Columbia River System Operation Review

Final Environmental Impact Statement

Appendix K

Resident Fish

BONNEVILLE POWER ADMINISTRATION

US Army Corps of Engineers
North Pacific Division

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

DOE/EIS-0170

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PUBLIC INVOLVEMENT IN THE SOR PROCESS

The Bureau of Reclamation, Corps of Engineers, and Bonneville Power Administration wish to thank those who reviewed the Columbia River System Operation Review (SOR) Draft EIS and appendices for their comments. Your comments have provided valuable public, agency, and tribal input to the SOR NEPA process. Throughout the SOR, we have made a continuing effort to keep the public informed and involved.

Fourteen public scoping meetings were held in 1990. A series of public roundtables was conducted in November 1991 to provide an update on the status of SOR studies. The lead agencies went back to most of the 14 communities in 1992 with 10 initial system operating strategies developed from the screening process. From those meetings and other consultations, seven SOS alternatives (with options) were developed and subjected to full–scale analysis. The analysis results were presented in the Draft EIS released in July 1994. The lead agencies also developed alternatives for the other proposed SOR actions, including a Columbia River Regional Forum for assisting in the determination of future SOSs, Pacific Northwest Coordination Agreement alternatives for power coordination, and Canadian Entitlement Allocation Agreements alternatives. A series of nine public meetings was held in September and October 1994 to present the Draft EIS and appendices and solicit public input on the SOR. The lead agencies received 282 formal written comments. Your comments have been used to revise and shape the alternatives presented in the Final EIS.

Regular newsletters on the progress of the SOR have been issued. Since 1990, 20 issues of *Streamline* have been sent to individuals, agencies, organizations, and tribes in the region on a mailing list of over 5,000. Several special publications explaining various aspects of the study have also been prepared and mailed to those on the mailing list. Those include:

The Columbia River: A System Under Stress
The Columbia River System: The Inside Story
Screening Analysis: A Summary
Screening Analysis: Volumes 1 and 2
Power System Coordination: A Guide to the Pacific Northwest Coordination Agreement
Modeling the System: How Computers are Used in Columbia River Planning
Daily/Hourly Hydrosystem Operation: How the Columbia River System Responds to Short–Term Needs

Copies of these documents, the Final EIS, and other appendices can be obtained from any of the lead agencies, or from libraries in your area.

Your questions and comments on these documents should be addressed to:

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Portland, OR 97208–2988

PREFACE: SETTING THE STAGE FOR THE SYSTEM OPERATION REVIEW

WHAT IS THE SOR AND WHY IS IT BEING CONDUCTED?

The Columbia River System is a vast and complex combination of Federal and non–Federal facilities used for many purposes including power production, irrigation, navigation, flood control, recreation, fish and wildlife habitat and municipal and industrial water supply. Each river use competes for the limited water resources in the Columbia River Basin.

To date, responsibility for managing these river uses has been shared by a number of Federal, state, and local agencies. Operation of the Federal Columbia River system is the responsibility of the Bureau of Reclamation (Reclamation), Corps of Engineers (Corps) and Bonneville Power Administration (BPA).

The System Operation Review (SOR) is a study and environmental compliance process being used by the three Federal agencies to analyze future operations of the system and river use issues. The goal of the SOR is to achieve a coordinated system operation strategy for the river that better meets the needs of all river users. The SOR began in early 1990, prior to the filing of petitions for endangered status for several salmon species under the Endangered Species Act.

The comprehensive review of Columbia River operations encompassed by the SOR was prompted by the need for Federal decisions to (1) develop a coordinated system operating strategy (SOS) for managing the multiple uses of the system into the 21st century; (2) provide interested parties with a continuing and increased long–term role in system planning (Columbia River Regional Forum); (3) renegotiate and renew the Pacific Northwest Coordination Agreement (PNCA), a contractual arrangement among the region's major hydroelectric–generating utilities and affected Federal agencies to provide for coordinated power generation on the Columbia River system; and (4) renew or develop new Canadian Entitlement Allocation Agreements (contracts that divide Canada's share of Columbia River Treaty downstream power benefits and obligations among three participating public utility districts and BPA). The review provides the environmental analysis required by the National Environmental Policy Act (NEPA).

This technical appendix addresses only the effects of alternative system operating strategies for managing the Columbia River system. The environmental impact statement (EIS) itself and some of the other appendices present analyses of the alternative approaches to the other three decisions considered as part of the SOR.

WHO IS CONDUCTING THE SOR?

The SOR is a joint project of Reclamation, the Corps, and BPA—the three agencies that share responsibility and legal authority for managing the Federal Columbia River System. The National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), and National Park Service (NPS), as agencies with both jurisdiction and expertise with regard to some aspects of the SOR, are cooperating agencies. They contribute information, analysis, and recommendations where appropriate. The U.S. Forest Service (USFS) was also a cooperating agency, but asked to be removed from that role in 1994 after assessing its role and the press of other activities.

HOW IS THE SOR BEING CONDUCTED?

The system operating strategies analyzed in the SOR could have significant environmental impacts. The study team developed a three–stage process—scoping, screening, and full–scale analysis of the strategies—to address the many issues relevant to the SOR.

At the core of the analysis are 10 work groups. The work groups include members of the lead and cooperating agencies, state and local government agencies, representatives of Indian tribes, and members of the public. Each of these work groups has a single river use (resource) to consider.

Early in the process during the screening phase, the 10 work groups were asked to develop an alternative for project and system operations that would provide the greatest benefit to their river use, and one or more alternatives that, while not ideal, would provide an acceptable environment for their river use. Some groups responded with alternatives that were evaluated in this early phase and, to some extent, influenced the alternatives evaluated in the Draft and Final EIS. Additional alternatives came from scoping for the SOR and from other institutional sources within the region. The screening analysis studied 90 system operation alternatives.

Other work groups were subsequently formed to provide projectwide analysis, such as economics, river operation simulation, and public involvement.

The three–phase analysis process is described briefly below.

- **Scoping/Pilot Study**—After holding public meetings in 14 cities around the region, and coordinating with local, state, and Federal agencies and Indian tribes, the lead agencies established the geographic and jurisdictional scope of the study and defined the issues that would drive the EIS. The geographic area for the study is the Columbia River Basin (Figure P–1). The jurisdictional scope of the SOR encompasses the 14 Federal projects on the Columbia and lower Snake Rivers that are operated by the Corps and Reclamation and coordinated for hydropower under the PNCA. BPA markets the power produced at these facilities. A pilot study examining three alternatives in four river resource areas was completed to test the decision analysis method proposed for use in the SOR.
- **Screening**—Work groups, involving regional experts and Federal agency staff, were created for 10 resource areas and several support functions. The work groups developed computer screening models and applied them to the 90 alternatives identified during screening. They compared the impacts to a baseline operating year—1992—and ranked each alternative according to its impact on their resource or river use. The lead agencies reviewed the results with the public in a series of regional meetings in September 1992.
- **Full–Scale Analysis**—Based on public comment received on the screening results, the study team sorted, categorized, and blended the alternatives into seven basic types of operating strategies. These alternative strategies, which have multiple options, were then subjected to detailed impact analysis. Twenty–one possible options were evaluated. Results and tradeoffs for each resource or river use were discussed in separate technical appendices and summarized in the Draft EIS. Public review and comment on the Draft EIS was conducted during the summer and fall of 1994. The lead agencies adjusted the alternatives based on the comments, eliminating a few options and substituting new options, and reevaluated them during the past 8 months. Results are summarized in the Final EIS.

Alternatives for the Pacific Northwest Coordination Agreement (PNCA), the Columbia River Regional Forum (Forum), and the Canadian Entitlement Allocation Agreements (CEAA) did not use the three–stage process described above. The environmental impacts from the PNCA and CEAA were not significant and there were no anticipated impacts from the Regional Forum. The procedures used to analyze alternatives for these actions are described in their respective technical appendices.

For detailed information on alternatives presented in the Draft EIS, refer to that document and its appendices.

WHAT SOS ALTERNATIVES ARE CONSIDERED IN THE FINAL EIS?

Seven alternative System Operating Strategies (SOS) were considered in the Draft EIS. Each of the seven SOSs contained several options bringing the total number of alternatives considered to 21. Based on review of the Draft EIS and corresponding adjustments, the agencies have identified 7 operating strategies that are evaluated in this Final EIS. Accounting for options, a total of 13 alternatives is now under consideration. Six of the alternatives remain unchanged from the specific options considered in the Draft EIS. One is a revision to a previously considered alternative, and the rest represent replacement or new alternatives. The basic categories of SOSs and the numbering convention remains the same as was used in the Draft EIS. However, because some of the alternatives have been dropped, the numbering of the final SOSs are not consecutive. There is one new SOS category, Settlement Discussion Alternatives, which is labeled SOS 9 and replaces the SOS 7 category. This category of alternatives arose as a consequence of litigation on the 1993 Biological Opinion and ESA Consultation for 1995.

The 13 system operating strategies for the Federal Columbia River system that are analyzed for the Final EIS are:

SOS 1a Pre Salmon Summit Operation represents operations as they existed from around 1983 through the 1990–91 operating year, prior to the ESA listing of three species of salmon as endangered or threatened.

SOS 1b Optimum Load–Following Operation represents operations as they existed prior to changes resulting from the Regional Act. It attempts to optimize the load–following capability of the system within certain constraints of reservoir operation.

SOS 2c Current Operation/No–Action Alternative represents an operation consistent with that specified in the Corps of Engineers' 1993 Supplemental EIS. It is similar to system operation that occurred in 1992 after three species of salmon were listed under ESA.

SOS 2d [New] 1994–98 Biological Opinion represents the 1994–98 Biological Opinion operation that includes up to 4 MAF flow augmentation on the Columbia, flow targets at McNary and Lower Granite, specific volume releases from Dworshak, Brownlee, and the Upper Snake, meeting sturgeon flows 3 out of 10 years, and operating lower Snake projects at MOP and John Day at MIP.

SOS 4c [Rev.] Stable Storage Operation with Modified Grand Coulee Flood Control attempts to achieve specific monthly elevation targets year round that improve the environmental conditions at storage projects for recreation, resident fish, and wildlife. Integrated Rules Curves (IRCs) at Libby and Hungry Horse are applied.

SOS 5b Natural River Operation draws down the four lower Snake River projects to near river bed levels for four and one–half months during the spring and summer salmon migration period, by assuming new low level outlets are constructed at each project.

SOS 5c [New] Permanent Natural River Operation operates the four lower Snake River projects to near river bed levels year round.

SOS 6b Fixed Drawdown Operation draws down the four lower Snake River projects to near spillway crest levels for four and one–half months during the spring and summer salmon migration period.

SOS 6d Lower Granite Drawdown Operation draws down Lower Granite project only to near spillway crest level for four and one–half months.

SOS 9a [New] Detailed Fishery Operating Plan includes flow targets at The Dalles based on the previous year's end–of–year storage content, specific volumes of releases for the Snake River, the drawdown of Lower Snake River projects to near spillway crest level for four and one–half months, specified spill percentages, and no fish transportation.

SOS 9b [New] Adaptive Management establishes flow targets at McNary and Lower Granite based on runoff forecasts, with specific volumes of releases to meet Lower Granite flow targets and specific spill percentages at run–of–river projects.

SOS 9c [New] Balanced Impacts Operation draws down the four lower Snake River projects near spillway crest levels for two and one–half months during the spring salmon migration period. Refill begins after July 15. This alternative also provides 1994–98 Biological Opinion flow augmentation, integrated rule curve operation at Libby and Hungry Horse, a reduced flow target at Lower Granite due to drawdown, winter drawup at Albeni Falls, and spill to achieve no higher than 120 percent daily average for total dissolved gas.

SOS PA Preferred Alternative represents the operation proposed by NMFS and USFWS in their Biological Opinions for 1995 and future years; this SOS operates the storage projects to meet flood control rule curves in the fall and winter in order to meet spring and summer flow targets for Lower Granite and McNary, and includes summer draft limits for the storage projects.

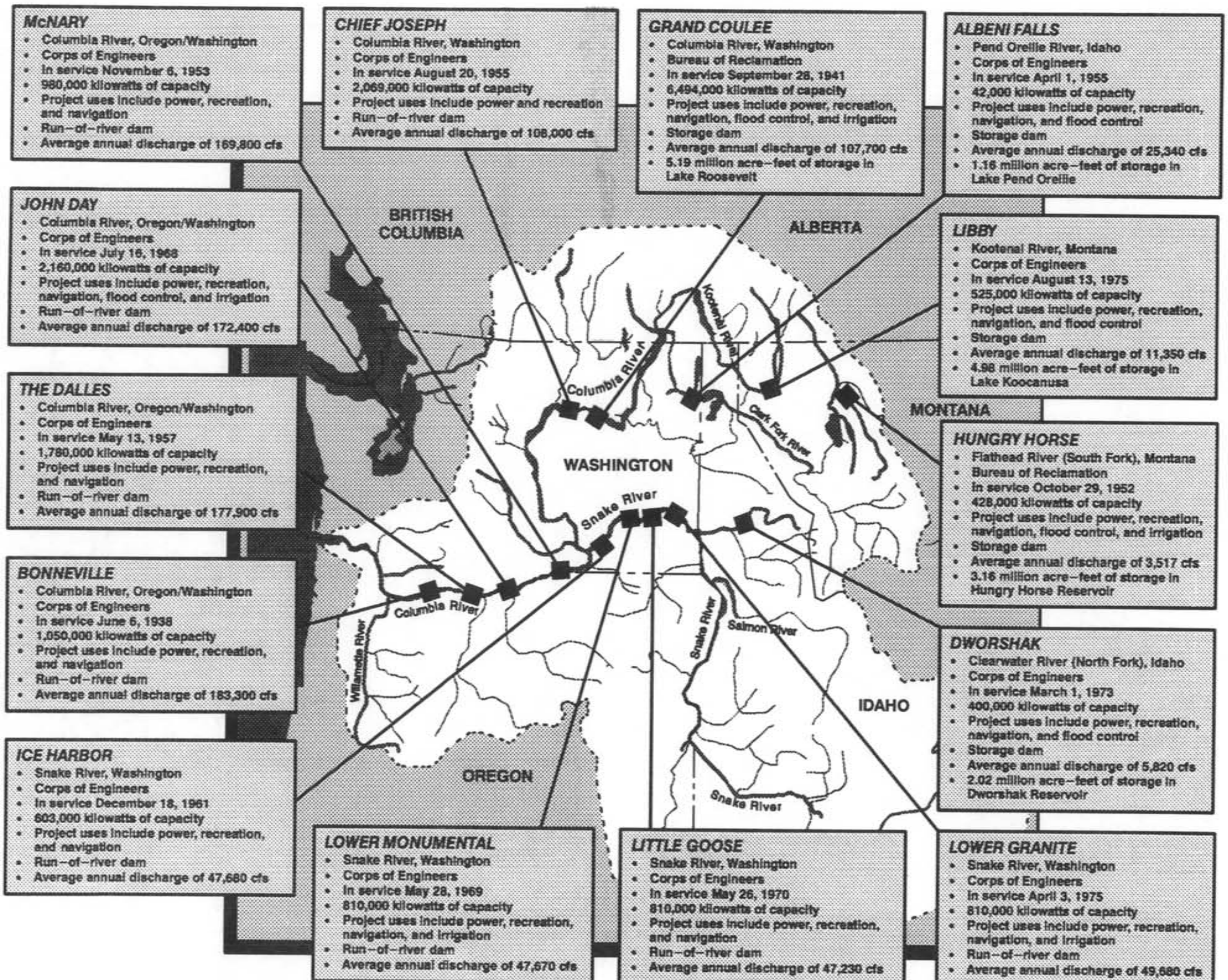
WHAT DO THE TECHNICAL APPENDICES COVER?

This technical appendix is 1 of 20 prepared for the SOR. They are:

A. River Operation Simulation
B. Air Quality
C. Anadromous Fish & Juvenile Fish Transportation
D. Cultural Resources
E. Flood Control
F. Irrigation/Municipal and Industrial Water Supply
G. Land Use and Development
H. Navigation
I. Power
J. Recreation
K. Resident Fish
L. Soils, Geology, and Groundwater
M. Water Quality
N. Wildlife
O. Economic and Social Impacts
P. Canadian Entitlement Allocation Agreements
Q. Columbia River Regional Forum
R. Pacific Northwest Coordination Agreement
S. U. S. Fish and Wildlife Service Coordination Act Report
T. Comments and Responses

Each appendix presents a detailed description of the work group's analysis of alternatives, from the scoping process through full–scale analysis. Several appendices address specific SOR functions (e.g., River Operation Simulation), rather than individual resources, or the institutional alternatives (e.g., PNCA) being considered within the SOR. The technical appendices provide the basis for developing and analyzing alternative system operating strategies in the EIS. The EIS presents an integrated review of the vast wealth of information contained in the appendices, with a focus on key issues and impacts. In addition, the three agencies have prepared a brief summary of the EIS to highlight issues critical to decision makers and the public.

There are many interrelationships among the different resources and river uses, and some of the appendices provide supporting data for analyses presented in other appendices. This Resident Fish appendix supports Appendices on Wildlife and Recreation. For complete coverage of all aspects of these other uses, readers may wish to review all 3 appendices in concert.



1 million acre feet = 1 234 million cubic meters
1 cubic foot per second = 0.028 cubic meters per second

Figure P–1. Projects in the System Operation Review.

TABLE OF CONTENTS

TABLE OF CONTENTS – CONT

TABLE OF CONTENTS - CONT

TABLE OF CONTENTS – CONT

TABLE OF CONTENTS – CONT

TABLE OF CONTENTS – CONT

TABLE OF CONTENTS – CONT

LIST OF TABLES

LIST OF TABLES – CONT

LIST OF FIGURES

LIST OF FIGURES - CONT

Figure	Title	Page

LIST OF FIGURES – CONT

LIST OF FIGURES – CONT

CHAPTER 1

INTRODUCTION: SCOPE AND PROCESS

The fisheries resources of the Columbia Basin comprise not only anadromous (sea–run) salmon and other species, but also resident (sea–run) species. Because of their huge cultural and economic importance to the region, salmon and steelhead have dwarfed other fishes in the public mind. However, the resident species have profound ecological significance themselves; their role in the basin's ecosystem cannot be underestimated. They hold many places in the food web, not only as prey and predators for other fish and wildlife, but as quarry for humans as well. Species such as kokanee, white sturgeon and whitefish have been sought by tribal and commercial fisheries. These and others, such as trout, chars, and burbot have also been sought by recreational anglers. Resident fish have helped fuel an economy that helps the region live up to its reputation as an outdoor playground. Exotics such as brook trout, bass, perch, carp, and walleye were introduced from the eastern US (carp in fact originated in Europe) in earlier decades, and continue to provide strong sport fisheries here.

