 5/1 to 5/31 | 1.66 | 0.3 | 0.2 | 1.3 | 119.0 | >130 | 120.5 | 131.6 | 72.6 | 79.4 |
| Option G 5/ | 5/1 to5/31 | 0.40 | 0.0 | 0.0 | 0.0 | 18.0 | 20.0 | 18.0 | 20.0 | 45.0 | 50.0 |
| Option H | 4/15 to 5/31 | 0.48 | 0.0 | 0.0 | 0.0 | 17.0 | 19.0 | 17.0 | 19.0 | 37.0 | 41.3 |
| Option I 5/ | 5/1 to 5/31 | 0.13 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Option J | 4/15 to 5/31 | 0.41 | 0.0 | 0.0 | 0.0 | 9.0 | 10.0 | 9.0 | 10.0 | 22.0 | 24.4 |
| NPPC Plan 5/ | 4/16to6/15 | 0.39 | 0.0 | 0.0 | 0.0 | 18.0 | 22.0 | 18.0 | 22.0 | 46.2 | 56.4 |
| Target 200 kcfs 1/ | 5/1 to6/30 | 1.64 | 0.0 | 0.0 | 0.0 | 20.0 | 75.0 | 20.0 | >75.0 | 12.2 | 45.7 |

1/ Navigation costs for Lower Granite physical test in summer assumed to be half of Lower Granite to 710 (rounded); winter physical test assumed half of Lower Granite/Little Goose test. Dworshak assumed Options B through F would impact log navigation $290,000 per Potlatch estimate.
2/ Columbia River recreation assumed $2 million if all 4 at MOP, $1 million for JDA at 262.5', MCN at 337', and others at MOP.
3/ Prorated the $1 million to 4 projects based on total recreation.
4/ Assumes JDA power impacts are 1/2 of option = JDA at 262.5', MCN at 3[illegible]ON and JDA at MOP.
5/ Does not include power costs for Brownlee/Idaho Power.

explained below. The sources for the income and cost data were the crop budgets prepared for the Farm Business Management Reports by the Washington State University (WSU) Cooperative Extension.

For crops established over several years, it was assumed that alternatives causing loss of water for four or five months would kill the crop and result in high re-establishment costs (except on Bonneville pool where precipitation appears to be sufficient). These re-establishment costs were also estimated from the WSU data and were applied to apples, mixed orchards, grapes, alfalfa, and grass seed crops. Because of the magnitude of these costs, it is possible that farmers would find ways to deliver enough water to keep plants alive. Time constraints did not allow for examining use of alternative sources of water, water trucks, temporary irrigation methods, and other possible irrigation alternatives. For this reason, the re-establishment costs were used as a proxy for the impacts, even though it is possible that cheaper methods to maintain the plants could be found. This point will be examined further in a sensitivity analysis. No re-establishment costs were claimed for the 2-month drawdown because it was assumed plants would not die.

The direct costs to irrigation range from minimal impacts for the flow augmentation options (possible crop losses of about $0.2 million for some options affecting Brownlee) to $197 million with all eight lower Columbia and Snake River projects to MOP. A thorough discussion of the impacts is presented in Section 4.8 Agriculture.

The costs of modifying pumps and pipes were estimated at $19.7 million for projects drawn down to MOP and an additional $11.8 million with Ice Harbor Pool near spillway crest. With pool drawdowns, the pumping head would increase and pumping costs would increase by about $0.8 million for MOP and an additional $0.5 million for Ice Harbor to spillway crest. Each pump modification requires designs specifically for that site. Lead time for pump modifications is 10 to 14 months, so this is not an option in the short run.

Because pumping plant modifications could not be made before any 1992 options were implemented, these costs are not directly relevant to the cost-effectiveness analysis for the 1992 options. However, the pumping-related costs are identified here because they more nearly represent the longer-term net costs associated with river management actions that might be taken in future years. The cost effectiveness of various drawdown measures would therefore be considerably higher in future years after pumping plant modifications had been implemented.

**Recreation.** Recreation displacement was based on the assumption that if the physical facilities were not usable (e.g., a dry boat ramp), then the activity associated with that facility would be displaced to another reservoir or lost completely. In some cases, decreased use of overnight and day-use facilities oriented to water was also anticipated. No attempt was made to determine the reduction in quality of the recreation experience if the recreation activity continues, but with fewer attributes. Due to the lack of data or studies, the expected changes in visitation were not allocated to other recreation sites or activities. Therefore, the visitation changes may not be net losses of recreational activity to the region.

For the cost-effectiveness analysis, the economic value of recreation was assumed to be $5 per activity day. This value is taken from the Water Resources Council's "Principles and Guidelines" determination of general recreation values per visitor day of roughly $2 to $6 for 1990 conditions. This value is considerably lower than values determined from site-specific studies for reservoir recreation in the Northwest. For example, the study of willingness-to-pay values for a recreation day at Hungry Horse reservoir computed a value of $26 to $28 per recreation day (Ben Zvi, 1990). A recreation day may include several activities, and at Hungry Horse it was found that the average recreator participated in 3.5 activities. The low value of $5 was used because it was felt that the recreation activities that are displaced would be replaced by other activities and, hence, not totally lost to the region.

The direct costs to recreation were generally calculated by multiplying estimates of potentially displaced recreation days with each option (from Section 4.10), by the $5 unit day value. Potential displacement was not estimated directly for the lower Columbia River projects, but reasonable direct cost levels were assumed. The recreation costs range from zero with the Snake River projects at MOP to $3.7 million for the Snake River projects to near spillway crest from April 15 through August 15. Specific estimates of expected visitor displacement at lower Columbia River facilities could not be developed with the information available. Instead, the costs of recreation displacement were assumed to be $2 million with all four projects operated at MOP and $1 million with John Day at elevation 262.5, McNary at 337, and Bonneville and The Dalles at MOP. These assumptions were based on Corps recreation data and operating experience for the projects.

**Hydropower.** The impacts to power are summarized in three categories: loss in capacity, loss in firm energy, and loss in non-firm energy. The capacity impacts are often minor because the Northwest power system is considered to have capacity surplus except in certain situations. Major impacts to capacity (up to 3,200 MW) would occur with some of the options; however, major economic costs would occur in 1992 only if the capacity surplus is exceeded. For this reason, the OA/EIS valued estimated capacity losses for the first 1,000 MW in May and June at zero, and losses of 1,000 to 3,000 MW in May and June. All losses in other months were valued at $4/kW/month. Losses in excess of 3,000 MW in May and June were valued at $10/kW/month (see Section 4.9.2.2).

Firm energy impacts are determined by losses in the FELCC, which is the level of energy the power system can generate in the worst historical water condition. The FELCC is an assured amount of energy and carries a higher value than the non-firm energy. The EIS valued losses of FELCC at 35 mills/kwh, which is reflective of what BPA is currently paying for firm energy resources that it will acquire for the long term.

The non-firm energy is sold over a wide range of values based on market conditions at the time of sales. The availability of non-firm energy reduces the need for generation of energy with more costly generation resources. The value of this displacement represents the NED value; however, for this analysis the average cost for which BPA sells the power (15 mills/kwh) was used.

The power costs in Table 5.4-4 were provided by BPA and represent a range of possible impacts for each option. The direct costs to hydropower range from $20 to $24 million with the Snake River at MOP to $159 to $192 million with the Snake River projects near spillway crest from April 15 through August 15. It should be noted that for flow augmentation Option F (unlimited drafting), no capacity impacts were estimated; hence, impacts on the high side could be much greater than $130 million.

### 5.4.3.4 Comparative Evaluation of Options

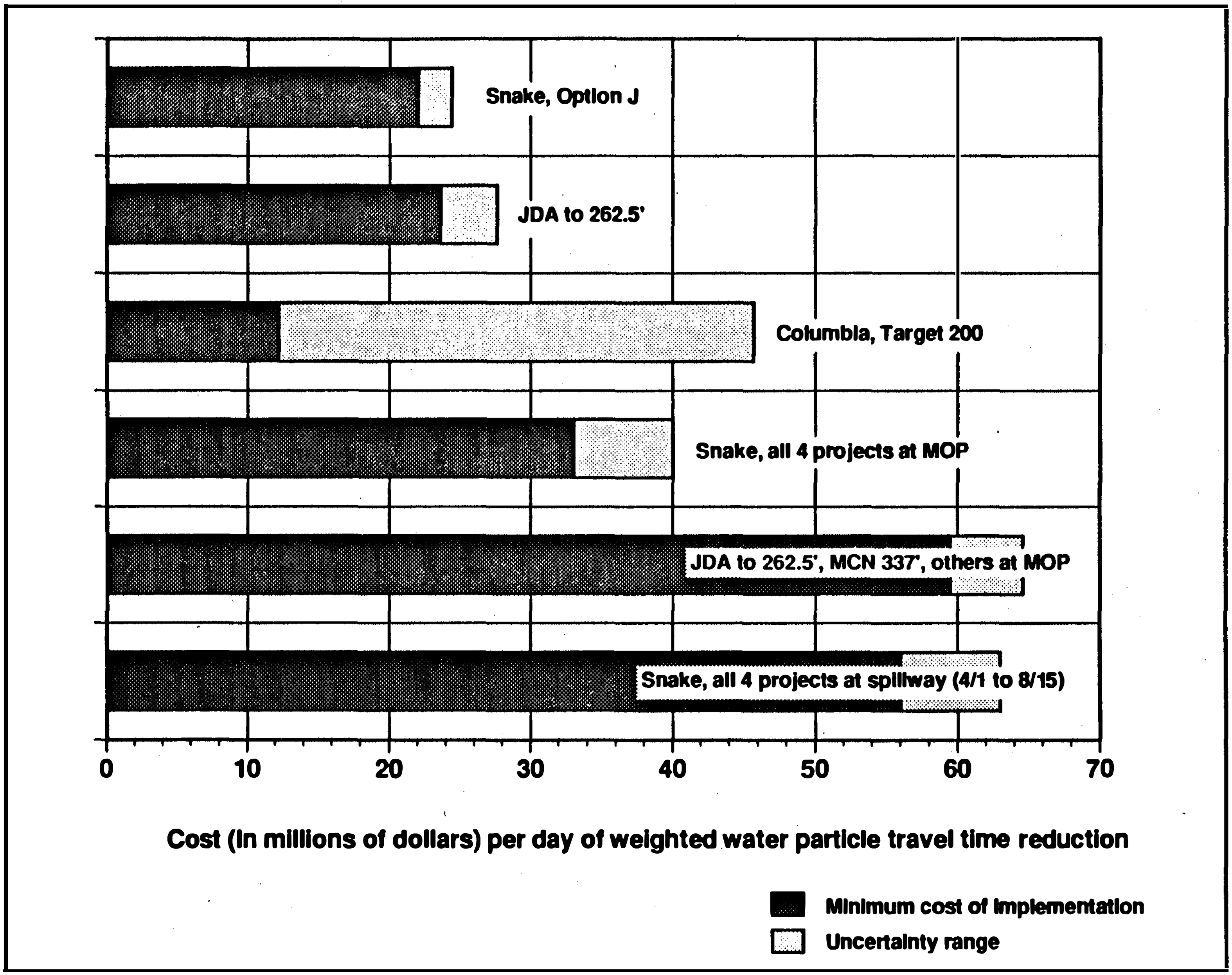
The last two columns in Table 5.4-4 present the total direct costs by option and the costs per day of reduced weighted water particle travel time for each alternative. Excluding the physical test options for a proposed 4-week test drawdown of Lower Granite or Lower Granite and Little Goose, which would have no effect on travel time, the total direct costs range from $9 to $10 million for the preferred Snake River flow augmentation (Option J) to $246 to $279 million for all four lower Snake River projects operated near spillway crest from April 15 to August 15. In cost-effectiveness terms, these two options range from a minimum of about $12 million to a maximum of $62 million per day of weighted water particle travel time reduction. Figure 5.4-1 presents a graphical depiction of the ranking of the cost-effectiveness of six options, indicating the range of costs and uncertainty. The four most cost-effective options are presented in order below.

COMPARATIVE EVALUATION OF DIRECT COSTS OF OPTIONS

| OPTION: | Cost Per Day, Weighted Reduced WPTT ($ million) |
|---|---|
| Target 200 | 12.2-45.7 |
| Snake River augmentation Option J | 22.0-24.4 |
| John Day Pool to 262.5' | 23.4-27.6 |
| Snake River projects to MOP | 33.5-40.2 |

### 5.4.3.5 Sensitivity Analysis

The purpose of the sensitivity analysis is to define the range of values that the direct costs may take depending on different possible conditions not




ACOE144

Figure 5.4-1. Cost of Options Ranking.

related to the proposed options. The results of the sensitivity analysis are presented in Table 5.4-5. For navigation costs, low values assume all grains can be stored, and the high value assumes all grain is moved by rail. For irrigation, the low value assumes pump modification costs plus increased operating costs, and the high value assumes net income loss, fixed costs, and re-establishment costs.

For recreation, the low value applies the Water Resource Council's minimum value of $2.20 per recreation day, and the high value uses a $15 per recreation day value which is based on Idaho fishing values and the Hungry Horse study (Ben Zvi, 1990). The sensitivity analysis yields the potential range of the cost per day reduced weighted water particle travel time for each option in order to provide information regarding the uncertainty surrounding many of the estimates of direct costs.

### 5.4.4 Public Acceptability

#### 5.4.4.1 General

The cooperating agencies measured the public acceptability of the alternatives considered in two different ways. The first was based upon public comments to the draft OA/EIS. The second was the development of the NPPC's Fish and Wildlife Program Amendments (NPPC, 1991b). Both the OA/EIS and the NPPC plan included extensive public involvement programs. Further, the NPPC Amendments are approved by Council members that represent the interests of Oregon, Washington, Idaho, and Montana. Thus, both sets of actions represent the input of the general public, special interest groups, and governments of the entire region.

#### 5.4.4.2 Reservoir Drawdown

**Lower Snake River.** The majority of commentors (State and Federal agencies, organizations, and individuals) to the draft OA/EIS indicated an understanding that the four-reservoir drawdown on the lower Snake River to near spillway elevation is not implementable in 1992. There was no support identified for drafting Lower Granite Reservoir to elevation 710 with the remaining reservoirs at MOP. However, the option of lowering all four reservoirs to MOP in 1992 was strongly supported by the States of Washington, Oregon, and Idaho, and the Fish and Wildlife Service. In addition, the NPPC plan recommends the implementation of drawdown to MOP of the four lower Snake River reservoirs.

**Lower Columbia River.** Most of the comments that addressed the drawdown of the lower Columbia River reservoirs to MOP recognized the significant impacts to irrigation. Therefore, there was little support for this option. There was, however, support for drawdowns that would minimize impacts to irrigation (i.e., John Day to elevation 262.5, McNary to 337, and Bonneville and The Dalles to MOP).

The plan supported and included in the NPPC plan consists of drafting only John Day to the minimum level to accommodate irrigation interests. This drawdown would cover the period of May 1 through August 31.

#### 5.4.4.3 Flow Augmentation

Although many comments to the draft OA/EIS identified modifications or new flow augmentation options on both the Snake and Columbia rivers, the general perception is strong support for flow augmentation. In response to these comments, a new augmentation alternative on the Snake River was added to the final OA/EIS.

NPPC also recommends implementation of flow augmentation on both the Snake and Columbia rivers for 1992.

#### 5.4.4.4 Storage Releases for Temperature Control

Comments on the draft OA/EIS concerning storage releases for temperature control ranged from strong support to support for only additional study. The majority of comments identified the need for more studies to address uncertainties in the effectiveness (timing of releases and target temperatures).

These same uncertainties prompted the NPPC to recommend additional field experimentation (involving releases from Dworshak) to be implemented in 1992.

## Table 5.4-5. Sensitivity analysis of cost-effectiveness, average water year.

| Alternative/Option | Period | Weighted Reduction WPTT (low) | (high) | Direct Costs ($ Millions) Navigation (low) | (high) | Irrigation (low) | (high) | Recreation (low) | (high) | Power (low) | (high) | Total (low) | (high) | Cost/Reduced Wt. Travel Time ($mil/day reduced) (low) | (high) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **RESERVOIR DRAWDOWN** | | | | | | | | | | | | | | | |
| **Snake River** | | | | | | | | | | | | | | | |
| All 4 Projects to MOP | 4/1 TO 7/31 | 0.6 | 0.6 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 20.0 | 24.0 | 20.1 | 24.1 | 33.5 | 40.2 |
| All 4 Projects to Near Spillway | 4/15 TO 8/15 | 4.5 | 4.5 | 5.6 | 6.4 | 12.3 | 83.0 | 1.6 | 11.0 | 159.0 | 192.0 | 178.5 | 292.4 | 39.7 | 65.0 |
| All 4 Projects to Near Spillway | 4/15 TO 6/15 | 3.0 | 3.8 | 2.7 | 3.7 | 12.3 | 83.0 | 0.6 | 3.8 | 125.0 | 159.0 | 140.6 | 249.5 | 46.9 | 65.7 |
| LWG to 710', Others to MOP | 4/1 TO 6/15 | 0.8 | 1.0 | 1.6 | 2.3 | 0.1 | 0.1 | 0.3 | 2.0 | 43.0 | 52.0 | 45.0 | 56.4 | 56.3 | 56.4 |
| LWG to Near Spillway, LGS to MOP −20' | 3/1 TO 3/31 | NA | | 1.2 | 1.7 | 0.0 | 0.0 | 0.0 | 0.3 | 8.0 | 20.0 | 7.2 | 22.0 | NA | NA |
| LWG to Near Spillway | 2/1 TO 2/28 | NA | | 0.3 | 0.3 | 0.0 | 0.0 | 0.0 | 0.3 | 6.0 | 20.0 | 6.3 | 20.6 | NA | NA |
| LWG to Near Spillway | 7/15 TO 8/15 | NA | | 0.5 | 0.5 | 0.0 | 0.0 | 0.3 | 2.3 | 6.0 | 20.0 | 6.8 | 22.6 | NA | NA |
| **Lower Columbia** | | | | | | | | | | | | | | | |
| All 4 Projects to MOP | 4/1 TO 8/31 | 2.1 | 2.1 | 0.0 | 0.0 | 20.5 | 233.7 | 0.9 | 6.0 | 42.0 | 50.0 | 63.4 | 289.7 | 30.2 | 138.0 |
| JDA to 262.5, MCN to 337', Others to MOP | 4/1 TO 8/31 | 1.6 | 1.6 | 0.0 | 0.0 | 1.5 | 52.0 | 0.4 | 3.0 | 41.0 | 49.0 | 42.9 | 104.0 | 26.8 | 65.0 |
| JDA to 262.5' | 5/1 TO 5/31 | 0.96 | 0.96 | 0.0 | 0.0 | 0.3 | 1.9 | 0.0 | 0.3 | 23.0 | 27.0 | 23.3 | 29.2 | 24.3 | 30.4 |
| MCN to 337', BON and TDA to MOP | 5/1 TO 5/31 | 0.62 | 0.62 | 0.0 | 0.0 | 1.2 | 50.0 | 0.4 | 2.7 | 35.0 | 39.0 | 36.6 | 91.7 | 59.0 | 147.9 |
| **FLOW AUGMENTATION** | | | | | | | | | | | | | | | |
| **Snake River** | | | | | | | | | | | | | | | |
| Option B | 5/1 TO 5/31 | 0.84 | 0.84 | 0.3 | 0.3 | 0.0 | 0.2 | 0.2 | 1.1 | 35.0 | 40.0 | 35.5 | 41.6 | 42.3 | 49.5 |
| Option C | 5/1 TO 6/30 | 0.74 | 0.74 | 0.3 | 0.3 | 0.0 | 0.2 | 0.1 | 0.3 | 35.0 | 40.0 | 35.4 | 40.8 | 47.8 | 55.1 |
| Option D | 5/1 TO 5/31 | 0.84 | 0.84 | 0.3 | 0.3 | 0.0 | 0.2 | 0.1 | 1.0 | 35.0 | 40.0 | 35.4 | 41.5 | 42.1 | 49.4 |
| Option D | 5/1 TO 6/30 | 0.74 | 0.74 | 0.3 | 0.3 | 0.0 | 0.2 | 0.0 | 0.2 | 35.0 | 40.0 | 35.3 | 40.7 | 47.7 | 55.0 |
| Option F | 5/1 TO 5/31 | 1.66 | 1.66 | 0.3 | 0.3 | 0.2 | 0.2 | 0.6 | 4.0 | 119.0 | >130.0 | 120.1 | 134.5 | 72.3 | 81.0 |
| Option G | 5/1 TO 5/31 | 0.40 | 0.40 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 18.0 | 20.0 | 18.0 | 20.2 | 45.0 | 50.5 |
| Option H | 4/15 TO 5/31 | 0.46 | 0.46 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 17.0 | 19.0 | 17.0 | 19.1 | 37.0 | 41.5 |
| Option I | 5/1 TO 5/31 | 0.13 | 0.13 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 1.5 |
| Option J | 4/15 TO 5/31 | 0.41 | 0.41 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.0 | 10.0 | 9.0 | 10.0 | 22.0 | 24.4 |
| NPPC Plan | 4/16 TO 6/15 | 0.39 | 0.39 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 18.0 | 22.0 | 18.0 | 22.0 | 46.2 | 56.4 |
| **Columbia River** | | | | | | | | | | | | | | | |
| Target 200 kcfs | 5/1 TO 6/30 | 1.64 | 1.64 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 20.0 | 75.0 | 20.0 | 75.0 | 12.2 | 45.7 |

#### 5.4.4.5 Physical Test Drawdown

A large number of comments supported the implementation of a 4 to 6 week physical test of a two-reservoir (Lower Granite and Little Goose) drawdown. As a result, this alternative has been added to the final OA/EIS. There was overwhelming opposition to a 4-week drawdown of Lower Granite to near spillway crest during the period of July 15 to August 15. This is primarily due to the impacts to anadromous fish during this period. There generally seemed to be support for a 4-week drawdown of Lower Granite during February. However, this action could not be implemented until 1993, because the NEPA process for this action cannot be completed in time for implementation in 1992. The States of Washington, Oregon, and Idaho, and NMFS and FWS support a 4-week test in March 1991, if it can be demonstrated that the test would not likely affect endangered or threatened species.

### 5.4.5 Plan Selection Conclusions

Based on performance against the five plan selection criteria, summary conclusions from the evaluation of the options are presented below.

#### 5.4.5.1 Snake River Drawdown

**Lower Granite to Elevation 710 with the Remaining Projects to MOP.** The drawdown of Lower Granite Reservoir to elevation 710 would result in many significant environmental impacts. These include:

- Possible increases in the dissolved gas (atmospheric) levels to the lethal stage; and
- Adult fish passage problems associated with spilling 100 percent of the flow at Lower Granite and creating an extremely turbulent condition in the tailrace area that would disorient adult salmon and prevent them from entering the fish ladder entrances.

In addition, this alternative received no support based on comments received during the Draft OA/EIS public review. As a result, this alternative was eliminated from further consideration.

**Drawdown to MOP.** The drawdown of all four projects to MOP appears to be cost-effective. Whereas the benefits to water particle travel time are not considered to be significant, the economic and environmental effects are also very small. The major impact is to power, resulting in a loss to some peaking capacity. This alternative was implemented in 1991 without significant incident. It also has been incorporated within the NPPC Fish and Wildlife Management Program, and based upon comments received on the Draft OA/EIS, this alternative has public support. This option is recommended for implementation for 1992.

#### 5.4.5.2 Columbia River Drawdown

**Drawdown to MOP.** Drawdown of the four lower Columbia River projects to MOP was eliminated from further consideration primarily due to a lack of cost-effectiveness. With this alternative, the economic impacts within the John Day and McNary reservoirs were very high, primarily due to the loss of irrigation.

**Drawdown of John Day to 262.5, McNary to 337, and Bonneville and The Dalles to MOP.** Although this alternative appeared to be cost-effective, the benefits to water particle travel time were very low, particularly within Bonneville, The Dalles, and McNary reservoirs. The maximum combined reduction in water particle travel time for these reservoirs was approximately one-half of one day. This small reduction in water particle travel time is considered to be negligible when taking into account the level of detail used in the evaluations and the combined water particle travel time of the existing reservoir system. Therefore, even the relatively minor impacts associated with these drawdowns is unwarranted.

Drawdown of John Day Reservoir to 262.5 was implemented in 1991. The reservoir was raised when needed to mitigate for impacts to irrigation. This action resulted in no significant impacts for 1991 and can be implemented again in 1992. This drawdown will provide a reduction in water particle travel time, ranging from 1/2 to 2 days depending on the flow conditions. This alternative is supported by the public and has been included as part of the NPPC's Fish and Wildlife Management Program. This option is recommended for implementation for 1992.

### 5.4.5.3 Snake River Flow Augmentation

A number of the flow augmentation options evaluated for the Snake River appear to be cost-effective. However, due to limitations of modeling using monthly averages and a constant allocation of water budget versus the actual daily operation and shapeable water budget, the cost-effectiveness analysis was unable to distinguish much difference between each specific augmentation option.

Storage from Brownlee has been eliminated from further consideration and will not be recommended for implementation in 1992. Although use of Brownlee storage would be beneficial for flow augmentation purposes, the cooperating agencies do not have any authority to control Brownlee operation for fish passage.

The preferred option for 1992 is one which follows the NPPC plan if the April Lower Granite runoff forecast is less than 16 MAF and Option J if the forecast is 16 MAF or greater. This provided a balance of improving water particle travel time (compared with the Base Case) and impacts to Dworshak, primarily associated with the probability of refill. Each plan by itself was strong in certain areas and weak in others. The NPPC plan provides more flow augmentation than Option J in the low runoff years (forecast runoff of 16 MAF or less). However, in mid-range runoff forecasts, Option J provides more water budget than the NPPC plan and a better probability of refill in years when the 100 kcfs target flow at Lower Granite can be provided without a large contribution from Dworshak. Based on early forecasts for 1992 runoff, preliminary estimates of refill probability at Dworshak for the preferred plan is 77 percent. This option incorporates a substantial portion of the NPPC Fish and Wildlife Plan and is recommended for implementation in 1992.

### 5.4.5.4 Columbia River Flow Augmentation

The time frame for completing this OA/EIS was very short. Therefore, the scope of study was limited. One of the limits was the number of storage reservoirs on the Columbia River that could be included for evaluation. For example, Libby and Hungry Horse (large storage reservoirs in Montana) were excluded. As a result, the amount of flow augmentation on the Columbia River was also limited. Due to the limited scope, Target 200 was the only flow proposal evaluated in this OA/EIS. Studies addressing actions for 1993 and beyond will evaluate additional flow augmentation proposals on the Columbia River.

The evaluations indicated that the Target 200 proposal is cost-effective and has acceptable environmental effects. This proposal has the same effects as the proposal identified in the NPPC amended program. Therefore, it is considered to be the same and have regional acceptance and is recommended for implementation in 1992.

### 5.4.5.5 Temperature Control for Adults

The temperature control studies, both field and computer model, conducted in 1991 are still considered to be preliminary because the data and results remain inconclusive. The limited cool water releases from Dworshak in 1991 resulted in lower river temperatures within Lower Granite and Little Goose reservoirs. Results from the COLTEMP model indicated that large volumes (1 MAF) of cool water would be required to meet the temperature objectives at the mouth of the Snake River. This would lower Dworshak Reservoir approximately 50 feet, resulting in substantial negative environmental impacts. In addition, there is a lack of information available concerning the biological benefits (timing of releases and target temperature) to implement a 50-foot drawdown.