When dams were constructed on the Columbia River system, many spawning grounds historically used by anadromous fish were cut off to them. With salmon and steelhead no longer present in many upper basin waters, resident fish have taken on new importance in recent years. The Columbia Basin Fish and Wildlife Authority (CBFWA), made up of tribal, state, and Federal fish and wildlife agencies, has developed a resident fish substitutions policy which recognizes this. The Northwest Power Planning Council, through its Columbia Basin Fish and Wildlife Plan, acknowledges the role of dams in the resident fish ecosystem, and attempts to correct impacts that have resulted from construction and operation of the regional hydropower system.

Despite their recognition by many as an important component of the basin ecosystem, resident fish have taken a back seat to anadromous fish in research and management efforts. The result is that in some areas, especially the mainstem parts of the Columbia and Snake Rivers, very little is known about resident fish. Comprehensive data are often lacking regarding populations, life history requirements, and habitat use.

Nonetheless, the Resident Fish Work Group (RFWG) has attempted to characterize and evaluate impacts of dam operation on an extremely complex and diverse integrated resource. Not only is this required under the National Environmental Policy Act (NEPA) for SOR, there are resident fish populations that have status under the Federal Endangered Species Act (ESA) or equivalent state regulations (Kootenai River white sturgeon, Snake River white sturgeon, sandroller, shorthead and torrent sculpins, bull trout, westslope cutthroat trout, redband trout, and burbot).

The RFWG has also attempted to develop operating alternatives that benefit not only resident fish, but anadromous fish, wildlife, and other human interests as well. We have recognized the co–evolution of resident fish, anadromous fish, and other integrated resources in the basin.

Because of this ecological integration, each native species has an intrinsic worth beyond what may be recognized. The RFWG has implicitly taken to heart the first rule of tinkering: never throw out any of the parts.

1.1 SUMMARY OF RESIDENT FISH ISSUES AND CONCERNS RAISED DURING THE SCOPING PROCESS

1.1.1 Initial Scoping

The Corps of Engineers, Bonneville Power Administration, and Bureau of Reclamation (the three operating agencies) conducted a scoping process consisting of a series of regionwide public meetings and solicitation of written comments in the summer of 1990. Upper–basin commenters were the most likely to target resident fish issues, especially where there were no anadromous fish.

The following includes issues raised in the public scoping process, as well as those brought for consideration by members of the Resident Fish Work Group (RFWG). The work group members' issues (those raised in addition to comments from the public are marked with an asterisk [*]) tended to be specific rather than general, whereas those from the public were both.

1.1.1.1 General Comments

There were many comments that related to fish and wildlife in general. According to some, the baseline condition for fish and wildlife should not be the existing condition, but instead, pre–dam conditions. At least one commenter said that it would have to be acknowledged that irreversible changes had occurred in the system, and that dam removal would be necessary to restore fisheries to a totally natural state. One comment, though not fishery–specific, indicated that a priority should be put on what is left, since what is already lost is gone, but another suggested a "phase–out of all engineered restraints on the system" so that human use would adapt to natural systems.

General concerns that were voiced indicated that fish and wildlife and their habitat should be protected, and that ecologically acceptable operating standards must be met. To that end, direct involvement in SOR, and in fact in the PNCA and CEAA's, by fish and wildlife agencies as well as tribes was seen as necessary. There were statements that the river in general should be managed with wildlife and fisheries, as well as native ecosystems, as the primary concerns. Others wanted management for fish with their recreational value in mind. River health assessment, including water quality, was mentioned as a goal. Natural resources as a priority over maximum power sales was also cited, though for some the goal was simply equal consideration among water uses. In fact, it was mentioned that people wanted better fisheries and would be willing to pay higher power rates for them. One comment stated that Columbia Basin fish and wildlife resources were of "regional, national, and international importance." However, many others felt that fish were the object of excessive concern, and wanted more emphasis on uses for people.

1.1.1.2 Specific Comments

There were many individual issues identified by the public as well as by members of the work group; they are listed below. (Note that the language of many of the comments is that of the commentors and may reflect perspectives not necessarily shared by fishery managers.) Some of the items brought in by the public were ouotetside the scope of the RFWG's task. Disposition of each of the remaining items is noted in parentheses at the end of each item.

Upper basin concerns

- (see also, 1.1.1.2 Upper Snake)
- Water should not be supplied for anadromous fish in the lower Columbia to the detriment of headwater resources. (Impacts of all SOSs were evaluated for upper–basin resident fish.)
- Canada should take some responsibility to ensure that other economic interests do not irreparably harm fish resources (this is outside the scope [US] of SOR).
- Anadromous fish flows are carrying resident fish out of storage reservoirs (evaluated by RFWG).
- Maintain upper–basin instream flows possibly through water–rights purchases (outside of SOR scope, which pertains to operation of PNCA dams).

Columbia River Flow Proposal

- SOR should account for the Columbia River Flow Proposal of the Columbia Basin Fish and Wildlife Authority, which includes reservoir levels and flows designed to protect resident fish (would be considered in SOS formation).

Other agreements

- Other agreements, such as mitigation agreements, should be considered in SOR (these have been accounted for as they apply to resident fish).

Substitution of other species

- Other fish species should be considered for their adaptability to existing river conditions, including "maximum power operation." Use landlocked salmon as one substitute (cannot implement through SOR––operating agencies are not fisheries managers).

Use of other study results

- SOR should make use of fisheries studies being conducted under other auspices. Libby and Hungry Horse models by the Montana Dept. of Fish, Wildlife and Parks were specifically mentioned (this is being done).

Tradeoffs

- Tradeoffs involving fish and wildlife should be based on agency/tribal recommendations. One comment compared resident fish negatively with anadromous salmonids. Another felt that reservoir fisheries were always better than the river fisheries which had previously existed in impounded reaches. Another comment: decisions belong with fish managers. (Tradeoffs are in the jurisdiction of fish and wildlife managers; impacts will be evaluated. To the extent that permanent habitat alterations occur, some tradeoffs are out of the control of fisheries managers).

Tradeoff Issues:

- Resident fishes vs anadromous fish
- Resident fishes vs power
- Resident fishes vs recreation
- Native fishes vs water regulation

Other fish–related activities, authorities

- How will SOR deal with the NPPC Fish and Wildlife Program? (SOR operating alternatives may overlap NPPC proposed operating measures, but will be evaluated for system-wide effects and utility.)
- How will SOR interact with Endangered Species Act actions? (ESA status is accounted for in RFWG activities––special consideration was given to their needs, when known, in formulation of SOS 4, and in impact evaluations.)

Coordination Contract Committee

- Should have open meetings with fish and wildlife represented (not applicable––this committee is not a part of SOR).

Water quality

- SOR should account for specific water quality variables including temperature and dissolved gases (this is being done with fisheries interests in mind).
- Review selective withdrawal for temperature control for fish (if temperature control is of concern at any project, or is negatively impacted for any SOS, it may be listed as a possible mitigation measure).
- Clear up current water quality problems in Columbia. (If operations affect water quality, evaluations should indicate deficiencies. See Water Quality Work Group evaluation.)

Flow fluctuations (load following)

- Flow fluctuations (mentioned by a commenter regarding operation of Libby Dam) are detrimental to insects on which fish feed, and should be reduced (considered by RFWG in SOS formulation and evaluation).

Power drafting at storage projects

- Impacts fish and wildlife due to difficulty in refilling (evaluated by RFWG).
- Impacts food organisms for fish (evaluated by RFWG).
- Peak demand should not be covered by hydro projects because of impacts to fish (evaluated by RFWG, though the capability to quantita-

tively model flows and impacts on this time scale did not exist).

Riparian habitat

- Should be considered and protected (includes Libby) (evaluated by Wildlife Work Group).

Benefits to fish and wildlife from efforts of agriculture, power producers

- SOR should account for efficiencies and other sources of benefits from water users to fish and wildlife (considered by RFWG in evaluation of operational alternatives; however, little was apparent as a result of operational efficiencies).

Wildlife–related
(these are from Wildlife Work Group)

- Operational effects on resident fish which are osprey prey (considered to the extent that specific prey items and locations are known by RFWG)*.
- Operational effects on carp (which damage waterfowl nesting areas when they spawn in spring) (RFWG did not have specific information on carp to allow detailed analysis)*

Contaminants

- A problem for fish (and other organisms, including humans) at Lake Roosevelt, exacerbated by water level changes (addressed by Water Quality Work Group).

Management of fish species

- (None of these were applicable as the operating agencies are not fish managers. Furthermore, use of the term "trash fish" is a value judgment with which participants from fisheries management agencies are not necessarily in agreement.)
- Control squawfish and lampreys (predators/ parasites)
- Management of "trash fish"
- Put pike in (unknown) reservoir

Rule curves

- These are critical to resident fish (The RFWG agrees and accounts for them in the analysis).
- Should operate to a higher minimum pool (evaluations include rule curve modifications).

Native species priority

- First priority should be preservation of native runs of salmon and steelhead "as well as other wildlife habitat." (noted––however, the RFWG considers native resident fish of equally high priority, and points out that there are resident species which are candidates for threatened/endangered status)

Nonoperational mitigation solutions

(These were suggested by outside commenters and will be considered; the RFWG will also formulate other suggestions)

- Develop artificial spawning streams fed by well water.
- Improve habitat by fertilization
- Compensate fisheries interests for flushing of fish from storage reservoirs as a result of drafting for power, flood control and water budget/spill for anadromous fish.

Hatcheries

- One commenter said fish culture should be used as a solution (this could be considered as nonoperational mitigation in some specific instances).
- Another said hatcheries are a part of the problem (not part of SOR scope to consider this issue).

Sturgeon habitat

- Should enhance/restore lost habitat (RFWG addressing operationally).

Flathead Lake ecosystem/Clark Fork River (Kerr Dam)

- Needs to be considered (RFWG incorporates into analysis).
- Maintain good water quality (RFWG/Water Quality Work Group addresses).
- Promote enhancement of native fisheries (SOR cannot consider enhancement, but would seek opportunities to optimize project operation for the benefit of native fishes).
- Concern for westslope cutthroat, bull trout (RFWG incorporates into analysis, SOS recommendations)*.

Hungry Horse Reservoir/Flathead River (Hungry Horse Dam)

- Concern for westslope cutthroat, bull trout (RFWG incorporates into analysis, SOS recommendations)*.
- Temperature control needed to provide warmer water downstream during growing season (this is part of Hungry Horse mitigation plan, not SOR, but is a matter for consideration in project operation once it is constructed)*.

Lake Pend Oreille/Pend Oreille River (Albeni Falls Dam)

- Need a fishery study (various studies are being done as part of resident fish evaluation efforts).
- Winter pool levels too low now for kokanee spawning--gravel does not get subjected to cleaning action of waves for long enough prior to spawning (RFWG is incorporating into analysis and SOS recommendations)*.
- Operation of project creates loss of winter habitat in river above dam--should try higher winter pool levels (RFWG is incorporating into analysis and SOS recommendations)*.

Lake Roosevelt (Grand Coulee Dam)

- Water budget operations are flushing fish out of reservoir (RFWG impact evaluations and SOS recommendations attempt to account for this).
- Power operations entrain fish* (RFWG impact evaluations and SOS recommendations attempt to account for this).
- Water retention time the major factor in primary productivity--need at least 30 days retention time to provide enough nutrients for good productivity, which benefits fish productivity (RFWG is incorporating into analysis and SOS recommendations)*.

Lake Koocanusa/Kootenai River (Libby Dam)

- Raise minimum pool from 2287' to 2337' (RFWG has incorporated Integrated Rule Curves in SOS 4--these are different from existing rule curves, higher than this suggestion).
- Fill by June 1 (not part of Integrated Rule Curves).
- Delay drawdown until after Labor Day (incorporated in Integrated Rule Curves).
- Operate to "enhance and sustain optimal native and introduced game fish populations." (SOS 4 attempts to benefit resident fish)
- Consider an alternative "which is strongly biased toward protecting and enhancing the fishery resource of the Kootenai River..." (RFWG has developed an alternative that seeks to benefit resident fish along with other values)
- Consider a reregulation dam below Libby to protect resident fish from flow fluctuations (not considered at this point).
- Three-ft/day river level fluctuations damaging to fish, their spawning areas, and their food (noted--RFWG incorporates minimizing load following into SOS 4).

- Set flow regimens to help reestablish sturgeon and burbot (ling) populations (this is a goal of SOS 4).
- Upramping and high level releases should be done at night; keep river level steady and lower during daylight from April 1 through Oct. 1. (noted; not specifically incorporated by RFWG in an SOS [not clear if this is for recreation])
- Concern for westslope cutthroat, bull trout, white sturgeon (RFWG incorporates into analysis, SOS recommendations).
- Maintain good fish flows in context of Canal Flats diversion (noted but not clear if this is in SOR scope).
- Concern for Murray Springs Fish Hatchery (noted).
- Spring flows must be enhanced to assist spawning of white sturgeon (RFWG incorporates into SOS 4)*.
- Lake Koocanusa acts as nutrient sink (see Kootenay Lake, below) (RFWG and Water Quality WG addressing to extent possible)*.

Kootenay Lake/Kootenay River

- Nutrient impoverishment due to trapping of nutrients upriver in Lake Koocanusa (RFWG and Water Quality WG incorporating to extent possible)*.

Upper Snake

- Should be incorporated in SOR . Note: This was a strong issue for some who believed that a comprehensive basin planning effort was not possible without inclusion of the Upper Snake and other non–PNCA projects. The Nez Perce tribal representative for the RFWG was adamant on this point. However, the reason for their exclusion was that the renewal of the PNCA was the impetus for the SOR, and was thus used to define its scope.
- Is outside the scope of SOR (noted).

Dworshak Reservoir/Clearwater River

- Drafting for anadromous fish
  - creates habitat problems for spring shore spawners (RFWG evaluating)*.
  - entrains kokanee (RFWG evaluating)*.
  - precludes establishment of aquatic macrophytes and limits production in the littoral zone

John Day/Lower Columbia R.; Lower Granite/ Snake River

- Drawdowns for anadromous fish
  - dewater shallow habitat, impacting resident fish (RFWG evaluating)*.
  - flush resident fish down the river (RFWG evaluating)*.

Other comments received on (unknown) projects

- Resident sturgeon (RFWG attempting to evaluate)*
- Squawfish (RFWG attempting to evaluate)*
- Unknown specific projects (issues mentioned in public scoping) (RFWG is accounting for issues it is aware of to the best of ability; other responses noted for selected issues below)
- Exposure of walleye spawning areas from spring drawdown (Lake Roosevelt?)
- Put phosphates back in water (Libby?)
- Improve local fisheries, including net pen programs (Lake Roosevelt? Lake Rufus Woods?)
- Review selective withdrawal for temperature control for fish (Libby?)
- Restore Montana flows to as natural a regimen as possible (noted––RFWG incorporates in SOS 4).

- Put pike in (unknown) reservoir (not applicable– –operating agencies are not fisheries managers).

1.1.2 Results of subsequent public involvement

Comments received at mid–point meetings held around the region in September and October of 1992, and specific to resident fish, are detailed in the attached information (Praxis, 1992). Many of the concerns are similar to those voiced at the outset. Specific issues also reflect earlier input. The primary differences are reactions to the draft SOS's and how they affect individual resources. As well, however, one commenter felt that the RFWG did not consider effects of flow augmentation actions on fish above Hells Canyon (in fact, Brownlee is part of the RFWG analysis). Another felt that resident fish were mainly exotic and wondered whether they were being favored over anadromous stocks (note that many resident stocks are in fact native and some are candidates for action under endangered species legislation).

1.1.3 US Fish and Wildlife Service Planning Aid Letter

The US Fish and Wildlife Service (USFWS) Boise Field Office submitted a Planning Aid Letter dated September 17, 1992, as part of their responsibilities for SOR under the Fish and Wildlife Coordination Act. They raised several points with regard to resident fish in that document, which is appended in the 'Letters' technical exhibit. These points relate to specific draft operating strategies, which were since revised. In particular they detailed status and concerns about the Kootenai River white sturgeon.

1.2 WORK GROUP FORMATION AND COORDINATION

1.2.1 Work Group Formation

The RFWG was one of the four work groups that were activated in fall of 1990 to construct pilot models. The group at that point consisted of representatives of the three operating agencies, and a technical facilitator from SDG Consultants. Shortly after getting started, the group brought in biologists from the Montana Department of Fish, Wildlife and Parks (MDFWP) to help construct a model framework based on MDFWP's Hungry Horse reservoir fisheries model.

In the spring of 1991, selected resident fish experts from around the region were recruited to participate in the scope issues for the screening analysis, and to assist in the construction of screening models. This participation was expanded for full–scale analysis beginning in fall of 1992. The biologists involved during screening remained key for the full–scale analysis because of the importance of resident fish issues and the existing information development at the screening projects. The organizations represented from screening onward include the Idaho Dept. of Fish and Game (IDFG), MDFWP, Nez Perce Tribe, USFWS, Upper Columbia United Tribes, Spokane Tribe, Colville Confederated Tribes, the University of Idaho, and the Idaho Power Company. Others represented are found in the List of Preparers.

1.2.2 Other informed public

Other agencies, tribes, organizations and individuals were kept apprised of work group meetings, and received meeting notices, and summaries of the meeting results and work group activities. A list is provided as the 'Interested Parties' technical exhibit. Some interested parties attended meetings, but very few, due in part to the travel expense which would be incurred in most cases to come from other parts of the region to the meeting location.

1.2.3 Work Group Coordination

The RFWG was coordinated through meetings and correspondence. It obtained guidance from the SOR managers, and provided input and feedback on management direction. It gathered technical information from appropriate sources in the basin. The RFWG coordinated with several other work groups for specific reasons, as follows:

1.2.3.1 Work Group Interdependencies

These were needs for information and evaluation results that work groups had of each other. Interactions for Resident Fish in this category included:

Wildlife:

- Operating effects on fish upon which osprey feed.
- Operating effects on carp, whose spawning impacts waterfowl habitat.

Recreation:

- How operating effects on resident fish would translate into effects on recreation use (sportfishing).

Cultural Resources:

- How operating effects on resident fish would translate into effects on tribal treaty fishing rights.

Water Quality:

- Operating effects on temperature, dissolved gases, nutrients, and any other variables of importance to resident fish.

1.2.3.2 SOS Formulation

The second category of work group coordination for Resident Fish involved formulation of SOS 4, the Stable Pools SOS. This SOS was a compromise alternative that was oriented toward providing suitable conditions for resident fish, wildlife, and recreation, while maintaining flood control protection and minimizing power generation impacts. SOS 4 also attempted to provide anadromous fish flows. Thus, work groups representing all of these interests worked together to formulate this SOS.

Specifications for SOS 4 are appended as an exhibit (Detailed Description of SOS 4). These include provisions for each operating project. Furthermore, the SOS in general was broken down into 4 versions. SOS 4a provides for resident fish, recreation and wildlife, with flood control accounted for, and in general, integrated rule curves to provide shared risk between resident fish and power. Resident fish would benefit both in reservoirs and in the reaches downstream, including Kootenai River white sturgeon, a candidate for listing under the Endangered Species Act. SOS 4b adds flows in the Snake River for anadromous fish. SOS 4a1 and 4b1 operate Libby and Hungry Horse on upper flood control rule curves in fall and winter, but use integrated rule curves in spring and summer. SOS 4a3 and 4b3 employ integrated rule curves (IRC's) all year round for both Libby and Hungry Horse. When IRC's are used, it is in a tiered fashion, such that critical–year power drafting is progressively deeper in each year of the 4–year critical sequence. This tiered approach allows, for instance, the water requirements for Kootenai River sturgeon to be met in a manner that is based on the amount of water available.

Note: SOS 4a2 and 4b2 were formulated earlier in the full–scale phase of SOS, but were eliminated because their effect was redundant. They were based on specific flow requirements out of Libby, but it was discovered that 4a3 and 4b3 were able to do the same thing on a IRC–driven basis. The original terminology was retained to avoid confusion.

SOS 4 requirements for Grand Coulee include limiting flood control drawdown, but this was at first not as well–represented in the hydrologic model results as anticipated. SOS 4c attempts to correct this. It is also intended that water retention time in spring and summer should be maximized, in order to maximize integrated productivity. This requires some filling in spring, and then a gradual draft to help provide for salmon flows downriver.

At Lake Pend Oreille, there are two basic requirements. First, fall and winter draft is limited from the base case to increase kokanee shore–spawning habitat suitability. Second, a full pool in spring is allowed, after which the pool is dropped 2.5 feet from full. This allows fertilization of deltas and other low–lying habitat with nutrients from the spring runoff, and then when the land is exposed allows vegetation to take hold and provide valuable wildlife habitat.

At Dworshak under SOS 4b, some volume is provided for salmon migration; otherwise, under 4a, an attempt is made to limit drawdown to protect near-shore fish habitat, support food production, and minimize entrainment of kokanee from the reservoir.

For Libby, constraints on drawdown are imposed, to increase productivity of food organisms for fish, and to limit entrainment of fish from the reservoir. Downstream objectives, again, include sturgeon habitat values as well as trout habitat values.

At Hungry Horse, reservoir objectives are similar to Libby. Downstream channel maintenance is also an objective, so that fines are flushed out and values for salmonids and their food organisms are increased.

Integrated Rule Curves

Although hydropower is relatively benign compared with other traditional generation techniques, environmental effects of hydropower facilities are well documented and costly in terms of loss of recreation, food production and fisheries maintenance.

Presently, the strategy for operating projects within the hydrosystem is driven by sets of 'rule curves' developed by policy makers and engineers. The rule curve is a graphical description of desired surface elevation of a reservoir for flood control or hydropower over time. For flood control rule curves, the surface elevation should not exceed that mandated by the rule curve on a given date, except for brief periods when high runoff is impounded; that water is then released as soon as possible to get back down to the curve to maintain flood storage space. Power drafting curves are not rule curves *per se*, but they do represent draft requirements to maintain load generating capacity under a given set of conditions.

Integrated Rule Curves, as their name implies, are a new set of rule curves for dam operations designed to enhance integrated production. A product of the Montana Department of Fish, Wildlife and Parks (MDFWP), the IRCs were developed originally for Hungry Horse Reservoir and Lake Koocanusa and associated river basins; however, the IRC operational strategy has been incorporated into the RFWG's SOS 4 to improve conditions for all resident and anadromous fish species in the Columbia River System within the realities of flood control and power production.

Problems occur for resident fish in reservoirs when reservoirs are drawn down beginning in summer or early fall. The reduced volume and surface area limit the fall food supply and volume of optimal water temperatures during critical trout growth period. Surface elevations continue to decline during winter, arriving at the lowest point in the annual cycle during April. Deep drafts reduce food production and concentrate prey fish, including young trout, with predators such as the northern squawfish. Of greatest concern is the freezing and desiccation of aquatic insect larvae in the bottom sediments. These insects provide the primary spring food supply for westlope cutthroat trout, a species of special concern in Montana, and other important game and forage species. Deep drawdowns also increase the probability that the reservoirs will fail to refill. Refill failure negatively impacts recreation, and reduces integrated production,which in turn decreases fish survival and growth in the reservoirs.

The IRCs were designed to limit the duration and frequencies of deep drawdowns and reservoir refill failure. Reduced drawdown protects aquatic insect larvae, assuring that a large percentage of insects will survive to emerge as pupae and adults that provide an important springtime food supply for fish. Increased refill frequency maximizes integrated production during the warm months. Early refill provides an ample volume of optimal temperature water for fish growth and spawning, and a large surface area for the deposition of terrestrial insects from the surrounding landscape. Proper refill timing also assures that passage into spawning and rearing habitat in tributaries is maintained for species of special concern, including westslope cutthroat trout and bull trout.

Integrated Rule Curves are intended to provide a solution to the apparent conflict between resident fish and anadromous salmon concerns within the physical realities of flood control and power. The ongoing salmon recovery program can cause important changes in storage reservoir operation. Anadromous fish require high water velocities in the Lower Columbia to aid in their migrations. This requires releases from storage reservoirs during the May through July period. Historically, the reservoirs refilled from mid–April through early July, and discharges were reduced to specified minimum limits. Thus, if the reservoirs are drawn down deeply in April, releases for the water budget can further reduce the probability of refilling the reservoirs. Refill failures effect the ability of the system to supply water budget flows in subsequent years. Also, a lack of stored water could compromise the system's ability to maintain minimum flows required to maintain resident fish species in critical river reaches.

IRCs were developed to balance the conflict between anadromous and resident fish by reducing drawdown during the fall through early spring period in the headwater reservoirs, for water availability during late May and June. Deep drafts and refill failures could then be minimized while serving the needs of anadromous species. Spawning cues for river species such as the Kootenai white sturgeon and spring spawning trout are simultaneously provided.

Admittedly, adoption of the IRCs and proposed operational strategy will carry initial costs. Yet, the costs of species restoration are significant as well. Flexible river flow and reservoir elevational targets allow for compromise among the often competing uses in the basin. System models have shown that flow requirements for anadromous fish can be achieved, when hydrologically possible, without sacrificing native resident fish populations. Coordinated springtime releases from the storage projects can achieve a protracted runoff, with peaks removed to avoid flooding. The extended runoff aids salmon migration in the lower Columbia and creates a four–month marketing block for interregional power exports. Imported power during fall and winter allows headwater reservoirs to store water explicitly for release during spring. Resident fish benefit from high reservoir elevations, decreased drawdowns and improved refill probability.

1.3 SCOPE OF WORK GROUP'S EFFORT

The efforts of the RFWG were directed specifically towards the nonmigratory (resident) fish that inhabit the Columbia River Basin. These fish are distinct from the anadromous fish whose restoration has been the subject of an extremely large expenditure of effort and funds. Resident species are in many cases economically important, or have some status with regard to endangered species legislation, and as such merited focused attention. Most of the information on resident fish has been gathered in the upper basin storage project areas, above present (and in many cases historical), anadromous fish ranges. However, despite the lack of information in lower parts of the basin, the RFWG also recognized that those areas were important, and attempted to gather as much information as possible with which to conduct an analysis. That analysis has been by necessity more qualitative than quantitative in many cases because of the lack of data.

1.4 SCREENING PROCESS

The screening phase for the RFWG included formulation of several operating alternatives, and the evaluation of these and the rest of a total of 90 alternatives. The RFWG alternatives did include one "ideal" alternative, in which all storage projects were kept full and passed natural inflows year round, as well as other alternatives with specific objectives for one or more projects. They also included a compromise set of alternatives, which formed the basis for further development of a compromise SOS for full–scale analysis. The RFWG screening analysis was based on the MDFWP reservoir models for Libby and Hungry Horse, and relationships developed using specific data available for fisheries at other screening projects (see Chapter 3 of this Appendix, and Screening Analysis [Vol. 1––Aug. 1992] for more detailed information).

1.5 SELECTION OF ALTERNATIVES

Public input during the midpoint review meetings in September–October 1992 indicated some support for compromise alternatives among the 10 draft SOSs. These allowed for anadromous fish flows, flood control and resident fish. The final SOSs included one that was an adaptation of those into a broader compromise with specific provisions for resident fish, wildlife, recreation, flood control, and anadromous fish, and was coordinated with the Power Work Group.

1.6 FULL-SCALE ANALYSIS

The Libby and Hungry Horse models were used in full–scale analysis, and to the extent possible, were also used as a template for other reservoirs. Full–scale analysis was expanded to other locations in the basin besides those used in screening. This included primarily non–quantitative evaluation due to limitations in existing data. Full–scale quantitative modeling was revised where possible to provide results on fish population dynamics over a 50–year period of record. For more details, see Chapters 3, 4, and 5 of this Appendix.

CHAPTER 2

RESIDENT FISHERIES IN THE COLUMBIA RIVER BASIN TODAY

2.1 OVERVIEW OF RESIDENT FISHERIES IN THE COLUMBIA RIVER BASIN

2.1.1 Importance of Resident Fish in the Columbia River Basin

Resident fish species are the only fish species locally present in over half of the Columbia River basin. Even before dams were constructed by humans, natural obstacles such as Shoshone and Spokane Falls prevented anadromous fish from reaching large areas of the Columbia River basin (Figure 2–1). Waterfalls and other natural barriers exist on numerous small tributary streams, and other water–bodies are in some way unsuitable for anadromous fish. Of course, resident fish also exist in watercourses open to anadromous fish.

The portion of the Columbia River basin in which only resident fish exist has expanded in historic times. For example, dam construction has further limited the range of anadromous fish. Chief Joseph and Hells Canyon Dams now block passage to large portions of the Columbia and Snake Rivers, respectively, that were previously open to fish migration. Impassable dams and other human–made obstacles are also present on many smaller Columbia River basin tributaries.

Impassable dams and declines in anadromous salmonid runs have resulted in the loss of energy transport from ocean environments to stream ecosystems. Both eggs and carcasses of anadromous salmonids serve as food for resident fish and wildlife and often contribute a large amount of nutrients to stream systems. This energy has been lost from systems to which anadromous fish have been denied access. However, despite habitat alterations and other adverse human–caused conditions in many areas, some type of resident fish is present in almost every permanent water body in the Columbia River basin.

The recreational fisheries provided by resident species in the Columbia River basin are often more important than anadromous fisheries even in areas when anadromous fish exist. This is because of the depressed state of many of the anadromous fisheries (low catch rates or season closure), because anadromous fisheries are usually highly seasonal, and because of the generally higher cost of participating in anadromous fisheries. The Kootenai River white sturgeon was formally listed as endangered by the USFWS on September 7, 1994.

Resident fishes are important in the Columbia River basin beyond their popularity in sport fisheries. For example, native Americans in the Columbia River basin have traditionally and currently use resident fish for subsistence purposes. Species which are not large enough or are inaccessible to sport or subsistence fishers can also be important because they serve as food sources for other fish and wildlife. Resident fish species are also valuable for aesthetic reasons and because they contribute to the diversity of life in the Columbia River basin.

Described in this chapter are the resident fisheries of the rivers, lakes, and reservoirs potentially affected by the operation of the Federal Columbia River Power System (FCRPS) (Figure 2–1). Because the FCRPS projects are generally located on mainstem rivers, the fisheries of smaller tributary streams are generally not affected by Federal hydroelectric power production and are not described in this report. Some resident fish species in unregulated tributary streams have the potential to be affected by hydroelectric projects if the projects prevent migration and gene flow between these streams.

2.1.2 Resident Fish Species Native to the Columbia River Basin

Table 2–1 provides a list of resident fish species present in the Columbia Basin, with native species designated by an asterisk. Table 2–2 provides a matrix of resident fish species known or assumed to occur in the reservoirs and rivers described in this chapter.

Native species of the Columbia River basin are generally adapted to cold or cool flowing water, although some thrive in lakes and rivers. Many native species, however, have declined in abundance due to human–caused alteration of habitat. While the most obvious examples of habitat alterations in the Columbia River basin are the dams of FCRPS, other activities, such as land use practices, water withdrawals, and pollution, have caused reductions in native resident fish stocks. A further factor in the decline of some resident fish species has been predation and competition from introduced fish species. Some fish species are native to one portion of the Columbia River basin but have been transplanted to another area of the basin, and have affected native stocks in their new range through competition, predation, and hybridization.

2.1.3 Resident Fish Species Introduced to the Columbia River basin

Those fish species without an asterisk in Table 2–1 are not native to the Columbia River basin. Most are from other parts of North America (three are from Europe) and have been transplanted to the Basin. Most of the introductions have been made by fisheries agencies or by anglers for the purpose of improving sport or food fisheries. Many introduced fish species have adapted well to Columbia River basin waters; non–native salmonids are abundant in many rivers and streams, and warm– and cool–water species are especially common in reservoirs and other human–altered bodies of water.

Introduced fish species have the potential to reduce the populations of native species through predation, competition, hybridization, and other interactions.

2.1.4 Potential Federal Threatened/Endangered Species

2.1.4.1 Kootenai River White Sturgeon

On June 11, 1992, conservation groups headed by the Idaho Conservation League petitioned the US. Fish and Wildlife Service (USFWS) to list the Kootenai River white sturgeon (*Acipenser transmontanus*) under the Endangered Species Act (ESA). The USFWS proposed listing Kootenai River white sturgeon as endangered in a July 7, 1993 notice in the Federal Register, stating that the population is in danger of extinction throughout its range. The Kootenai River white sturgeon was formally listed as endangered by USFWS on September 7, 1994.

The Kootenai River population of white sturgeon is believed to have been isolated between Kootenai Falls (approximately 30 miles downstream of Libby Dam) and Bonnington Falls, downstream of Kootenay Lake, for approximately 10,000 years (Figure 2–2) (Apperson and Anders, 1991; Setter and Brannon, 1992). There apparently has been no recruitment to the fishery since before Libby Dam went into operation in the early 1970s, except for some fish from the 1974 year class. Spawning has occurred since 1977 (including in 1993), but is not known to have been successful at producing recruits to the population (Apperson and Anders, 1991). The current population is estimated to consist of about 880 individuals.

Researchers have hypothesized that the decreased springtime river flows below Libby Dam contributed to spawning failures in recent years (Apperson and Anders, 1990). Spawning of sturgeon in the lower Columbia River appears to be correlated with increasing flows and increasing water temperatures in the spring (Apperson and Anders, 1991). The only aggregations of white sturgeon in spawning condition observed in the Kootenai River moved to an area of higher flows during a period that both flows and temperatures were increasing in June 1990 and 1991 (Apperson and Anders, 1991). Reproductive problems were also documented in the 1960s and were thought to be caused by pollution. Concern has focused on contaminants predation, and nutrients as well as spawning and rearing flow conditions since then. Individual mature white sturgeon do not spawn in every year.