Additional field tests are recommended in 1992. This test will further evaluate the effectiveness of cool water releases on improving migration conditions. The information collected from this test will also be used to verify the COLTEMP model projections. The NPPC supports this action and has included this action in their amendment plan.

### 5.4.5.6 Physical Test Drawdown

The objective of this alternative is to collect data, to be used in the development of long-term studies associated with drawdown proposals on the lower Snake River. Although the test is not considered to be a biological test, information obtained will assist in making long-term decisions regarding means to improve migration conditions. Since the objective is not to increase water particle travel time, cost-effectiveness is not a criteria.

**Lower Granite to Near Spillway.** This alternative could be implemented or July 15, 1992 or February 1993. The July 15 test was determined to impact adult and juvenile salmon migration, although this period is not considered to be a peak migration season. As a result the National Marine Fisheries Service did not support this period, and it was eliminated. The February 1993 test was not heavily supported by the region. Regional interests wanted a test in 1992; therefore, the February test was eliminated from further consideration.

**Two-Reservoir Drawdown Test: Lower Granite and Little Goose.** The two-reservoir drawdown test has strong regional support. This is evident based upon comments received to the draft OA/EIS and the fact that it has been included in the NPPC Fish and Wildlife plan. By performing the test in 1992, the information can be used in long-term drawdown studies identified in the NPPC Fish and Wildlife plan. By drawing down two sequential reservoirs, the tailwater conditions at Lower Granite Dam will be similar to four reservoir drawdown conditions. This test will also provide some information that is unattainable through three-dimensional laboratory models (i.e., turbine operation, gas saturation levels, etc.). The data collected will also validate ongoing modeling efforts and projections.

## 5.5 PREFERRED PLAN OF ACTION FOR 1992

### 5.5.1 Description of Plan

The cooperating agencies did not elect to identify a preferred alternative for 1992 river operations in the draft OA/EIS. Because of the complexity of the issues and potential options, the agencies wanted to obtain public review of the various options and their effects before selecting a preferred plan. By deferring selection of a preferred plan to the final OA/EIS, the cooperating agencies were able to more efficiently coordinate plan selection and evaluation with the NPPC planning process.

As a result of the analysis presented in the draft OA/EIS, public review of the document, and further analysis in response to review comments, the cooperating agencies have selected a set of options that comprise the preferred alternative for 1992. The preferred alternative includes the following measures discussed previously in Sections 3.2.2 through 3.2.5:

- Drafting all 4 lower Snake River projects to MOP from April 1 to July 31.

- Conducting a two-reservoir drawdown test at Lower Granite and Little Goose reservoirs on the lower Snake River in March.

- John Day Pool would be drafted to near elevation 262.5 starting on May 1 and ending on May 31. This elevation will be maintained for as long as possible without impacting irrigators located on the reservoir. The pool will be raised accordingly to ensure that irrigators are not affected.

- Lower Snake River flow augmentation of 900 KAF or more from Dworshak based on total basin forecast (April-July) of 16 MAF (or less) at Lower Granite. This volume of water is in addition to any minimum flow release requirements at Dworshak. When run-off forecasts are above 16 MAF, the above volume will be provided with the following conditions:

  1) When natural flows at Lower Granite Dame exceed 100 kcfs, the volume of water from Dworshak will be reduced.

  2) Additional water from Dworshak (above 900 KAF) will be released when refill probability is in excess of 70 percent.

  Dworshak will be operated to MRCs and flood control shift to Grand Coulee would occur when the forecast April to July inflow to Dworshak is less than 2.6 MAF.

- Lower Columbia River flow augmentation of up to 6.4 MAF if January through July runoff is 80 MAF or less and 3.4 MAF if runoff is 90 MAF or more during the months of May and June. Mean monthly flows of about 200 kcfs at The Dalles are expected.

- Field studies will be conducted in August 1992 to test the effectiveness of cool water releases from Dworshak Dam to reduce water temperatures in the lower Snake River to benefit adult fall chinook. If Dworshak is full or nearly full by the end of July, draft the reservoir up to 20 feet in August as needed for the temperature control evaluation. This could results in Dworshak releases of up to 360 KAF. In September, beginning immediately after Labor Day, release up to 200,000 acre-feet of additional cool water from Dworshak reservoir, as needed for the temperature control evaluations. If Dworshak reservoir is not full, use of Dworshak for temperature control will be addressed in the July meeting of the Fish Operations Executive Committee.

The environmental effects of these individual components of the preferred alternative are discussed in detail in Section 4. The collective effects and the basis for selecting this plan are addressed in Section 5.

## 5.5.2 Monitoring/Evaluation Plan

This is an outline of a monitoring and evaluation plan for a test drawdown of Lower Granite Reservoir to near spillway crest elevation, and Little Goose Reservoir to a point at which the Lower Granite tailwater elevation is equivalent to that which would exist with Little Goose drawn down to near spillway crest. The proposed time frame for this test is a 4-week period beginning March 1, 1992. A more detailed plan will be completed prior to test initiation.

### 5.5.2.1 Objective

The objective of the proposed physical test is to evaluate environmental and structural/physical effects of reservoir drawdown to near spillway crest elevation. Potential effects on structural integrity of project facilities, bank erosion, sediment resuspension, anadromous and resident fish and other aquatic organisms, water quality, water velocities, wildlife, cultural resources, and recreation are to be monitored where appropriate. However, some data obtained during the test will represent acute/immediate effects of this test, and may not be representative of conditions likely to occur should the system be operated in such a fashion over longer periods of time. Data and observations gathered will be for use in designing long-term reservoir drawdown operations.

### 5.5.2.2 Basic Test Design

Beginning on March 1, Lower Granite Reservoir will be drafted from MOP to an elevation of 705 mean feet above msl at a maximum rate of 2 feet per day. All water will be passed through the turbines as long as possible (see below for description of this testing). While Lower Granite Reservoir is maintained between elevation 705 and 703 msl, Little Goose Reservoir will be drafted 2 feet per day until the tailwater is equivalent to near spillway crest or until flows dictate the need to begin refill in order to have all fish facilities operable by April 1. If flows allow, Little Goose will be drafted and subsequently, Lower Granite Reservoir will be drafted the remaining elevation to near spillway crest (at a rate of two feet per day). The reason for this design will be explained below in the section on dam safety.

The above scenario assumes that no structural problems occur, turbines are functional throughout the range of head, and conditions remain safe. Any one of several factors may necessitate a change in test design. It is understood that involved parties will be in close coordination before and during the test period. The proposed basic test plan is therefore an "ideal" but may have to be modified to some extent. It was generally agreed that all possible information would be gathered during the drafting and refill process, even if it is not possible to achieve near spillway crest elevations.

### 5.5.2.3 Structural/Physical Monitoring

**Turbine Operation.** The turbines at Lower Granite and Little Goose will theoretically operate within the head range proposed for this test without significant risk of unit damage, although this has never been field-tested. The following objectives have been identified for turbine testing:

(1) Determine/verify the operating power range of the turbines as the head and tailwater levels are drawn down.

(2) Determine (if possible) the change in relative efficiency in the turbines.

(3) Determine if installation of draft tube bulkheads decrease cavitation or vibration intensity.

Turbines will be operated and cooling water systems for turbine, generators, transformers, and transformer deluge systems will be monitored as the pools are lowered. Instrumentation will be installed in Units 3, 4, and 5 at Lower Granite. Standard length submerged traveling screens will be installed in Units 3 and 4, and simulated extended length submerged screening devices will be installed in Unit 5. Turbine operation will be measured as each pool is lowered approximately 10 feet.

**Safety.** Safety issues primarily concern dam embankments and stilling basins. A sectional model of the spillway is currently being constructed at the Corps' Waterways Experiment Station and will be used to determine maximum spill levels allowable under proposed head and tailwater elevations. Effects of spill on the stilling basin will be field-tested to verify model results by drafting Lower Granite Reservoir to elevation 705, spilling in accordance with model test results for several hours while drafting to 703, and then shutting off the spill to allow inspection of the basin. Lower Granite Reservoir will be refilled to 705 prior to the next test. This test will be performed each day as Little Goose Reservoir is drafted up to 15 feet below (to whatever elevation is equivalent to near spillway crest and is possible under flow conditions). The stilling basin will be surveyed for possible physical damage on an alternate-day basis, unless model results indicate the need for examination following each spill test.

A Lower Granite forebay elevation of 703 to 705 for this portion of the test is required to maintain spillway gate control of the flow at each tailwater elevation until it is known whether stilling basin damage is occurring. The two-foot range of head will allow simulation of higher flows without having a significant impact on test conditions since this water surface elevation is within the near spillway crest range under higher flows.

Embankments will be monitored on a continuous basis throughout the test period.

**Reservoir Structures.** Railroad and highway embankments, the Lewiston levee system, and all other areas potentially at risk of failure will be monitored on an as-needed basis. Inspections will be made both on the ground and from the air. Types of fill material used in the levees and embankments will be recorded for future reference, where possible. Areas of slumping will be documented. The encapsulated toxic waste fill area will be monitored through groundwater wells that will be installed in the winter of 1991 to 1992.

Contaminant concentrations in the groundwater at the encapsulated fill will be compared before, during, and after the test period.

### 5.5.2.4 Environmental Monitoring

**Water Quality/Velocity Monitoring.**

Dissolved Gas Levels. The primary objective of this monitoring is to determine the levels of dissolved gas supersaturation that will occur with consecutive reservoirs at near spillway crest elevations, and over as wide a flow range as possible. (Note: this portion of the test may be substantially altered based on results of fall chinook redd surveys. Decisions will be made at a future date.) Dissolved gas levels will be monitored above and below Lower Granite Dam before, during, and after periods of spill during the stilling basin test, and during any subsequent tests performed once both pools are at near spillway crest elevations. Stationary tensionometers will be mounted on the upstream face of the dams and on the spillway shore approximately one-quarter mile downstream (all four lower Snake dams). These instruments will record dissolved gas levels and temperatures on an hourly basis. Immediately prior to initiation of spill, transects will be taken across the reservoir in the forebay of Lower Granite Dam. Dissolved gas levels will be recorded at surface and 15' depth (compensation point) at approximately 1,000-foot distances. Following a one-hour stabilization period, transects (at north, center, and south locations across the river, surface and 15' depths at each) will be taken in line with the downstream stationary tensionometers, and at one-mile intervals for the remainder of the spill duration. Dissipation rates will also be evaluated through use of the forebay instruments at subsequent dams. This test procedure will be repeated each day during the stilling basin test operations.

Upon completion of stilling basin tests and reservoir drafting of both pools to near spillway crest elevation or the equivalent (if flows allow), various combinations of spill and powerhouse flows will be tested to evaluate tailrace flow patterns and dissolved gas levels.

Stationary tensionometers will continue to record dissolved gas levels on an hourly basis. Transects will be taken, as explained above, except that the additional time frame up to 8 to 10 hours (instead of only 2+) may be used to track the rate of dissolved gas level dissipation as the supersaturated water moves downstream. Transects will be taken every mile for the first four miles, then every other mile for the next six, and finally every five miles after that until reaching Little Goose forebay. (If Little Goose is forced to spill, this procedure will also take place below this project as well, using Corps personnel.)

Data will be analyzed to determine at what head and tailrace levels the conditions are created that result in increased dissolved gas supersaturation. These data potentially will be evaluated along with sectional model studies ongoing at Waterways Experiment Station and to further calibrate the dissolved gas mathematical model under these extreme operating conditions.

In the event that turbines cannot be operated as the reservoirs are drafted and refilled during this test process, and model tests indicate that spill is acceptable as long as Lower Granite tailwater is maintained within normal operating pool elevations, water flow may be passed over the spillway. The decision on this element will be made sometime in late January based on modeling results. If spill is acceptable, dissolved gas levels will be monitored. Should dissolved gas supersaturation levels become excessive, the test will be stopped and refill initiated. This is to protect possible fall chinook alevins below Lower Granite.

Sediments. The effects of the reservoir drawdown test on turbidity levels throughout the lower Snake River projects will be documented. It is acknowledged that levels observed, if elevated because of the drawdown process, are not necessarily indicative of levels that would be found under a long-term drawdown operation since sediments have built up over time and would likely be flushed from the system during initial drawdowns.

Transparency (Secchi disk) will be measured in each of the four lower Snake River adult fish ladders. Additional transparency measurements will be taken at each of the transects identified necessary for reservoir velocity measurements (see below). Corps staff are currently developing the details needed to gather suspended sediment loads, etc. This plan will include measurements in the Clearwater and Snake rivers above the confluence. Since sediment load coming into the system varies with flow, weather conditions such as rainstorms, etc., these measurements will be used to identify general trends.

Nutrients associated with suspended sediments are available for algal bloom formation. Although low water temperatures and short days during this test period preclude increased algal productivity, nutrient levels will be monitored, if possible, to assess the potential for eutrophication. The monitoring plan will include sampling at selected reservoir sites and the Snake and Clearwater rivers above the confluence.

Velocity. The objectives for this effort are: (1) to validate the existing model used to calculate average water particle velocity, and (2) to obtain velocity profiles in the reservoirs at normal and low pool to help evaluate relative changes in velocities at given points.

Water Temperature. Water temperature is not of significant concern during the test time period, but will be measured at each location where other data are gathered (velocity, turbidity, suspended sediment, dissolved gas). In addition, temperatures may be measured using infrared sensing equipment during reservoir monitoring flights.

### Fish and Other Aquatic Organisms

Anadromous Fish. Since there will be very few juveniles in the system during the proposed test period, and adult passage will be blocked at Lower Granite once the reservoir elevation is below 710 and at Little Goose once it drops below MOP, these issues are not a specific part of the test design. However, fish condition, such as injury and gas bubble disease, will be monitored at all points fish are collected: adults through the ladders at operational facilities (at Lower Granite until elevation 710, and at Lower Monumental and other downstream facilities), and juveniles collected in the gatewells at Lower Granite and Little Goose. It is unknown at this point how many juveniles will be obtained in Lower Granite and Little Goose gatewells if the turbines remain functional throughout the reservoir drawdown, but it is believed to be a relatively small number. Up to 100 of each major species, chinook and steelhead, (all fish if less than 100) will be anesthetized and examined approximately two times per week (unless excessive numbers dictate more frequently). Data obtained from monitoring efforts will be given to the test coordination team on a daily basis for evaluation. (See section below on "Coordination".)

Lower Granite Reservoir may be a rearing area for wild summer chinook, as well as fall chinook. These fish may be present in late winter and thus be affected by loss of low velocity shallow-water habitat areas as the reservoir is drafted. Efforts will be made to sample areas throughout Lower Granite Reservoir before, during, and after the test drawdown to determine effect of the type of operation on rearing juvenile salmonids.

Sampling below Lower Granite Dam in 1991 suggests that fall chinook may spawn within this location. An attempt is currently being made to locate any potential spawning areas. If redds are discovered, Little Goose Reservoir will not be drafted below the elevation at which they are located. Whether or not redds are located, the evaluation plan will include measures to prevent mortalities and redd destruction, such as boat patrol as Little Goose Reservoir is lowered and cessation of spill if levels exceed those determined to be safe for fall chinook alevins.

The emergency fish ladder exit will be used to pass adult salmonids for approximately the first 11 days of reservoir drafting. Existing radio-tracking equipment will be used to verify that fish passing the adult trap are subsequently exiting the ladder. Additional information on adult steelhead within the system will be gathered through the ongoing Evaluation of Adult Fish Passage on the Lower Snake River (FWS).

Resident Fish. Squawfish - Potential plans to evaluate squawfish include radio-tagging fish prior to reservoir drawdown and tracking before, during, and following the test.

Other Resident Fish and Aquatic Organisms. Plans are in the process of development.

**Wildlife.** Impacts to waterfowl and shorebirds, wetland and riparian habitats, and furbearers will be monitored and evaluated. Areas where land bridges and new islands become exposed will be identified through aerial photography, field observation, and mapping. Predator access/ occurrence and impact on bridged islands will be monitored through direct field observation or population index methodology. Impacts to existing goose nesting structure use will be monitored through field observation and comparison of previous years' nesting data. Forbearer dens and areas of concentrated activity will be located and impacts monitored through field observation and possible expansion of an existing radio-telemetry study.

All wildlife riparian and drawdown zone field observations will be documented, indicating species, behavior, location, number, time of day, habitat being utilized, and historic frequency of occurrence in preparation for possible long-term monitoring and mitigation recommendations.

**Cultural Resources.** A plan for monitoring archaeological sites is being developed.

**Recreation.** Visitation data will continue to be collected at each of the Corps recreation areas that are open during the March through April time frame. Data will be compared to previous years' visitation rates during periods with similar ambient temperatures and weather conditions. This time frame is not considered a high-use period, with the possible exceptions of fishermen.

### 5.5.2.5 Risks Involved in Testing Program

Certain risks will be involved in implementing a drawdown of this type. The above outline includes steps to minimize these risks where possible, but will not eliminate them. The following potential risks have been identified, but the list is not all-inclusive:

(1) Erosion downstream of the project and an undermining of the stilling basin.

(2) Damage to reservoir embankments and structures, including embankment failures, marina and port facilities, etc.

(3) Potential dewatering and/or injury of fall chinook (fish will still be in the gravel during the proposed time frame).

(4) Potential exposure of resident and anadromous fish (including in-gravel fall chinook), and other aquatic organisms to high dissolved gas levels.

**Contingencies.** In the event of the following occurrences, the test will be canceled and the reservoir either refilled or maintained at the level necessary to accomplish repairs:

(1) Damage to project structures, including dam and/or reservoir embankments, levees stilling basin, etc.

(2) Turbines fail to be operable and dissolved gas levels below Lower Granite are increased to levels lethal for fall chinook alevins because of 100 percent spill for extended length of time;

Note: Damage to the structural integrity of the dam or the levee system will likely require repair prior to refill.

A decision tree for the test process is being developed and will be coordinated with the interagency test design group, as well as all involved parties.

**Coordination.** An operations management center will be set up at Lower Granite Dam for the duration of the test period. An interagency coordination team and plan are being developed to ensure that decisions can be made quickly in the event of unanticipated events and/or emergencies. Possible emergencies fall into two major categories: structural and biological. The coordination plan will identify appropriate steps in either event.

### 5.5.2.6 Additional Monitoring

**Effects of in-season flow augmentation and MOP elevations.** The effects of these operations will be evaluated through ongoing studies. Juvenile fish travel time is monitored through the FPC's Smolt Monitoring Program. Effect of stable pool elevations on resident fish and other aquatic organisms will be addressed through the Lower Granite In-Water Disposal Test monitoring efforts.

**Lower Snake River Temperature Control.** Releases of cool water from Dworshak Dam will be monitored again in 1992. The monitoring plan will be developed in cooperation with the fish agencies and tribes. Data analysis is ongoing and will be incorporated into the coming year's plans.

**Table 5.4-1.** Comparison of reservoir drawdown options.

| | Snake River | | |
|---|---|---|---|
| Resource/Issue | All 4 projects to MOP (April 1 to July 31) | All 4 projects to near spillway (April 15 to August 15) | All 4 projects to near spillway (April 15 to June 15) |
| **WATER QUALITY** | • Insignificant changes in gas saturation levels, temperatures, turbidity, and other parameters. | • Potential gas saturation increase of up to 130 to 150 percent, gradually increasing from one project to the next (110 acceptable State standard and EPA criteria).<br>• Potential minor temperature change, possible peak barrier shift and reduction.<br>• Noticeable increase in turbidity. | • Similar to spillway drawdown to August 15 except with a decrease in duration. |
| **ANADROMOUS FISH** | • Water particle travel time reduced by a maximum of 7 percent (normally half of this) over entire range of flows.<br>• Smolt travel time reductions through Lower Granite Pool (assuming, because of lack of specific data, that smolt travel time is equal to water particle travel time) would be the same as changes in water particle travel time over entire flow range (maximum 7 percent reduction, normally half that).<br>• Minor potential smolt travel time changes from Lower Granite to Ice Harbor, most changes less than 1 day reduction, or at most 6 percent change from existing.<br>• Absolute percent smolt survival increases from Lower Granite Pool to Ice Harbor Dam, depending on the models used, ranges from 3.9 to 0.2 percent at medium flow (80 kcfs), with lower percent increases at higher flows.<br>• Minor reduction in rearing habitat for subyearling chinook. | • Water particle travel time reduced by about 54 percent over entire range of flows.<br>• Smolt travel time from Lower Granite Pool potentially reduced significantly, depending on the model, by 17.4 to 10.8 days at a low flow of 40 kcfs, by 4.6 to 3.7 days at a medium flow of 80 kcfs, and greater than 2.2 days to less than 0.7 days at a high flow of 120 kcfs.<br>• Absolute smolt survival change is unknown but may be worsened from existing conditions by 1) elimination of fish transport from all Snake River facilities subjecting typically transported fish to longer travel times, 2) increased mortality from significantly increased high gas supersaturation levels, 3) increased downstream predation and turbine mortality for typically transported fish, 4) significant loss of shallow-water rearing habitat in the Snake River, and 5) reduced benthic and pelagic food production. | • Similar to spillway drawdown to August 15 except with a decrease in duration of certain negative effects (e.g., reduced food production, increased predation, gas supersaturation mortality, effects from elimination of bypass/collection/transport facilities).<br>• Reduced adverse effects to adults and subyearling chinook relative to longer drawdown as discussed above. |



ACOE/1-5-92/23:03/01644A

| Snake River | | | Columbia River | |
|---|---|---|---|---|
| Lower Granite to near spillway (February 1993 or July 15 to August 15) | Lower Granite to 710 feet (April 15 to June 15) | Lower Granite/ Little Goose drawdown test (March) | All 4 projects to MOP (April 1 to August 31) | John Day at 262.5 feet, McNary at 337 feet, remainder at MOP (April 1 to August 31) |
| • Gas saturation increase but less severe than dropping all 4 to near spillway crest.<br>• Potential increase in turbidity. | • Gas saturation could rise to 120 percent (and up to 140 percent below Lower Granite); elevated saturation levels also experienced downstream (110 percent acceptable State standard and EPA criteria).<br>• Potential increase in turbidity. | • Potential elevated gas saturation levels.<br>• Potential temporary increases in turbidity. | • Potential gas saturation slightly higher than existing, possibly rising to 120 percent with maximum up to 130 percent (110 percent acceptable State standard and EPA criteria).<br>• Greater daily fluctuations in temperatures and increased daily maximums.<br>• Temperature maximums potentially reached weeks earlier in Lakes Wallula, Umatilla, Celilo, and Bonneville.<br>• Minimal localized impacts to turbid | • Potential gas saturation the same as existing levels between 115 and 120 percent (110 percent acceptable State standard and EPA criteria).<br>• Temperatures remain within typical range. |
| • Effects similar to reduction to MOP except as discussed below.<br>• Water particle travel time reduced by about 3.5, 1.6, and 0.8 days over flows of 40, 80, and 120 kcfs through Lower Granite pool (others see above).<br>• Survival increases, similar to reduction to MOP for all Snake River Projects, would occur for summer test but may be less for reasons presented for reduction to near spillway crest (see above).<br>• July option proposed to be conducted during the latter part of the subyearling smolt migration. Effects on travel time and survival of these fish are unknown.<br>• During the July and August alternative although turbine mortality would be eliminated at Lower Granite Dam, juvenile subyearling survival may be worsened because 1) no juvenile fish | • Effects similar to reduction to MOP except as discussed below.<br>• Water particle travel time reduced by 2.3, 1.2, and 0.8 days for flows ranging from 40, 80, and 120 kcfs, respectively, in Lower Granite Pool or about 44 percent from existing (others shown above).<br>• Assume smolt travel time potentially reduced through Lower Granite Pool the same as water particle travel time.<br>• Absolute smolt mortality through Lower Granite Pool potentially reduced by 1.6, 0.8, and 0.6 percent for flows 40, 80, and 120 kcfs, respectively, if <u>only</u> travel time is considered.<br>• Although turbine mortality would be reduced at Lower Granite Dam, other factors will possibly | • Effects similar to reduction to MOP except as discussed below.<br>• Water particle travel time reduced by about 3.5, 1.6, and 0.8 days over flows of 40, 80, and 120 kcfs through Lower Granite pool. Little Goose water particle travel time reduced between MOP and spillway crest.<br>• Juvenile passage survival not affected as limited passage occurring.<br>• Potential reduced rearing habitat and habitat quality for fall chinook in Little Goose and Lower Granite pools.<br>• Potential partial stranding of fall chinook fry or alevins in gravel in Little Goose Pool.<br>• No adult passage | • Water particle travel time reduced by about 16 to 19 percent from maximum pool over entire range of flows. Actual reduction about 10 percent relative to existing operation.<br>• Smolt travel time through lower Columbia system potentially reduced by 2.5 to 2.0 days at 160 kcfs, 2.0 to 1.2 days at 200 kcfs, and 1.6 to -0.5 at 260 kcfs.<br>• Absolute smolt survival through lower Columbia system potentially increased by 1.8 to 1.4 percent at 160 kcfs, from 1.4 to 0.8 percent at 200 kcfs, and from 1.6 to -0.4 percent at 260 kcfs.<br>• At The Dalles, efficiency of sluiceway bypass could be reduced forcing more fish through turbines increasing mortality.<br>• At John Day and McNary, turbine efficiency is reduced, poten- | • Water particle travel time reduced by about 12 to 14 percent from maximum pool over entire flow range.<br>• Smolt survival through lower Columbia system reduced by slightly less than reduction for all at MOP.<br>• At The Dalles, efficiency of sluiceway bypass could be reduced forcing more fish through turbines, increasing mortality.<br>• Slight increase in gas saturation at The Dalles and Bonneville with minor effects on fish, especially under high flows.<br>• Minor reduction in shallow-water habitat at The Dalles and Bonneville not expected to cause adverse effects on rearing to any stock. |