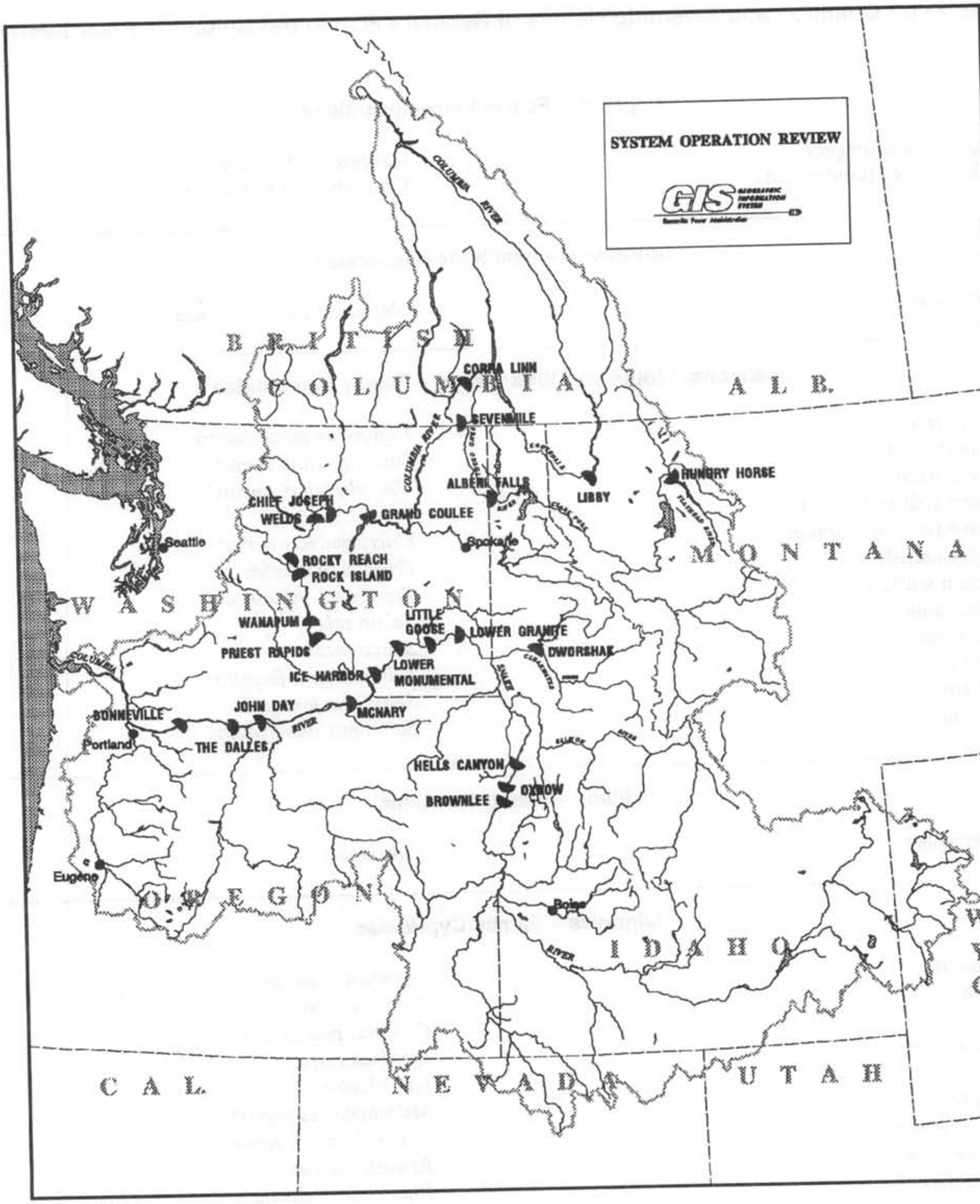


Figure 2–1. Map of the Columbia Basin, showing Federal Columbia River Power System (FCRPS) dams

Table 2–1. Common and Scientific Names of Resident Fish in the Columbia River System

Lampreys – Family Petromyzontidae	
Western brook lamprey	*Lampetra richardsoni**
Pacific lamprey (landlocked)	*Entosphenus tridentatus**
Sturgeons – Family Acipenseridae	
White sturgeon	*Acipenser transmontanus**
Salmons, Trouts and Whitefishes – Family Salmonidae	
Lake whitefish	*Coregonus clupeaformis*
Cutthroat trout	*Oncorhynchus clarki**
Rainbow trout (includes redband trout)	*Oncorhynchus mykiss**
Kokanee (sockeye salmon)	*Oncorhynchus nerka**
Pygmy whitefish	*Prosopium coulteri**
Mountain whitefish	*Prosopium williamsoni**
Atlantic salmon	*Salmo salar*
Brown trout	*Salmo trutta*
Bull trout	*Salvelinus confluentus**
Brook trout	*Salvelinus fontinalis*
Lake trout	*Salvelinus namaycush*
Pikes – Family Esocidae	
Northern pike	*Esox lucius*
Minnows – Family Cyprinidae	
Chiselmouth	*Acrocheilus alutaceus**
Goldfish	*Carassius auratus*
Lake chub	*Couesius plumbeus**
Common carp	*Cyprinus carpio*
Tui chub	*Gila bicolor*
Peamouth	*Mylocheilus caurinus**
Northern squawfish	*Ptychocheilus oregonensis**
Longnose dace	*Rhinichthys cataractae**
Leopard dace	*Rhinichthys falcatus**
Speckled dace	*Rhinichthys osculus**
Redside shiner	*Richardsonius balteatus**
Tench	*Tinca tinca*

Table 2–1. Common and Scientific Names of Resident Fish in the Columbia River System – CONT

Suckers – Family Catostomidae	
Longnose sucker	*Catostomus catostomus**
Bridgelip sucker	*Catostomus columbianus**
Largescale sucker	*Catostomus macrocheilus**
Mountain sucker	*Catostomus platyrhynchus**
Catfishes – Family Ictaluridae	
Black bullhead	*Amiurus melas*
Yellow bullhead	*Amiurus natalis*
Brown bullhead	*Amiurus nebulosus*
Channel catfish	*Ictalurus punctatus*
Tadpole madtom	*Noturus gyrinus*
Flathead catfish	*Pylodictus olivaris*
Livebearers – Family Poeciliidae	
Mosquitofish	*Gambusia affinis*
Cods – Family Gadidae	
Burbot	*Lota lota**
Sticklebacks – Family Gasterosteidae	
Three–spine stickleback	*Gasterosteus aculeatus**
Troutperches – Family Percopsidae	
Sandroller	*Percopsis transmontana**
Sunfishes – Family Centrarchidae	
Pumpkinseed	*Lepomis gibbosus*
Warmouth	*Lepomis gulosus*
Bluegill	*Lepomis macrochirus*
Smallmouth bass	*Micropterus dolomieui*
Largemouth bass	*Micropterus salmoides*

Table 2–1. Common and Scientific Names of Resident Fish in the Columbia River System – CONT

Sunfishes – Family Centrarchidae – CONT	
White crappie	*Pomoxis annularis*
Black crappie	*Pomoxis nigromaculatus*
Perches – Family Percidae	
Yellow Perch	*Perca flavescens*
Walleye	*Stizostedion vitreum*
Sculpins – Family Cottidae	
Coastrange sculpin	*Cottus aleuticus**
Prickly sculpin	*Cottus asper**
Mottled sculpin	*Cottus bairdi**
Piute sculpin	*Cottus beldingi**
Slimy sculpin	*Cottus cognatus**
Shorthead sculpin	*Cottus confusus**
Reticulate sculpin	*Cottus perplexus**
Torrent sculpin	*Cottus rhotheus**

* Species native to the Columbia Basin

The IDFG and the Kootenai Tribe of Idaho have been researching this population under Bonneville Power Administration (BPA) funding since the late 1980s and will continue to do so for the time being. Various proposals have been prepared for flow enhancement in spring to encourage spawning.

2.1.4.2 Bull Trout

On October 30, 1992, the USFWS was petitioned to consider bull trout (*Salvelinus confluentus*) for listing as a threatened or endangered species under the ESA. On May 17, 1993 the USFWS published in the Federal Register a notice that it had determined that the petitions had merit and began the one–year status review for listing. On June 7, 1994, the USFWS announced that listing of the bull trout in the lower 48 states was 'warranted but precluded' by other higher priority species. Bull trout are also state Species of Special Concern in Montana and Idaho. The species occurs in many of the potentially affected reservoirs including Lake Koocanusa (and the Kootenai River), Hungry Horse (and the Flathead River and its South Fork), Lake Pend Oreille (and the Pend Oreille River), Roosevelt, and Dworshak.

Bull trout (a char, formerly known as Dolly Varden *Salvelinus malma*, but now considered distinct from this species) spawn primarily in tributaries in fall and the eggs hatch in March (Thomas, 1992; Zubik and Fraley, 1987; Fraley and Shepard, 1989). They spawn in loosely compacted gravel and cobble and often at sites with groundwater infiltration. As is the case for most salmonids, the presence of high quantities (>30 percent) of silt and sand in the gravel negatively affects egg survival (Pratt, 1992). During the incubation period, high flows can scour redds while excessively low flows can expose redds to freezing temperatures (Thomas, 1992).

Table 2–2. Matrix of resident fish species known or assumed to occur in the reservoirs and rivers described in this chapter

	Mica/Revelstoke/Arrow	Lake Koocanusa	Kootenai River	Kootenay Lake	Hungry Horse Res.	Upper Flathead River	Flathead Lake	Lower Flathead River	Clark Fork River	Lake Pend Oreille	Pend Oreille River	Lake Roosevelt	Lake Rufus Woods	Mid–Columbia R–O–R	Hanford Reach	Hells Canyon Complex	Hells Canyon Reach	Dworshak Reservoir	Lower Clearwater R	Lower Snake R–O–R	Lower Columbia R–O–R	Below Bonneville
W. brook lamprey																		X			X	
White sturgeon	X	X	X	X							X	X	X	X	X	X	X		X	X	X	X
Lake whitefish	X						X		X	X	X	X	X		X							
Cutthroat trout	X	X	X		X	X	X	X	X	X	X	X	X		X			X	X			X
Rainbow trout	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Kokanee	X	X	X	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	
Pygmy whitefish	X				X		X			X		X										
Mountain whitefish	X	X		X	X		X	X	X	X	X	X	X	X	X		X	X	X	X	X	
Brown trout								X	X		X	X	X							X		
Bull trout	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Brook trout	X						X	X		X	X	X	X					X				
Lake trout							X			X												
Northern pike								X	X									X				
Chiselmouth												X	X	X	X	X	X	X	X	X	X	
Goldfish											X										X	
Lake chub	X		X								X											
Common carp	X										X	X	X	X	X	X	X		X	X	X	X
Tui chub																						X
Peamouth	X	X	X				X	X	X	X	X	X	X	X	X	X				X	X	
Northern squawfish	X	X			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Longnose dace	X		X						X	X					X	X	X	X	X	X		
Leopard dace	X														X	X						
Speckled dace													X		X			X	X	X	X	
Redside shiner	X	X	X				X		X	X	X	X	X	X	X	X	X	X	X	X	X	
Tench										X	X	X			X							
Longnose sucker	X	X	X		X		X		X	X	X	X	X			X						
Bridgelip sucker	X											X	X	X	X	X	X	X	X	X	X	
Largescale sucker	X	X	X		X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	
Mountain sucker															X							
Black bullhead									X		X			X	X	X						
Yellow bullhead															X					X		

Table 2–2. Matrix of resident fish species known or assumed to occur in the reservoirs and rivers described in this chapter – CONT

	Mica/Revelstoke/Arrow	Lake Koocanusa	Kootenai River	Kootenay Lake	Hungry Horse Res.	Upper Flathead River	Flathead Lake	Lower Flathead River	Clark Fork River	Lake Pend Oreille	Pend Oreille River	Lake Roosevelt	Lake Rufus Woods	Mid–Columbia R–O–R	Hanford Reach	Hells Canyon Complex	Hells Canyon Reach	Dworshak Reservoir	Lower Clearwater R	Lower Snake R–O–R	Lower Columbia R–O–R	Below Bonneville
Brown bullhead			X							X	X	X		X				X	X	X	X	
Channel catfish															X	X	X		X	X	X	
Tadpole madtom																X	X			X	X	
Flathead catfish																X				X		
Mosquitofish																				X	X	
Burbot	X	X	X	X					X			X	X		X							
3–spine stickleback														X	X						X	X
Sandroller			X											X	X				X	X	X	X
Pumpkinseed			X						X	X	X	X		X	X	X	X	X	X	X	X	
Warmouth																X				X		
Bluegill														X	X	X			X	X	X	
Smallmouth bass									X			X		X	X	X	X	X	X	X	X	
Largemouth bass								X	X	X	X	X			X	X		X	X	X	X	
White crappie												X			X	X				X	X	
Black crappie										X	X	X	X	X	X	X	X	X	X	X	X	
Yellow perch		X	X				X		X	X	X	X	X		X	X				X	X	
Walleye	X										X	X	X	X	X					X	X	
Sculpin spp.											X	X		X		X		X				
Coastrange sculpin																						X
Prickly sculpin	X												X		X					X	X	
Mottled sculpin															X					X		
Paiute sculpin												X			X				X	X		
Slimy sculpin	X		X				X		X	X												
Shorthead sculpin						X	X	X														X
Reticulate sculpin															X							
Torrent sculpin	X		X							X	X		X		X			X	X			

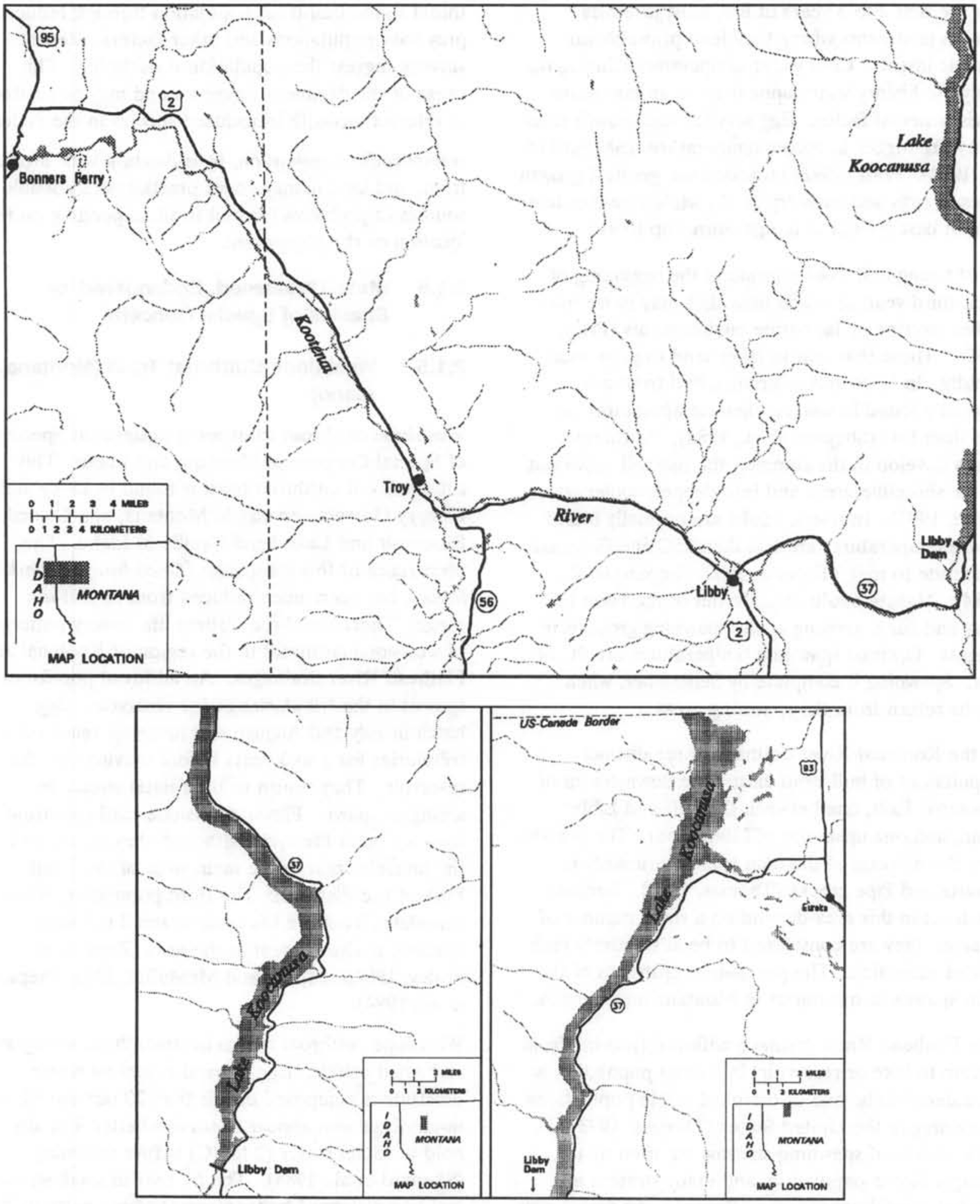


Figure 2–2. Map of US Portion of Kootenai River, Libby Dam, Lake Koocanusa and vicinity

For the first 2 to 3 years of life, most juveniles remain in streams where they feed primarily on aquatic insects. Cool water temperatures during the early life history states appear to be an important environmental factor. Egg survival and growth rates of fry are higher in cooler temperatures (Shepard et al., 1984). Pratt (1992) indicated the greatest growth rates in eggs and early fry at 4C, while juveniles later exhibit best growth at temperatures up to 9C.

Most young bull trout migrate at the beginning of their third year, at which time they may move into either riverine or lacustrine environments (Pratt, 1992). Those that rear in lakes tend to grow more rapidly. In lakes and reservoirs, bull trout are normally found in waters where temperatures are less than 15C (Shepard et al., 1984). As thermoclines develop in the summer, the fish will move out of the shoreline areas and into deeper, cooler water (Pratt, 1992). In rivers, adults are normally found where temperatures are less than 15C and flows are moderate to high (Thomas, 1992; Shepard et al., 1984). Mature adults migrate out of the lakes in May and June, arriving at the spawning grounds in August. Optimal spawning temperatures are 9C or less. Spawning is complete by September, when adults return from the spawning areas.

In the Kootenai River drainage, three distinct populations of bull trout exist: one downstream of Kootenai Falls, one between the falls and Libby Dam, and one upstream of Libby Dam. The population downstream of the dam spawns primarily in Quartz and Pipe creeks (Thomas, 1992). Because the trout in this area depend on a small number of streams, they are considered to be at relatively high risk of extinction. The population upstream of the dam spawns in tributaries in Montana and Canada.

The Flathead River drainage adfluvial (moving from stream to lake or reservoir) bull trout population is considered to be one of the most viable populations remaining in the United States (Thomas, 1992). A wide variety of spawning streams are used by the Hungry Horse population, and many streams are located in wilderness areas. Recent deep drawdowns of Hungry Horse reservoir (1993–4) have reduced the productivity of the reservoir, resulting in some threat to the bull trout population through reduced prey base populations and other factors. Recent surveys suggest the population is declining. The cause of the decline is unknown and may be related to interactions with introduced species in the system.

Interspecific competition, hybridization with brook trout, and land management practices are possible sources of problems for bull trout, depending on the location of the population.

2.1.5 State Threatened, Endangered, or Species of Special Concern

2.1.5.1 Westslope Cutthroat Trout (Montana, Idaho)

Westslope cutthroat trout are a designated Species of Special Concern in Montana and Idaho. This subspecies of cutthroat trout is found in Libby and Hungry Horse reservoirs in Montana, and Dworshak Reservoir and Lake Pend Oreille in Idaho. This occurrence of this subspecies (*Oncorhynchus clarki lewisi*), has been much reduced from its historic range. There are three distinct life history patterns of westslope cutthroat in the region of Kootenai and Flathead River drainages. An adfluvial population spawns in the tributaries of the reservoir. Eggs hatch in July and August, and juveniles rear in the tributaries for 1 to 3 years before moving into the reservoir. They return to their natal stream in spring to spawn. Fluvial westslope cutthroat trout have a similar life cycle, although they spawn and the juveniles rear in the main stem of the South Fork of the Flathead. The third population, which completes its entire life cycle in small tributary streams, is also present in the area (Zubik and Fraley, 1987; Shepard and McMullin, 1983; Shepard et al., 1984).