**Table 5.4-1 (continued).** Comparison of reservoir drawdown options.

| | Snake River | | |
|---|---|---|---|
| Resource/Issue | All 4 projects to MOP (April 1 to July 31) | All 4 projects to near spillway (April 15 to August 15) | All 4 projects to near spillway (April 15 to June 15) |
| **ANADROMOUS FISH (CONTINUED)** | | • Elimination of all adult fish passage during drawdown and reservoir refilling period, eliminating passage of all spring and summer chinook.<br>• Temperature peak would be shifted several weeks earlier, possibly impeding early portion of the adult run. Cooler temperatures could benefit later portions of the run. | |
| **RESIDENT FISH** | • Spawning and rearing habitat reduced.<br>• Possible benefits to spawning success due to stabilized water surface elevations. | • Large reductions in suitable shallow-water spawning habitat.<br>• Reduced benthic and plankton production and, hence, prey availability, with reduced fish growth.<br>• Increased gas saturation.<br>• Increased fish mortality. | • Similar to all projects near spillway with decrease in duration. |
| **TERRESTRIAL ECOLOGY** | • Minimal impacts to (a) aquatic plants and invertebrates; (b) riparian communities; (c) wetlands; and (d) wildlife.<br>• Potential temporary increase in herbaceous vegetation within drawdown zone. | • Substantial loss of aquatic plant and invertebrate communities associated with shallow-water habitat.<br>• Substantial changes to riparian communities; greatest at Lower Granite, Little Goose, and Lower Monumental.<br>• Wetlands would experience severe moisture stress. | • Similar to spillway drawdown above; decrease in duration/severity. |

| Snake River | | | Columbia River | |
|---|---|---|---|---|
| Lower Granite to near spillway (February 1993 or July 15 to August 15) | Lower Granite to 710 feet (April 15 to June 15) | Lower Granite/ Little Goose drawdown test (March) | All 4 projects to MOP (April 1 to August 31) | John Day at 262.5 feet, McNary at 337 feet, remainder at MOP (April 1 to August 31) |
| transport from Lower Granite Dam, 2) increased mortality from high gas supersaturation in Little Goose Pool, 3) increased predation in Lower Granite Pool from predator concentration, 4) possible increased spillway passage mortality, 5) increased downstream turbine passage and predation mortality for fish typically transported, and 6) reduced shallow-water rearing habitat in Lower Granite Pool. • No adult passage above Lower Granite during drawdown periods affecting adult summer chinook and lesser portions of fall chinook and summer steelhead. | reduce overall survival including: 1) no transport of fish from Lower Granite Dam, 2) increased mortality from higher gas supersaturation levels in Little Goose Pool, 3) increased predation in Lower Granite Pool on subyearlings from predator concentration, 4) possible increased mortality from spillway passage, 5) increased downstream turbine and predation mortality for fish typically transported at Lower Granite, and 6) reduced shallow-water rearing habitat in Lower Granite Pool for subyearling chinook. • Adult migration may be greatly impeded or eliminated at Lower Granite. | above Little Goose during drawdown periods delaying less than 3 percent of summer steelhead. • Enhance upstream migration success of some fall chinook and steelhead in late August through early September by lowering temperature to less than 70°F two weeks earlier than current conditions. • Enhance growth of part of Dworshak hatchery steelhead for limited (20 day) period). | tially increasing mortality of fish passing through turbines by about 1.3 and 1 percent, respectively. • Slight increase in gas saturation, especially under high flows, with minor effects on fish. • Minor reduction in shallow-water habitat reduces rearing habitat for subyearling chinook. | |
| • Similar effects on Lower Granite as in all projects to near spillway and other projects similar to that described under MOP. | • Greatly reduced spawning habitat in Lower Granite. • Reduced benthic and plankton production in Lower Granite. • Reduced fish growth in Lower Granite. • Other projects as in MOP. | • Potential shifting of resident fish populations between pools. • Reduction in suitable shallow-water foraging habitat. • Reduced benthic production. • Increased gas saturation and predation. | • Spawning and rearing habitat reduced. • Possible benefits to spawning success due to stabilized water surface elevations. • Possible reduction in plankton production. | • Possible enhanced spawning and rearing conditions. |
| • Identical to near spillway crest drawdown at Lower Granite; decrease in duration and severity; MOP effects at remainder. | • Effects similar to Lower Granite at spillway, others at MOP. | • Impacts to vegetation and wildlife similar to those described for four-month spillway crest option at Lower Granite and Little Goose pools, but considerably less severe except for nesting waterfowl. | • Exposure of over 10,000 acres of shallow-water habitat, most at Umatilla NWR resulting in significant loss of shallow-water habitat. • Significant impacts to riparian communities at John Day and McNary, and in the Umatilla and | • MOP impacts could be expected for Bonneville and The Dalles. • Impact to John Day and McNary would be similar but less severe than those at MOP; MOP impacts at Bonneville and The Dalles are described above. |

**Table 5.4-1 (continued).** Comparison of reservoir drawdown options.

| | Snake River | | |
|---|---|---|---|
| Resource/Issue | All 4 projects to MOP (April 1 to July 31) | All 4 projects to near spillway (April 15 to August 15) | All 4 projects to near spillway (April 15 to June 15) |
| **TERRESTRIAL ECOLOGY (CONTINUED)** | | • Islands used for goose nesting would be land-bridged, increasing predation. Nest platforms used by geese would become useless.<br>• Decrease in prey species upon which raptors depend for food; possible increase in vulnerability of raptor prey species; and possible increase snag abundance in riparian zones.<br>• Adverse impact to upland game birds, big game, furbearers, reptiles, amphibians, small mammals, bats, State and Federally listed species, and others from reduced riparian and wetland habitats. | |
| **GEOLOGY AND SOILS** | • Slight increase in slope movement rates.<br>• Minimal shoreline erosion of beaches, recreation facilities, roads, and railroad grades.<br>• Potential adverse effects will be negated by dredging in early 1992. | • Increased beach erosion.<br>• Exposure of substantial portion of unprotected railroad and highway embankment.<br>• Wave erosion would likely affect dam embankments. | • Similar to near spillway crest drawdown but with decrease in duration. |
| **AIR QUALITY** | • A slightly but no significant change from present air quality. | • Most exposed shoreline and bottom areas, therefore most widespread fugitive dust and odors. No significant air quality impact. | • Similar to near spillway crest drawdown from April 15 to August 15 except with decreased duration. |
| **TRANSPORTATION** | • Potential adverse impacts from limited access to terminals negated by dredging in early 1992. | • Barge transportation on lower Snake closed for 5 months.<br>• Total transportation costs for all commodities increased by $5.7 million.<br>• Potential barge rate increase from 25 to 40 percent to compensate for revenue loss. | • Barge transportation on lower Snake closed for 3 months.<br>• Total transportation costs for all commodities increased by $2.8 million.<br>• Potential barge rate increase of 20 percent to recover lost revenues. |

| Snake River | | | Columbia River | |
|---|---|---|---|---|
| Lower Granite to near spillway (February 1993 or July 15 to August 15) | Lower Granite to 710 feet (April 15 to June 15) | Lower Granite/ Little Goose drawdown test (March) | All 4 projects to MOP (April 1 to August 31) | John Day at 262.5 feet, McNary at 337 feet, remainder at MOP (April 1 to August 31) |
| | | | McNary NWRs. Significant impacts on wetland development at John Day and McNary. • Impacts to waterfowl nesting and aquatic furbearers are expected to be most significant at John Day. | |
| • Effects proportional to near spillway and MOP noted above previously. | • Effects proportional to near spillway and MOP noted previously. | • Same as spillway effects for Lower Granite and Little Goose but lesser potential because of reduced duration. | • Slight increase in slope movement rates. • Minimal shoreline erosion of beaches, recreation facilities, roads, and railroad | • Effects similar to MOP for The Dalles and Bonneville, minimal for John Day, McNary. |
| • See spillway and MOP effects above. | • See spillway and MOP effects above. | • See spillway effects. | • Slightly more exposed reservoir shoreline and bottom areas but no significant change from present air quality. | • See spillway and MOP effects. |
| • Barge service on Lower Granite interrupted for one month. • Total transportation costs increased by nearly $0.4 million. | • Barge service on Lower Granite closed for 3 months. • Total transportation costs increased by $0.9 million. | • Barge service on Lower Granite and Little Goose interrupted for up to 6 weeks. • Total transportation costs increased by approximately $0.5 million. | •Potential adverse impacts from limited access to terminals negated by dredging in early 1992. | • Similar to MOP effects. |

**Table 5.4-1 (continued).** Comparison of reservoir drawdown options.

| | Snake River | | |
|---|---|---|---|
| Resource/Issue | All 4 projects to MOP (April 1 to July 31) | All 4 projects to near spillway (April 15 to August 15) | All 4 projects to near spillway (April 15 to June 15) |
| **TRANSPORTATION (CONTINUED)** | | • Refill could reduce water depths below Bonneville by 1 to 2 feet, with potential added shipping cost of up to $0.6 million. | |
| **AGRICULTURE** | • No effects on irrigation. | • No production from 56,000 irrigated acres in 1992, all on Ice Harbor.<br>• Lost net crop value and reestablishment costs of $83 million. | • Same as April 15 to August 15. |
| **POWER** | • Capacity loss would range from 550 MW to 1,400 depending on month (cost of $11 million).<br>• Minimal effect on firm energy availability.<br>• 800 to 1,200 MW-months lost in non-firm energy (cost of $9 million to $13 million). | • Capacity loss of 300 MW to 3,200 MW depending on month (cost of $42 million).<br>• Firm energy loss of 300 average megawatts (aMW) (cost of $90 million).<br>• 2,500 to 5,500 MW-months lost in non-firm energy (cost of $27 million to $60 million). | • Capacity loss of 1,600 to 3,200 MW (cost of $32 million).<br>• Firm energy loss of 240 aMW (cost of $72 million).<br>• 2,000 to 5,000 MW-months lost in non-firm energy (cost of $21 million to $55 million). |
| **RECREATION** | • Of 28 boat ramps, 14 would be of marginal use.<br>• Of 5 moorage facilities, 4 would be of marginal use.<br>• Of 11 swimming areas, 5 would be marginally usable and 4 would be unusable.<br>• No displaced visitation expected. | • All boat ramps, moorage facilities, and swimming areas in project areas would be unusable.<br>• Up to 733,000 recreation days would be displaced. | • Same physical effects as 4-month drawdown but for shorter duration.<br>• Up to 132,000 recreation days displaced. |



ACOE/1-5-92/23:03/01644A

| Snake River | | | Columbia River | |
|---|---|---|---|---|
| Lower Granite to near spillway (February 1993 or July 15 to August 15) | Lower Granite to 710 feet (April 15 to June 15) | Lower Granite/ Little Goose drawdown test (March) | All 4 projects to MOP (April 1 to August 31) | John Day at 262.5 feet, McNary at 337 feet, remainder at MOP (April 1 to August 31) |
| | | | | |
| • No effects on irrigation. | • No effects on irrigation. | • No effects on irrigation. | • No production from 226,000 irrigated acres in 1992, most at John Day.<br>• $197 million in lost agricultural production and reestablishment costs. | • No production from 13,000 irrigated acres in 1992, mostly at Bonneville.<br>• $52 million in lost agricultural production and reestablishment costs. |
| • Capacity loss of 800 MW (cost of $3 million to $8 million).<br>• Energy losses of 300 to 650 MW-months (cost of $3 million to $12 million; might be firm or non-firm energy, depending on water year. | • 1,100 to 1,800 MW capacity loss (cost of $11 million).<br>• Firm energy loss of 60 aMW (cost of $18 million).<br>• Non-firm energy loss of 1,000 to 1,800 MW-months (cost of $11 million to $20 million). | • Capacity loss of less than 600 MW.<br>• Firm or non-firm energy loss of 125 MW-months (cost of $1.5 million to $3 million). | • Capacity loss of 1,500 to 2,400 MW (cost of $33 million).<br>• Minimal firm energy loss.<br>• Non-firm energy loss of 850 to 1,600 MW-months (cost of $9 million to $17 million). | • 1,500 to 2,400 MW capacity loss (cost of $33 million).<br>• Minimal firm energy loss.<br>• Non-firm energy loss of750 to 1,500 MW-months (cost of $8 million to $16 million). |
| • Lower Granite boat ramps unusable. 12 of 17 ramps at the other projects of marginal use.<br>• Lower Granite moorage facilities unusable; 2 of 3 moorage facilities at the other projects marginally usable.<br>• All swimming areas at Lower Granite and Little Goose unusable.<br>• Up to 158,000 visitor days displaced with summer test, 20,000 winter. | • Same effects as drawing down Lower Granite to near spillway crest.<br>• Estimated 132,000 recreation days displaced. | • All boat ramps and moorage facilities would be unusable at Lower Granite and Little Goose for up to 1 month.<br>• Estimated displacement of up to 33,000 recreation days in March, about one-third devoted to fishing. | • 13 of 39 boat ramps of marginal use, 13 unusable (with planned dredging).<br>• 8 of 17 moorage facilities of marginal use (with dredging).<br>• 15 of 20 swimming areas unusable.<br>• Visitation displaced, not quantified. | All Projects:<br>• 11 boat ramps of marginal use, 11 unusable (with dredging).<br>• 3 moorage facilities of marginal use (with dredging).<br>• 11 swimming areas unusable.<br>• Visitation displaced, not quantified.<br>John Day:<br>• 9 of 12 ramps at John Day usable, 5 fully functional.<br>• 5 of 7 moorage facilities at John Day fully functional, other 2 marginally usable.<br>• 408 swimming areas at John Day not functional. |

**Table 5.4-1 (continued).** Comparison of reservoir drawdown options.

| | Snake River | | |
|---|---|---|---|
| Resource/Issue | All 4 projects to MOP (April 1 to July 31) | All 4 projects to near spillway (April 15 to August 15) | All 4 projects to near spillway (April 15 to June 15) |
| AESTHETICS | • Little change from existing, some exposed shallows. | • Large areas of lake bottom exposed including debris (tree stumps, rocks, etc.)<br>• Some reservoir-dependent-seep lakes and embayments would decrease in size or disappear.<br>• Negative impact on water clarity and color. | • Same effects as 4-month drawdown to near spillway crest, but for shorter duration. |
| CULTURAL | • Possible reduction in wave erosion because reservoirs would remain static rather than fluctuate weekly. | • Larger portions of cultural sites would be exposed to erosion, vandalism, vehicle traffic, abrasion, breakdown and movement of material. | • Anticipated less damage from shorter period of drawdown. |
| SOCIOECONOMICS | • No identifiable employment or income effects. | • Transportation: Temporary layoffs in barge industry.<br>• Agriculture: Near-term direct and indirect impact of $146 million from lost production, 2,500 jobs.<br>• Recreation: Potential shifts in $19.8 million in gross user expenditures; lost season revenues for concessionaires. | • Same industries affected as under 4-month drawdown to near spillway, but less effect on transportation.<br>• Recreation: Potential shift in $3.6 million in displaced gross expenditures; lost concession revenues for about one-third of peak season. |
| STRUCTURAL IMPACTS | • No significant adverse effects. | • Increased turbulence at dam stilling basins could cause scour and undermine stilling basins, lock walls, and locks.<br>• Would cause unstable dam embankments.<br>• Lewiston and Marmes levees would be undermined by waves.<br>• Reduced soil bearing capacity and possible settlement, resulting in damage to facilities. | • Same above except with decrease in duration. |

| Snake River | | | Columbia River | |
|---|---|---|---|---|
| Lower Granite to near spillway (February 1993 or July 15 to August 15) | Lower Granite to 710 feet (April 15 to June 15) | Lower Granite/ Little Goose drawdown test (March) | All 4 projects to MOP (April 1 to August 31) | John Day at 262.5 feet, McNary at 337 feet, remainder at MOP (April 1 to August 31) |
| • Same effects for Lower Granite as near spillway. | • Same effects for Lower Granite as near spillway but to slightly less degree. | • Similar impacts as spillway crest alternative at Lower Granite and Little Goose, but for shorter duration with fewer viewers present.<br>• Little change at John Day from existing conditions. | • Significant exposed shallows at John Day and McNary. | • Little change from existing conditions. |
| • See effects of near spillway and MOP. | • See effects of near spillway and MOP. Four-week duration of this test would result in shorter exposure of cultural sites and, therefore, anticipated less impact. | • Similar impacts as Lower Granite/Little Goose to near spillway, John Day to 262.5. | • See drawdown of lower Snake reservoirs to MOP. | • Little change on John Day and McNary; MOP effects to The Dalles and Bonneville. |
| • No identifiable employment or income effects.<br>• Recreation: Potential shifts in $0.5 million (winter test) or $4.3 million (summer test) in displaced gross user expenditures; lost concessionaire revenues. | • Effects similar to Lower Granite at near spillway and others to MOP. | • No effect on agriculture likely; no or minimal effects on barge industry.<br>• Recreation: Potential shifts in $0.9 million in displaced gross user expenditures; lost concessionaire revenues. | • Agriculture: Near-term gross impact of $586 million from lost production; 10,000 jobs lost.<br>• Recreation: Potential shifts in minimum of $4 million in gross user expenditures. | • Agriculture: Near-term gross impact of $43.5 million from lost production; 740 jobs lost. |
| • Same effects for Lower Granite as for drawdown to near spillway crest. | • Similar to drawdown to near spillway crest. | • Same as spillway effect for Lower Granite and Little Goose but lesser potential because of reduced duration. | • No adverse effects to stilling basins. | • Effects to Bonneville and The Dalles similar to MOP. No adverse effects to John Day and McNary. |

**Table 5.4-1 (continued).** Comparison of reservoir drawdown options.

| | Snake River | | |
|---|---|---|---|
| Resource/Issue | All 4 projects to MOP (April 1 to July 31) | All 4 projects to near spillway (April 15 to August 15) | All 4 projects to near spillway (April 15 to June 15) |
| STRUCTURAL IMPACTS (CONTINUED) | | • Railroad and highway embankments exposed; wave erosion could result in unstable fill and ultimately failure.<br>• Potential scour could undermine Red Wolf Bridge piers.<br>• Elimination of buoyancy from reservoir water could cause failure of Lyons Ferry water supply pipeline. | |



ACOE/1-5-92/23:03/01644A

| Snake River | | | Columbia River | |
|---|---|---|---|---|
| Lower Granite to near spillway (February 1993 or July 15 to August 15) | Lower Granite to 710 feet (April 15 to June 15) | Lower Granite/ Little Goose drawdown test (March) | All 4 projects to MOP (April 1 to August 31) | John Day at 262.5 feet, McNary at 337 feet, remainder at MOP (April 1 to August 31) |
| | | • Same as spillway effect for Lower Granite and Little Goose but lesser potential because of reduced duration. | | |

**Table 5.4-2.** Comparison of flow augmentation, combination, and temperature control options.

| Resource/Issue | Flow Augmentation Impacts | Combination Impacts | Temperature Control Impacts |
|---|---|---|---|
| WATER QUALITY | **Dworshak**<br>• Decreased water temperatures below Dworshak Dam, particularly in Clearwater and lower Snake rivers, largest reductions with greatest flow releases (e.g., 1,200 KAF).<br>• Slightly improved water quality of lower Snake by dilution from cleaner Northfork water with the less clean mainstem Snake water.<br>• Slight potential increase in dissolved gas levels in mainstem Snake below the dams.<br><br>**Brownlee**<br>• Degraded chemical water quality of lower Snake River by flow augmentation from Brownlee.<br><br>**Grand Coulee**<br>• Degraded top values, normal during a high-flow year.<br>• Greater fluctuations in temperatures and increased daily maximums (still within normal range). | • Effects additive; see drawdown and augmentation. | • Significant positive impact on temperature at Lower Granite. Anticipate shift in temperature profile of approximately 2 to 3 weeks at Lower Granite.<br>• No significant change in temperature expected at Ice Harbor. |
| ANADROMOUS FISH | • Most flow augmentation alternatives primarily with water from Dworshak, Hells Canyon, or a combination increasing flow in the Snake River into the Columbia below the confluence of the Snake and Columbia rivers. Available storage and discharge capability allowing for a flow rate increase of 0 to 28 kcfs from these two Snake River reservoirs and limited periods of flow at these rates over what currently occurs. All alternatives designed to increase flow in May, some including parts of April and June without consideration of the available flow for later periods. Exact flow dependent on what is currently available and target flows selected. With flow from Grand Coulee, an increase of flow by 0 kcfs to more than 30 kcfs in the Columbia River only. | • Effects additive; see drawdown and augmentation. | • Enhance upstream migration success of some fall chinook and steelhead in late August through early September by potentially lowering 2 weeks earlier than current conditions.<br>• Reduced growth of part of Dworshak hatchery steelhead. |

**Table 5.4-2 (continued).** Comparison of flow augmentation, combination, and temperature control options.

| Resource/Issue | Flow Augmentation Impacts | Combination Impacts | Temperature Control Impacts |
|---|---|---|---|
| **ANADROMOUS FISH (CONTINUED)** | • Greatest effect on water particle travel time from high augmentation of 20 kcfs: in the Snake River during low flow (60 kcfs) at maximum pool 8 days, or 22 percent reduction; at medium flow (100 kcfs) 2.8 days, or 14 percent reduction. In the Columbia River reach, 5 days reduction at low flow (100 kcfs) to 7 days at high flow (300 kcfs).<br>• Smolt travel time in the Snake River 4 to 8 days reduction at low flow (40 kcfs) and 1 to 2 days at medium flow (80 kcfs).<br>• In the Columbia River reach 2 to 3 days reduction of smolt travel time at low flow (160 kcfs) and 1 to 2 days at medium flow (200 kcfs).<br>• Flow augmentation reduces available flow in the summer (July to September) possibly affecting summer downstream migrants.<br>• Minor potential gas saturation level increases.<br>• No effect on adult migration.<br>• Effects on absolute smolt survival for both Columbia and Snake River combined for a flow augmentation of 20 kcfs range from 5.6 to 14.2 percent for low flows (Snake 40 kcfs, Columbia 160 kcfs); 1.1 to 11.5 percent for medium flows (Snake 80 kcfs, Columbia 200 kcfs); and 0.1 to | | |
| **RESIDENT FISH** | **Dworshak**<br>• Increased entrainment of kokanee and trout.<br>• Slightly reduced plankton production thereby reducing food sources for fish.<br>• Reduced spawning success.<br>• Slight cooling of Clearwater River, delaying biological processes.<br>• Reduced effects with flood control shift.<br><br>**Brownlee**<br>• Increases in entrainment of fish with small to moderate withdrawals.<br>• Reduced benthic and planktonic production with moderate releases. | • Effects additive; see drawdown and augmentation. | |

Table 5.4-2 (continued). Comparison of flow augmentation, combination, and temperature control options.

| Resource/Issue | Flow Augmentation Impacts | Combination Impacts | Temperature Control Impacts |
|---|---|---|---|
| **RESIDENT FISH (CONTINUED)** | • Impacts on spawning success, feeding success, and survival with unrestricted draft increasing with magnitude of withdrawal.<br>• Reduced effects with flood control shift.<br><br>**Grand Coulee**<br>• Potential significant impacts (positive and adverse) at Lake Roosevelt to net pen operations.<br>• Increased entrainment of fish.<br>• Impacts to zooplankton development. | | |
| **TERRESTRIAL ECOLOGY** | • Minimal impacts on Brownlee, Dworshak, Grand Coulee, or downstream pools vegetation or wildlife. | • Effects additive; see drawdown and augmentation. | • Minimal impacts to vegetation expected on Dworshak pool. |
| **GEOLOGY AND SOILS** | • Increase in erosion and sedimentation.<br>• Variability among options. | • Effects additive; see drawdown and augmentation. | • No significant impacts because drawdown and discharge are within normal operating ranges. |
| **AIR QUALITY** | • Incremental increases from present in extent and duration of exposed bottom areas with some resulting fugitive dust, particularly at Dworshak and to lesser extent at Brownlee. | • Effects additive; see drawdown and augmentation. | • See flow augmentation effects. |
| **TRANSPORTATION** | • Dworshak log transport costs increased by $0.3 million for Options B through F. | • Effects additive; see drawdown and augmentation. | • Possible late-season interruption of log transportation at Dworshak. |
| **AGRICULTURE** | • Increased probability of no production from 460 acres and crop losses valued at $220,000. | • Effects additive; see drawdown and augmentation. | • No effect on agriculture. |
| **POWER** | **Snake River**<br>• Firm energy losses range from 40 aMW with Option J to 450 to 500 aMW with unrestricted releases from Dworshak and Brownlee (cost $12 million to $146 million).<br>• Large capacity impacts in fall and winter (unquantified) in cases of unrestricted draft. | • Effects additive; see drawdown and augmentation. | |

**Table 5.4-2 (continued).** Comparison of flow augmentation, combination, and temperature control options.

| Resource/Issue | Flow Augmentation Impacts | Combination Impacts | Temperature Control Impacts |
|---|---|---|---|
| **POWER (CONTINUED)** | • Corresponding net gain in non-firm of $1 to $27 million.<br>• Corresponding total costs ranging from $9 to $130+ million.<br><br>**Columbia River**<br>• Increase in total system costs ranging from $20 million to $75 million for Target 200 options. | | |
| **RECREATION** | • Displaced visitor days at Dworshak range from 1,300 for fixed draft of 600 KAF in May/flood control/MRC to 268,000 for unlimited draft to meet 140 kcfs target.<br>• Very low probability of access or visitation changes at Lake Roosevelt.<br>• Minimal access or visitation effects at Brownlee, except with unrestricted draft. | • Effects additive; see drawdown and augmentation. | • By mid-August Dworshak may be approximately 10 feet below normal, swimming areas unusable or marginally usable, moorage and gas docks marginally usable.<br>• By end of August, Dworshak pool may be 20 feet below normal, swimming areas unusable, moorage and gas docks marginally usable—the rest fully usable—difficulty accessing some mini-camp sites.<br>• Estimated potential displacement of up to 6,500 recreation days in August and 2,500 in September. Hunting access by foot constrained.<br>• Beaches reduced in area on the Clearwater River to varying degrees and fly fishing likely more difficult. |
| **AESTHETICS** | **Dworshak**<br>• Insignificant increase in lake bottom exposure with some drafts up to 1,200 KAF.<br>• Significant increase in vertical exposure of 30+ feet in summer with four fixed-draft, 1,200 KAF options.<br>• Severe increase in vertical exposure of 90+ feet with unrestricted draft.<br><br>**Brownlee**<br>• Minor May–June departure from existing conditions for most options.<br><br>**Grand Coulee**<br>• Insignificant changes from existing conditions. | • Effects additive; see drawdown and augmentation. | •Dworshak Pool may be 20 feet below normal by end of August, exposing shoreline area during period of highest visitation. |

**Table 5.4-2 (continued).** Comparison of flow augmentation, combination, and temperature control options.

| Resource/Issue | Flow Augmentation Impacts | Combination Impacts | Temperature Control Impacts |
|---|---|---|---|
| CULTURAL | **Dworshak**<br>• Increased exposure of cultural sites from drawdown increasing erosion and human-caused damage.<br>• Greatest negative impact would occur with unlimited withdrawals to meet flows of 140 kcfs during May.<br>• Shift of flood control to Grand Coulee would reduce negative impacts because reservoir elevation would be 6 to 13 feet higher.<br>**Grand Coulee**<br>• Typically, no change in ongoing effects upon cultural resources is anticipated. In some years, drawdown might occur earlier than the historical norm, which could cause incremental increases in ongoing adverse effects from vandalism or erosion.<br>**Brownlee**<br>• Increased damage of cultural sites from erosion, livestock, vandalism, primarily with unrestricted draft. | • Effects additive; see drawdown and augmentation. | • Potential increased exposure of cultural sites from drawdown of Dworshak up to 20 feet below normal in August, increasing erosion and human-caused damage. |
| SOCIOECONOMICS | • Potential shifts in Dworshak recreation user expenditures ranging from $37,000 to $7.6 million.<br>• Insignificant to major loss of revenue for recreation businesses primarily Big Eddy Marina concession. | • Effects additive; see drawdown and augmentation. | • No effects on agriculture.<br>• No employment effects expected involving Dworshak log transport. |
| STRUCTURAL IMPACTS | • No significant effects, as augmentation would not be needed in high-flow years. | • Effects additive; see drawdown and augmentation. | • No significant impacts because drawdown and discharge are within normal operating ranges. |

# 6.0

# Agency Coordination and Public Involvement

# 1992 COLUMBIA RIVER SALMON FLOW MEASURES
# OA/EIS

## CONTENTS

# 6.0 AGENCY COORDINATION AND PUBLIC INVOLVEMENT

Because water management practices have the potential to affect such a diverse range of interests, it is essential for the Columbia River Salmon Flow Measures OA/EIS to be sensitive to the recommendations of all parties involved, including the many agencies responsible for managing the resources of the Columbia-Snake River system, and the general public. Recognizing that the document must be responsive to these recommendations, the Corps and its cooperating agencies initiated and are actively pursuing programs designed to establish a two-way dialogue with all parties concerned with operation of the river system. The draft version of this document, released in September 1991, was developed after a detailed scoping process inviting comment from the public and responsible agencies regarding what to address in the OA/EIS. Agencies and the public then had the opportunity to review and comment on the draft document. This final OA/EIS represents the efforts of the Corps and its cooperating agencies to incorporate comments received on the draft. This process, which is in full compliance with the requirements of the NEPA, ensures that the public and all relevant agencies have an active and substantial role in the decision-making process. More detailed information on the process of agency coordination and public involvement is provided in the following sections. Appendix N, Response to Comments, provides detailed documentation on the Corps' response to specific comments received on the draft version of the document.

## 6.1 Scoping Process

In compliance with NEPA, a series of six scoping meetings was conducted to invite comments from responsible agencies, the public, and specific interest groups regarding the preparation of the 1992 Columbia River Flow Measures OA/EIS. Scoping meetings were held in Lewiston, Orofino, and Boise, Idaho; Pasco and Grand Coulee, Washington; and Portland, Oregon from June 3 to June 11, 1991. The Corps announced the meetings in scoping letters dated May 20 and 28. The first letter provided background information on the project, described four proposed alternatives for water management practices, and raised 21 proposed impact issues to be considered in the OA/EIS.

A panel of five agency members led each meeting and began by delivering an informative presentation detailing the project's background and the OA/EIS process. The presentation was supplemented with a slide show with graphics illustrating key points, narrative discussion of the issues involved, and pictures of the projects and affected resources. When time permitted, questions from the audience were entertained before the official public comment period. The public then gave comments regarding the scope of the project; the maximum comment time per speaker ranged from 3 to 5 minutes, depending on the number of speakers. The public was also invited to submit written comments regarding the project. After the public comment period, additional questions from the audience were answered. When the meetings had officially adjourned, panel members were available to discuss the project with interested parties face-to-face.

About 275 people who were not affiliated with the cooperating agency team attended the six scoping meetings. Of this number, 65 people spoke about issues to be addressed in the OA/EIS. Attendance ranged from about 20 to 25 (at Orofino) to 60 to 65 (at Pasco and Boise). The Corps also received about 110 letters regarding the OA/EIS. Written and oral comments were received from elected officials; representatives of federal, state, and tribal agencies; members of the agricultural, navigation, recreation, and forest products industries; representatives of local utilities; members of the commercial fishing industry; sport fishermen; people from environmental and conservation groups; and members of local economic development councils.

Scoping comments provided valuable information on specific operations, regions, and concerns that were useful in developing the draft OA/EIS. The comments included recommendations on the geographic scope of the OA/EIS, agency coordination, alternatives to be considered, technical impact issues, and the basis for reaching a decision. Suggestions on alternative actions ranged from eliminating all of the Corps dams—restoring the river system to its natural state—to operating the system without any changes, as it has been in the recent past. All of the comments received, both written and oral, were summarized in a single scoping summary document for reference and review by the people responsible for preparing the OA/EIS. In addition, a project factsheet describing the scoping process and summarizing the general nature of the comments received was also sent to nearly 3,000 people in mid-August.

## 6.2 REVIEW OF THE DRAFT OA/EIS

The draft OA/EIS, officially released on September 27, 1991, was sent to a total of 1,500 people. Recipients included representatives from federal, state, and local agencies; elected officials at the federal, state, and municipal levels; tribal organizations; public libraries; public utility districts; members of the agricultural, forest products, recreation, transportation, and other industry interest groups; environmental conservation organizations; and the general public, particularly those who attended the scoping meetings held in June 1991. To facilitate comment on the draft document, a series of six workshops/public meetings was held in late October 1991 in the same cities that hosted the scoping meetings. The cooperating agencies publicized the meetings in a series of three announcements placed in a total of six newspapers published throughout the region, with several radio announcements on six radio stations in the region, and in a factsheet mailed out to approximately 2,300 people in early October. In addition to announcing the workshops/meetings, the factsheet provided general background information on the project, summarized the various alternatives and their environmental effects, and described the public involvement process.

The workshops/meetings were conducted in compliance with the NEPA requirement of providing at least a 45-day public comment period for draft EISs. A panel of five agency members led each meeting and began by delivering a brief, informal presentation explaining the study process and the various alternatives included in the document. A workshop session followed this presentation, with audience members assembling in smaller groups to discuss specific issues such as fish and water quality, transportation and navigation, and recreation and cultural resources. The workgroups, led by agency staff responsible for preparation of the OA/EIS, provided a format for the cooperating agencies to work with the public in a more personal environment, answering many questions that would be difficult to address in larger groups. A summary of discussions conducted in each workgroup was then presented to the entire audience.

Following the workgroup sessions, a formal public meeting session was conducted to accept official comment on the contents of the draft OA/EIS. The maximum comment time per speaker was generally set at about five minutes so that all people who wanted to comment were given the opportunity. The public was also invited to submit written comments until November 15, 1991. As at the scoping meetings, panel members and agency specialists were available to discuss the project with interested parties face-to-face when the meetings had officially adjourned. In addition, presentation graphics (such as a slide show for the initial presentation, large hanging maps, and diagrams of project operations) were prepared to help explain the project.

About 200 people who were not affiliated with the cooperating agency team attended the six workshops/public meetings. Of this number, 68 people offered verbal comment on the draft OA/EIS, and 7 submitted written statements for the record. Attendance ranged from about 13 at Grand Coulee to 54 at Lewiston. The Corps also received 134 letters regarding the document. Written and verbal comments were received from elected officials; representatives of federal, state, local, and tribal agencies; members of the agricultural, navigation, recreation, and forest products industries; representatives of local utilities; members of the commercial fishing industry; sport fishermen; people from environmental conservation groups; members of local economic development councils; and unaffiliated interested individuals.

Comments on the draft OA/EIS provided valuable information on specific operations, regions, and concerns that was useful in revising the document. The comments covered a wide range of issues concerning the effects of the alternatives offered in the draft OA/EIS, and addressed other alternatives that did not fall within the scope of this OA/EIS, including harvest, hatcheries, fish transport, and structural modifications. For the specific comments, and the cooperating agencies' responses to these comments, see Appendix N of this document.

## 6.3 FUTURE PUBLIC INVOLVEMENT EFFORTS

The activities outlined above helped define the scope of the OA/EIS and improve its responsiveness to public interests and concerns. More activities are planned to help keep the public informed of significant developments and to provide interested members of the public an opportunity to further participate in the OA/EIS process.

### 6.3.1 Factsheets

The effort to keep the public informed of progress on the OA/EIS has included a series of factsheets. Release of the factsheets corresponds to project milestones. Factsheet No. 1 (issued in August 1991) presented a summary of the scoping process. Factsheet No. 2 (issued in conjunction with the draft OA/EIS) summarized the draft OA/EIS and provided information on the upcoming schedule, future opportunities for public involvement, and announced the public workshops and public hearings held in October. Factsheet No. 3 (issued shortly before the final OA/EIS) summarized the final OA/EIS, described the proposed actions for 1992, and summarized comments received on the draft OA/EIS. All issues of the factsheet provided the names, addresses, and phone numbers of cooperating agency personnel to contact for more information.

### 6.3.2 Public Information Meetings

To provide information to the public regarding the preferred alternative and the actions required to implement this alternative, two public information meetings have been scheduled, one in Washington and one in Idaho. The Corps will explain proposed changes in the operation of the reservoirs to improve salmon passage for 1992 and the impacts of those changes. Although this is not a formal hearing, the public will be given the opportunity to ask questions about the planned work. The meetings are scheduled as follows:

**Tuesday, January 28, 1992**
7 to 9 p.m.
Ramada Inn
621 21st Street
**Lewiston, Idaho**

**Wednesday, January 29, 1992**
7 to 9 p.m.
Red Lion Inn
2525 North 20th
**Pasco, Washington**

### 6.3.3 Press Releases

To encourage local media coverage of significant OA/EIS issues, press releases have been sent in conjunction with each issue of the factsheet and a press release is planned for the release of the final OA/EIS. Although press releases do not guarantee media coverage, they provide agency contact information in case members of the media wish to obtain more information from the Corps when writing stories.

## 6.4 AGENCY COORDINATION

### 6.4.1 Cooperating Agencies

The Columbia River Salmon Flow Measures final OA/EIS was prepared by the Walla Walla District of the Corps with help from BPA and BoR, both of which are cooperating agencies. These three agencies share the primary responsibilities for operation of the federal projects on the Columbia-Snake River system. The Corps is the lead agency because it designed, built, and operates most of the dams included in the project scope. BPA is a cooperating agency because of its regional power marketing operations responsibility and coordinating role with regional utilities. Because operation of the Grand Coulee project, which is managed by the BoR, is instrumental to the flow augmentation alternatives, the Bureau was also included as a cooperating agency. The Corps decided to prepare an OA/EIS in spring 1991 in response to regional deliberations over the proposed listing of several salmon stocks under the Endangered Species Act.

# 6 Agency Coordination and Public Involvement

During the Salmon Summit process, the Corps was urged by many participants to draft the four lower Snake River projects to near spillway crest levels for the 1991 migration. Other participants suggested a short-term test drawdown during the spring of 1991 to determine the physical effects of such a drawdown and help evaluate potential future measures. The Corps deferred action on both requests for 1991 because internal agency analysis concluded that operating the projects below established minimum pool levels was not addressed by existing NEPA documentation and would require original environmental analysis. The Corps further concluded that a full OA/EIS would be required, rather than an environmental assessment, because major reservoir drawdowns would likely have significant impacts on the physical, ecological, and human environment.

In response to this Corps position regarding major 1991 actions, the advocates of Columbia-Snake River flow measures requested that the Corps prepare the environmental documentation. necessary to address such actions for the 1992 migration. The Corps began the internal scoping process in April 1991, identifying the potential actions that could be considered and the likely types of associated impacts. The Corps also initiated a series of coordination meetings with BPA and BoR staff, as well as with other federal and state resource agencies.

Further coordination of early scoping for the OA/EIS was conducted through a series of three formal meetings on development of a test protocol for a 1992 reservoir drawdown. These meetings were held on April 5 in Lewiston, Idaho; April 12 in Kennewick, Washington; and April 18 in Portland, Oregon. These meetings were incorporated within planning sessions among Salmon Summit participants (participants included the broad spectrum of river user and resource management interests). Corps staff presented their preliminary scoping materials and requested input on the nature and scope of actions to consider for 1992, and the types of testing and monitoring results desired for inclusion in these actions. Following the test protocol development meetings, the cooperating agencies entered further planning discussions and prepared for the formal scoping process.

A Notice of Intent to conduct the OA/EIS was published in the Federal Register on May 10, 1991. This was followed by distribution of the scoping letters and media announcements of the scoping meetings.

The preliminary draft version of the OA/EIS was prepared by August 10, 1991. The preliminary draft was circulated among a team of approximately 50 technical reviewers from BPA, BoR, and the Corps (at the Walla Walla District, Portland District, North Pacific Division, and Washington D.C. Headquarters levels). It was also reviewed by staff from the State and Regional offices of the U.S. Fish and Wildlife Service. Comments and suggestions made by the agency review team were then incorporated into the draft OA/EIS, which was issued on September 27, 1991.

The preliminary final version of this OA/EIS, which incorporated the comments received during the 50-day review of the draft OA/EIS, was sent to a team of approximately 50 technical reviewers from BPA, BoR, and the Corps (at the Walla Walla District, Portland District, North Pacific Division, and office of the Chief Engineer in Washington D.C.) on December 13, 1991. It was also reviewed by staff from the State and Regional offices of the U.S. Fish and Wildlife Service, and staff from the National Marine Fisheries Service. Comments and suggestions made by the agency review team were then incorporated into this final OA/EIS, officially issued January 2, 1992.

## 6.4.2 Other Agencies

Although the Corps, BoR, and BPA are the three cooperating agencies responsible for developing the OA/EIS, input was sought and considered from all agencies responsible for or affected by river management practices. These other agencies were encouraged to participate by submitting scoping comments and any information that would be helpful in developing the OA/EIS and by reviewing and commenting on the draft OA/EIS.

It should be noted that one of the most frequent scoping comments received from members of the public was a suggestion to include both FWS and NMFS as cooperating agencies. In fact, the Corps had numerous discussions with the FWS regarding possible cooperating agency status. Because of the short time frame and the substantial amount of resources necessary to complete this OA/EIS, FWS concluded it could not assume such a substantive role but would participate in a less extensive role than as a full cooperating agency. Because NMFS is responsible for the decision about listing the salmon stocks, the agency must be an impartial reviewer of the OA/EIS. Therefore, it could have been considered a conflict of interest for NMFS to be a cooperating agency.

The Corps continued the agency coordination process throughout the development of the OA/EIS. The scoping letters invited comment from all responsible agencies regarding what to address in the OA/EIS. Approximately 23 agencies responded by providing verbal comment at the scoping meetings and/or submitting written comments. Agencies and elected officials that provided scoping comment included:

- National Park Service, Coulee Dam National Recreation Area
- U.S. Fish and Wildlife Service, Pacific Northwest Region
- U.S. Forest Service, Hells Canyon National Recreation Area
- U.S. Representative Richard Stallings
- U.S. Senator Steve Symms
- Colville Confederated Tribes
- Idaho Department of Fish & Game
- Idaho Office of the Attorney General
- Idaho State Representative Charles Cuddy
- Idaho State Senator Karl Brooks
- Montana Office of the Governor
- Oregon State Marine Board
- Oregon State Senator Scott Duff
- Washington State Department of Transportation, District 5
- Wyoming Game and Fish Department
- Arlington Chamber of Commerce
- Benton County Public Utility District
- Franklin County Public Utility District
- City of Kennewick
- Madison County Office of the Sheriff
- Minidoka County Board of Commissioners
- Okanogan County Commissioners Office
- Orofino Chamber of Commerce

During the 50-day review period on the draft OA/EIS, approximately 40 agencies, elected officials, and tribal organizations provided verbal or written comment on the document. For a comprehensive list, see Appendix N.

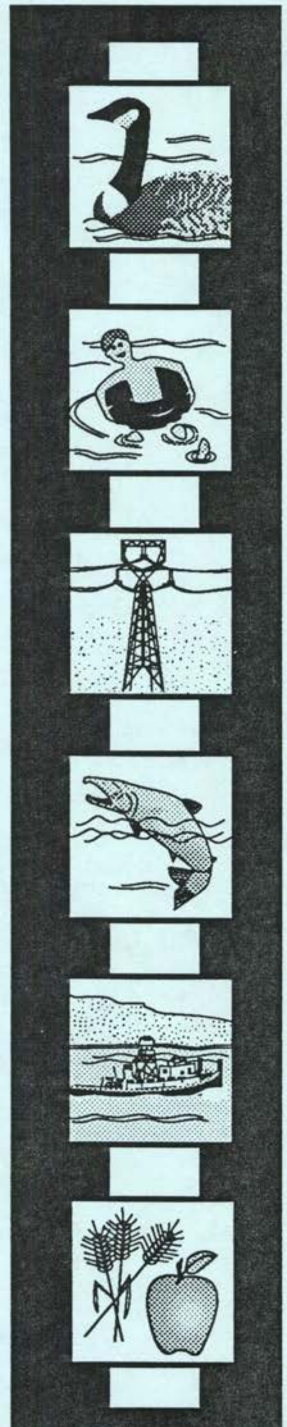
In addition, the Corps, BPA, and BoR conducted extensive coordination by telephone and meetings. These contacts occurred throughout the OA/EIS process and are too numerous to catalog. They involved both policy-level discussions concerning proposed alternatives and their implementation, and requests for specific information needed for the OA/EIS. Participants in these contacts included the full spectrum of agencies and officials described above, plus a variety of organizations representing river users and other interested parties.

### 6.4.3 Future Agency Coordination

After the final OA/EIS has been issued, a ROD, documenting actions to be taken in 1992, is scheduled to be signed February 14, 1992. Coordination with agencies and the public will continue up to and beyond the issuance of the ROD.

# 7.0

# Schedule



# 1992 COLUMBIA RIVER SALMON FLOW MEASURES
# OA/EIS

## CONTENTS



## TABLES

# 7.0 SCHEDULE

To produce a ROD in time for NMFS to consider when making decisions regarding actions to accompany the Endangered Species Act listing of the Snake River sockeye salmon and proposed listings of the salmon stocks, the 1992 Columbia River Salmon Flow Measures OA/EIS is being developed on an accelerated schedule. The EIS process officially began on May 10, 1991 when the Corps announced the EIS with a Notice of Intent published in the Federal Register. The cooperating agencies then began the process of collecting information and data to be included in the study. A preliminary draft OA/EIS was written and distributed to various agencies for an initial review. Agency comments were incorporated into the document, and the draft OA/EIS was sent to the EPA and the public for official review. A 50-day public comment period was held on the draft OA/EIS, during which time the public and agencies were invited to comment on the contents of the draft document. These comments were incorporated into the final OA/EIS. Like the draft OA/EIS, a preliminary final OA/EIS was first circulated for initial agency review. After release of the final OA/EIS, a 15-day public review period will be held. Two public information meetings, one in Washington and one in Idaho, are scheduled to answer questions and provide more detail on the preferred plan. The ROD, the final step in the EIS process, is scheduled to be signed on February 14, 1992.

Major milestones of this schedule, including public involvement and agency coordination events that are discussed in Section 5.0, are presented in Table 7-1.

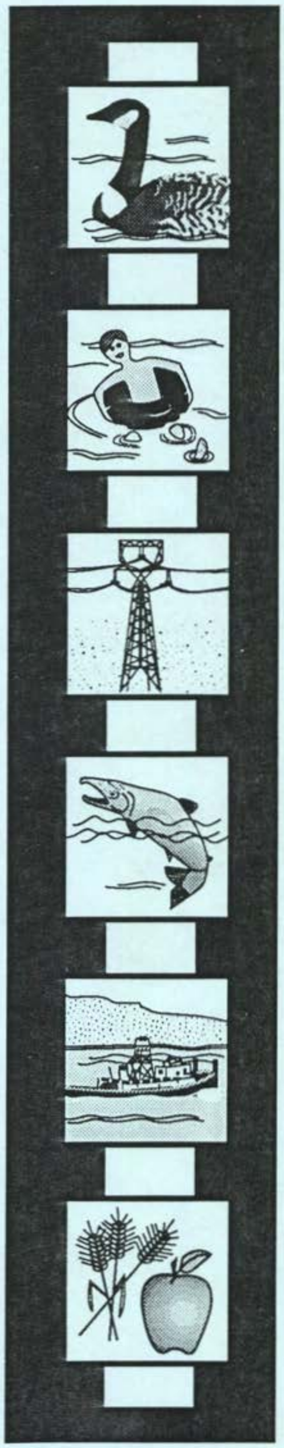
# 7 SCHEDULE

Table 7-1. Major milestones of the EIS schedule

| Date | Milestone |
|---|---|
| *1991* | |
| 10 May | Notice of Intent published in the Federal Register |
| 13 May | Begin Data/Information Collection |
| 3—11 June | Public Scoping Meetings (held in Lewiston, Orofino, Boise ID; Pasco and Grand Coulee, WA; and Portland, OR) |
| 1 Aug | Complete Public Involvement Plan |
| 14 Aug | Preliminary draft OA/EIS available for concurrent agency review |
| Mid-Aug | Factsheet No. 1 is released |
| 28 Aug | Agency review of preliminary draft OA/EIS completed |
| 20 Sept | Draft OA/EIS sent to EPA |
| 27 Sept | Begin 50-day review of draft OA/EIS |
| Late Sept | Factsheet No. 2 is released |
| Mid-Oct | Public Meetings and Workshops |
| 15 Nov | End of 50-day review period |
| 13 Dec | Preliminary final OA/EIS available for concurrent agency review |
| 20 Dec | Agency review completed |
| *1992* | |
| Early Jan | Factsheet No. 3 is released |
| 15 Jan | Final OA/EIS sent to EPA |
| 28, 29 Jan | Public information meetings |
| 24 Jan | Begin 15-day review of final OA/EIS |
| 7 Feb | End of 15-day review period; Review need to modify Record of Decision |
| 14 February | Record of Decision on 1992 operations released |

# 8.0

# Compliance with Environmental Statutes



# 1992 COLUMBIA RIVER SALMON FLOW MEASURES
# OA/EIS

## CONTENTS

# 8.0 COMPLIANCE WITH APPLICABLE FEDERAL ENVIRONMENTAL STATUTES AND REGULATIONS

The following section is a discussion of Federal laws, regulations and orders that may apply to the proposed 1992 flow measures. The section is a preliminary review only; further analyses are continuing to confirm applicability of each law or regulation, and incorporate the impact conclusions for the respective resource areas. Final results of the analyses will be outlined in the draft EIS.

## 8.1 Reservoir Salvage Act

The Reservoir Salvage Act as amended in 1974 by the Archaeological and Historic Preservation Act provides for preservation of historical and archaeological data that might otherwise be irreparably lost or destroyed by flooding or alterations of terrain as a result of any Federal project.

## 8.2 National Historic Preservation Act

The National Historic Preservation Act requires that Federal agencies evaluate the effects of Federal undertakings on historical, archeological, and cultural resources, and consult with State Historic Preservation Officers (SHPO) regarding adverse cultural resources impacts.

The first step in the process is to identify cultural resources included on (or eligible for inclusion on) the National Register that are located in or near the project area. The second step is to identify the possible effects of proposed actions. The lead agency must examine whether feasible alternatives exist that would avoid such effects. If an effect cannot reasonably be avoided, measures must be taken to minimize or mitigate the potential effects.

Currently, sufficient information is not available for all cultural resource sites within the study area to determine if they are eligible for inclusion on the National Register. Implementation of any of the drawdown alternatives would impact cultural sites to varying degrees. Larger areas of sites will be exposed during low pool. Sites normally inundated may be exposed and subject to erosion and vandalism. Repeated cycles of exposure and inundation may result in accelerated decomposition of organic materials contained within sites. New reservoir operating conditions may require an accelerated program of site testing to determine National Register eligibility and increased mitigation efforts.

## 8.3 Executive Order 11593, Protection and Enhancement of the Cultural Environment

Order 11593 requires Federal agencies to inventory and nominate those cultural properties evaluated as significant for addition to the National Register. It further requires monitoring so as to maintain cultural properties, and administering such properties in spirit of "stewardship."

## 8.4 Clean Air Act

The Clean Air Act (CAA) regulates emissions into the air. Controls on stationary and mobile sources of emissions are implemented through combined Federal, State, and local programs. Pursuant to the CAA, EPA has promulgated National Ambient Air Quality Standards, National Emission Standards for Hazardous Air Pollutants, and New Source Performance Standards. The proposed action will result in discharge of particulate matter (fugitive dust) from dewatered reservoir bottoms, and may indirectly result in additional air emissions from thermal powerplants used to replace lost hydroelectric power.

## 8.5 Clean Water Act

The Clean Water Act sets national goals and policies to eliminate discharge of water pollutants into navigable waters, regulate discharge of toxic pollutants, and prohibit discharge of pollutants from point sources without permits. The Act also authorizes EPA to establish water quality criteria that are used by States to establish specific water quality standards.

Dissolved gas supersaturation associated with Corps dams in the Columbia-Snake River System has consistently exceeded the EPA criterion and the

Oregon and Washington State water quality standards of 110 percent saturation. However, the Corps does not consider the release of water from its dams as point sources of discharge but does everything practicable to meet state water quality standards.

The major water quality issues pertaining to the water release alternatives are increased dissolved gas saturation levels and higher water temperatures. The alternatives would cause further departure from required water quality levels. A larger volume of water spilled at the dams, over a longer time would result in gas saturation values near to or above 120 percent. There will also be localized water quality changes because of exposed sewer outfalls, as well as changes in mixing zone characteristics. Water temperature increases in the pools of the lower Columbia River dams would increase to near maximum recorded levels.

## 8.6 ENDANGERED SPECIES ACT

The Endangered Species Act (ESA) of 1973 provides a means for conserving various species of fish, wildlife, and plants that are threatened with extinction. Section 7(a) of the ESA requires Federal agencies, in consultation with the DOI and the NMFS, as appropriate, to ensure that the actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their critical habitats. Actions that might jeopardize listed species include direct and indirect effects, as well as the cumulative effects of other actions.

Federal regulations on endangered species coordination (50 CFR 402.12) also require that Federal agencies prepare biological assessments of the potential effects of major construction actions on listed or proposed endangered species and critical habitat.

Two threatened and endangered species under the purview of the FWS are expected to occur in the vicinity of most of the potentially affected projects. Specifically, resident and migrant peregrine falcons and bald eagles are known to inhabit in the area of these projects. Project-related impacts to peregrine falcons are not expected because there is a substantial and diverse prey base for peregrine falcons to forage upon. Evaluations of impacts on other portions of the system are continuing.

The proposed action, itself, is in response to proposed listing of several salmon stocks under the ESA. Major portions of the EIS address the various positive and negative potential effects on these fish from the flow measures under consideration.

## 8.7 FISH AND WILDLIFE COORDINATION ACT

The Act authorizes DOI to provide assistance to and cooperate with Federal, State, and public or private agencies and organizations in the development, protection, rearing and stocking of all species of wildlife resources and their habitat and in controlling losses from disease or other causes. Consultation is required with FWS when any waterbody is controlled or modified for any purpose. FWS surveys and investigations must be made a part of any report or engineering survey that is prepared. Federal agencies authorized to construct or operate water-control projects are authorized to modify or add to the structure and operation of those projects in order to accommodate the means and measures for conservation of fish and wildlife.

Operation of the pools at lower levels will reduce the amount of shallow-water habitat. Shallow-water habitat is important for spawning and rearing for a number of resident fish species, and their spawning success may be reduced. Additional impacts on vegetation and wildlife are outlined in the EIS. The Corps is consulting with FWS regarding implementation of the proposed measures. The two agencies agreed that the FWS would be a participating agency in the EIS process, but that preparation of a formal coordination Act report by the FWS would not be feasible under the circumstances.

## 8.8 NATIONAL ENVIRONMENTAL POLICY ACT

The National Environmental Policy Act provides a commitment to conduct Federal activities in a manner that protects the environment and requires that an EIS be included in every recommendation or report on proposals for legislation and other major federal actions significantly affecting the quality of the human environment. Development of this EIS document meets NEPA requirements for the proposed action.

## 8.9 EXECUTIVE ORDER 11988, FLOODPLAIN MANAGEMENT

Executive Order 11988 requires Federal agencies to evaluate the potential effects of any actions it may take in a floodplain to ensure that its planning programs and budget request reflects consideration of flood hazards and floodplain management. Alternatives to those actions must be considered to avoid adverse effects in the floodplain or to minimize potential harm.