Westslope cutthroat spawn in streambeds with gravel and small cobble. Egg survival is highest where substrate is composed of less than 20 percent silt and sand. Eggs also appear to survive better if adults hold in cooler water (2 to 4C) before spawning (Shepard et al., 1984). The fry rear in small streams and backwaters of larger streams where currents are slow. The fish move into faster, deeper water as they grow. In lakes, the trout tend to move to deeper waters in summer as surface waters warm to temperatures greater than 18C.)

2.1.5.2 Redband Trout (Montana, Idaho)

Redband trout (*Oncorhynchus mykiss*) are a rainbow trout found in a number of forms in a number of areas of the inland West and have variously been described as being rainbow, cutthroat, or undescribed species of trout (Behnke 1986). They physically resemble both rainbow and cutthroat trout and are, for the most part, restricted to small streams in arid regions of California, Oregon, Nevada, and Idaho. Behnke (1992) considers nearly all rainbow trout east of the Cascades to be of the redband subspecies. Allendorf (1980) determined that some (apparent) rainbow trout in certain streams in the Kootenai River drainage of Montana were genetically distinct from hatchery rainbow trout in Montana and were also distinct from steelhead/rainbow stocks in Washington, Oregon and Idaho. These fish have been recognized by Montana as redband trout and are considered a Species of Special Concern in that state and in Idaho.

2.1.5.3 Shorthead and Torrent Sculpin (Montana)

Freshwater sculpins are small fish which inhabit streams and cold lakes. They generally eat aquatic invertebrates, small fish and fish eggs. Over a dozen species exist in the Pacific Northwest. In the upper Columbia River basin, Montana has listed two sculpins as Species of Special Concern. These are the shorthead sculpin (*Cottus confusus*), which is found in the Flathead River drainage, and the torrent sculpin (*Cottus rhotheus*), in the Kootenai River drainage. Both of these species are common and widespread in other parts of the Columbia River system, but are limited in distribution in Montana.

2.1.5.4 Snake River White Sturgeon (Idaho)

White sturgeon exist in Idaho in two different river drainages: the Kootenai, and the Snake. Kootenai River white sturgeon have been proposed for listing under the Federal Endangered Species Act and are described above in 2.1.4.1. In the Snake River, white sturgeon are known to historically exist from the mouth to Shoshone Falls, a passage barrier to all anadromous fish in southern Idaho. Some also exist in the lower Salmon River. Prior to construction of the many dams on the middle and lower Snake Rivers, white sturgeon in the Snake River theoretically had the ability to engage in anadromous behavior, and almost certainly were migratory within the Columbia basin. Although navigation locks and fish ladders on the Corps' lower Snake and Columbia River dams may allow some upstream migration, Snake River sturgeon are essentially a resident fish stock.

Because white sturgeon require flowing water to reproduce, their habitat has been much reduced in the Snake River. The highest density of white sturgeon in the Snake River exists in the Hells Canyon Reach. Because of habitat alteration and much reduced population, Idaho considers Snake River white sturgeon to be a Species of Concern.

2.1.5.5 Sandroller (Idaho)

Sandrollers (*Percopsis transmontana*) are small fish which are widespread, although apparently not abundant, in the lower Columbia River basin, where they are found mostly in large streams such as the mainstem Columbia, Yakima and Cowlitz Rivers (Wydoski and Whitney 1979). In Idaho, a few have been collected from the Snake and lower Clearwater Rivers in the vicinity of Lewiston (Simpson and Wallace 1982). Because of their apparent rarity and limited distribution, they are considered a Species of Concern in Idaho. In Washington, sandrollers are listed as a State Monitor Species.

2.1.5.6 Burbot (Idaho)

Burbot (*Lota lota*) are the only freshwater member of the cod family and the species ranges throughout Canada, the northern United States, and parts of northern Eurasia (Wydoski and Whitney 1989). Burbot, which can grow to over 50 pounds (22 kg) and are a popular sportfish in some areas, prefer to inhabit cold lakes and large rivers (Simpson and Wallace 1982). In Idaho, burbot are though to exist only in the Kootenai River system and considered to be a State Threatened Species (see 2.2.1.6, below, for further information).

2.1.6 Resident Fish Management, Laws, and Regulations

Resident fish species are managed by state agencies and tribes. For the most part, management efforts are focused on sportfishing species such as trout, kokanee, bass, and sunfish as well as walleye and sturgeon. In addition to managing sportfish, the state agencies also sometimes engage in the removal of undesirable species, and may manage or protect non–game species.

State laws and regulations set catch, possession, size, and season limits and restrict gear types for anglers pursuing resident gamefish. States and tribes also have laws or guidelines which protect rare organisms, including fish. Interstate transport of resident fish may be subject to federal statutes. The federal Endangered Species Act also restricts the taking of listed species, as well as impacts to habitat. Several Columbia River basin resident fish species (Kootenai River white sturgeon, bull trout) may be listed in the future, but none are currently officially threatened or endangered.

Tribal fisheries have placed increasing importance on resident fish as a result of the decline of anadromous species.

2.1.7 Other Resident Fish Studies and Sources of Information

The information for this appendix has been drawn from many sources, including reports by tribal, state and federal fisheries agencies. Many of the reports cited have been funded and published by the BPA and are available from that agency. Additional and specific information on resident fish is available from tribal and state fisheries agencies.

2.2 RESIDENT FISH COMMUNITIES AND ISSUES AT SPECIFIC PROJECTS

2.2.1 Specific Projects and River Reaches – Upper Columbia River and Tributaries

2.2.1.1 Kinbasket Lake (McNaughton Reservoir, Mica Dam)

Mica Dam, 646 feet high and completed in 1973, forms a storage reservoir of about 107,000 acres (43,300 ha) and 20 million acre–feet at full pool on the Columbia River in British Columbia, Canada (Figure 2–3), and is owned by B.C. Hydro. Annual drawdowns can exceed 80 feet (24.4 m) and mean water retention time is 15 months. Turbine discharge is erratic, due to daily and seasonal fluctuations in power production and water availability. The reservoir is also used, under the PNCA, to stabilize flows lower down in the Columbia River System, including the FCRPS. Mica Dam inundated several lakes, including the natural Kinbasket Lake. The reservoir is extremely infertile (ultra–oligotrophic), with high dissolved oxygen levels and mild thermal stratification in the summer.

Prior to reservoir formation, the lakes and streams subsequently inundated supported mountain whitefish, bull, brook and rainbow trout, and burbot. The current sport fishery of Kinbasket Lake includes these species and kokanee, which spawn in the upper Columbia River and other reservoir tributaries. Yearly drawdowns are believed to inhibit shallow–water production and may interfere with spawning migrations to tributary streams. The drawdowns also interfere with sportfishing, due to decreased boat access (Hirst 1991).

2.2.1.2 Revelstoke Reservoir

Revelstoke Dam, 574 feet (175 m) high and completed in 1984, forms a run–of–river reservoir of about 25,000 acres (10,118 ha) and 1.8 million acre–feet at full pool on the Columbia River in British Columbia, Canada (Figure 2–3), and is owned by B.C. Hydro. Mica Dam discharges directly into the upper portion of the impoundment. Mean water retention time is about 27 days. The reservoir is ultra–oligotrophic, with high dissolved oxygen levels and thermal stratification in the summer. Mean depth of Revelstoke Reservoir is about 50 feet (15.2 m).

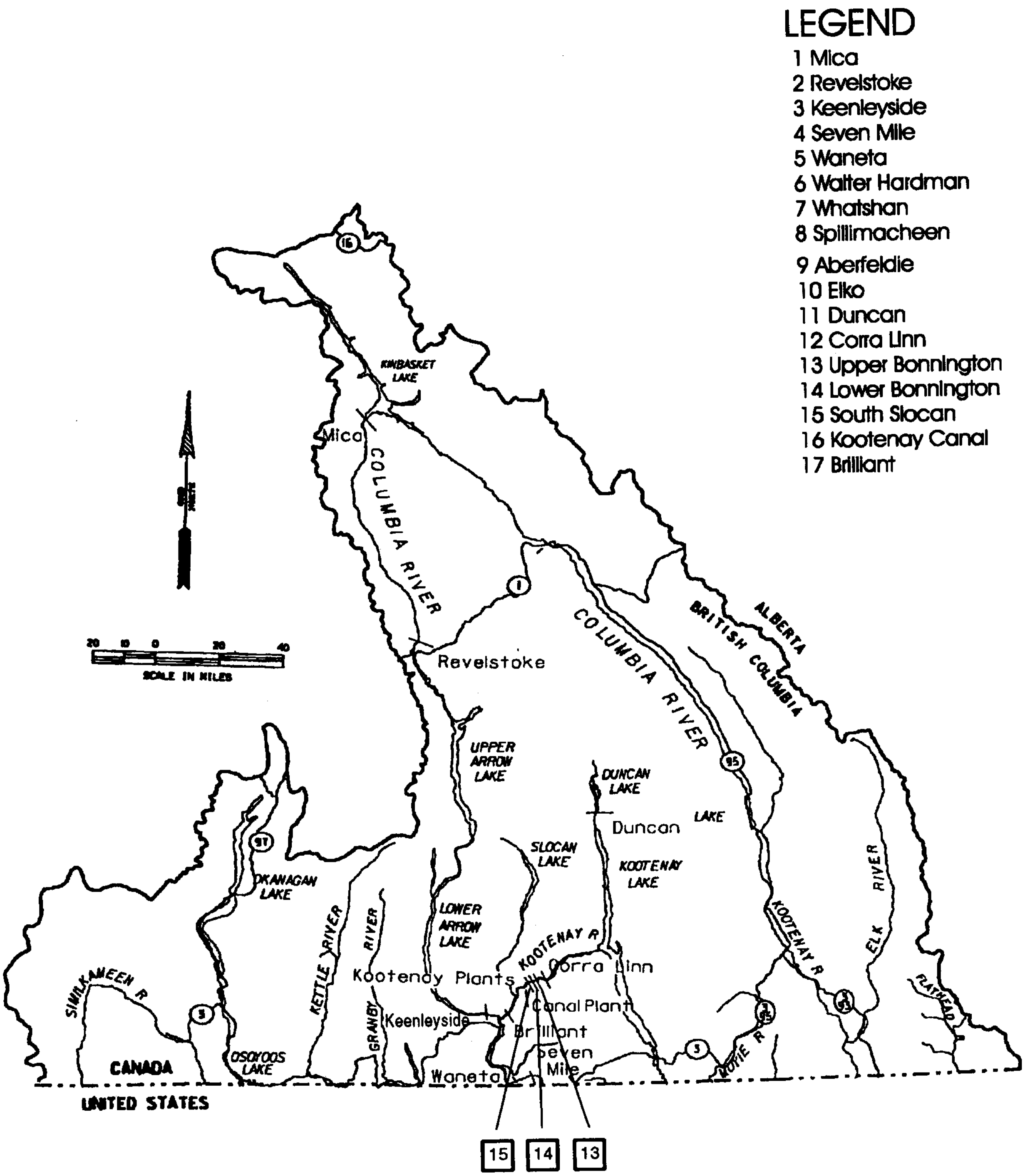


Figure 2–3. Map of the Canadian Hydropower Projects and Rivers

Prior to reservoir formation, the Columbia River and tributary streams subsequently inundated supported mountain whitefish, bull, brook, cutthroat and rainbow trout, burbot, and white sturgeon. Kokanee also were present in the reach from the downstream Arrow Lakes. An additional 7 species of non–game fish were also documented. The same species are now present in the impoundment, although the relative abundance of non–game species appears to have increased. The current sport fishery of Revelstoke Reservoir is mainly for rainbow and cutthroat trout, but catch rates are low. Productivity of the reservoir is believed to be inhibited due to low water retention time, and entrainment of fish and plankton through the dam also reduces fish populations (Hirst 1991).

2.2.1.3 Arrow Lakes (Hugh Keenleyside Dam)

Hugh Keenleyside Dam, 190 feet (57.9 m) high and completed in 1967, forms a storage reservoir of about 130,000 acres (52,611 ha) and 8 million acre–feet at full pool on the Columbia River in British Columbia, Canada (Figure 2–3). Keenleyside Dam, owned by B.C. Hydro, inundated Upper and Lower Arrow Lakes, which had a combined surface area of about 97,000 acres (39,2556 ha). The dam is not equipped with hydroelectric turbines, but the reservoir is generally operated to optimize power generation and flood control in the Columbia River in the United States. As a result, annual drawdowns can exceed 65 feet (19.8 m), with a reservoir evacuation of 60 to 85 percent. The reservoir is oligotrophic and does not become thermally stratified. Revelstoke Dam discharges directly into the upper portion of the impoundment.

The Arrow Lakes, Columbia River, and tributary streams which were subsequently inundated by the reservoir supported mountain whitefish, bull and rainbow trout, kokanee, and white sturgeon. The current sport fishery of Arrow Lakes is mainly for rainbow and bull trout, and kokanee. Catch rate for trout has declined, especially since the construction of Revelstoke Dam, which cut off spawning access to tributaries. Kokanee harvest rates have increased, however, so that kokanee compose the majority of the fishery. Yearly drawdowns reduce the amount of productive shallow–water areas and interfere with sportfishing success. Large numbers of fish are entrained through the sluices and ports of Keenleyside Dam into the Columbia River (Hirst 1991). Entrainment of sportfish is a concern, as are elevated total gas pressure levels due to higher flows being discharged through the spillways rather than the low level ports.

2.2.1.4 Columbia River below Arrow Lakes

Below Keenleyside Dam, the Columbia River flows freely until it reaches the head of Lake Roosevelt, a few miles downstream of the international boundary (Figure 2–3). The fish community of the river includes a large percentage of non–game species such as redside shiners, but also supports trout, kokanee, whitefish, walleye, burbot and white sturgeon. There is evidence that some rainbow trout and kokanee spend portions of their lives in both the Columbia River reach below Keenleyside Dam and in Lake Roosevelt.

Immediate downstream fish habitat is subject to considerable flow and water level fluctuations from Keenleyside Dam, which results in dewatering trout redds and stranding juvenile fish of various species especially rainbow trout and kokanee.

2.2.1.5 Lake Koocanusa (Libby Dam)

Lake Koocanusa was formed when the Kootenai River was impounded by Libby Dam in 1972 (Figure 2–2). At full pool, the reservoir has a maximum depth of 350 feet (106.7 meters [m]) and a mean depth of 126 feet (38.4 m). Historically, the reservoir has been drafted in fall and winter and refilled during spring and early summer, with maximum pool in July and August. Under past operation, Lake Koocanusa did not fully refill due to inadequate runoff in about one out of five years (Corps, 1985). The average maximum draft between 1977 and 1993 has been 116.5 feet (35.5 m). The reservoir has weak thermal stability during stratification (Brian Marotz, MDFWP, personal communication). During the most severe reservoir drawdowns, Lake Koocanusa almost fully recedes from the Canadian portion of the reservoir (Hirst 1991).

The most important game fish in the reservoir include kokanee, westslope cutthroat trout, rainbow trout, bull trout, and burbot (Fraley et al., 1989). Bull trout have been petitioned for listing under the ESA. Several warm–water species such as largemouth bass, pumpkinseed, and yellow perch also inhabit the reservoir, but are apparently present only in low numbers. In 1985, kokanee accounted for 96 percent of the number of fish harvested from the reservoir (Chisholm and Hamlin, 1987). The Kamloops strain of rainbow trout has been introduced to Lake Koocanusa by the MDFWP to feed on kokanee. A reduction in the number of kokanee in Lake Koocanusa would likely increase their average size. Stocked Kamloops rainbow trout will also provide a trophy fishery as they attain their ultimate large size.

Entrainment (passage of fish through turbines or spillways) of kokanee through Libby Dam occurs, but has not been shown to be a major detriment to the population (Don Skaar, MDFWP, personal communication). Of greater concern is the drafting of Lake Koocanusa (to as deep as 170 feet (51.8 m) below full pool) for hydropower generation. This has been shown to cause impacts to production of zooplankton and benthic organisms, and to decrease the availability of terrestrial insects, especially when refill is not achieved. Decreases in the availability of prey organisms can lead to decreased fish growth. Total dissolved gas saturation levels of 140% were measured below Keenleyside Dam at times in 1991 and 1993.

2.2.1.6 Kootenai River

An excellent rainbow trout fishery (up to 30 pounds [13.6 kilograms {kg}]) and a sizable mountain whitefish population are present in the Kootenai River below Libby Dam (Figure 2–2). The Kootenai River also supports a population of white sturgeon, which was recently listed as endangered under the ESA on September 7, 1994. As discussed above in Section 2.1.4.1, springtime spawning flows (hence Libby Dam operation) are an issue in the reproductive success of this population, Resource managers are seeking greatly enhanced flows over the current minimums, for the May through July time period. The established minimum flow in the Kootenai River below Libby Dam is 4,000 cfs (113.2 cubic meters per second [cms]) to protect insect production and juvenile salmonid rearing. Little is known about burbot in the Kootenai River, but the IDFG and MDFWP are concerned that the population may be stressed. These agencies are currently conducting research to gain information on the population structure and habits of burbot in the Kootenai River and on the effects of flow level on burbot and trout habitat (Don Skaar, MDFWP, personal communication).

Table 4–6 indicates provision of spring and summer flows to benefit sturgeon in the Kootenai River. Some flows were met, but neither SOS 2c nor 2d provided June spawning flows.