The real and potential impacts of the flow measures under consideration on flood control capability are considered negligible. Flood storage capacity at some upstream reservoirs could be diminished with flow augmentation measures, but this capacity would be shifted elsewhere to maintain overall system flood control capacity. Further, flood storage shifts would only be implemented if projected runoff were relatively low, in which case the risk of flooding would also be reduced. Reservoir drawdown would, if anything, enhance the flood control capacity of the system during the time of drawdown. However, further study is underway to confirm these conclusions.

## 8.10 EXECUTIVE ORDER 11990, PROTECTION OF WETLANDS

Executive Order 11990 authorizes Federal agencies to take actions to minimize the destruction, loss or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands when undertaking Federal activities and programs. All new construction in wetlands must be avoided.

Emergent wetlands communities are prevalent in several areas under study. Should these wetlands depend upon full pool levels for water supply, either through subirrigation or shallow inundation, they could be expected to be lost or species composition to be altered. Mudflats may also be exposed.

## 8.11 FEDERAL WATER PROJECT RECREATION ACT

In the planning of any Federal navigation, flood control, reclamation or water resource project, the Federal Water Project Recreation Act requires that full consideration be given to the opportunities, which the project affords for outdoor recreation and fish and wildlife enhancement. The Act requires planning with respect to development of recreation potential. Projects must be constructed, maintained and operated in such a manner if recreational opportunities are consistent with the purpose of the project.

Recreation sites have been developed at all of the Federal projects involved in the proposed action and are operated by a variety of entities. Developed facilities and informal use areas at these projects could experience minimal to significant impacts from reservoir drawdown, depending upon the drawdown alternative. Specific types of impacts could include dewatering boat ramps, docks, marinas, and swimming beaches. Water-oriented campgrounds and day-use areas could become less desirable because of exposed shoreline and increased distance to water. Similar impacts could occur at upstream storage reservoirs as a result of flow augmentation, which could cause reservoir elevations to be lower than under normal operation.

## 8.12 PACIFIC NORTHWEST ELECTRIC POWER PLANNING AND CONSERVATION ACT

The Northwest Power Act was passed by Congress on December 5, 1980. This law created the eight-member NPPC. The Council was entrusted with adopting a Fish and Wildlife Program for the Columbia River Basin by November 1982 and preparing a 20-year Regional Electric Power and Conservation Plan by April 1983. The plans are periodically updated.

The Council's Fish and Wildlife Program established a number of goals for restoring and protecting fish populations in the basin. These goals have led to changes in how the Coordinated Columbia River System is operated. One of the most notable changes is the Water Budget, which provides for the release of specific amounts of water in the upper Columbia River and on the Snake River to help the juvenile salmon migrate downstream in the spring.

Both reservoir drawdown and flow augmentation would temporarily reduce the power generation capability of the affected projects. As a short-term action, the proposed 1992 flow measures would not have a direct bearing on the NPPC's regional power plan. Nevertheless, the cooperating agencies are coordinating with the NPPC regarding the power generation implications of the proposed action.

The Act also directs the NPPC to provide fish and wildlife resources with equitable treatment in the operation of the river system and to prepare a program to manage and protect fish and wildlife resources. Through its Fish and Wildlife Program activities, the NPPC is developing its own proposals to protect the threatened and endangered salmon stocks. The cooperating agencies have also been coordinating with the NPPC to better integrate the proposed flow measures with the NPPC process for priority salmon actions.

## 8.13 CEQ MEMORANDUM, AUGUST 11, 1990, ANALYSIS OF IMPACTS ON PRIME OR UNIQUE AGRICULTURAL LANDS IN IMPLEMENTING NEPA

The CEO Memorandum establishes criteria to identify and take into account the adverse effects of Federal programs on the preservation of prime and unique farmland, to consider alternative actions, as appropriate, that could lessen adverse effect, and to ensure the programs are consistent with all state and local programs for protection of farmland. The proposed actions were determined not to have a direct impact on prime or unique agricultural lands; direct impacts would be confined to the reservoirs. Reservoir drawdown could temporarily interrupt the supply of water to irrigated prime farmlands, but this interruption would not displace or diminish the productive capacity of these lands.

## 8.14 COASTAL ZONE MANAGEMENT ACT

Federal agencies conducting or supporting activities directly affecting the coastal zone must conduct or support those activities in a manner that is consistent with approved State coastal zone management programs. A State coastal zone management program (developed under State law and guided by the Act) sets forth objectives, policies and standards to guide public and private uses of lands and waters in the coastal zone. The coastal zone as defined in the Act extends inland to the extent necessary to control shorelines.

Washington and Oregon have approved coastal management programs, both of which list seven types of Federal activities directly affecting the coastal zone. The proposed actions appear to have minimal or no effect on water levels or use downstream of Bonneville Dam, which is the upstream extent of the coastal zone.

## 8.15 ESTUARY PROTECTION ACT

The purpose of the Act is to establish a program to protect, conserve, and restore estuaries. It includes provisions to Federally manage estuarine areas in coordination with States and requires that all Federal projects consider impacts on estuarine areas. The Act does not effect an Agency's authority for existing programs within an estuary. The impact of the proposed action on the Columbia River estuaries is currently under review, but the impact appears to be minimal or nonexistent.

## 8.16 LAND AND WATER CONSERVATION FUND ACT

The Land and Water Conservation Fund Act assists in preserving, developing and ensuring accessibility of outdoor recreation resources. The Act establishes specific Federal funding for acquisition, development, and preservation and grants to states and localities. Numerous recreation sites and public land parcels along the affected projects have been acquired or developed with LWCF monies. Maintenance and use of these resources could be temporarily impaired by the proposed actions, but the intended uses would not be precluded or displaced on a long-term basis.

## 8.17 MARINE, PROTECTION, RESEARCH AND SANCTUARIES ACT

The Marine, Protection, Research and Sanctuaries Act regulates dumping of material into the ocean and prevents or strictly limits the dumping of any material that would adversely affect human health, welfare, the marine environment, ecological systems or economic potentialities. As the Corps action will not result in the dumping of material into the ocean, the Act does not apply.

## 8.18 RIVER AND HARBORS ACT

The River and Harbors Act prohibits constructing bridges, dams, dikes or causeways over harbors or navigable waters of the United States without approval of the Corps. The act also prohibits any obstruction to the navigable capacity of any waters of the United States.

Under the alternatives being considered, the impacts on commercial (barge) navigation will vary with the degree of reservoir drawdown. Some difficulty in navigation could be encountered with reservoir drawdown to minimum pool levels, because of localized sediment accumulation. Reservoir drawdown to levels much below minimum pool would completely interrupt commercial navigation on the lower Snake River from approximately 1.5 to 6 months.

## 8.19 WATERSHED PROTECTION AND FLOOD PROTECTION ACT

The purpose of the Watershed Protection and Flood Protection Act is to protect watersheds from erosion, floodwater and sediment damages. It provides assistance programs to local organizations to conduct investigations and surveys, prepare plans and estimates, develop soil and water conservation practices and install improvement works for protection of watersheds. The proposed alternatives do not appear to violate any watershed protection requirements.

## 8.20 WILD AND SCENIC RIVERS ACT

The Wild and Scenic Rivers Act establishes requirements applicable to water resource projects affecting wild, scenic or recreational rivers within the National Wild and Scenic Rivers System, as well as rivers designated on the National Rivers Inventory. Under the Act, a Federal agency may not assist the construction of a water resources project that would have a direct and adverse effect on the free-flowing, scenic and natural values of a wild or scenic river. If the project would affect the free-flowing characteristics of a designated river or unreasonably diminish the scenic, recreational, and fish and wildlife values present in the area, such activities should be undertaken in a manner that would minimize adverse impacts and should be developed in consultation with the NPS.

Several portions of the Snake River have been designated under the Wild and Scenic Rivers System. The Hells Canyon reach of the Snake is of primary interest, which is downstream of Brownlee reservoir. Flow augmentation options involving release of stored water from Brownlee would temporarily elevate flows in Hells Canyon over what would otherwise occur. However, these flow levels would be well within the range of regulated flows normally experienced in Hells Canyon. The Corps is coordinating with the U.S. Forest Service, which administers this reach of the river.

Several tributaries to the Snake and Columbia rivers have also been added to the Wild and Scenic Rivers System. These include portions of the Klickitat and White Salmon rivers in Washington and the Sandy, Deschutes, John Day, Grande Ronde, and Imnaha rivers in Oregon. The proposed actions would not adversely affect these protected resources.

## 8.21 NATIONAL WILDLIFE REFUGE SYSTEM ADMINISTRATION ACT

The primary purpose of the National Wildlife Refuge Administration Act is to consolidate various categories of wildlife ranges and refuges for management under one program. The Act provides protection for both wildlife and refuge lands from destruction and injury. The Act also provides authority for the regulation of hunting and fishing within refuge boundaries. The applicability of these requirements to the project are currently being evaluated.

## 8.22 COLUMBIA RIVER GORGE NATIONAL SCENIC AREA ACT

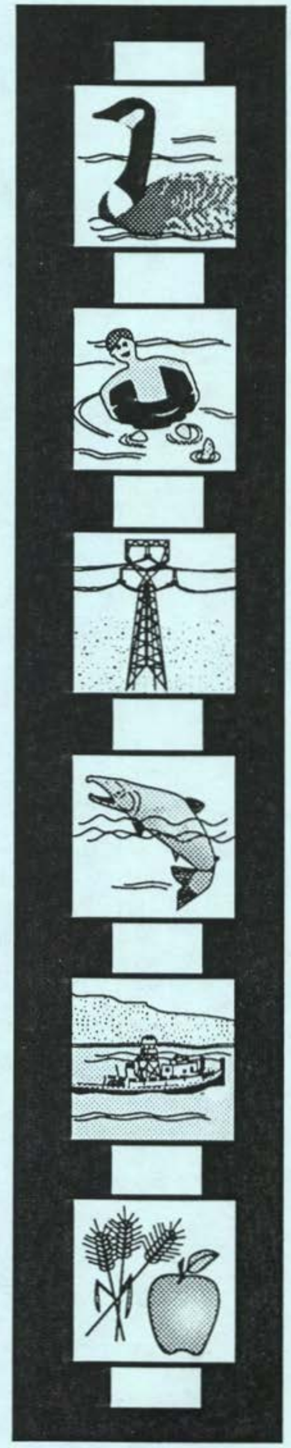
The Columbia River Gorge National Scenic Area (Scenic Area) was established as a Federally recognized and protected area by Congress on November 17, 1986, through Public Law (P.L.) 99-663. The Scenic Area Act also created the bi-state Columbia River Gorge Commission and directed the Commission and the U.S. Forest Service to jointly develop a management plan for the Scenic Area. The management plan will reflect legislatively established purposes, which include a mandate to protect and provide for the enhancement of the scenic, cultural, recreational, and natural resources of the Scenic Area. A draft management plan was released in October 1990; a final plan is still under review and has not yet been adopted. The proposed goals of the plan are broad and are not directly affected by the actions proposed for 1992 by the cooperating agencies.

## 8.23 STATE AND LOCAL PLANS AND LAWS

The CEQ regulations (40 CFR 1506.2) require consideration of the consistency of a proposed action with approved state and local plans and laws. Given the schedule demands for the EIS and the extremely large number of state and local jurisdictions within the study area, the cooperating agencies have not been able to review all of the individual plans and laws that may be applicable. Based on the orientation and typically limited applicability of state and local authorities to the Federal multi-purpose projects, the cooperating agencies assume the proposed actions would generally be consistent with state and local plans and laws. (Issues surrounding the applicability of state and local laws are currently under discussion.) However, the Corps is still discussing proposed actions with state and local governments.

# 9.0

# List of Preparers



1992 COLUMBIA RIVER SALMON FLOW MEASURES
OA/EIS

CONTENTS



TABLES

# 9.0 LIST OF PREPARERS

The 1992 Flow Measures OA/EIS was prepared by an interdisciplinary team consisting of the U.S. Army Corps of Engineers, the Bonneville Power Administration, and the Bureau of Reclamation. Ebasco Environmental, a consulting firm under contract to the Corps, helped the cooperating agency team in developing the OA/EIS. Ebasco was assisted by BST and Associates, operating as a subcontractor. In addition, information was provided by Don Chapman Consultants, Inc., regarding fisheries issues; Dr. David Bennett of the University of Idaho regarding resident fisheries issues; and Washington State University, Center for Northwest Anthropology, regarding archaeological research. Contributions by individual preparers were subject to revision during the internal review process.

Individuals responsible for preparing this OA/EIS are listed in Tables 9-1 to 9-6, organized by agency and consultant. Because of the number of people involved in coordinating this study, the information presented in these tables is limited to the names, education and years of experience, experience and expertise, and general roles these individuals had in developing the OA/EIS.

**Table 9-1.** List of preparers, U.S. Army Corps of Engineers, Walla Walla District.

| Name | Education/ Years of Experience | Experience and Expertise | Role in OA/EIS Preparation |
|---|---|---|---|
| Greg Graham<br>Civil Engineer | B.S. Civil Engineering<br>10 years | Civil engineering<br>Water resource planning | Project Manager |
| Teri Barila<br>Fisheries Biologist | M.S. Fisheries Management<br>10 years | Fisheries management<br>Fisheries biology | Flow survival,<br>Bypass<br>Transport |
| Jimmie Brown<br>Outdoor Recreation Planner | B.S. Landscape Archit.<br>23 years | Recreation planning<br>Landscape architecture | Recreation impacts |
| Jim Buck<br>Outdoor Recreation Planner | B.S. Recreation & Park Administration<br>13 years | Recreation planning | Recreation impacts |
| Paul Fredericks<br>Economist | M.A. Economics<br>27 years | Economics | Navigation |
| Dave Hurson<br>Fisheries Biologist | B.S. Fisheries<br>14 years | Fisheries biology | Fish bypass |
| John Leier<br>Archaeologist | M.A. Anthropology/ Archaeology<br>10 years | Archaeology<br>Cultural resources | Cultural resources |
| Mark Lindgren<br>Hydraulic Engineer | M.S. Civil Engineering<br>15 years | Hydraulic engineering | Fish passage<br>Spillway characteristics<br>Water quality |
| William MacDonald<br>Wildlife Biologist | B.S. Wildlife Biology<br>14 years | Wildlife biology<br>Wetlands ecology<br>Natural resources development and planning<br>Regulatory actions | OA/EIS management<br>Scoping |
| Peter Poolman<br>Outdoor Recreation Planner | B.S. Forest Mgmt.<br>13 years | Environmental resources coordination<br>Recreation planning<br>Resource management | Environmental coordination<br>Public involvement |
| David Reese<br>Hydraulic Engineer | M.S.Civil Engineering<br>18 years | Hydraulics | Water particle travel time and velocities |

**Table 9-1.** List of preparers, U.S. Army Corps of Engineers, Walla Walla District (continued).

| Name | Education/ Years of Experience | Experience and Expertise | Role in OA/EIS Preparation |
|---|---|---|---|
| Lynn Reese<br>Hydraulic Engineer | B.S. Civil Engineering<br>10 years | Hydraulic design<br>Hydraulic engineering | Fish passage<br>Spillway characteristics<br>Water quality |
| Sandy Shelin<br>Wildlife Biologist | B.S. Wildlife Science<br>12 years | Wildlife biology<br>Environmental resources | Environmental coordination |
| Darrel Sunday<br>Wildlife Biologist | B.S. Wildlife<br>17 years | Habitat restoration<br>Natural resource management | Wildlife impacts |
| Al Sutlick<br>Wildlife Biologist | B.S. Wildlife Biology<br>14 years | Wildlife biology<br>Range management<br>Native plant restoration | Wildlife resources |
| Gina Trafton<br>Economist | B.A. Economics<br>4 years | Agricultural economics | Irrigation<br>Socioeconomics |
| Richard Weller<br>Civil Engineer | M.S. Civil Engineering<br>22 years | Soil mechanics<br>Geotechnical engineering | Geotechnical engineering |
| Sarah Wik<br>Fisheries Biologist | M.S. Environmental Science<br>B.S. Biology<br>11 years | Fisheries management<br>Fisheries biology<br>Water quality<br>Limnology | Water quality<br>Fisheries |

**Table 9-2.** List of preparers, U.S. Army Corps of Engineers, Portland District.

| Name | Education/ Years of Experience | Experience and Expertise | Role in OA/EIS Preparation |
|---|---|---|---|
| Richard A. Cassidy<br>Environmental Engineer | B.A. Biology<br>M.S. Zoology<br>M.S. Env. Engineering<br>21 years | Aquatic biology<br>Hydraulic engineering<br>Environmental engineering | Water quality<br>Reservoir regulation |
| Geoff Dorsey<br>Wildlife Biologist | M.S. Wildlife Science<br>B.S. Wildlife Science<br>11 years | Wildlife science<br>Wildlife biology | Wildlife resources |
| Bruce Duffe<br>Hydraulic Engineer | M.S. Env. Engineering<br>B.S. Civil Engineering<br>15 years | Hydrology | General hydraulics |
| John Ferguson<br>Fisheries Biologist | M.S. Aquatic Ecology<br>B.S. Fish & Wildlife Biology<br>15 years | Fisheries | Anadromous fish<br>Flow survival<br>Turbine passage |
| Philip L. Grubaugh<br>Geotechnical Engineer | B.A. Geology<br>38 years | Geology<br>Geotechnical engineering | Geology<br>Geotechnical engineering<br>Foundation/materials<br>Groundwater |
| L. D. Hamilton<br>Environmental Specialist | M.A. Geography/Biology<br>B.A. Geography<br>17 years | OA/EIS coordination, writing, editing<br>Biology<br>Community planning<br>Outdoor recreation planning | Team leader<br>OA/EIS coordination<br>In-lieu fishing |
| Laura L. Hicks<br>Hydraulic Engineer | B.S. Civil Engineering<br>10 years | Navigation/planning studies | Navigation<br>Irrigation |
| Joseph Hise<br>Economist | M.A. Economics<br>B.S. Economics<br>20 years | Regional economics | Socioeconomics |
| Gary A. Johnson<br>Fisheries Biologist | B.S. Zoology<br>18 years | Fisheries biology | Adult/juvenile passage<br>Mitigation<br>Propagation |
| Kim W. Larson<br>Fisheries Biologist | M.S. Fisheries<br>B.S. Zoology<br>18 years | Fisheries biology | Resident fish<br>Predation<br>Juvenile migration |

**Table 9-2.** List of preparers, U.S. Army Corps of Engineers, Portland District (continued).

| Name | Education/ Years of Experience | Experience and Expertise | Role in OA/EIS Preparation |
|---|---|---|---|
| Ed Magner<br>Hydraulic Engineer | M.S. Civil Engineering<br>B.S. Civil Engineering<br>17 years | Hydraulic design<br>Hydraulic performance mathematics | Projects design review<br>Analysis of hydraulic impacts |
| Robert Peak<br>Geographer | M.A. Geography<br>B.A. Geography<br>15 years | Photogrammetry<br>Surveying<br>GIS/remote sensing | GIS<br>Remote sensing<br>Survey and mapping |
| Rock Peters<br>Fisheries Biologist | B.S. Wildlife Science<br>13 years | Fisheries biology | Anadromous fish<br>Juvenile fish<br>Hatcheries |
| Matthew Rea<br>Outdoor Recreation Planner | B.S. Outdoor Recreation Planning<br>12 years | Recreation planning<br>Master planning | Recreation |
| Steven J. Stevens<br>Landscape Architect | B.S. Landscape Architecture<br>20 years | OA/EIS preparation<br>Planning studies | OA/EIS scope<br>Review |
| James Stow<br>Hydraulic Engineer | B.S. Civil Engineering<br>12 years | Hydraulic design<br>Design of lock and dams | Hydraulic impacts |
| Jay Sturgill<br>Physical Scientist | B.S. Geology<br>25 years | Geotechnical design<br>Environmental assessment | Geology and soils |
| Lynda Walker<br>Archaeologist | M.A. Anthropology<br>B.S. Anthropology<br>16 years | Archaeology<br>Outdoor recreation planning | Cultural resources |
| Robert E. Willis<br>Biologist | M.S. Biology<br>B.S. Biology<br>16 years | Fish and wildlife biology | Supervisor,<br>Fish and wildlife<br>Cultural resources |
| Nancy Yun<br>Civil Engineer | B.S. Engineering<br>10 years | Planning studies | Draft OA/EIS<br>Study management |

**Table 9-3.** List of preparers, Bonneville Power Administration.

| Name | Education/ Years of Experience | Experience and Expertise | Role in OA/EIS Preparation |
|---|---|---|---|
| Thomas Morse<br>Public Utilities Specialist | Ph.D. Ecology<br>M.S. Wildlife Management<br>B.S. Wildlife Management<br>25 years | Terrestrial Ecology<br>Project management & coordination | OA/EIS Manager |
| Carolyn Davey<br>Public Utilities Specialist | B.A. Planning, Public Policy<br>1 year | Public utilities<br>Planning | Planning |
| Dan Daley<br>Fisheries Biologist | M.S. Fisheries Biology<br>B.S. Fisheries Biology<br>13 years | Fisheries biology<br>Resident fish | Resident fish |
| Paul Ferron<br>Electrical Engineer | B.S. Electrical Engineering<br>Physiology<br>9 years | Electrical engineering<br>Physiology | Electric power |
| Carlene Fleskes<br>Public Utilities Assistant | 7 years | Public involvement<br>Report preparation | Planning |
| William Gordon<br>Hydraulic Engineer | B.S. Civil Engineering<br>30 years | Hydraulic engineering | Power system coordinator |
| Robert Neal<br>Civil Engineer | B.S. Physics<br>13 years | Civil engineering | Power effects |
| Audrey Perino<br>Industry Economics | M.A. Economics<br>B.A. Mathematics<br>13 years | Economics<br>Project management & coordination | Power effects |
| Terry Thompson<br>Electrical Engineer | B.S. Electrical Engineering<br>24 years | Electrical engineering | Power effects |

**Table 9-4.** List of preparers, Bureau of Reclamation.

| Name | Education/ Years of Experience | Experience and Expertise | Role in OA/EIS Preparation |
|---|---|---|---|
| Ronald McKown<br>Environmental Compliance and Study Manager | Ph.D. Speciation<br>M.S. Biology/Agriculture<br>B.S. Biology/Agriculture<br>22 years | Environmental compliance studies<br>Biological studies | OA/EIS coordination |
| Douglas James<br>Environmental Officer | B.A. Sociology<br>29 years | Urban planning<br>Demography | Agency input |

Table 9-5. List of preparers, Ebasco Environmental (consultant).

| Name | Education/ Years of Experience | Experience and Expertise | Role in OA/EIS Preparation |
|---|---|---|---|
| Chris Lawson<br>Resource Planner | M.A. Geography<br>B.S. Geography<br>11 years | Multidisciplinary environmental studies<br>Hydroelectric operations<br>Environmental assessments<br>Regulations | Project Manager |
| Judith Schneider<br>Communications Specialist | B.A. English/History<br>22 years | Public involvement<br>Communications<br>Project management | Assistant<br>Project Manager |
| Kay Amundson<br>Graphic Artist | 4 years | Graphic design<br>Computer-generated graphics<br>Desktop publishing | Graphics |
| Alan Carpenter<br>Air Quality Specialist | M.S.E. Env. Eng<br>M.S. Nuclear Physics<br>B.S. Physics/Math<br>16 years | Air pollution control<br>Solid waste management | Air quality |
| Peter Carr<br>Public Involvement Specialist | B.S. Journalism<br>3 years | Public involvement<br>Technical editing and writing | Agency coordination/<br>Public involvement |
| Dominick DellaSala<br>Wildlife Biologist | Ph.D. Wildlife Mgt<br>M.S. Ecology<br>B.S. Biology<br>12 years | Wildlife & endangered species management<br>Wildlife habitat relationships | Terrestrial Ecology |
| Kate Engel<br>Wildlife Biologist | M.S. Wildlife Ecology<br>B.S. Wildlife Science<br>12 years | Avian ecology<br>Terrestrial ecology<br>Wildlife/human conflicts | Terrestrial Ecology |
| George Faison<br>Regulatory Analyst | M.PA. Environ. Mgt<br>B.A. Political Science<br>13 years | Regulatory analysis<br>Policy evaluation | Compliance with<br>regulations |
| Irene Gilbertson<br>Economist | M.A. Economics<br>B.S. Economics<br>3 years | Natural resource economics<br>Environmental economics<br>Policy analysis | Socioeconomics |

**Table 9-5.** List of preparers, Ebasco Environmental (continued).

| Name | Education/ Years of Experience | Experience and Expertise | Role in OA/EIS Preparation |
|---|---|---|---|
| Domoni Glass<br>Fisheries Biologist | B.S. Fisheries Biology<br>11 years | Fisheries management<br>Fisheries biology | Resident Fish |
| Mark Greenig<br>Landscape Resource Planner | M.U.P. Urban Planning<br>B.S. Landscape Arch.<br>10 years | Visual resources<br>Recreation planning & design<br>Site planning & design | Principal Author<br>Recreation & Aesthetics |
| Ellen Hall<br>Economist | Ph.D. Forest Ecology<br>M.Ag. Agricultural Economics<br>B.A. History/Economics<br>16 years | Natural resources and economic analysis<br>Energy planning and development | Agriculture |
| Coreen Johnson-Dean<br>Technical Editor | B.A. English<br>2 years | Technical writing and editing<br>Document production | Lead Editor<br>Document Production Manager |
| Roger Kadeg<br>Water Quality Specialist | M.S.E. Env. Engineering<br>M.S. Analytical Chemistry<br>B.S. Physics<br>14 years | Water quality<br>Environmental chemistry<br>Wastewater engineering<br>Solid and hazardous waste management | Water Quality |
| John Knutzen<br>Aquatic Scientist | M.S. Fisheries<br>B.S. Biology<br>12 years | Aquatic resources<br>Water quality<br>Fisheries | Anadromous Fish |
| Fred Minagar, P.E.<br>Project Manager<br>Transportation Services | B.S. Civil Engineering<br>M.S. Transport. Engineering<br>10 years | Traffic engineering<br>Transportation planning<br>Computer modeling<br>Highway financing | Transportation |
| Stacie Morgan<br>Technical Editor | B.A. Tech. Communication<br>1 year | Technical editing<br>Document production | Technical editor |
| Jack Mowreader, P.E.<br>Consulting Engineer | B.S. Civil Engineering<br>19 years | Civil engineering<br>Water resource projects<br>Environmental services | Project Director<br>Senior review |
| Greg Poremba<br>Socioeconomics Specialist | Ph.D. Sociology<br>M.A. Sociology/Statistics<br>B.A. Sociology/Anthro<br>12 years | Sociology<br>Demographics<br>Regulations<br>Recreation and land use | Socioeconomics |

Table 9-5. List of preparers, Ebasco Environmental (continued).

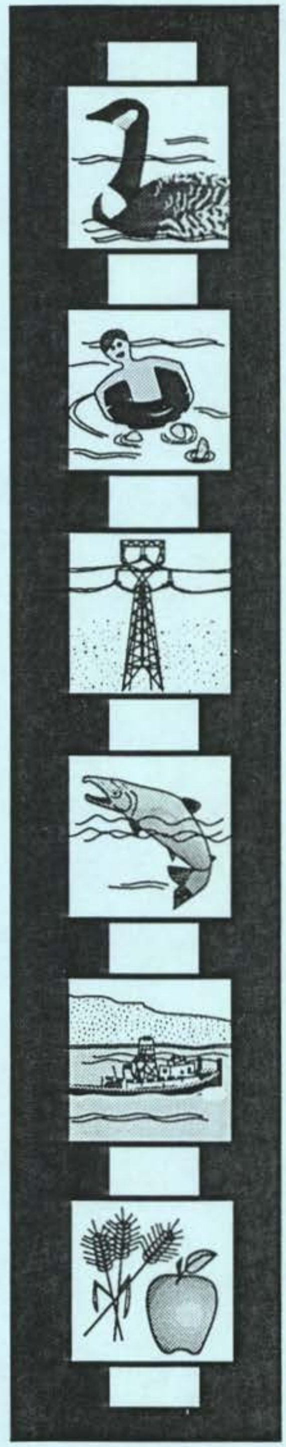
| Name | Education/ Years of Experience | Experience and Expertise | Role in OA/EIS Preparation |
|---|---|---|---|
| Tim Richards<br>Graphic Artist | 17 years | Graphic design/production<br>Computer-generated graphics<br>Illustration<br>Architectural design | Graphics, Illustrations |
| William Shaffer, P.E.<br>Environmental Engineer | M.B.A.<br>B.S. Env. Engineering<br>14 years | Water resource engineering<br>Hydroelectric operations and Evaluation<br>Hydrology<br>Environmental assessments | Reservoir Regulation |
| Tom Stewart<br>Geomorphologist | Ph.D. Physical Geography<br>M.S. Physical Geography<br>B.A. Physical Geography<br>12 years | Geology<br>Sedimentology<br>Hydrology<br>Environmental geology | Geology and Soils |
| Danene Warnock<br>Graphic Artist | B.A. Anthropology<br>13 years | Graphic design<br>Computer-generated graphics<br>Desktop publishing | Graphics |
| Tracey Wegehaupt<br>Risk Assessment Specialist | B.S. Chemical Engineering<br>3 years | Risk assessment<br>Chemical engineering | Toxics and Disease Organisms |
| Laurence Wright, T.E.<br>Transportation Engineer | M.S. Transport. Engineering<br>B.A. Public Admin. & Plan.<br>20 years | Transportation engineering<br>Transportation/travel planning<br>Traffic operations | Transportation |

Table 9-6. List of preparers, BST Associates (consultant).

| Name | Education/ Years of Experience | Experience and Expertise | Role in OA/EIS Preparation |
|---|---|---|---|
| Paul Sorensen<br>Principal | M.A. Economics<br>B.A. Economics | Waterfront planning and development<br>Economic assessment | Transportation |
| Brian Winningham<br>Economic Research | B.A. Business<br>B.A. Economics | Economic research<br>Economic modeling<br>OA/EIS preparation | Transportation |

# 10.0

# Distribution List



1991 COLUMBIA RIVER SALMON FLOW MEASURES
OA/EIS

CONTENTS

# 10.0 DISTRIBUTION LIST

The Columbia River Salmon Flow Measures final OA/EIS is being distributed to a variety of parties, including elected officials at the local, State, and Federal levels; tribal organizations; State, Regional, and Federal agencies; an array of special interest group organizations; academic institutions; and interested individuals. The document is also being sent to libraries located throughout the affected project area. Because operation of the Columbia-Snake River System has substantial regional impacts, a large number of people have indicated an interest in reading the document. As of this writing, approximately 900 copies of the document are being printed for distribution. In addition, many people who are not on the mailing list specifically for the final OA/EIS will be sent a copy of the Executive Summary.

In compliance with regulations established by the Council on Environmental Quality, officials, agencies, organizations, and individuals receiving the OA/EIS are listed below. Because of the evolving nature of the distribution list, other parties not listed below will also receive the document.

Honorable Larry E. Craig
United States Senate

Honorable Larry E. Craig
United States Senate

Honorable Larry Craig
United States Senate

Honorable Larry Craig
United States Senate

Honorable Larry Craig
United States Senate

Honorable Larry LaRocco
U.S. House of Representatives

Honorable Steven D. Symms
United States Senate

Honorable Steven D. Symms
United States Senate

Honorable Steven D. Symms
United States Senate

Honorable Mark O. Hatfield
United States Senate

Honorable Mark O. Hatfield
United States Senate

Honorable Mark Hatfield
United States Senate

Honorable Bob Packwood
United States Senate

Honorable Bob Packwood
United States Senate

Honorable Brock Adams
United States Senate

Honorable Brock Adams
United States Senate

Honorable Brock Adams
United States Senate

Honorable Slade Gorton
United States Senate

Honorable Slade Gorton
United States Senate

Honorable G. Edward Dickey

Honorable Slade Gorton
United States Senate

Honorable Thomas S. Foley
U.S. House of Representatives

Honorable Thomas S. Foley
U.S. House of Representatives

Honorable Thomas S. Foley
U.S. House of Representatives

Honorable Sid Morrison
U.S. House of Representatives

Honorable Sid Morrison
U.S. House of Representatives

Honorable Norman D. Dicks
U.S. House of Representatives

Honorable Norman D. Dicks
U.S. House of Representatives

Honorable Larry LaRocco
U.S. House of Representatives

Honorable Sid Morrison
U.S. House of Representatives

Honorable Richard Stallings
U.S. House of Representatives

Honorable Richard Stallings
U.S. House of Representatives

Honorable Richard Stallings
U.S. House of Representatives

Honorable Richard Stallings
U.S. House of Representatives

Honorable Ron Wyden
U.S. House of Representatives

Honorable Max Baucus
United States Senate

Honorable Max Baucus
United States Senate

Honorable Conrad Burns
United States Senate

Honorable Conrad Burns
United States Senate

Honorable Malcom Wallop
United States Senate

Honorable Alan K. Simpson
United States Senate

Honorable Craig Thomas
U.S. House of Representatives

Honorable Pat Williams
U.S. House of Representatives

Honorable Ron Marlenee
U.S. House of Representatives

Honorable Malcom Wallop
United States Senate

Honorable Alan K. Simpson
United States Senate

Honorable Pat Williams
U.S. House of Representatives

Honorable Ron Marlenee
U.S. House of Representatives

# 10 Distribution List

Honorable Cecil D. Andrus
Governor of Idaho

Honorable Stan Stephens
Governor of Montana

Honorable Barbara Roberts
Governor of Oregon

Honorable Booth Gardner
Governor of Washington

Honorable Mike Sullivan
Governor of Wyoming

Benton County Treasurer

Clarkston Chamber of Commerce

Charles B. Long
Mayor of Bingen

Skamania County Chamber of Commerce

Agricultural Stabilization & Conservation Service

Bureau of Indian Affairs

Bureau of Land Management

Bureau of Reclamation

Bureau. of Water & Power Div. of Energy & Res.

Columbia River Gorge Commission

Columbia River Intertribal Fish Commission

Colville Confederated Tribes Fish and Wildlife Department

Department of Commerce

Department of Health & Human Services

Department of Housing and Urban Devlop

Dept. of Housing and Urban Devlop.

Dept. of the Army North Pacific Div. Corps of Engineers

Dept. of the Army Portland Dist. Corps of Engineers

U.S. Army Corps of Engineers Walla Walla Dist.

Dept. of the Army USACE

Ecology & Conservation Office

DOl Highways

Federal Emergency Management Admin Region 10

Federal Emergency Management Admin.

Federal Energy Regulatory Commission

Federal Highway Admin.

Fish and Wildlife Subcommittee
Lake Roosevelt Forum

Government Accounting Office

Maurice Ellsworth & D. Marc Haws
U.S. Attorneys

National Marine Fisheries Service

National Oceanic & Atmospheric Admin

National Park Service

National Weather Service

Pacific Fishery Management Council

Pacific Northwest Utilities Conference Commit.

Public Power Council

Seattle District U.S. Army Corps of Engineers

Shoshone-Bannock Tribes Fort Hall Indian Reservation

Soil Conservation Service

U.S. Bureau of Mines

U.S. Coast Guard

U.S. Department of Energy

U.S. Department of Justice Lands and Natural Resources Division

U.S. Department of the Interior

U.S. Environmental Protection Agency

U.S. Environmental Protection Agency Region 1

U.S. Environmental Protection Agency Region 8

U.S. Fish and Wildlife Service

U.S. Forest Service

U.S. Geological Survey

U.S. House of Representatives
Merchant Marine & Fisheries Committee

Dept. of Horticulture & Landscape Arch.

Idaho Attorney General's Office

Idaho Consumer Affairs, Inc.

Idaho Cooperative Fishery Research Unit

Idaho Department of Agriculture

Idaho Department of Fish and Game

Idaho Department of Health and Welfare

Idaho Department of Parks and Recreation

Idaho Department of Transportation

Idaho Department of Water Resources

Idaho Division of Financial Management

Idaho State Historical Society

Idaho Water Resource Board

North Central District Health Dept. (Idaho)

North Central District Health Dept. (Idaho)

Montana Dept. of Fish, Wildlife, & Parks

Montana Dept. of Nat. Resources & Conserv.

Montana Governor's Office

Lt. Governor's Office (Montana)

Oregon Department of Agriculture

Oregon Department of Energy

Oregon Department of Environmental Quality

Oregon Department of Fish and Wildlife

Oregon Department of Fish and Wildlife

Oregon Department of Land Conservation and Development

Oregon Department of Parks & Recreation

Oregon Department of Transportation

Oregon Dept. of Environmental Quality

Oregon Dept. of Geology & Mineral Industries

Oregon Division of State Lands

Oregon Economic Development Department

Oregon Farm Bureau Federation

Oregon Natural Heritage Council

Oregon Public Utilities Commission

Oregon Salmon Commission

Oregon State Clearing House

Oregon State Historic Preservation Office

Oregon State Library

Oregon State Marine Board

Oregon Water Resources Commission

Oregon Water Resources Dept.

Intergovernmental Relations Div. (Oregon)

Washington Dept. of Agriculture

Washington Dept. of Ecology

Washington Dept. of Fisheries

Washington Dept. of Natural Resources

Washington Dept. of Trade

Washington Dept. of Transportation

Washington Dept. of Wildlife

Washington Energy Office

Washington Senate Committee Services

Washington St. Parks & Recreation Comm.

Washington State Potato Commission

Washington State University

Washington State Water Resources Assoc.

Washington Wilderness Coalition

Office of Archaeology and Historic Washington State

Wyoming Dept. of Game and Fish

Wyoming State Engineering Office

American Waterways Operators

Central Ferry Terminal Association, Inc.

Dept. of Biology, Eastern Washington Univ.

Direct Service Industries, Inc.

Goodman Group

Idaho Water Users Association, Inc.

Kelly Creek Flycasters

Lake Roosevelt Forum

Northwest Resource Information Center, Inc.

Pacific Northwest Waterways Association

Pacific Region

Resource Management International

Rural Electrification Assoc.

Sawtooth Wildlife Council

Sierra Club Northwest Region

Sierra Club Cascade Chapter

The Dalles Irrigation District

The Mountaineers

Trout Unlimited

Trout Unlimited

Umatilla Electric Cooperative Association

University of Idaho

Upper Col. United Tribes Fish. Research Ctr. Research Office

Wasco County Farm Bureau

Washington Association of Wheat Growers

Agri-Northwest

Benton County PUD

Bonneville Power Administration

Broetje Orchards

Cheran Orchards, Inc.

Clallam County PUD

Clark Jennings & Associates, Inc.

Columbia Grain International, Inc.

Don Chapman Consultants

Ebasco Environmental

Elam, Burke, and Boyd

Franklin County PUD

G.H. Bowers Engineering

Gehrke's Gink

Genesee Union Warehouse Company

Gunkel Orchards

Idaho Power Company

James River Corporation

Ken Casavant

Lewis-Clark Terminal Association, Inc.

Pacific Grinding Wheel Company, Inc.

Pacific Power & Light Company

Pend Oreille County PUD #1

Pioneer Irrigation District Elam, Burke and Boyd

Port of Kalama

Port of Lewiston

Port of Portland

Port of Whitman County

Potlatch, Corp.

Pritchard Appraisal & Farm Finan. Consulting

Rosholt, Robertson & Tucker

Settlers Irrigation District

Arlington Public Library

Asotin Public Library

Blackfoot Public Library

Boardman Public Library

Boise State University Government Documents Library

Bonneville Public Library

Brewster Public Library

Bridgeport Public Library

Burley Public Library

Caldwell Public Library

Camas Public Library

Cascade Locks Public Library

Cashmere Public Library

Chelan Public Library

City of Boise Public Library

Clarkston Public Library

Colfax Public Library

Colorado State University Library

Columbia Basin College Library Media Center

Colville Public Library

Connell Public Library

Coulee Dam Public Library

Dayton Public Library

Emmett Public Library

Goldendale Public Library

Grand Coulee Public Library

Hermiston Public Library

Hood River Public Library

Idaho Falls Public Library

Idaho State Library

Kennewick Public Library

Kettle Falls Public Library

Lewiston Public Library

Milton-Freewater Public Library

Moscow Public Library

Multnomah County Library

Nampa Public Library

Nyssa Public Library

Olympia Public Library

Ontario Public Library

Orofino Public Library

Pasco Public Library

Payette Public Library

Pendleton Public Library

Penrose Memorial Library Whitman College

Pocatello Public Library

Pomeroy Public Library

Portland Public Library

Prosser Public Library

Pullman Public Library

Richland Public Library

Rupert Public Library

Salem Public Library

Salmon Public Library

Seattle Public Library

Spokane Public Library

Stevenson Public Library

The Dalles Public Library

Twin Falls Public Library

Umatilla Public Library

University of Washington Library

Vancouver Public Library

Walla Walla Public Library

Washington State Library

Washougal Public Library

Weiser Public Library

Wenatchee Public Library

White Salmon Public Library

Yakima Public Library

Don Olowinski

Hawley Troxell

Greg White

Carene Cooper

Ken Struckmeyer

Eric Young

Ed Henderson

William and Marjorie Hayes

Stephen A. Wille

Jami Delmore

Janet Burcham

Ron and Mimsi Wise

Janet L. Stewart

Kurt Fuerstenau

Jeanette Germain

Robert Shank

Peggy Jo Randall

John C. Burke

Patricia J. Fong

Ron Vigil

Dennis Baird

Dustin J.E. Miller

Charles Mabbott

D. Grave de Peralta

Joanne M. Roberts.

Colleen Wright

James M. Baker

Ron Mason

Kip Dieringer

Tom Kovalicky

Karen Lewis

Richard Johnson

May Reed

Paul Worden

Van Walkley

William Mathews

Stephen L. Barr

Paul Shaffer

Nancy Roberts

Kathy Munger

Clint Watkins

Lee Gray

Lawrence Hickman

Ralph Broetje

Ron Appleby

R. Thomas Mackay

Lynn Tominaga

Ed Chaney

Claire Ross

# 11.0

# Glossary

# 1992 COLUMBIA RIVER SALMON FLOW MEASURES
# OA/EIS

## CONTENTS

# 11.0 GLOSSARY AND ACRONYMS

ACEC - Areas of Critical Environmental Concern

Acre-foot - The volume of water that will cover 1 acre to a depth of 1 foot.

aMW - Average megawatt; the average amount of energy (number of megawatts) supplied or demanded over a specified period of time.

Anadromous fish - Fish, such as salmon or steelhead trout, that hatch in freshwater, migrate, mature in the ocean, and return to fresh water as adults to spawn.

Annual operating plan - A yearly plan for operating storage reservoirs on the Columbia River. Such a plan is specifically required by the Columbia River Treaty and by the Pacific Northwest Coordination Agreement.

Assured refill curve - A curve showing minimum elevations which must be maintained at each project to ensure refill, even if the third lowest historical water year occurred; it sets limits on the production of energy.

Augmenting - Increasing; in this application, increasing river flows above levels that would occur under normal operations by releasing water from storage reservoirs.

Baseload - In a demand sense, a load that varies only slightly in level over a specified time period. In a supply sense, a plant that operates most efficiently at a relatively constant level of generation.

BIA - Bureau of Indian Affairs

BDU - bone dry unit

BKD - Bacterial kidney disease

BLM - Bureau of Land Management

BNRR - Burlington Northern Railroad

BoR - Bureau of Reclamation

BP - Before the present time

BPA - Bonneville Power Administration

Bypass system - Structure at a dam that provides a route for fish to move through or around the dam without going through the turbines.

CAA - Clean Air Act

Capacity - The maximum sustainable amount of power that can be produced by a generator or carried by a transmission facility at any instant.

Capacity/energy exchange - A transaction in which one utility provides another with capacity service in exchange for additional amounts of firm energy (exchange energy) or money, under specified conditions, usually during offpeak hours.

CBFWA - Columbia Basin Fish and Wildlife Authority

Corps - U.S. Army Corps of Engineers

CPO - Coordinated Plan of Operations

CRBG - Columbia River Basalt Group

CRGNSA - Columbia River Gorge National Scenic Area

CRITFC - Columbia River Intertribal Fish Commission

Critical period - That portion of the historical 50-year streamflow record that would produce the least amount of energy with all reservoirs drafted from full to empty. For the past several years of planning, the critical period has been from September 1928 through February 1932.

Critical rule curves - A set of curves which define reservoir elevations that must be maintained to ensure that firm system requirements (both power and non-power) can be met under the most adverse historical streamflow conditions. Critical rule curves are derived for all four years in the critical period. They are used to guide reservoir operation for power.

CRM - Columbia river mile

CRSMA - Columbia River Salmon Mitigation Analysis

Cubic feet per second (cfs) - A unit of measurement pertaining to flow of water. One cfs is equal to 449 gallons per minute.

Demand - The rate at which electric energy is used, whether at a given instant or averaged over any designated period.

Discharge - Volume of water flowing in a given stream at a given time, usually expressed in cubic feet per second.

Displacement - The substitution of less expensive energy for more expensive thermal energy (usually hydroelectric energy transmitted from the Pacific Northwest or Canada to substitute for more expensive coal and oil-fired generation in California). Such displacement means that the thermal plants can reduce or shut down their production, saving money and often reducing air pollution.

Draft - Release of water from a storage reservoir.

Drawdown - The distance that the water surface of a reservoir is lowered from a given elevation as water is released from the reservoir.

DSI - Direct Service Industry

Edaphic - Of or relating to soil, especially as it affects living organisms.

EIS - Environmental Impact Statement

Endemism - Native or limited to a certain region (endemic).

Energy content curves - A set of curves which establish limits on the amount of reservoir drawdown permitted for non-firm energy production.

EPA - U.S. Environmental Protection Agency

ESA - Endangered Species Act

Escapement - Number of salmon that actually return to a stream to spawn.

FCRPS - Federal Columbia River Power System

FELCC - Firm Energy Load Carrying Capacity; the amount of energy the region's generating system, or an individual utility or project, can be called on to produce on a firm basis during actual operations. FELCC is made up of both hydro and non-hydro resources, including power purchases. The hydro portion of FELCC is based on the energy that could be produced if critical period water conditions were to reoccur.

Firm energy - Guaranteed or assured energy.

Fish Hatchery - A facility in which fish eggs are hatched and incubated and juvenile fish are reared for release to lakes or rivers.

Fish ladders - A series of ascending pools constructed to enable salmon or other fish to swim upstream around or over a dam.

Fish passage facilities - Features of a dam that enable fish to move around, through, or over without harm. Generally an upstream fish ladder or a downstream bypass conduit.

Flip lips - Also known as spill deflectors; modifications made to the spillways of some Columbia-Snake River projects to deflect flows and reduce the deep plunging flows that create high-dissolved gas levels.

Flood control rule curve - A curve, or family of curves, indicating reservoir drawdown required to control flood flows. (also called Mandatory Rule Curve or Upper Rule Curve).

Flow - The volume of water passing a given point per unit of time.

FOB - Free-on-board, without charge for delivery to and placing on board a carrier at a specific point.

Forebay - The portion of a reservoir at a hydroelectric plant that is immediately upstream of the generating station.

FPC - Fish Passage Center

fps - feet per second

Freshet - A rapid temporary rise in streamflow caused by heavy rains or rapid snowmelt.

full pool - The maximum level of a reservoir under its established normal operating range.

FWS - U.S. Fish and Wildlife Service

FY - Fiscal year

Gas supersaturation - Concentrations of dissolved gas in water that are above the saturation (100 percent capacity) level of the water.

Generation - Act or process of producing electric energy from other forms of energy; also the amount of electric energy so produced.

HCNRA - Hells Canyon National Recreation Area

HMU - Habitat Management Unit

Hydraulic head - The vertical distance between the surface of the reservoir and the surface of the river immediately downstream from the turbine and dam. "High head" means a great distance.

Hydraulic jump - A transition in water flow when water accelerates over a local steep gradient and enters a lower gradient immediately downstream. The water accelerates, its surface lowers, and accumulates energy. At the lower gradient, the flow decelerates, the water surface rises, and the accumulated energy is dissipated in a region of extremely turbulent flow.

Hydroelectric - The production of electric power through use of the gravitational force of falling water.

Hydrology - The science dealing with the continuous cycle of evapotranspiration, precipitation, and runoff.

Hydrometeorological observations - Rainfall, snowpack, and other climatic measurements used to predict runoff.

ICC - Interstate Commerce Commission

IDFG - Idaho Department of Fish and Game

INHP - Idaho Natural Heritage Program

Intake - The entrance to a conduit through a dam, diversion works, or pumping station.

Interchange energy - Electric energy received by one utility system usually in exchange for energy to be delivered to another system at another time or place. Interchange energy is to be distinguished from a direct purchase or sale, although accumulated energy balances are sometimes settled in cash.

Interruptible power - A supply of power, which by agreement, can be shut off on relatively short notice (from minutes to a few days).

IPC - Idaho Power Company

ITD - Idaho Transportation Department

Juvenile - The early stage in the life cycle of anadromous fish when they migrate downstream to the ocean.

KAF - thousand acre-feet

kcfs - 1,000 cfs

kV - kilo volt (1,000 volts)

Levee - An embankment constructed to prevent a river from overflowing.

Load - The amount of electric power or energy delivered or required at any specified point or points on a system. Load originates primarily at the energy-consuming equipment of the customers.

Locks - A chambered structure of a waterway closed off with gates for the purpose of raising or lowering the water level within the lock chamber so ships can move along the waterway.

Low pool - At or near the minimum level of a reservoir under its established normal operating range.

LTSA - Long-Term Spill Agreement

MAF - million acre-feet

Mainstem - The principal portion of a river in a river basin, as opposed to the tributary streams and smaller rivers that feed into it.

Megawatts (MW) - A megawatt is one million watts, a measure of electrical power.

mg/l - milligram per liter

Mid-Columbia - The section of the Columbia River from Chief Joseph Dam to its junction with the Snake River.

MOP - minimum operating pool; the minimum elevation of the established normal operating range of a reservoir.

MPN - most probable number

MRCs - mandatory flood control rule curves

msl - mean sea level

MW - megawatt(s)

MWh - megawatt hour(s)

NED - national economic development

NEPA - National Environmental Policy Act

NFH - National Fish Hatchery

Nitrogen supersaturation - A condition of water in which the concentration of dissolved nitrogen exceeds the saturation level of the water. Excess nitrogen can harm the circulatory systems of fish.

NMFS - National Marine Fisheries Service

Non-power operating requirements - Operating requirements at hydroelectric projects that pertain to navigation, flood control, recreation, irrigation, and other non-power uses of the river.

Non-firm energy - Energy available when water conditions are better than critical; such energy is sold on an interruptible (non-guaranteed) basis. Also called secondary energy.

Northwest Power Pool (NWPP) - Made up of BPA, the Corps, Reclamation, and public and private utilities in the Northwest, British Columbia, and Alberta. The group's primary functions are administering the Pacific Northwest Coordination Agreement and Northwest Power Pool Committee activities. The NWPP maintains a central staff in Portland known as the NWPP Coordinating Group.

NPDES - National Pollutant Discharge Elimination System

NPPC - Northwest Power Planning Council

NPS - National Park Service

NRHP - National Register of Historic Places

NTU - nephelometric turbidity units

NWR - National Wildlife Refuge

OA/EIS - Options Analysis/Environmental Impact Statement

Offpeak hours - Period of relatively low demand for electrical energy, as specified by the supplier (such as the middle of the night).

ONA - Outstanding Natural Areas

ONHP - Oregon Natural Heritage Program

Operating limits - Limits or requirements that must be factored into the planning process for operating reservoirs and generating projects. (Also see operating requirements, below.)

Operating requirements - Guidelines and limits that must be followed in the operation of a reservoir or generating project. These requirements may originate in authorizing legislation, physical plant limitations or other sources.

Operating rule curve - A curve, or family of curves, indicating how a reservoir is to be operated under specific conditions and for specific purposes.

Operating year - The 12-month period from August 1 through July 31.

Outages - Periods, both planned and unexpected, during which the transmission of power stops or a particular power-producing facility ceases to function.

Pacific Northwest Coordination Agreement - A binding agreement among BPA, the Corps, Reclamation, and the major generating utilities in the Pacific Northwest that stemmed from the Columbia River Treaty. The Agreement specifies a multitude of operating rules, criteria, and procedures for coordinating operation of the system for power production. It directs operation of major generating facilities as though they belonged to a single owner.

PAHs - polyaromatic hydrocarbons

PCBs - polychlorinated biphenyls

PCPI - per capita personal income

Peak loads - The maximum electrical demand in a stated period of time. It may be the maximum instantaneous load or the maximum average load within a designated period of time.

PNUCC - Pacific Northwest Utilities Conference Committee

Pool - Reservoir; a body of water impounded by a dam.

ppm - parts per million

Project outflow - The volume of water per unit of time discharged from a project.

Proportional draft - A condition in which all reservoirs are drafted in the same proportion to meet firm loads.

PSC - Pacific Salmon Commission

PUD - Public Utility District

Redds - Salmon spawning nests in gravel.

Refill - The point at which the storage reservoirs of the hydro system are considered "full" from the seasonal snowmelt runoff.

Reliability - For a power system, a measure of the degree of certainty that the system will continue to meet load for a specified period of time.

Reservoir draft rate - The rate at which water, released from storage behind a dam, reduces the elevation of the reservoir.

Reservoir elevations - The levels of the water stored behind dams.

Reservoir storage - The volume of water in a reservoir at a given time.

Resident fish - Fish species that reside in fresh water throughout their lives.

Residualism - A condition in which migrating juvenile salmonid smolts lose their urge to migrate, physiologically revert to their freshwater life form, and remain in fresh water rather than migrate to sea.

RM - River Mile

RNA - Research Natural Areas

ROD - Record of Decision

Rule curves - Water levels, represented graphically as curves, that guide reservoir operations.

Run-of-river dams - Hydroelectric generating plants that operate based only on available streamflow and some short-term storage (hourly, daily, or weekly).

Run-of-river reservoirs - The pools or impoundments formed behind run-of-river dams.

Salmonids - Of or pertaining to fish of the family Salmonidae, including salmon, trout, and steelhead.

SAM - System Analysis Model, a mathematical model developed and operated by BPA to simulate the operation of the integrated Northwest hydroelectric system.

Secondary energy - Hydroelectric energy in excess of firm energy, often used to displace thermal resources. Also called non-firm energy.

Shaping - The scheduling and operation of generating resources to meet changing load levels. Load shaping on a hydro system usually involves the adjustment of storage releases so that generation and load are continuously in balance.