On October 6, 1994, the Kootenai River population of white sturgeon (*Acipenser transmontanus*) was listed as endangered under the Endangered Species Act. The population is land–locked, confined to about 270 river kilometers (168 mi.) in Montana, Idaho, and British Columbia, Canada. The range extends from Kootenai Falls in Montana to Corra Linn Dam at the outlet from Kootenay Lake, B.C. B.C. Ministry of Environment is investigating the status of white sturgeon in Duncan Reservoir which flows into Kootenay Lake, British Columbia. It is not presently known if white sturgeon are successfully spawning and recruiting to the Duncan Reservoir population. An aging population in the Kootenai River and Kootenay Lake is believed to number slightly over 800 individuals.

The Kootenai River population of white sturgeon (*Acipenser transmontanus*) is believed to have been isolated within Kootenay Lake, British Columbia and Kootenai River upstream to Kootenai Falls, Montana, since the last ice age more than 10,000 years ago. The population is genetically distinct from other Pacific Northwest populations, and tends to be smaller. Protein electrophoresis indicated that genetic heterozygosity is less pronounced in the Kootenai population than elsewhere in the Columbia

System. No white sturgeon over 90 Kg (200 lbs.) have been reported from the Kootenai River System.

The size and age of first sexual maturity is variable within the species. Females mature between 15 and 25 years, whereas males may mature at age 12. Females spawn only once every two to eight years.

Juvenile recruitment to the Kootenai River population has been low since the mid–1960s. With few exceptions, almost no recruitment to this population has occurred since 1972 when Libby Dam began impounding water. A small number of recruits from a cohort spawned in 1974 indicated that a fairly successful spawning event. A few other recruits have been aged from spawning events during the early 1970s. The limited recruitment is insufficient to maintain the existing population.

Mature adults, originating from spawning events more than 20 years ago (pre–1972) are progressing toward senescence; it is unknown how long the remaining adults will be fertile. Unless spawning success and recruitment improves, the white sturgeon population is expected to become functionally extinct within 40 years.

Research results suggest that reduced spring flows, unnatural flow fluctuations and an altered thermal regime caused by Libby Dam operation, have interrupted spawning behavior and recruitment. Power operations can cause rapid changes in dissolved gasses and physicochemical properties of the tailwater. Habitat conditions in the spawning areas may also affect spawning and rearing success.

Blocked backwater and slough habitat, and shifts in the abundance and quality of food organisms, may have impacted juvenile survival during the first year of life. Experimental hatchery introductions have indicated that some individuals have survived introduction to the system at age II and III.

Discharge temperature from Libby Dam can be controlled by operating a device called "selective withdrawal" which directs appropriate layers of the reservoir into the turbine penstocks. The resulting thermal regime in the Kootenai River is slightly cooler than natural during the summer (≈15°C) and generally warmer during winter (≈4°C rather than 0–2°C under natural mid–winter conditions). The lower temperature is a physical limitation because dense water in the reservoir bottom remains near 4°C year round. The upper temperature was selected by biologists to improve growth conditions for riverine fish species.

At present, an agreement between Corps and Montana FWP restrict the withdrawal depths to greater than 50 feet beneath the current surface elevation. This agreement was designed to reduce the entrainment of fish through the turbines. Water can not be withdrawn within 25 feet of the surface because of a physical limit at the project to avoid turbine cavitation and surface vortices. Thus, as the reservoir begins to stratify during early spring, the warming surface waters are unavailable to the selective withdrawal device until the warm layer thickens to over 50 feet in depth. This may postpone the release of warm water during some years beyond that expected under natural conditions.

Discharge volumes are dictated by a minimum flow limit (4 kcfs) and flood control requirements (International Joint Commission). The rate of flow fluctuation is limited by agreement to protect riverine species. The dam is operated to maximize hydropower efficiency within these guidelines. Hydropower and flood control operations generally store water during spring runoff, then release this storage during fall and winter to produce electricity during periods of peak energy consumption. This effectively eliminates high flow events during the historic runoff event.

White sturgeon historically responded to spring runoff and warming water temperatures by moving upstream to spawning areas and developing physiologically in preparation for spawning. The reproductive act generally occurred above substrate greater than 6 meters (20 ft.) deep at column velocities less than 0.24 m/second (0.77 ft. per second). Water temperatures typically ranged from 14 to 20°C (57 to 68°F). However, during 1994, fertile eggs were collected and aged backwards to spawning events at 8.6 to 12.9°C and relatively low discharges (13 to 20 kcfs at Bonners Ferry). The spawning period began earlier than expected (May 15 to June 20), over substrate that was of smaller particles than is considered optimal for survival. It remains uncertain whether any juveniles survived from this year class.

2.2.1.7 Duncan Reservoir

Duncan Dam was constructed at the outlet of the natural Duncan Lake, where it impounded the Duncan River in 1967 (Figure 2–3). The dam, owned and operated by B.C. Hydro, is an earthfill structure approximately 130 feet (40 m) high which impounds a reservoir with a surface area of about 17,600 acres at full pool (7,140 ha) with an mean depth of about 80 feet (24 m). The dam is not equipped for power generation, but is used for water storage for downstream hydroelectric facilities and for flood control. The reservoir is typically drafted in late winter of each year to less than 5 percent of its storage volume (up to 90 feet [27 m] below full pool. Releases from the dam are often at their highest in December and January, which is the reverse of the unregulated hydrograph. The new flow regime likely affects the limnology of Kootenay Lake, into which the Duncan River flows (Hirst 1991).

Duncan Lake was and Duncan Reservoir is considered to be unproductive to very unproductive due to low levels of phosphorus inflow, relatively short residence time, and cold water temperatures. The water level fluctuations which now occur due to dam operation undoubtedly also negatively affect the reservoir's productivity. Based on anglers' reports, the pre–impoundment Duncan Lake supported small numbers of rainbow trout, bull trout, and white sturgeon. In 1979, however, kokanee were reported to be the dominant sportfish in the reservoir, followed by bull trout, burbot, and mountain whitefish, with small numbers of rainbow trout. Relatively few anglers are known to use the reservoir, perhaps prefering the more readily accessible and productive Kootenay Lake (Hirst 1991).

2.2.1.8 Kootenay Lake (Corra Linn Dam)

Kootenay Lake is a natural lake in British Columbia, Canada, with its outlet controlled by Corra Linn Dam (Figure 2–3). Corra Linn Dam is operated as a part of the West Kootenay Power System. The dam, completed in 1932, has raised the natural lake level by about 8 feet (2.4 m), which is used as storage for hydro–electric generation. The lake has a surface area of about 96,000 acres (38,900 hectares [ha]) at full pool and the lake level fluctuates over the 8 feet (2.4 m) provided by Corra Linn Dam.

Kootenay Lake is currently and was originally infertile (oligotrophic), although from the 1950s through the mid–1970s, the lake was subject to nutrient loading from fertilizer factories on the Kootenay River in Canada above Lake Koocanusa. Pollution abatement measures have eliminated phosphorus and nitrogen–laden effluent from the factories, while Libby and Duncan Dams are apparently retaining nutrients which would have normally entered Kootenay Lake. It is likely that phosphorus loading in Kootenay Lake is now lower than the early 1950s, prior to construction of the fertilizer factories. Recent fertilization programs are intended to increase productivity in the North Arm of Kootenay Lake (Korman et al. 1990).

Kootenay Lake supports populations of rainbow trout, bull trout, kokanee, mountain whitefish, and burbot. It also serves as habitat for the Kootenai River white sturgeon for much of the year. One race of Kootenay Lake rainbow trout, the Gerrard or Kamloops stock, matures at a later age than most stocks, and can sometime grow to over 40 pounds (18 kg). Kokanee are the most abundant game fish in the lake and consist of 3 genetically distinct populations. Fluctuations in the kokanee populations in Kootenay Lake have been attributed to eutrophication (nutrient enrichment), overfishing, and poor reproductive success due to water level fluctuation. The current low kokanee population levels in Kootenay Lake affect not only sportfishing for kokanee, but also affects the Gerrard rainbow trout population, as kokanee are the major prey species for this stock (Hirst 1991). Kootenai/Kootenay River white sturgeon are believed to rear and feed (i.e., spend considerable time) in Kootenay Lake.

2.2.1.9 Lower Kootenay River Reservoirs

Four small run–of–river reservoirs are present on the lower Kootenay River below Corra Linn Dam

(Kootenay Lake) (Figure 2–3). These reservoirs, in downstream order, are Upper Bonnington, Lower Bonnington, South Slocan, and Brilliant, and are operated as part of the West Kootenay Power System. The dams of these projects are from 20 to 130 feet (6.1 to 39.6 m) high and were constructed from 1908 to 1944. The reservoirs have little or no storage capacity. Water quality is similar to that of Kootenay Lake. Fish species present in the reservoirs include rainbow trout, bull trout, mountain whitefish, peamouth, and northern squawfish. White sturgeon probably inhabited these areas before impoundment by the dams, and anecdotal references exist to their continued presence. Fish in these reservoirs are subject to entrainment, and the nutrient–deficient inflow from Kootenay Lake likely limits productivity (Hirst 1991).

2.2.1.10 Hungry Horse Reservoir

Hungry Horse Dam was completed on the South Fork of the Flathead River (about 5 miles [8 km] upstream of its confluence with the Flathead River) by the Bureau of Reclamation in 1953 and impounds a reservoir, at full pool, of about 33 miles (53 km) in length (Figure 2–4). At full pool, the reservoir is 23,800 acres (9,632 ha) in area, with a maximum drawdown level of 224 feet (68 m).

The geology of the watershed of the South Fork Flathead River is relatively deficient in carbonates and phosphorus, so the reservoir has low to very low productivity (oligotrophic to ultra–oligotrophic) (May et al. 1988). Thermal stratification usually occurs in late spring, summer, and early fall. Water quality is considered to be excellent. The reservoir is typically drafted in December through March and filled to full pool by July. Some drafting occurs in late summer and fall for power production. The average annual drawdown since 1954 has been 86.2 feet (26.3 m), although recent drawdowns have exceeded 180 feet (54.9 m) (Brian Marotz, MDFWP, personal communication).

Westslope cutthroat trout and bull trout are listed as Species of Special Concern in Montana and bull trout and are the most important game species in the reservoir. Bull trout are considered a candidate for listing under ESA. Both species spawn in reservoir tributary streams. Late season drawdowns, however, are believed to affect these populations by 1) reducing the availability of prey, 2) increasing competition in the reduced reservoir volume, and 3) making juveniles more accessible to predation (May et al. 1988). Hungry Horse Reservoir has one of two fishable bull trout populations in Montana, according to fishing regulations..

2.2.1.11 Flathead River and South Fork Flathead River

The South Fork of the Flathead River joins the main Flathead River about 5 miles (8 kilometers [km]) downstream of Hungry Horse Dam (Figure 2–4). Before construction of Hungry Horse Dam, the South Fork was a major spawning area for several species from Flathead Lake including westslope cutthroat trout, bull trout, and kokanee (Zubik and Fraley, 1987; Fraley and Graham, 1982). Bull trout and kokanee spawn in the fall (September and October) and cutthroat trout spawn in spring in the river and its tributaries (Fraley et al., 1989; Beattie and Clancy, 1987). A minimum stream flow of 3,500 cfs (99 cms) in August through March to has been implemented in the mainstem Flathead River at Columbia Falls by the Bureau of Reclamation (Bureau). Water releases from the bottom levels of Hungry Horse Reservoir, coupled with lack of temperature control, have provided below–optimum temperatures and drastic temperature fluctuations in the river. This has resulted in low fish growth rates. A mitigation plan is being implemented to provide temperature control.

2.2.1.12 Flathead Lake

At more than 117,000 acres (47,350 ha), Flathead Lake has the largest surface area of any natural freshwater lake in the contiguous United States west of the Mississippi River (Figure 2–4). Flow from the lake is controlled by Kerr Dam, which was completed in 1938 and is located on the lower Flathead River about 4 miles (6.4 km) downstream of the lake's natural outlet. The operation of Kerr Dam by Montana Power Company normally causes water level fluctuations in Flathead Lake of about 10 feet (3 m), with the highest elevations generally maintained in the summer recreation season. Drawdown for flood control and power generation generally begins in mid–September, with minimum pool reached by April 15.

Flathead Lake has fluctuated between infertile to moderately fertile (oligomesotrophic) (Stanford et al. 1991). The lake has a mean depth of about 107 feet (32.6 m) and a maximum depth of about 370 feet (112.8 m). The 124 miles (200 km) of shoreline has many protected bays and inlets whose shorelines are composed primarily of gravel, cobbles, boulders and bedrock.

Kokanee were introduced into Flathead Lake in 1916 and by 1933 had become well established and supported a popular fishery (Alvord 1975). Within the past 20 years, however, the kokanee fishery has declined, in part due to predation by lake trout, competition from *Mysis* shrimp, and reproductive failure. The major factor in the decline, however, is believed to be a decrease in reproduction due to water surface area fluctuations caused by Kerr Dam (shoreline spawners) and Hungry Horse Dam (upper Flathead River spawners).

Variations in flow releases from Hungry Horse Dam during the spawning and incubation period have negatively affected the production of Flathead Lake populations which spawn in the upper Flathead and South Fork Flathead Rivers (Fraley and Decker–Hess, 1987).

Besides kokanee, Flathead Lake supports a large lake trout fishery. Other important gamefish include cutthroat, bull trout, lake whitefish, and yellow perch.

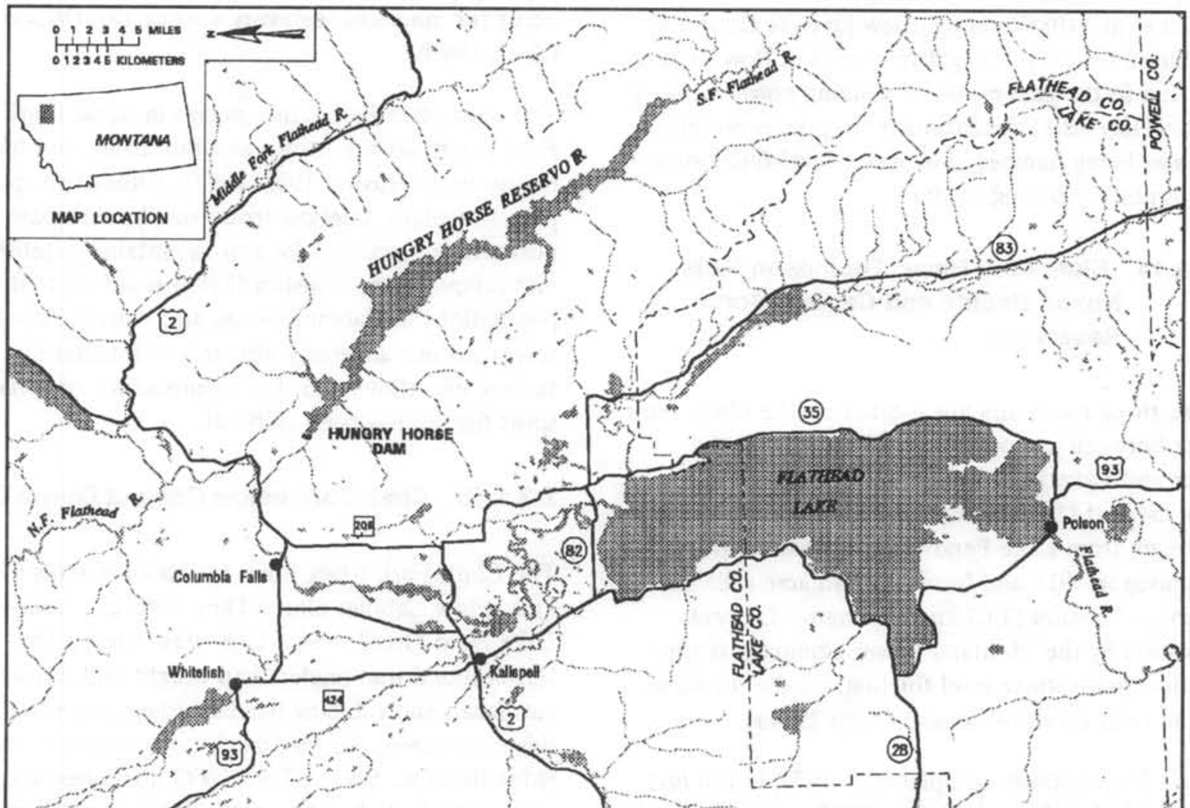


Figure 2–4. Map of Hungry Horse Project, Flathead River, and Flathead Lake

2.2.1.13 Lower Flathead River

The lower Flathead River flows for 72 miles (116 km) below Kerr Dam to its confluence with the Clark Fork River, near Paradise, Montana (Figure 2–4). Outflow from Kerr Dam varies from 53,200 to 55,000 cfs (147 to 1,557 cms) and the annual average discharge of the lower Flathead is over 11,000 cfs (311 cms). The summer water temperatures in the lower Flathead River are 3 to 4 C higher than the river above Flathead Lake, due to warming in the lake. The river has a relatively low gradient and drains a nearly 1,500 square mile (3,885 square km) watershed (DosSantos et al. 1988).

The dominant gamefish species in the lower Flathead River include mountain whitefish, brown trout, rainbow trout, and northern pike (DosSantos et al. 1988). Small populations of cutthroat trout, bull trout, and largemouth bass are also present. DosSantos et al. (1988) sampled few juvenile trout and attributed this to the negative effects of flow fluctuation due to the generation of peaking power at Kerr Dam. They also felt that northern pike reproduction was being hampered by water level fluctuation and limited spawning habitat.

2.2.1.14 Clark Fork River, Thompson Falls, Noxon Rapids and Cabinet Gorge Reservoirs

These three reservoirs are located on the Clark Fork River between its confluence with the Flathead River and Lake Pend Oreille). Thompson Falls Dam, 54 feet (16.5 m) high and 69 miles (111 km) upstream from Lake Pend Oreille, was constructed beginning in 1913 and forms a 1,446 acre (585 ha) reservoir 12 miles (19.3 km) in length. Current operation by the Montana Power Company is run–of–river, with water level fluctuations due to variation in river flow (Wood and Olsen 1984a).

Noxon Rapids Dam, completed in 1959, is 180 feet (72.9 m) in height and forms a 7,900 acre (3,197 ha) reservoir on the Clark Fork River. The dam is located about 29 miles (47 km) upstream from Lake Pend Oreille and the reservoir extends about 38 miles (61 km) upstream to near the tailwater of Thompson Falls Dam. The dam is operated by Washington Water Power Company for peaking power, with maximum daily and weekly water level fluctuations of 2 and 10 feet (0.6 and 3 m), respectively. Annual water surface elevation fluctuation up to 36 feet (11 m) may occur (Wood and Olsen 1984b).