SHPO - State Historic Preservation Officer

Smolt - A juvenile salmon or steelhead migrating to the ocean and undergoing physiological changes to adapt its body from a freshwater to a saltwater environment.

SOR - System Operation Review

Spawning - The releasing and fertilizing of eggs by fish.

Spill - Water passed over a spillway or through regulating outlets without going through turbines to produce electricity. Spill can be forced, when there is no storage capability and flows exceed turbine capacity, or planned, for example, when water is spilled to enhance juvenile fish survival.

Spillway - Overflow structure of a dam.

Storage reservoirs - Reservoirs that provide space for retaining water from springtime snowmelts. Retained water is released as necessary for multiple uses—power production, fish passage, irrigation, and navigation.

Streamflow - The rate at which water passes a given point in a stream, usually expressed in cubic feet per second (cfs).

Subyearlings - Juvenile fish less than one year old.

Surplus energy - Energy generated that is beyond the immediate needs of the producing system. This energy is frequently sold on an interruptible basis.

Tailrace - The canal or channel that carries water away from a dam.

Thermal power plant - Generating plant which converts heat energy into electrical energy. Coal, oil and gas-fired power plants, and nuclear power plants are common thermal resources.

TPU - transportation and public utilities

Tules - The name commonly applied to fall chinook salmon originating on the lower Columbia River.

Turbine - Machinery that converts kinetic energy of a moving fluid, such as falling water, to mechanical or electrical power.

Upriver brights - The name commonly applied to fall chinook salmon originating on the middle Columbia River, primarily in the area below Priest Rapids Dam.

UPRR - Union Pacific Railroad

Usable storage - Water occupying active storage capacity of a reservoir.

Usable storage capacity - The portion of the reservoir storage capacity in which water normally is stored or from which water is withdrawn for beneficial uses, in compliance with operating agreements.

USFS - U.S. Forest Service

USGS - U.S. Geological Survey

USLE - Universal Soil Loss Equation

Variable energy content curve (VECC) - The January through July portion of the energy content curve. The VECC is based on the expected amount of spring runoff.

Velocity - Speed; the time rate of linear motion in a given direction.

Water Budget - A part of the Northwest Power Planning Council's Fish and Wildlife Program calling for a volume of water to be reserved and released during the spring, if needed, to assist in the downstream migration of juvenile salmon and steelhead.

Water particle travel time - The theoretical time that a water particle would take to travel through a given reservoir or river reach. It is calculated by dividing the flow (volume of water per unit time) by the cross-sectional area of the channel.

Water Rights - Priority claims to water. In western states, water rights are based on the principle "first in time, first in right," meaning older claims take precedence over more recent ones.

WDW - Washington Department of Wildlife

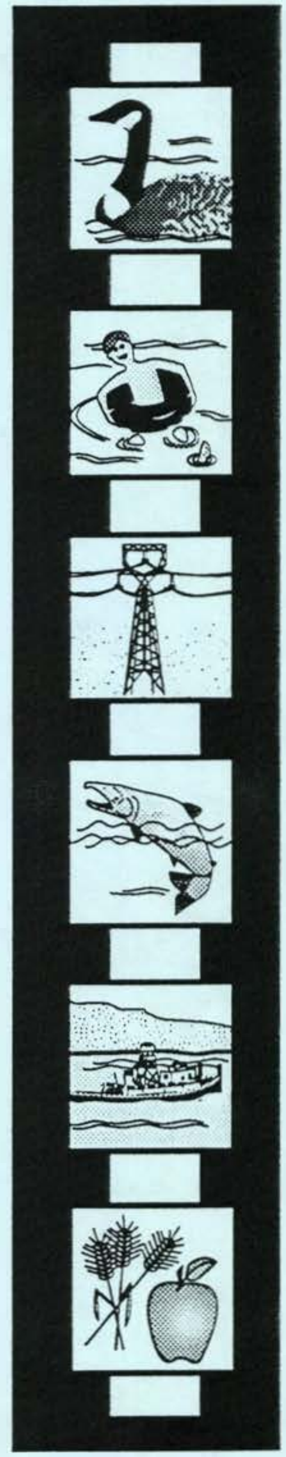
WNHP - Washington Natural Heritage Program

WSDOT - Washington State Department of Transportation

Xerophytic - Plant types that are structurally adapted for life and growth with a limited water supply.

# 12.0

# References



# 1992 COLUMBIA RIVER SALMON FLOW MEASURES OA/EIS

## CONTENTS

Page No.

# 12.0 REFERENCES

Abt Associates, Inc. 1978. Impacts of Reservoir Operations on Recreation for Anderson Ranch Reservoir and Bureau of Reclamation Reservoirs in General. Bureau of Reclamation, Boise, Idaho.

Alabaster, J.S. and R. Lloyd. 1982. Water Quality Criteria for Freshwater Fish. Butterworths, London, England.

Anonymous. 1983. Wintering Waterfowl Redistribution Plan Columbia Basin Oregon/Washington. 1983. 45 pp.

Anthony, R.G., R.L. Knight, G.T. Allen, B.R. McClelland, and J.I. Hodges. 1982. Habitat Use by Nesting and Roosting Bald Eagles in the Pacific Northwest. Transactions of the 47th North American Wildlife and Natural Resources Conference 47:332-342.

Asherin, D.A. and J.J. Claar. 1976. Inventory of Riparian Habitats and Associated Wildlife along the Columbia and Snake Rivers. Corps North Pacific Division. Volume 3A. 556 pp.

Asherin, D.A. and M.L. Orme. 1978. Inventory of Riparian Habitats and Associated Wildlife along the Lower Clearwater River and Dworshak Reservoir. Corps North Pacific Division. Volume V. 477 pp.

Baker, V.R., Greeley, R., Komar, P.D., Swanson, D.A., and Waitt, R.B., Jr. 1987. Columbia and Snake River Plains. *In*: W.L. Graf (ed.), pp. 403-468, Geomorphic Systems of North America, Boulder, Colorado, Geological Society of America, Centennial Special, Volume 2.

Battelle Pacific Northwest Laboratory. 1986. Sediment Quality of Proposed 1987 Dredge Site, Lewiston, Idaho. Prepared for U.S. Army Corps of Engineers, Walla Walla District. July 1986.

Bayha, K. editor. 1974. Anatomy of a River: A Report of the Hells Canyon Controlled Flow Task Force. Pacific Northwest River Basins Commission. 203 pp.

Beamesderfer, R.C., B.E. Rieman, L.J. Bledsoe, and S. Vigg. 1990. Management Implications of a Model of Predation by a Resident Fish on Juvenile Salmonids Migrating through a Columbia River Reservoir. North American Journal of Fisheries Management, 10:290-304.

Beckman, L.G., J.F. Novotny, W.R. Parson, and T.T. Tarrell. 1985. Assessment of the Fisheries and Limnology in Lake F.D. Roosevelt 1980-1983. U.S. Fish and Wildlife Service. Final Report to U.S. Bureau of Reclamation. Contract No. WPRS-0-07-10-X0216; FWS-14-06-009-904. 168 pp.

Bell, M.C. 1986. Fisheries Handbook of Engineering Requirements and Biological Criteria. 290 pp.

Bell, M.C., Z.E. Parkhurst, R.G. Porter, M. Stevens. 1976. Effects of Power Peaking on Survival of Juvenile Fish at Lower Columbia and Snake River Dams. Report to U.S. Army Corps of Engineers, North Pacific Division. Contract DACW57-75-C-0173

Ben-Zvi, S. 1990. Evaluation of NonPower Impacts from Reservoir Drawdown at Hungry Horse Reservoir. A Report Prepared for the United States Department of Interior, Bureau of Reclamation, Pacific Northwest Region, Boise, Idaho. Samuel Ben-Zvi and Associates, Fort Collins, Colorado.

Bennett, D.H. 1991. Snake River Salmon Mitigation Analysis, Resident Fishes. College of Forestry, Wildlife, and Range Sciences, University of Idaho, Moscow, Idaho.

Bennett, D.H., J. Chandler, and G. Chandler. 1991. Lower Granite Reservoir In-Water Disposal Test: Monitoring Fish and Benthic Community Activity at Disposal and Reference Sites in Lower Granite Reservoir, Washington, Year 2 (1989). Department of Fish and Wildlife Resources, University of Idaho, Moscow, Idaho.

# 12 REFERENCES


Bennett, D.H., T.S. Curet, T.J. Dresser, Jr. 1991. Abundance of Age-0 Fall Chinook Salmon in Little Goose Reservoir, Washington, Spring 1991. Department of Fish and Wildlife Resources, University of Idaho, Moscow, Idaho.

Bennett, D.H., L.K. Dunsmoor, and J.A. Chandler. 1988. Fish and Benthic Community Abundance at Proposed In-Water Disposal Sites, Lower Granite Reservoir (1987). U.S. Army Corps of Engineers. Walla Walla, Washington.

Bennett, D.H. and L.K. Dunsmoor. 1986. Food and Availability of Prey for Smallmouth Bass *Micropterus dolomieu:* Lacepede, in Brownlee Reservoir, Idaho. M.S. Thesis, University of Idaho. Moscow, Idaho.

Bennett, D.H. and I.C. Shrier. 1986. Effects of Sediment Dredging and In-Water Disposal on Fishes in Lower Granite Reservoir, Idaho-Washington. U.S. Army Corps of Engineers. Walla Walla, Washington.

Bennett, D.H., P.M. Bratovich, W. Knox, D. Palmer, and H. Hansel. 1983. Status of the Warmwater Fishery and the Potential of Improving Warmwater Fish Habitat in the Lower Snake River reservoirs. Final Report. U.S. Army Corps of Engineers. Walla Walla, Washington.

Bent, A.C. 1961. Life Histories of North American Birds of Prey, Part 2. Dover Publications, Inc. New York.

Berggren, T.J. and M.J. Filardo. 1991. An Analysis of Variables Influencing the Migration of Juvenile Salmonids in the Snake and Lower Columbia Rivers. FPC report submitted to the ESA record, 38 pp.

BNA (Bureau of National Affairs, Inc.). 1991. Environment Reporter - State Water Laws - States of Idaho, Oregon, and Washington. Bureau of National Affairs, Inc. Washington D.C.

Bottom, D.L., and K.K. Jones. 1990. Species Composition, Distribution, and Invertebrate Prey Fish Assemblages in the Columbia River Estuary. Progressive Oceanography, Volume 25. pp. 243-270.

Boyer, P.B. 1974. Lower Columbia and Lower Snake Rivers - Nitrogen (Gas) Supersaturation and Related Data Analysis and Interpretation. U.S. Army Corps of Engineers, North Pacific Division. Portland, Oregon.

BPA (Bonneville Power Administration). 1985. Hells Canyon Environmental Investigation, Final Report. U.S. Department of Energy, Bonneville Power Administration. Portland, Oregon.

BPA. 1990. The Non-Treaty Storage Agreement, Environmental Assessment. DOE/EA-0451. U.S. Department of Energy, Bonneville Power Administration. Portland, Oregon.

BPA. 1984. Status Review of Wildlife Mitigation at Columbian Basin Hydroelectric Projects, Columbia Mainstem and Lower Snake Facilities. Final Report, Appendices A, B, and C.

BPA, Corps, and BoR (Bureau of Reclamation). 1991. System Operation Review, The Inside Story (Draft). U.S. Department of Energy, Bonneville Power Administration, U.S. Department of the Army, Corps of Engineers, North Pacific Division, U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Region. Portland, Oregon.

Brett, J.R. 1952. Temperature Tolerance in Young Pacific Salmon, Genus *Oncorhynchus*. J. Fish. Res. Bd. Canada 9:265-323.

Brown, E.R. (Tech. Ed.). 1985. Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington. U.S. Department of Agriculture Publ. No. R6-F&WL - 192-1985.

Buettner, E. Undated. Factors Associated with Chinook Salmon Movement in Lower Granite Reservoir. Idaho Department of Fish and Game. Boise, Idaho.

Busacca, A.J., D.K. McCool, R.I. Papendick, and D.L. Young. 1985. Dynamic Impacts of Erosion Processes on Productivity of Soils in the Palouse. *In:* Proceedings of the National Symposium on Erosion and Soil Productivity, 10-11 December 1984, New Orleans, Louisiana, American Society of Civil Engineers, pp. 152-169.

Call, M.W. 1978. Nesting Habitats and Surveying Techniques for Common Western Raptors. U.S. Department of the Interior, Bureau of Land Management Technical Note TN-316. Denver, Colorado. 115 pp.

CBFWA (Columbia Basin Fish and Wildlife Authority). 1991a. The Biological and Technical Justification for the Flow Proposal of the Columbia Basin Fish and Wildlife Authority. CBFWA. Portland, Oregon. 72 pp.

CBFWA. 1991b. Integrated System Plan for Salmon and Steelhead Production in the Columbia River Basin. Columbia Basin System Planning, 449 p.

Ceballos, J.R., S.W. Pettit, and J.L. McKern. 1991. Fish Transportation Oversite Team Annual Report 1990. Transport Operations on the Snake and Columbia Rivers. NOAA Technical Memorandum, NMFS F/NWR-29. National Marine Fisheries Service, Portland, Oregon. 75 pp. plus appendices.

Chapman, D., et al. 1991. Status of Snake River Chinook Salmon. Technical Report submitted to PNUCC. Don Chapman Consultants, Inc. Boise, Idaho.

Chapman, D.W., W.S. Platts, D. Park, and M. Hill. 1990. Status of Snake River Sockeye Salmon. Final Report for Pacific Northwest Utilities Conference Committee. Don Chapman Consultants, Inc. Boise, Idaho. 90 pp.

Chapman, D.W. 1986. Salmon and Steelhead Abundance in the Columbia River in the 19th Century. Transactions of the American Fisheries Society, 115:662-670.

Chilcote, M., S. Leider, and J. Loch. 1986. Differential Reproductive Success of Hatchery and Wild Summer-Run Steelhead Under Natural Conditions. Trans. Amer. Fish. Soci. 115: 726-735.

COFO (Committee on Fishery Operations). 1982. 1981 Annual Report of the Columbia River Water Management Group.

Corps (U.S. Army Corps of Engineers). 1991a. Principles of Reservoir Regulation. U.S. Army Corps of Engineers, Portland District. Portland, Oregon.

Corps. 1991b. Annual Fish Passage Report. 1990. Portland and Walla Walla Districts.

Corps. 1991c. Environmental Assessment, Columbia River Emergency Dredging, Non-Federal Facilities. U.S. Army Corps of Engineers, Portland District. Portland, Oregon.

Corps. 1991d. Non-Federal Navigation Dredging and Beneficial Use of Dredge Materials in the Columbia, Snake, and Clearwater Rivers Environmental Assessment. U.S. Army Corps of Engineers, Walla Walla District. Walla Walla, Washington.

Corps. 1990a. Wildlife Impact Assessment--Bonneville, The Dalles and John Day Projects, Oregon and Washington. Prepared by USFWS. BPA Project No. 87-110 and 88-112.

# 12 References


Corps. 1990b. 1990 Dissolved Gas Monitoring for the Columbia and Snake Rivers - Summary Report and Data Analysis. Corps of Engineers, North Pacific Division, Fish and Water Quality Unit, Reservoir Control Center, Water Management.

Corps. 1990c. Natural Resource Management System; Project Visitation Data 1985-1989. Unpublished. U.S. Army Corps of Engineers, Portland District. Portland, Oregon.

Corps. 1989a. Water Control Manual for McNary Lock and Dam, Columbia River, Oregon and Washington. U.S. Army Corps of Engineers, Walla Walla District. Walla Walla, Washington.

Corps. 1989b. The Lower Snake River Project: Ice Harbor-Lower Monumental-Little Goose-Lower Granite. Brochure. U.S. Army Corps of Engineers, Walla Walla District. Walla Walla, Washington.

Corps. 1988a. Water Control Manual for Lower Granite Lock and Dam. U.S. Army Corps of Engineers, Walla Walla District. Walla Walla, Washington.

Corps. 1988b. Water Control Manual for Little Goose Lock and Dam, Snake River, Washington. U.S. Army Corps of Engineers, Walla Walla District. Walla Walla, Washington.

Corps. 1988c. Water Control Manual for Lower Monumental Lock and Dam, Snake River, Washington. U.S. Army Corps of Engineers, Walla Walla District. Walla Walla, Washington.

Corps. 1988d. Water Control Manual for Ice Harbor Lock and Dam. U.S. Army Corps of Engineers, Walla Walla District. Walla Walla, Washington.

Corps. 1988e. Mid-Columbia River Projects Master Plan for Resource Use; Regional Overview. U.S. Army Engineer District. Portland, Oregon.

Corps. 1987. Final Environmental Assessment of Proposed Lower Granite 1988 Interim Flood Control Dredging. Lower Granite Lock and Dam Project. U.S. Army Corps of Engineers, Walla Walla District. Walla Walla, Washington. December 1987.

Corps. 1986a. Port of Coos Bay, Oregon, and Ports on Columbia-Snake River System. Port Series Handbook, Number 33. U.S. Army Corps of Engineers, Fort Belvoir, Virginia.

Corps. 1986b. Water Control Manual for Dworshak Dam and Reservoir, North Fork, Clearwater River, Idaho. U.S. Army Corps of Engineers, Walla Walla District. Walla Walla, Washington.

Corps. 1984. Columbia River Basin Master Water Control Manual. U.S. Army Corps of Engineers, North Pacific Division. Portland, Oregon.

Corps. 1983. Vancouver to The Dalles, Columbia River Channel Maintenance, Environmental Assessment. Portland, Oregon.

Corps. 1980. Columbia Basin Water Withdrawals Environmental Review; Appendix G - Recreation. U.S. Army Engineer District. Portland, Oregon.

Corps. 1979. Columbia Basin Water Withdrawal Environmental Review, Appendix A: Land Use. U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

Corps. 1977. Vancouver to The Dalles, Columbia River Channel Maintenance, Final EIS. Portland, Oregon.

Corps. 1976. The Dalles Lock and Dam Master Plan; Design Memorandum No. 20B. U.S. Army Corps of Engineers, Portland District. Portland, Oregon.

Corps. 1976. John Day Lock and Dam Master Plan; Design Memorandum No. 25B. U.S. Army Corps of Engineers, Portland District. Portland, Oregon.

Corps. 1975. Final Impact Statement, Dworshak. U.S. Army Corps of Engineers, Walla Walla District. Walla Walla, Washington.

Corps. 1974a. Bonneville Master Plan; Design Memorandum No. 1B. U.S. Army Corps of Engineers, Portland District. Portland, Oregon.

Corps. 1974b. The Dalles Lock & Dam Master Plan, Design Memorandum No. 20b. U.S. Army Corps of Engineers, Portland District. Portland, Oregon.

Corps. 1974c. Construction, Operation and Management, Columbia River, Umatilla to The Dalles, Final EIS. U.S. Army Corps of Engineers, Portland District. Portland, Oregon.

Corps. 1973. Modifications for Peaking Design Memorandum No. 1; Protective Works Upstream Supplement No. 3. U.S. Army Corps of Engineers, Portland District. Portland, Oregon.

Corps. 1972. Modification for Peaking, The Dalles to Vancouver, Final EIS. Portland, Oregon.

Corps. 1968. John Day Dam, Columbia River, Washington and Oregon, Reservoir Regulation Manual. U.S. Army Corps of Engineers, Portland District. Portland, Oregon.

Corps. 1963. Fish Passage Through Turbines. Progress Report No. 5. U.S. Army Corps of Engineers, Walla Walla District. Walla Walla, Washington.

Corps. 1962. Bonneville Dam, Columbia River, Washington and Oregon, Reservoir Regulation Manual. U.S. Army Corps of Engineers, Portland District. Portland, Oregon.

Corps. 1961a. The Dalles Dam, Columbia River Reservoir, Washington and Oregon, Reservoir Regulation Manual. U.S. Army Corps of Engineers, Portland District. Portland, Oregon.

Corps. 1961b. Fish Passage through Turbines. Progress Report No. 4. U.S. Army Corps of Engineers, Walla Walla District. Walla Walla, Washington.

Corps. Undated. A Preliminary Investigation on Environmental and Social Impacts Resulting from Deeper Drafting of Dworshak Reservoir. Final Report. North Fork Clearwater River, Idaho. U.S. Army Corps of Engineers. Walla Walla District. Walla Walla, Washington.

Cramer, F.K. and R.C. Oligher. 1961. Fish Passage Through Turbines. U.S. Army Corps of Engineers, Walla Walla District, Progress Report No. 3.

Crawford, N.H., D.L. Hey, and R.L. Street. 1976. Columbia River Water Temperature Study. Final Report, Contract DACW57-75-C-0304. Prepared by Hydrocomp, Inc. for U.S. Army Corps of Engineers, North Pacific Region.

Daubenmire, R., and J.B. Daubenmire. 1984. Forest Vegetation of Eastern Washington and Northern Idaho. Agricultural Research Center, Washington State University. Pullman, Washington. 104 pp.

Dauble, D.D., T.L. Page, and R. William Hanf, Jr. 1989. Spatial Distribution of Juvenile Salmonids in the Hanford Reach, Columbia River. Fishery Bulletin, U.S. 87:775-790.

DeLorme. 1988. Washington Atlas & Gazetteer. DeLorme Mapping Company. Freeport, Maine.

Ebel, W.J. 1979. Effects of Atmospheric Gas Supersaturation on Survival of Fish and Evaluation of Proposed Solutions. In: United States Army Corps of Engineers. Fifth Progress Report on Fisheries Engineering Research Program 1973-1978. Portland District Fish and Wildlife Section. Portland, Oregon.

Ebel, W. and H. Raymond. 1976. Effects of Atmospheric Gas Saturation on Salmon and Steelhead Trout of the Snake and Columbia Rivers. U.S. National Marine Fisheries Service Review, 38(7): 1-14.

Ebel, W., H. Raymond, G. Monan, W. Farr, and G. Tanonaka. 1975. Effect of Atmospheric Gas Supersaturation Caused by Dams on Salmon and Steelhead Trout of the Snake and Columbia Rivers. National Marine Fisheries Service, Northwest Fisheries Center, Seattle, Washington.

Elliott, D.G. and R.J. Pascho. 1991. Juvenile Fish Transportation: Impact of Bacterial Kidney Disease on Survival of Spring/Summer Chinook Salmon Stocks. Annual Report, 1989 (Contract E86880047). Prepared by the U.S. Fish and Wildlife Service, Seattle, Washington, for the U.S. Army Corps of Engineers.

EPA (Environmental Protection Agency). 1989. Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A). Office of Emergency and Remedial Response. EPA/540-89/002. December 1989.

EPA and NMFS. 1971. Columbia River Thermal Effects Study. Volume 1. Biological Effects Study. U.S. Environmental Protection Agency and National Marine Fisheries Service.

Evergreen Pacific. 1991. River Cruising Atlas: Columbia, Snake, Willamette. Romar Books Ltd. Seattle, Washington.

Faler, M.P., L.M. Miller, and K.I. Welke. 1988. Effects of Variation in Flow on Distributions of Northern Squawfish in the Columbia River Below McNary Dam. North American Journal of Fisheries Management 8:30-35.

Falter, C.M. 1982. Limnology of Dworshak Reservoir in a Low-Flow Year. Final Report submitted to the U.S. Army Corps of Engineers. Walla Walla, Washington.

Federal Highway Administration. 1983. Visual Impact Assessment for Highway Projects. U.S. Department of Transportation, Federal Highway Administration, Contract DOT-FH-11-9694. Washington, D.C.

Fielder, P.C., and R.G. Starkey. 1986. Bald Eagle Perch-Sites in Eastern Washington. Northwest Science 60:186-188.

Fielder, P.C. 1982. Food Habits of Bald Eagles Along the Mid-Columbia River, Washington. Murrelet 63:46-50.

Fulton, L.A. 1968. Spawning Areas and Abundance of Chinook Salmon (*Oncorhynchus tshawytsha*) in the Columbia River Basin Past and Present. Special Scientific Report—Fisheries No. 571. Fish and Wildlife Service. Washington, D.C.

FPC (Fish Passage Center). 1991a. Fish Passage Managers 1990 Annual Report. Annual Report to Bonneville Power Administration.

FPC. 1991b. Final Weekly Report #91-26. Fish Passage Center. Portland, Oregon. November 22, 1991.

FPC. 1989. Fish Passage Managers 1988 Annual Report. Prepared by the Columbia Basin Fish and Wildlife Authority for the Bonneville Power Administration. 84 pp.

FPC. 1988. Fish Passage Managers 1987 Annual Report. Annual Report to Bonneville Power Administration.

Franklin, J.F., and C.T. Dyrness. 1973. Natural Vegetation of Oregon and Washington. U.S. Department of Agriculture, Forest Service General Technical Report PNW-8. Portland, Oregon. 417 pp.

FWPCA (Federal Water Pollution Control Administration). 1967. Water Temperature Influences, Effects, and Control. Proceedings of the 12th Pacific Northwest Symposium on Water Pollution Research. November 7, 1963. Corvallis, Oregon.

FWS (U.S. Fish and Wildlife Service). 1986. Recovery Plan for the Pacific Bald Eagle. U.S. Fish and Wildlife Service. Portland, Oregon. 160 pp.

Galster, R.W. 1989. Engineering Geology in Washington Volume I. Washington Division of Geology and Earth Resources Bulletin 78. Washington State Department of Natural Resources, Olympia, Washington.

Galster, R.W., Coombs, H.W. and Waldron, H.H. 1989. Engineering Geology in Washington: Introduction. *In*: Engineering Geology in Washington, Vol. I, Washington Division of Geology and Earth Resources Bulletin 78, pp. 3-12.

Galster, R.W. and J.W. Sager. 1989. Dams of the Lower Columbia River: Geologic Setting. *In*: R.W. Galster, ed., Engineering Geology of Washington, Volume 1, Washington Division of Geology and Earth Resources Bulletin 78, pp. 331-335.

Garrett, M., R.G. Anthony, J.W. Watson, and K. McGarigal. 1988. Ecology of Bald Eagles on the Lower Columbia River. Oregon Cooperative Wildlife Research Unit. Department of Fisheries and Wildlife, Oregon State University. 189 pp.

Gibson, G., R. Michimota, F. Young, and C. Junge. 1979. Passage Problems of Adult Columbia River Chinook Salmon and Steelhead, 1973-1978. Oregon Department of Fish and Wildlife.

Giorgi, A. 1991a. Mortality of Yearling Chinook Salmon Prior to Arrival at Lower Granite Dam on the Snake River. Prepared for Bonneville Power Administration, Portland, Oregon.

Giorgi, A. 1991b. Biological Issues Pertaining to Smolt Migration and Reservoir Drawdown in the Snake and Columbia Rivers with Special Reference to Salmon Species Petitioned for Listing under the Endangered Species Act. Proposed by U.S. Army Corps of Engineers and Bonneville Power Administration. Don Chapman Consultants, Inc.

Giorgi, A., D. Miller, and B. Sandford. 1990a. Migratory Behavior and Adult Contribution of Summer Outmigrating Subyearling Chinook Salmon in John Day Reservoir, 1981-1983. U.S. Department of Energy, Bonneville Power Administration. Division of Fish and Wildlife.

Giorgi, A., W. Muir, and S. McCutcheon. 1990b. The Parr-Smolt Transformation in Yearling Chinook Salmon: Implications for Downstream Passage. *In:* Proceedings of the AFS Western Division Meeting. Sun Valley, Idaho. July 1990.

Goldman, S.J., K. Jackson, and T.A. Bursztynsky. 1986. Erosion and Sediment Control Handbook. New York, NY: McGraw-Hill Book Company, Goodnight, W. 1971. Lake and Reservoir Investigations. Idaho Department of Fish and Game. Project F-53-R-6. 26 pp.

Hansen, P.J. 1989. Grand Coulee Dam. *In*: Engineering Geology in Washington, Vol. I. Washington State Department of Natural Resources, Division of Geology and Earth Resources Bulletin 78, pp. 419-430.

Hansen, A.J. 1977. Populations Dynamics and Night Roost Requirements of Bald Eagles Wintering in the Nooksack River Valley, Washington. Problem Scr. Huxley College of Environmental Studies, Western Washington University. Bellingham, Washington. 31 pp.

Henny, C.J., and M.W. Nelson. 1981. Decline and Present Status of Breeding Peregrine Falcons in Oregon. Murrelet 62:43-53.

Hitchcock, C.L. and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press. Seattle and London.

Hjort, R.C., B.C. Mundy and P.L. Hulett. 1981. Habitat Requirements for Resident Fishes in the Reservoirs of the Lower Columbia River. Final Contract Report to: U.S. Army Corps of Engineers, Portland District. Portland, Oregon. 180p.

Hunt, H.E. 1979. Behavioral Patterns of Breeding Peregrine Falcons. Unpublished. Humboldt State University. Humboldt, California. 51 pp.

Henry, R.L. 1991. Curtailed Transportation Use of the Columbia/Snake River: A Review of Impact on Product Marketing Cost. Idaho Transportation Council. Boise, Idaho.

ICC (Interstate Commerce Commission). 1990. Grain Car Supply - Conference of Interested Parties. Washington, D.C.

Idaho Department of Health and Welfare. 1982. Idaho Water Quality Status Report. Idaho Department of Health and Welfare. Boise, Idaho.

Idaho Power Company. 1990. Application for Amendment of License, Hells Canyon Hydroelectric Project. FERC No. 1971. Boise, Idaho.

ITD (Idaho Transportation Department) and WSDOT (Washington State Department of Transportation). 1987. Palouse Empire Regional Rail Study. Joint publication by the Idaho Transportation Department, Management Services Section and the Washington State Department of Transportation, Planning, Research and Public Transportation Division.

International North Pacific Fisheries Commission. 1991. Final Report of 1990 Observations of the Japanese High Seas Driftnet Fisheries in the North Pacific Ocean. Joint Report by the National Sections of Canada, Japan, and the United States. 198pp. (Available from: Driftnet Program Coordinator, Alaska Fisheries Science Center, 7600 Sand Point Way N.E., Seattle, Washington 98115-0070.)

IRZ Consulting and PACAM Engineering, Inc. 1991. Effects of the Columbia River Pool Draw-Down on Selected Pumping Stations in Washington. Prepared for Benton County PUD, Hermiston, Oregon, August 1991.

Isaacs, F.B. 1991. 1991 Mid-Winter Bald Eagle Survey for Oregon. Oregon Eagle Foundation, Memorandum. 4 pp.

Issacs, F.B., R.G. Anthony, and R.J. Anderson. 1983. Distribution and Productivity of Nesting Bald Eagles in Oregon, 1978-1982. Murrelet 64:33-38.

Junge, C.O., and A.L. Oakley. 1966. Trends in Production Rates for Upper Columbia River Runs of Salmon and Steelhead and Possible Effects of Turbidity Changes. Fish Commercial Oregon Research Briefs 12(1):22-43.

Karr, M., B. Tanovan, R. Turner, and D. Bennett. 1991. 1991 Snake River Water Temperature Control Project. Columbia River Inter-Tribal Fish Commission, U.S. Army Corps of Engineers, and University of Idaho.

Koski, C.H., S.W. Pettit, and J.L. McKern. 1990. Fish Transportation Oversite Team Annual Report 1990. NOAA Technical Memorandum, NMFS F/NWR-27. National Marine Fisheries Service, Portland, Oregon. 65 pp. plus appendices.

Kiefer, R.B. and K.A. Forster. 1990a. Intensive Evaluation and Monitoring of Chinook Salmon and Steelhead Trout Production, Crooked River and Upper Salmon River Sites. Annual Progress Report 1988. Bonneville Power Administration.

Kiefer, R.B and K.A. Forster. 1990b. Intensive Evaluation and Monitoring of Chinook Salmon and Steelhead Trout Production, Crooked River and Upper Salmon River Sites. Annual Progress Report 1989. Bonneville Power Administration.

Keister, G.P. 1981. Characteristics of Winter Roosts and Populations of Bald Eagles in the Klamath Basin. M.S. Thesis. Oregon State University. Corvallis, Oregon. 82 pp.

Keister, G.P., and R.G. Anthony. 1983. Characteristics of Bald Eagle Communal Roosts in the Klamath Basin, Oregon and California. Journal of Wildlife Management 47:1072-1079.

Kindley, R. 1991. The Flow/Survival/Travel Time Relationship: Review and Analysis of Supporting Information and Rationale for Flows for Juvenile Spring and Summer Chinook Migrations. Pacific Northwest Utilities Conference Committee (PNUCC). Portland, Oregon.

Krumpe, E.E. 1987. Clearwater River Recreation Survey. Department of Wildland Recreation Management, College of Forestry, Wildlife and Range Sciences. University of Idaho, Moscow, Idaho.

LaBolle, L.D., Jr. 1984. Importance of the Upper Littoral Zone as Rearing Area for Larval and Juvenile Fishes in a Columbia River Impoundment. Thesis. Oregon State University. Corvallis, Oregon.

Ledgerwood, R.D., E.M. Dawley, L.G. Gilbreath, P.J. Bentley, B.P. Sandford, and M.H. Schiewe. 1990. Relative Survival of Subyearling Chinook Salmon Which Have Passed Bonneville Dam via the Spillway or the Second Powerhouse Turbines or Bypass System in 1989, with Comparisons to 1987 and 1988. Report to U.S. Army Corps of Engineers, Contract E85890024/E86890097, 64 pp. plus Appendixes.

Lewke, R.E. and I. O. Buss. 1977. Impacts of impoundment to vertebrate animals and their habitats in the Snake River Canyon, Washington. Northwest Sci. 51:219-270.

Long, C.W., Krcma, R.F., and F.P. Ossiander. 1968. Research on Fingerling Mortality in Kaplan Turbines - 1968. U.S. Bureau of Commercial Fisheries, Biological Laboratory. Seattle, Washington.

Maiolie, M.A. 1988. Dworshak Dam Impacts Assessment and Fishery Investigation. Annual Report FY 1987. Prepared for U.S. Department Energy, Bonneville Power Administration, USFWS, Project No. 87-99.

Malde, H.E. 1968. The Catastrophic Late Pleistocene Bonneville Flood in the Snake River Plain, Idaho. U.S. Geological Survey Professional Paper 596, 52 pp.

Masten, Ruth A., et al. 1986. A Cultural Resources Inventory for the Grand Coulee Project: Douglas, Grant, Ferry, Lincoln, Okanogan, and Stevens Counties, Washington. Report 100-55. Archaeological and Historical Services, Eastern Washington University, Washington.

Matthews, G., S. Achord, J. Harmon, O. Johnson, D. Marsh, B. Sandford, N. Paasch, K. McIntyre, and K. Thomas. 1991. Evaluation of Transportation of Juvenile Salmonids and Related Research on the Columbia and Snake rivers, 1990 (Draft). Annual Report of Research to the U.S. Army Corps of Engineers. Available from Northwest Fisheries Science Center, Seattle, Washington.

Matthews, G., S. Harmon, S. Achord, O. Johnson, and L. Kubin. 1990. Evaluation of Transportation of Juvenile Salmonids and Related Research on the Columbia and Snake Rivers, 1989. Annual Report of Research to the U.S. Army Corps of Engineers.

Matthews, G.M. and R.S. Waples. 1991. Status Review for Snake River Spring and Summer Chinook Salmon. U.S. Department of Commerce. NOAA Technical Memorandum NMFS F/NWC-200, 75 pp.

McKern, J.L. 1976. Inventory of Riparian Habitats and Associated Wildlife along Columbia and Snake Rivers. Corps North Pacific Division. Volume 1 Summary. 100 pp.

Michak, P., E. Wood, B. Rodgers, and K. Amas. 1990. Augmented Fish Health Monitoring. Bonneville Power Administration.

Midwest Research Institute. 1974. Development of Emission Factors for Fugitive Dust Sources. Kansas City, Missouri. Prepared for U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. EPA 450/3-74-037.

Miklancic, F.J. 1989a. Ice Harbor Dam. *In*: Engineering Geology in Washington, Vol. I. Washington State Department of Natural Resources, Division of Geology and Earth Resources Bulletin 78, pp. 453-457.

Miklancic, F.J. 1989b. Lower Monumental Dam. *In*: Engineering Geology in Washington, Vol. I. Washington State Department of Natural Resources, Division of Geology and Earth Resources Bulletin 78, pp. 459-464.

Miller, D. and C. Sims. 1984. Effects of Flow on the Migratory Behavior and Survival of Juvenile Fall and Chinook Salmon in John Day Reservoir. Annual Report of Research to BPA, NOAA, NMFS, NWFC. Seattle, Washington. 25 pp. plus appendices.

Miller, D. and C. Sims. 1983. Effects of Flow on the Migratory Behavior and Survival of Juvenile Fall and Chinook Salmon in John Day Reservoir. Annual Report of Research to BPA, NOAA, NMFS, NWFC, Seattle, Washington, 25 pp. plus appendices.

Morrison Knudsen Corporation. 1991. Lower Snake River Projects Flow Evaluation Study. Prepared for the State of Idaho Governor's Office and Idaho Power Company. Boise, Idaho.

Mullan, J.W., M.B. Dell, S.G. Nays, and J.A. McGee. 1986. Some Factors Affecting Fish Production in the Mid-Columbia River 1934-1983. U.S. Fish and Wildlife Service Report No. FRI/FAO-86-15. Fisheries Assistance office.

Newcombe, C.P., and D.D. MacDonald. 1991. Effects of Suspended Sediments on Aquatic Ecosystems. North American Journal of Fisheries Management 11:72-82.

Nigro, A.A. (Ed.). 1990. Status and Habitat Requirements of White Sturgeon Populations in the Columbia River Downstream from McNary. Bonneville Power Administration, Portland, Oregon. 191 pp.

NPPC (Northwest Power Planning Council). 1991a. Priority Salmon Habitat and Production Proposals. Northwest Power Planning Council. Portland, Oregon.

NPPC. 1991b. Amendments to the Columbia River Basin Fish and Wildlife Program, Phase II. Document No. 91-31, December 11, 1991. Portland, Oregon.

NPPC. 1989. Salmon and steelhead system planning documentation. Prepared by the Monitoring and Evaluation Group. August 1, 1989.

NPPC. 1986. Compilation of Information on Salmon and Steelhead Losses in the Columbia River Basin. Portland, Oregon. 252 pp.

NPS (National Park Service). 1990. Monthly Visitation Figures at Coulee Dam National Recreation Area, 1990. U.S. Department of the Interior, National Park Service, Coulee Dam National Recreation Area, Coulee Dam, Washington. Unpublished.

NPS. 1989. Fluctuating Lake Level Mitigation Study. U.S. Department of the Interior, National Park Service, Denver Service Center. Denver, Colorado.

NPS. 1980. General Management Plan, Grand Coulee National Recreation Area. U.S. Department of the Interior, National Park Service, Coulee Dam National Recreation Area. Denver, Colorado.

NPS. Undated. Lake Roosevelt Official Map and Guide.

ODF&W and WDF (Oregon Department of Fish and Wildlife and Washington Department of Fisheries). 1991. Status Report, Columbia River Fish Runs and Fisheries 1960-90. July 1991.

Ogden Beeman and Associates. 1990. Lower Columbia River Channel Improvement Study. Prepared for the U.S. Army Corps of Engineers, Portland District. Portland, Oregon.

Pacific Coast American Peregrine Falcon Recovery Team. 1982. Pacific Coast Recovery Plan for the American Peregrine Falcon (*Falco peregrinus anatum*). 86 pp.

PSC (Pacific Salmon Commission). 1990. Joint Chinook Technical Committee. 1989 Annual Report. Vancouver, British Columbia. TCCH.NOOK(90)-3.

Parente, W.D. and J.G. Smith. 1981. Columbia River backwater study: Phase II. U.S. Fish and Wildlife Service. Vancouver, WA. 87 pages plus appendices.

Park, D. and J.B. Athearn. 1985. Comprehensive Report of Juvenile Salmon Transportation. United States Army Corps of Engineers, Walla Walla District. Walla Walla, Washington.

Pascho, R.J. and D.G. Elliott. 1989. Juvenile Fish Transportation: Impact of Bacterial Kidney Disease on Survival of Spring/Summer Chinook Salmon Stocks. Annual Report, 1988 (Contract E86880047). Prepared by the U.S. Fish and Wildlife Service, Seattle, Washington, for the U.S. Army Corps of Engineers.

Payne, N.F., G.P. Munger, J.W. Matthews, and R.D. Taber. 1976. Inventory of Vegetation and Wildlife in Riparian and other Habitats along the Upper Columbia River. Volume IVA. U.S. Army Corps of Engineers, North Pacific Division. Portland, Oregon. 560 pp.

Payne, N.F., G.P. Munger, J.W. Matthews, and R.D. Taber. 1975. Inventory of vegetation and wildlife in riparian and other habitats along the Upper Columbia River. Corps North Pacific Division. Volume 4A. 558 pp.

Peone, T.L., A.T. Scholz, J.R. Griffith, S. Graves, and M.G. Thatcher, Jr. 1990. Lake Roosevelt Fisheries Monitoring Program. Annual Report. Bonneville Power Administration. Portland, Oregon.

Petrosky, C.E. Undated. Analysis and Implications of Alternative Flow-Smolt Survival Models to Snake River Spring/Summer Chinook Recovery through Mainstem Velocity Improvements. Idaho Department of Fish and Game. Boise, Idaho.

PFMC (Pacific Fisheries Management Council). 1991. Review of 1990 Ocean Salmon Fisheries. PFMC. Portland, Oregon.

Poe, T.P. and B.E. Rieman. 1988. Predation by Resident Fish on Juvenile Salmonids in John Day Reservoir, 1983-1986. U.S. Department of Energy, Bonneville Power Administration. Portland, Oregon. 377 pp.

Port of Whitman County, Ken Casavant. Letter to U.S. ACOE received 11/26/91 (undated).

Pruter, A.T. and D.L. Alverson. 1972. The Columbia River Estuary and Adjacent Ocean Waters. University of Washington Press. Seattle, Washington.

Raymond, H.L. 1979. Effects of Dams and Impoundments on Migrations of Juvenile Chinook Salmon and Steelhead from the Snake River, 1966 to 1975. Transactions of the American Fisheries Society 108:505-529.

Raymond, H.L. 1988. Effects of Hydroelectric Development and Fisheries Enhancement on Spring and Summer Chinook Salmon and Steelhead in the Columbia Basin. North American Journal of Fisheries Management, 8:1-24.

Raymond, H.L. 1968. Migration Rates of Yearling Chinook Salmon in Relation to Flows and Impoundments in the Columbia and Snake Rivers. Transactions of the American Fisheries Society. 97:356-359.

Rieman, B.E. and R.C. Beamesderfer. 1988. Population Dynamics of Northern Squawfish and Potential Predation on Juvenile Salmonids in a Columbia River Reservoir. In: T.P. Poe and B.E. Rieman (eds.), Predation by Resident Fish on Juvenile Salmonids in John Day Reservoir, 1983-1986. Final Report (Contracts DE-A179-82BP34796 and DE-A179-82BP35097) to Bonneville Power Administration. Portland, Oregon.

Rieman, B.E., R.C. Beamesderfer, S. Vigg, and T.P. Poe. 1991. Estimated Loss of Juvenile Salmonids in Predation by Northern Squawfish, Walleyes, and Smallmouth Bass in John Day Reservoir, Columbia River. Transaction of the American Fisheries Societies, 120:448-458.

Rohrer, R.L. 1984. Federal Aid in Fish Restoration. Subproject III: Lake and Reservoir Investigations; Study I: Brownlee Reservoir Fish Population Dynamics, Community Structure and the Fishery. Idaho Fish and Game Fishery Research Report.

Roosevelt Recreational Enterprises. 1988. Boating Adventures in Lake Roosevelt Country.

Ruffner, J.A. and F.E. Bair (eds.). 1979. The Weather Almanac. Avon Books, New York, New York.

Rulifson, R.L. and G. Abel. 1971. Nitrogen Supersaturation in the Columbia and Snake Rivers. U.S. Environmental Protection Agency. Seattle, Washington. 116 pp.

Sager, J.W. 1989a. Bonneville Dam. *In*: Engineering Geology in Washington, Vol. I, Washington Division of Geology and Earth Resources Bulletin 78, pp. 337-346.

Sager, J.W. 1989b. The Dalles Dam. *In*: Engineering Geology in Washington, Vol. I, Washington Division of Geology and Earth Resources Bulletin 78, pp. 347-352.

Sager, J.W. 1989c. John Day Dam. *In*: Engineering Geology in Washington, Vol. I, Washington Division of Geology and Earth Resources Bulletin 78, pp. 353-358.

Sather-Blair, S., D. Vinson, and V. Saab. 1991. Lower Snake River Fish and Wildlife Compensation Plan. U.S. Army Corps of Engineers, Walla Walla District. 59 pp.

Schoeneman, D.E., R.T. Pressey, and C.O. Junge. 1961. Mortalities of Downstream Migrant Salmon at McNary Dam. Transactions of the American Fisheries Society, Vol. 90, No. 1, pp. 58-72.

Seattle Marine Laboratories. 1972. Nitrogen Monitoring Studies. Final Report, 1972. Submitted to Idaho Power Company, August 1972. 42 pp.

Sherwood, C.R., D.A. Jay, R.B. Harvey, P. Hamilton, and C.A. Simenstadt. 1990. Historical changes in the Columbia River Estuary. Progressive Oceanography. 25:229-352.

Sims, C., A. Giorgi, R. Johnsen, and D. Brege. 1983. Migrational Characteristics of Juvenile Salmon and Steelhead in the Columbia Basin - 1982. Final Report to USACE, NOAA, NMFS. 35 pp., plus appendices.

Sims, C. and D. Miller. 1982. Effects of Flow on the Migratory Behavior and Survival of Juvenile Fall and Chinook Salmon in John Day Reservoir. Annual Report of Research to BPA, NOAA, NMFS, NWFC, Seattle, Washington, 22 pp. plus appendices.

Sims, C.W. and F.J. Ossiander. 1981. Migrations of Juvenile Chinook Salmon and Steelhead in the Snake River, from 1973-1979, Research Summary. Contract DACW68-78-C-0038 to U.S. Army Corps of Engineers. Portland, Oregon.

Sprunt, A., IV, W.B. Roberston, Jr., S. Postupalsky, R.J. Hensel, C.E. Knoder, and F. J. Ligas. 1973. Comparative Productivity of Six Bald Eagle Populations. Trans. North American Wildlife and Natural Resources Conference 38:96-105.

Stalmaster, M.V. 1987. The Bald Eagle. Universe Books. New York.

Stalmaster, M.V., and J.R. Newman. 1979. Perch-Site Preferences of Wintering Bald Eagles in Northwest Washington. Journal of Wildlife Management 43:221-224.

Stalmaster, M.V. 1976. Winter Ecology and Effects of Human Activity on Bald Eagles in the Nooksack River Valley, Washington. M.S. Thesis. Western Washington State College. Bellingham, Washington. 100 pp.

Stober, Q.J., M.R. Griben, R.V. Walker, A.L. Setter, I. Nelson, J.C. Gislason, R.W. Tyler, and E.O. Salo. 1979. Columbia River Irrigation Withdrawal Environmental Review: Columbia River Fishery Study. Final Report. U.S. Army Corps of Engineers. Portland, Oregon.

Stober, Q.J., M.E. Kopache, and T.H. Jagielo. 1981. The Limnology of Lake Roosevelt. Final Report to the U.S. Fish and Wildlife Service. National Fisheries Research Institute, Seattle, Washington. Fisheries Research Institute, University of Washington, Seattle, Washington. FRI-VW 8106:116 pp.

Tabor, J. E. 1976. Inventory of Riparian Habitats and Associated Wildlife along the Columbia and Snake Rivers. Volume IIA and B. U.S. Army Corps of Engineers, North Pacific Division. Portland, Oregon. 861 pp.

Thomas, J.W. 1987. Wildlife Habitats in Managed Forests of the Blue Mountains of Oregon and Washington. U.S Department of Agriculture. Agriculture Handbook No. 553.

Turner, R. 1990. Memorandum for Record. Subject: Dworshak Temperature Releases, September 1990. October 12, U.S. Army Corps of Engineers, North Pacific Division, Fish and Water Quality Unit. Portland, Oregon.

Turner, R., J.R. Kaskie, Jr., and K.E. Kostorn. 1984. Evaluation of Adult Fish Passage at Ice Harbor and Lower Monumental Dams, 1982. U.S. Army Corps of Engineers. Cascade Lock, Oregon.

Turner, R., J.R. Kaskie, Jr., and K.E. Kostorn. 1983. Evaluations of Adult Fish Passage at Little Goose and Lower Granite Dams, 1981. U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

U.S. Bureau of Census. 1981a. 1980 Census of Population. Volume 1: Characteristics of the Population. Chapter A: Number of Inhabitants, Idaho. U.S. Department of Commerce, Bureau of the Census. September 1981.

U.S. Bureau of Census. 1981b. 1980 Census of Population. Volume 1: Characteristics of the Population. Chapter A: Number of Inhabitants, Oregon. U.S. Department of Commerce, Bureau of the Census. December 1981.

USDA (U.S. Department of Agriculture). 1987a. Census of Agriculture, Geographic Area Series, Part 12, Idaho. Washington, D.C.

USDA. 1987b. Census of Agriculture, Geographic Area Series, Part 37, Oregon. Washington, D.C.

USDA. 1987c. Census of Agriculture, Geographic Area Series, Part 47, Washington. Washington, D.C.

USDI (U.S. Department of the Interior). 1981. The Final Report of the National Reservoir Inundation Study, Volumes I and II, National Park Service, Southwest Cultural Resource Center. Santa Fe, New Mexico.

Vigg, S.L. and D.L. Watkins. 1991. Temperature Control and Flow Augmentation to Enhance Spawning Migration of Salmonids in the Snake River, Especially Fall Chinook Salmon. Bonneville Power Administration. Portland, Oregon.

Waples, R.S., R.P. Jones, Jr., B.R. Beckman, and G.A. Swan. 1991a. Status Review for Snake River Fall Chinook Salmon. U.S. Department of Commerce. NOAA Technical Memorandum NMFS F/NWC-201, 73 pp.

Waples, R.S., O.W. Johnson, and R.P. Jones. 1991b. Status Review for Snake River Sockeye Salmon. U.S. Department of Commerce. NOAA Technical Memorandum NMFS F/NWC-195, 23 pp.

Warren, J.S. 1989. Augmented Fish Health Monitoring. Annual Report. U.S. Fish and Wildlife Service. Funded by U.S. Department of Energy, Bonneville Power Administration. August 15, 1989.

Washington State Employment Security Commission. 1991. Labor Force and Employment in Washington State. Washington State Employment Security Commission, Labor Market and Economic Analysis Branch. May 1991.

Washington State Employment Security Commission. 1990. Annual Demographic Information. A Labor Market Information Report of the Labor Market and Economic Security Department. Prepared in Cooperation with the Employment and Training Administration, U.S. Department of Labor. November 1990.

Washington State Employment Security Commission. 1990. Labor Force and Employment in Washington State. Washington State Employment Security Commission, Labor Market and Economic Analysis Branch. May 1990.

Washington State Office of Financial Management. 1983. 1983 Population Trends for Washington State. State of Washington, Office of Financial Management. August 1983.

WASS (Washington Agricultural Statistics Service). 1990. Washington Agricultural Statistics. State of Washington Department of Agriculture, Tumwater, Washington.

Weber, K. G. 1954. Testing the Effect of a Bonneville Draft Tube on Fingerling Salmon. U.S. Department of Interior, Fish and Wildlife Service. Seattle, Washington.

Weinstein, M.N. 1979. Report on the 1979 Monitoring Program of the American Peregrine Falcon in the Dry Creek Critical Habitat Zone. Unpublished Report, U.S. Department of the Interior. 37 pp.

Weitkamp, D.E., and M. Katz. 1980. A Review of Dissolved Gas Supersaturation Literature. Transactions of the American Fisheries Society. 109:659-702.

Whitman, R.P., T.P. Quinn, and E.L. Brannon. 1982. Influence of Suspended Volcanic Ash on Homing Behavior of Adult Chinook Salmon. Transactions of the American Fisheries Society 11:63-69.

Winges, K. 1991. User's Guide for the Fugitive Dust Model (FDM) (Revised). Prepared for Region 10 of EPA, Seattle, Washington. EPA 910/9-88-202R.

WSU (Washington State University). 1990a. Establishment and Annual Production Costs for Washington Wine Grapes. Cooperative Extension Service Farm Business Management Report EB1588, Pullman, Washington, October 1990.

WSU. 1990b. Cost of Producing Crops under Center Pivot Irrigation, Columbia Basin, Washington. Cooperative Extension Service Farm Business Management Report EB1291, Pullman, Washington, January 1990.

WSU. 1989. Cost of Producing Bluegrass Seed in the Lincoln-Adams Area Under Center Pivot Irrigation. Cooperative Extension Service Farm Business Management Report EB1533, Pullman, Washington, July 1989.

WSU. 1988. Cost of Producing Sweet Corn for Processing, Columbia Basin, Washington. Cooperative Extension Service Farm Business Management Report EB1503, Pullman, Washington, July 1988.

WSU. 1985. 1985 Estimated Cost of Producing Red Delicious Apples, Columbia Basin, Central Washington. Cooperative Extension Service Farm Business Management Report EB1559, Pullman, Washington, August 1985.

WSU. Undated a. Summary of Variable Production Costs Per Acre for Irrigated Potatoes, Walla Walla County, Washington, 1990. Cooperative Extension Service unpublished printout, Pullman, Washington.

WSU. Undated b. Summary of Variable Production Costs Per Acre for Irrigated Pasture, Walla Walla County, Washington, 1990. Cooperative Extension Service unpublished printout, Pullman, Washington.

Wydoski, R.S. and R.R. Whitney. 1979. Inland Fishes of Washington. University of Washington, Seattle, Washington, 220 pp.

Zimmerman, M.A. and L.A. Rasmussen, 1981. Juvenile Salmonid Use of Three Columbia River Backwater Areas Proposed for Subimpoundment. U.S. Fish and Wildlife Service, Portland Field Office, Portland, Oregon, 27 pp

Zimowsky, P. 1990. Idaho Statesman, February 21, 1990. Boise, Idaho.

13.0

# Index

# 1992 COLUMBIA RIVER SALMON FLOW MEASURES OA/EIS

## CONTENTS

# 13. INDEX