Cabinet Gorge Dam is located about 9 miles (14.5 km) upstream from Lake Pend Oreille and impounds a reservoir of about 3,200 acres (1,295 ha). The reservoir extends upstream about 20 miles (32.2 km) to Noxon Rapids Dam. The dam was built in 1952 and is 140 feet (42.7 m) in height. Washington Water Power Company operates Cabinet Gorge Dam in coordination with Noxon Rapids Dam, with Cabinet Gorge functioning as a reregulating reservoir. Normal water level fluctuation is 2 to 3 (0.6 to 0.9 m) feet, although drawdowns of 15 feet (4.6 m) occur for maintenance every year or two (Wood and Olsen 1984b).

The most abundant game species in these Clark Fork reservoirs are brown and bull trout, and largemouth bass (Huston 1985, 1992). Other fish species present include rainbow trout, smallmouth bass, northern squawfish, lake and mountain whitefish, and yellow perch. Huston (1985) reported that fish populations in Cabinet Gorge and Noxon Rapids reservoirs are adversely affected by fluctuating surface elevations and that maintenance of a viable sport fishery has been difficult.

2.2.1.15 Clark Fork below Cabinet Gorge Dam

The Clark Fork River flows for about 9 miles (14.5 km) below Cabinet Gorge Dam before it reaches Lake Pend Oreille. In a 1989 creel survey, the IDFG found that anglers had caught bull, brown, cutthroat, and rainbow trout and kokanee were in this river reach, but that catch rates were very low (Maiolie et al. 1991). The IDFG attributed the apparently low abundance of salmonids to flow volume fluctuations from Cabinet Gorge Dam. This section of the Clark Fork supports some kokanee spawning from Lake Pend Oreille.

2.2.1.16 Lake Pend Oreille (Albeni Falls Dam)

Lake Pend Oreille is located in the panhandle region of northern Idaho (Figure 2–5). Tributaries of Lake Pend Oreille available to adfluvial fishes originate in the Selkirk Mountains to the northwest, the Cabinet Mountains to the northeast, and the Coeur d'Alene Mountains to the east.

Lake Pend Oreille is the largest natural lake in Idaho, with a surface area of nearly 95,000 acres (38,400 ha), mean depth of 538 feet (164 m) and maximum depth of about 1,150 feet (350.5 m). Mean surface elevation of Lake Pend Oreille is 2,063 feet (628.8 m) above mean sea level (msl). Most of the lake's volume (southern basin) is contained in a glacially overdeepened portion of the Purcell Trench with a mean depth of 715 feet (218 m). The north arm of the lake is shallower, with a mean depth of 98 feet (30 m) (Hoelscher 1993).

The Clark Fork River is Lake Pend Oreille's principal inlet, and is estimated to contribute as much as 90 percent of the annual inflow. The only surface outlet is the Pend Oreille River, located on the northwest portion of the lake.

The native sport fishes in Lake Pend Oreille are westslope cutthroat trout, bull trout, and mountain whitefish. Due to reduced numbers, westslope cutthroat trout is listed as state species of special concern and the USFWS considers bull trout a candidate species under ESA (see sections 2.1.4.2 and 2.1.5.1). Other sport fishes have been stocked or found their way into the lake over the years.

These species include: kokanee, rainbow trout, Gerrard (Kamloops) rainbow trout, lake whitefish, brook trout, brown trout, lake trout, yellow perch, black crappie, largemouth bass, brown bullhead, pumpkinseed, and northern pike.

The Gerrard rainbow trout of Lake Pend Oreille is an unusual stock of fish and attracts a large share of the angling effort at Lake Pend Oreille. Native to Kootenay Lake, British Columbia, this fish lives longer than other strains of rainbow trout and grows to an unusually large size on a diet of kokanee. A world record rainbow trout, weighing 37 pounds, was caught here in 1947.

From 1951 to 1965, the Lake Pend Oreille kokanee fishery was the most popular in Idaho. The sport and commercial fishery yielded an average annual harvest of about one million fish.

Fishing success for most salmonids saw dramatic declines between the 1950s and the 1980s. Kokanee harvest began to decline during the 1960s. It reached a low in 1986, and currently kokanee harvest is only 10 to 20 percent of its historic level. Bull trout harvest initially declined, and is currently fluctuating at a very depressed level. The westslope cutthroat trout fishery has declined more dramatically than any other Pend Oreille Lake fishery. It is now very reduced and is being supported by fingerling stocking, but to date, this has failed to increase the cutthroat fishery.

Several activities are believed to have caused the marked declines, although efforts have been made to correct the problems. Hydropower development on the inlet and outlet of the lake was likely the single most important contributor to the decline in sport fish numbers. Albeni Falls Dam, completed in 1952, fluctuated lake levels between summer and winter. Winter drawdown dewatered shoreline spawning areas and killed kokanee eggs in the gravel. Deeper lake drawdowns beginning in 1966 made much of the shoreline gravel beds unavailable to kokanee spawners. Most of the high quality gravel around the shores of the lake were found to be from 3 to 8 feet (0.9 to 2.4 m) below the summer pool elevation. The deeper drawdowns of up to 11 feet (3.4 m) forced kokanee to spawn in poor quality substrates; this practice is thought to have resulted in poor survival from eggs to fry.

Cabinet Gorge Dam on the Clark Fork River has been a complete migration block to all fishes since 1951, and eliminated hundreds of miles of tributary spawning and rearing areas historically available to Lake Pend Oreille fishes. Fluctuations of the river below the dam also killed kokanee eggs. Improper land use practices and natural catastrophes have resulted in degraded habitat in the remaining accessible tributaries. Since rainbow trout, westslope

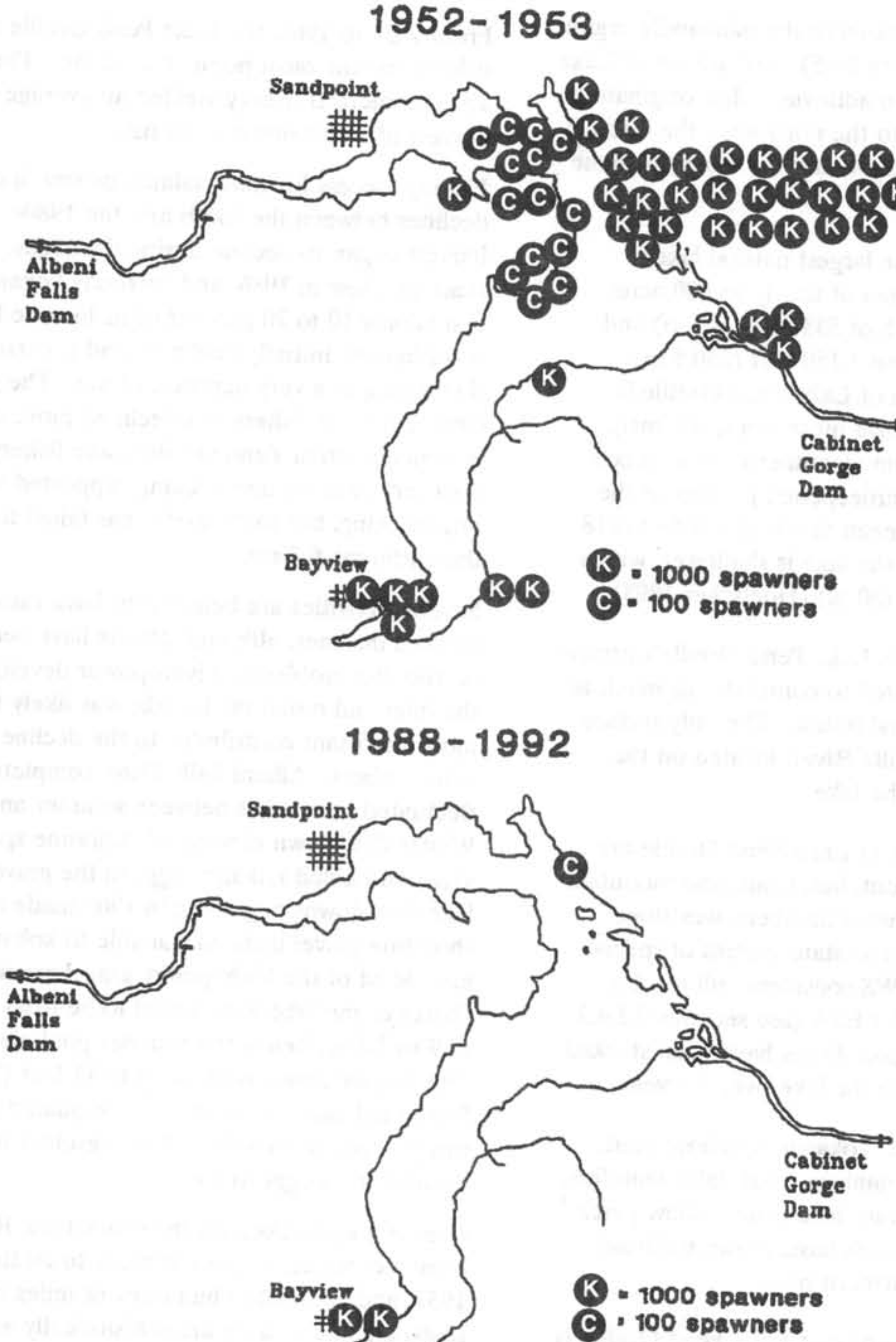


Figure 2-5. Map of Lake Pend Oreille, Idaho, showing historical (top) and recent (bottom) location of shoreline kokanee spawners.

cutthroat trout, and bull trout must spawn and rear for several years in tributary streams before migrating to the lake, changes to the streams have resulted in fewer fish in the lake.

Opossum shrimp *Mysis relicta* were introduced into Lake Pend Oreille in 1966. This small crustacean may compete with newly hatched kokanee fry for food sources, reducing the kokanee's survival during the first few weeks of life. Kokanee in Lake Pend Oreille, however, are growing well and the system is not thought to be food–limited.

Efforts have been made by public and private agencies to enhance the lake's fishery. During 1960 and 1961, bull trout spawning channels were constructed along the Clark Fork River by Washington Water Power Company (WWP). In 1964, all major bull trout spawning streams were closed to bull trout harvest. In 1967, the Corps changed the operation policy of Albeni Falls Dam to stabilize lake levels during the kokanee spawning and incubation period. The IDFG reduced the kokanee sport fishing limit and terminated the commercial fishery in 1973. The IDFG started stocking kokanee fry in 1974, and in 1985 began a cooperative effort with WWP and the BPA to further increase kokanee stocking from the Cabinet Gorge Hatchery. Lastly, the IDFG initiated very restrictive size and bag limits on both the tributary and lake fishery to enhance the trophy rainbow trout fishery, and stocked pure strain Gerrard rainbow trout from Kootenay Lake for several years to enhance wild rainbow trout genetics.

Intensive enhancement efforts have not recovered the fisheries. The wild segment of the kokanee population continues to decline, making recovery difficult. If the wild segment of the population is lost, maintaining a hatchery program will be unlikely. The kokanee stocking program has not resulted in increased abundance of adult fish. With low numbers of kokanee as forage, the abundance of rainbow and bull trout will also remain low.

2.2.1.17 Box Canyon Reservoir

Box Canyon Dam, on the Pend Oreille River in Washington, was completed in 1952 and forms the 7,371 acre (2,983 ha) run–of–river Box Canyon Reservoir. The dam is owned by the Public Utility District Number 1 of Pend Oreille County. The reservoir extends upstream about 56 miles (90 km) to the tailwaters of Albeni Falls Dam and water surface elevation varies over a 5 to 7 foot (1.5 to 2.1 m) range.

In studies by Ashe et al. (1991) and Bennett and Liter (1991), more than 20 fish species were sampled in Box Canyon Reservoir. Yellow perch, pumpkinseed, and largemouth bass were the game species of greatest abundance, while northern squawfish, tench, and largescale sucker were the most abundant non–game species. Several species of trout were sampled, but made up a tiny portion of the fish collected. Native trout species (westslope cutthroat and bull trout) are severely depleted, probably due to habitat alterations and introduction of exotic brook and brown trout. Bennett and Liter (1991), and Ashe et al. (1991) observed that lower water temperatures and overwinter kills appeared to the greatest limiting factors for largemouth bass, although competition of juvenile bass with yellow perch also appears to be a factor. Yellow perch growth appeared to be limited more by density dependent factors. Large areas of aquatic macrophytes also appeared to affect resident fish in Box Canyon Reservoir, as do water levels in slough areas, and spawning area dewatering. Certain reservoir operations may hinder migration into tributary streams from Box Canyon Reservoir by adfluvial trout species.

2.2.1.18 Boundary Reservoir

Boundary Dam (340 feet [103.6 m] in height) is located on the Pend Oreille River in Washington about 1 mile (1.6 km) upstream of the international border, and is owned by Seattle City Light. The run–of–river project is operated for peaking generation at low flows. Water surface elevation normally fluctuates over a range of about 20 feet (6 m), although daily fluctuation 5 to 10 feet (1.5 to 3 m). The reservoir is about 17.5 miles (28.1 km) in length (to the base of Box Canyon Dam) and has a surface area of about 1,640 acres (664 ha) at full pool. Two natural hydraulic controls exist in the reservoir

(Z Canyon and Metalline Falls) and cause water surface elevation fluctuations independent of dam operation. Information in Homa (1982) shows that the fish community of Boundary Reservoir is similar to that of Box Canyon Reservoir, immediately upstream.

2.2.1.19 Seven Mile Reservoir

Seven Mile Dam, 260 feet (79.2 m) in height and located on the Pend d'Oreille River in southern British Columbia, Canada, forms a run–of–river reservoir of about 900 acres (364 ha). The dam, owned by B.C. Hydro, was completed in 1979 and, at full pool, its reservoir extends to within a mile (1.6 km) of Boundary Dam, in the State of Washington. Pool level fluctuations are generally small, in the range of 3 to 7 feet (0.9 to 2.1 m), and mean water retention time is 1 to 2 days.

Seven Mile Reservoir supports mountain whitefish, rainbow trout and bull trout, but a large majority of the fish biomass consists of non–game species such as northern squawfish, peamouth, and longnose sucker. Yellow perch and pumpkinseed are also present.

2.2.1.20 Waneta Reservoir

Waneta Dam is 249 feet (75.9 m) in height and is located on the Pend d'Oreille River immediately above its confluence with the Columbia River in southern British Columbia, Canada. It is owned by the Consolidate Mining and Smelting Company. The run–of–river reservoir formed by the dam is similar in character and dimensions to Seven Mile Reservoir. The dam was completed in 1954 and at full pool, its reservoir extends to within a little more than a mile (1.6 km) of Seven Mile Dam.

Waneta Reservoir supports northern squawfish and redside shiners, and is believed to have a small number of game species, such as rainbow trout and mountain whitefish. White sturgeon spawning was recorded in June and July 1993 at the outlet of the Pend d'Oreille River. Changes in discharge from Lake Pend Oreille may affect water velocity and temperature and the spawning habitat suitability for white sturgeon. Lack of detailed information precludes determining the significance of these changes or of modeling the effects.

2.2.2 Specific Projects and River Reaches – Lake Roosevelt and Mid–Columbia River

2.2.2.1 Lake Roosevelt

Grand Coulee Dam, which impounds Lake Roosevelt, was completed in 1942 by the Bureau of Reclamation. The dam has three powerhouses, the last completed in 1974. Lake Roosevelt extends 151 miles (243 km) upstream from Grand Coulee Dam (River Mile 596.6 [River Kilometer 960]), nearly reaching the international boundary (Figure 2–6). The reservoir has more than 5 million acre–feet of storage capacity, and fluctuates 82 feet (25 m) from normal full pool to minimum operating pool. The authorized purposes of the project are power production, flood control, and irrigation.

Annual spring drawdowns affect nutrient levels, phytoplankton and zooplankton production in the reservoir due to decreases in water retention time (Beckman et al. 1985). Decreases in water retention time in April, May, and June reduce the growing season of zooplankton in the reservoir and result in delayed zooplankton development and decreased density and biomass. In general, when reservoir elevation and water retention time are high in the spring, zooplankton density and biomass are high and peak in late summer. Low water elevation and water retention time in the spring result in lower than normal zooplankton density and zooplankton biomass peaking later in the year than usual. Because kokanee, rainbow trout and young–of–the–year of walleye rely upon zooplankton as a major food source, water retention time of 30 to 35 days in the spring appears to be of critical importance to the Lake Roosevelt fishery throughout the year (Griffith and Scholz 1991, Peone et al. 1990). Nutrient loading of Lake Roosevelt from industrial waste in Canada will soon decrease because of the iminent modernization of the Cominco plant on the Columbia River reach above the reservoir. How this will affect reservoir productivity is unknown.

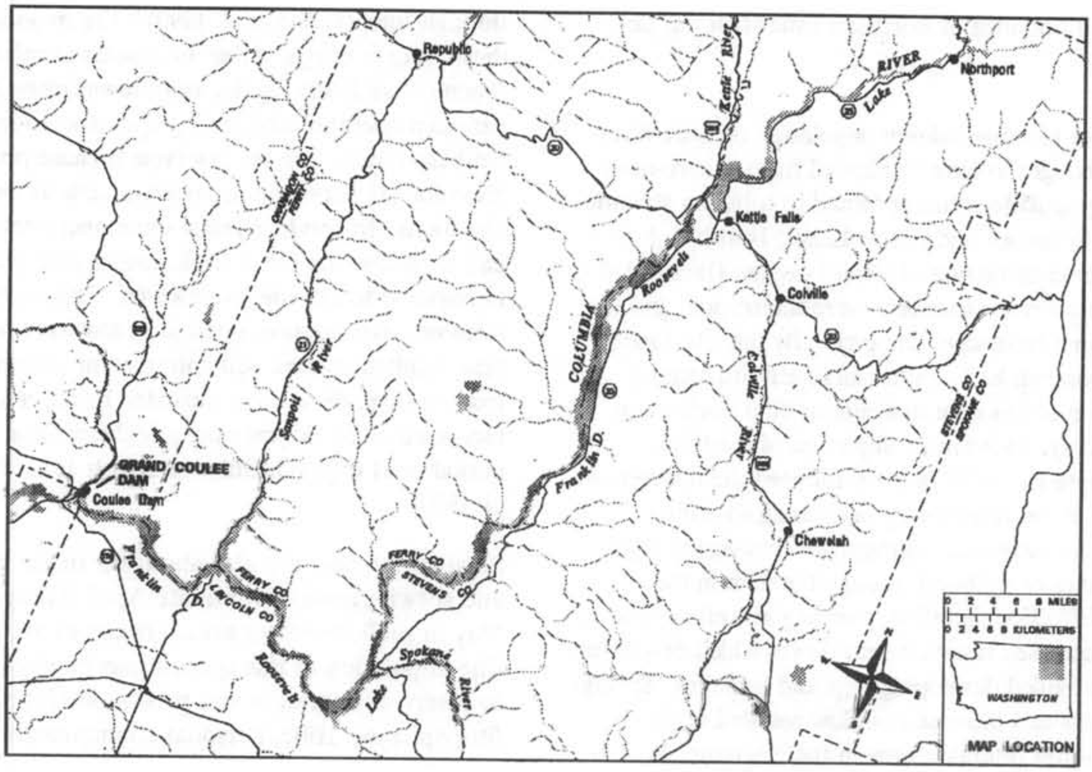


Figure 2–6. Map of Grand Coulee Dam and Lake Roosevelt

Lake Roosevelt stratifies only weakly, if at all (Crawford et al., 1976). Productivity in the reservoir is moderate to low and is affected by the relatively short water retention time. Average retention time ranges from 15 to 76 days and is shortest in spring and longest in fall and early winter (Beckman et al., 1985). Because of the short retention time, nutrients and plankton are rapidly flushed through the reservoir.

Perch, walleye, and suckers are the most abundant fish species in Lake Roosevelt based on relative abundance surveys between 1988 and 1990. Primary target species by anglers who expressed a preference include rainbow trout, walleye, sturgeon, kokanee, smallmouth bass, and yellow perch.

Walleye are an exotic species introduced into Lake Roosevelt during the 1940s and 1950s. They have thrived in the reservoir and are a primary gamefish species. Walleye spawn in the Spokane Arm of the reservoir in April and May (Beckman et al. 1985, Peone et al. 1990). Spawning success of walleye appears to be unaffected by current reservoir operations because the main spawning grounds lie in the upper Spokane Arm of the reservoir below Little Falls Dam, which is only slightly affected by drawdowns which occur on the mainstem of the reservoir. Young walleye are typically found in littoral (near-shore) areas associated with woody debris. Adults are most commonly found in pelagic (open water) areas during daylight hours and near the mouths of embayments and tributaries at night, where they come to feed (Peone et al. 1990). Yellow perch are a primary forage species for walleye in the reservoir and spawn in March and April. Beckman et al. (1985) found that reservoir drawdowns in late April and May affect the spawning success of perch. Therefore, perch spawning success may in part determine walleye production in the reservoir. Walleye appear to have a competitive advantage over the native northern squawfish in that walleye relative abundance has steadily increased while relative abundance of northern squawfish has decreased.

The native kokanee salmon population of Lake Roosevelt is thought to have originated from anadromous sockeye populations that spawned in tributary streams of Lake Roosevelt and Arrow Lakes, British Columbia. After construction of Grand Coulee Dam in 1939, anadromous runs of sockeye were interrupted and the fish began a landlocked life cycle. By the late 1960's, Lake Roosevelt had a rather large self–sustaining population of kokanee that supported a destination sport fishery. However, completion of the third powerhouse (in 1974) severely reduced the number of kokanee in the reservoir by decreasing spawning success and increasing entrainment (passage through the turbines or spillway) through the dam in the spring. Effective shoreline spawning was eliminated due to increased reservoir drawdowns which dewatered redds and killed developing eggs and juveniles. Spring drawdowns and increased outflow resulted in decreased water retention time in the reservoir. It appears that water retention times below 30 days in the spring result in the entrainment of kokanee through the dam. The magnitude of the relationship between entrainment losses and decreased water retention time is not entirely clear, although the consensus is that entrainment increases with decreasing water retention time. Reservoir operations during the past year have been linked to the decline and possible elimination of the native kokanee runs in some reservoir tributaries. Recently, two kokanee hatcheries were constructed as mitigation for the loss of anadromous salmon to the region and to replenish the decreasing kokanee population in Lake Roosevelt.

The rainbow trout fishery consists of native and stocked fish, with net–pen fish accounting for about 90 percent of the population in relative abundance surveys (Griffith and Scholz 1990). Natural reproduction of rainbows occurs in the tributaries of the reservoir. Rainbow trout are stocked within the reservoir by the Washington Department of Wildlife, the Colville Confederated Tribes, and the Spokane Tribal Hatchery. Extensive net–pen culture operations located throughout the reservoir raise trout to catchable size, then release them into the reservoir in May through June (Peone et al. 1990). The majority of these fish are caught within 14 months of release (Peone et al. 1990). Spring drawdowns often affect the net–pen operations by forcing operators to move their net pens farther into the reservoir because protected areas for the net–pens are not available at lower pool elevations. In previous years, some operators have had to release the fish in early, rather than late, spring in response to extreme drawdowns. This early release from net–pens during a period of low water retention time resulted in increased entrainment of rainbow trout through the dam as indicated by tag returns recovered as far downstream a McNary Dam in a time period of 41 days (Griffith and Scholz 1991, Peone et al. 1990).

Smallmouth bass are also abundant in the reservoir and spawn primarily from late April through mid–May in shallow–water areas (Peone et al., 1990). The population of this species may be declining due to reservoir operation and predation (Janelle Griffith, Spokane Tribe, personal communication).

A population of white sturgeon exists in Lake Roosevelt (Brannon and Sette 1992). The bull trout is considered to be a candidate species under the ESA by the USFWS (see section 2.1.4.2 for more information). The USFWS considers bull trout a candidate species for listing under the ESA. The Washington Department of Fish and Wildlife considers the population in Lake Roosevelt to be at high risk of extinction.

2.2.2.2 Lake Rufus Woods (Chief Joseph Reservoir)

Chief Joseph Dam was completed by the Corps of Engineers in 1955 at RM 545 (RK 877) of the Columbia River (Figure 2–7). Lake Rufus Woods is a run–of–river reservoir and extends about 52 miles to Grand Coulee Dam. To some extent, Lake Rufus Woods acts as reregulating reservoir for the releases from Grand Coulee Dam.

Erickson et al. (1984) conducted a survey of the resident fish community of the reservoir and found that fish abundance was very low. Squawfish, peamouth, and largescale suckers dominated their catch, with only a few sportfish species present (Table 2–3). Because

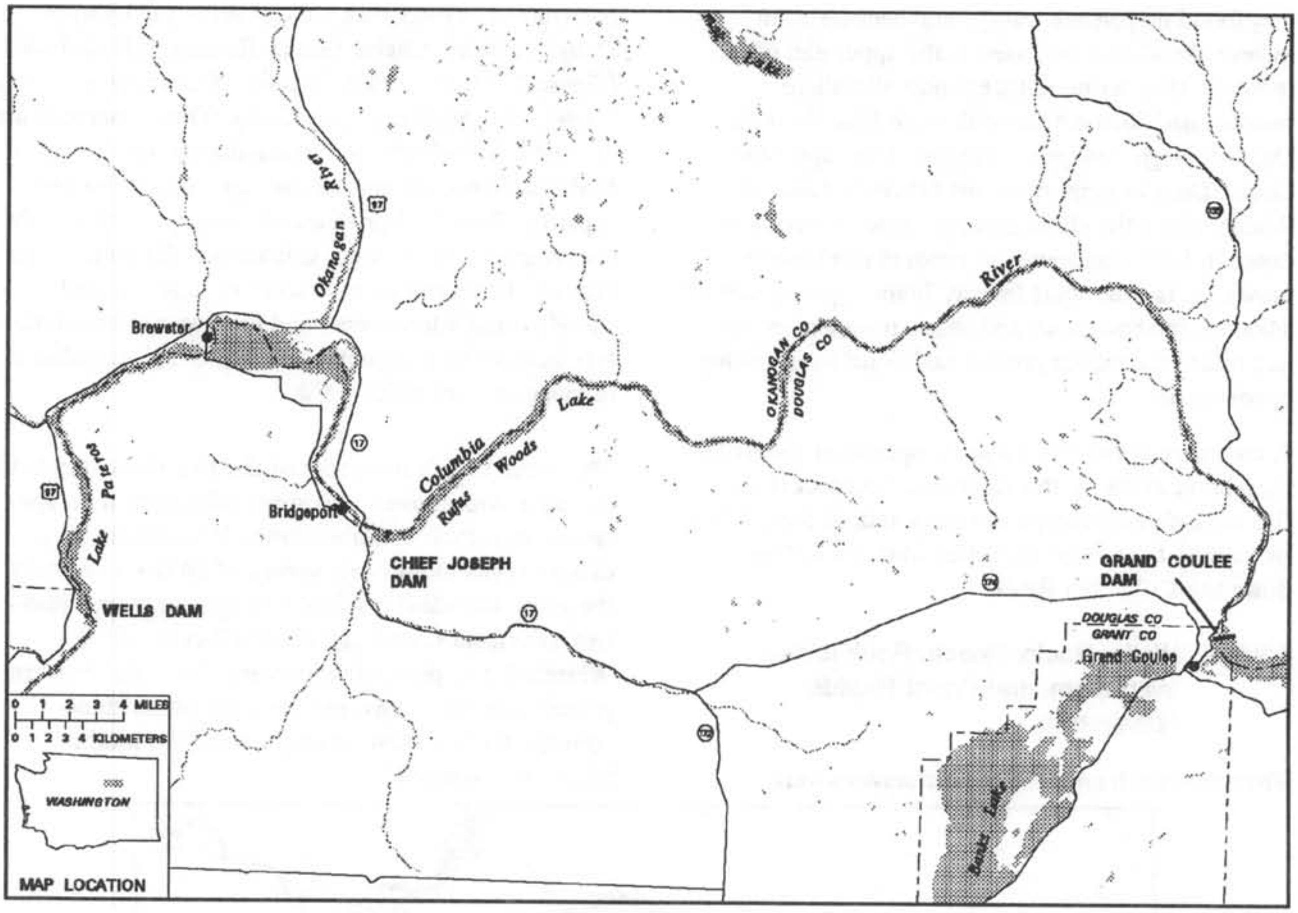


Figure 2–7. Map of Chief Joseph Dam and Lake Rufus Woods

Table 2–3. Characteristics of Mid–Columbia River Hydroelectric Projects

Reservoir Name	R.M. (R.K.)	Surface Area Acres (ha)	Reservoir Length Miles (km)
Wells	515.6 (829.8)	10,280 (4,160)	30 (48)
Rocky Reach	473.7 (762.3)	8,167 (3,305)	42 (68)
Rock Island	453.4 (729.7)	3,458 (1,399)	20 (32)
Wanapum	415.8 (669.2)	14,550 (5,888)	38 (61)
Priest Rapids	397.1 (639.1)	7,670 (3,104)	19 (31)

they found no juvenile walleye and because adult walleye abundance increased in the upper end of the reservoir, they surmised that almost all walleye sampled had been entrained through Grand Coulee Dam. Enough walleye are entrained through Grand Coulee Dam to support a sport fishery in Lake Rufus Woods. Since the elevation of the reservoir pool was raised in 1981, conditions for resident fish have improved, as has the sport fishery. Some reproduction of kokanee, rainbow trout, and brown trout also occurs, and these populations provide additional sport fishing opportunities.

A commercial net–pen rearing operation for Atlantic salmon exists on the reservoir. Some of these fish undoubtedly escape the pens and, in fact, Atlantic salmon have been identified at dams farther down the Columbia River.

2.2.2.3 Wells, Rocky Reach, Rock Island, Wanapum, and Priest Rapids Reservoirs

The dams which impound these reservoirs were constructed by the Public Utility Districts (PUDs) of Douglas (Wells), Chelan (Rocky Reach and Rock Island) (Figure 2–8), and Grant Counties (Wanapum and Priest Rapids), Washington (Figure 2–9). These reservoirs are operated for hydroelectric production as run–of–river facilities, with some limited daily and weekly peaking capacity. Table 2–3 provides a summary of some of the characteristics of the mid–Columbia PUD projects. In general, the reservoirs have relatively undeveloped shoreline and littoral zones and low water retention time, two factors which are not conducive to high abundance of many types of resident fish.

The resident fish resources of the five reservoirs have not been well studied, but some information on species composition and abundance is available. In a dissolved gas monitoring survey of all five reservoirs, the most abundant resident fish species were squawfish, stickleback, and suckers (Dell et al. 1975). Whitefish and pumpkinseed were the most abundant gamefish in this study, but resident gamefish accounted for less than two percent of the total of 32,289 fish sampled.

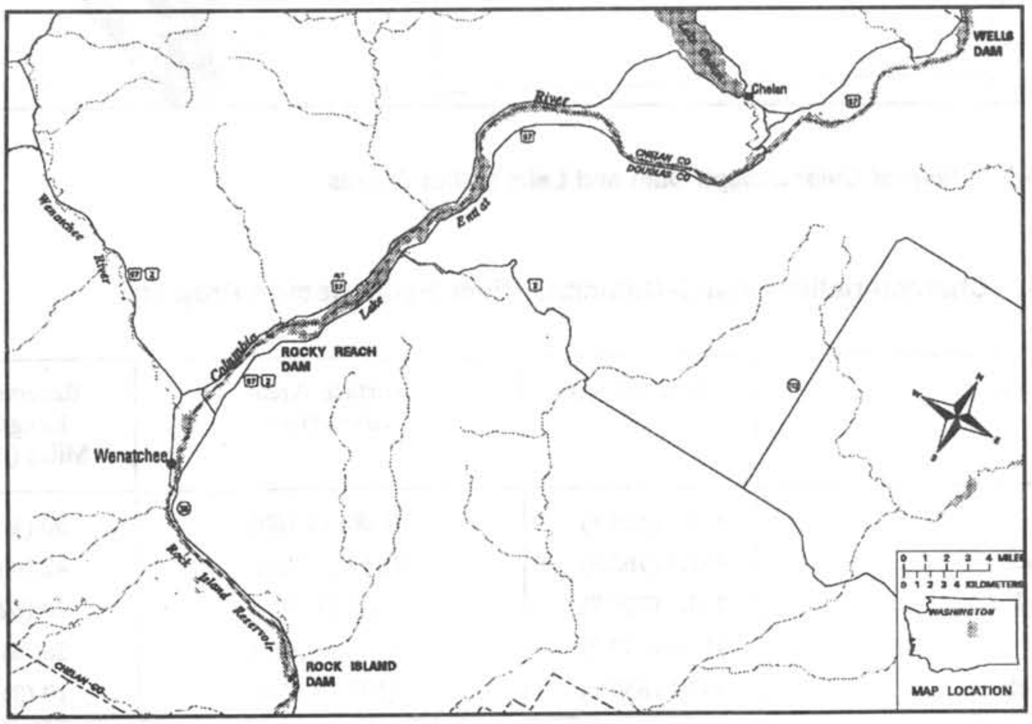


Figure 2–8. Map of Wells, Rocky Reach and Rock Island Reservoirs

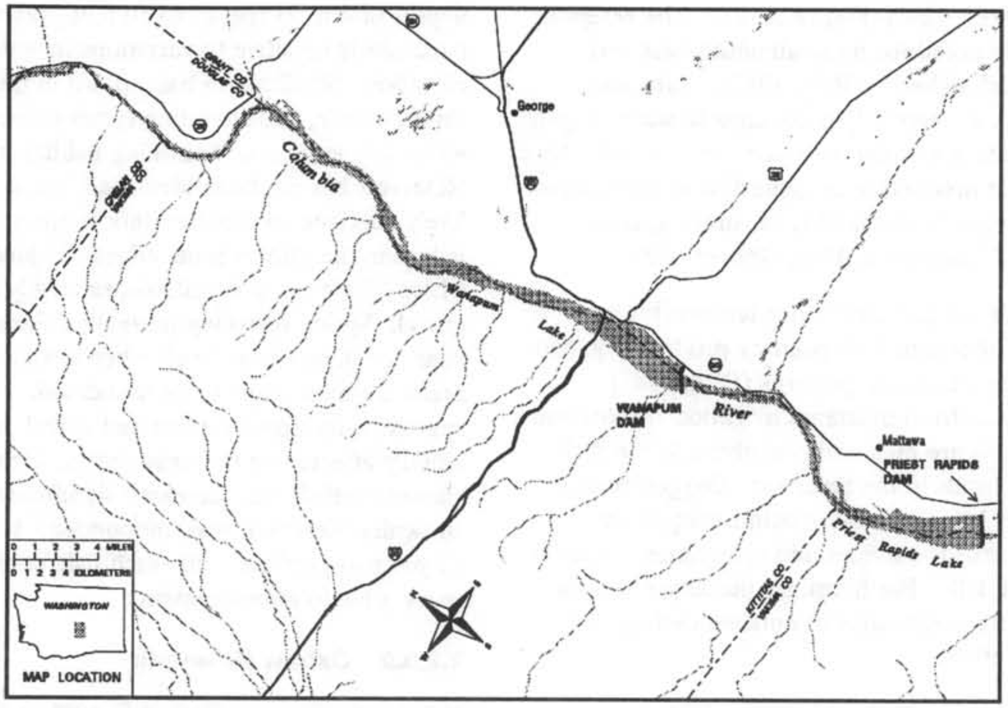


Figure 2–9. Map of Wanapum and Priest Rapids Reservoirs

Mullan et al. (1986) looked at fish ladder counts at mid–Columbia reservoirs and stated that the construction of the dams had radically altered fish abundance and species composition. They found that resident salmonids and sturgeon were scarce and concluded that the fish community was dominated by sticklebacks, minnows, and suckers. They also felt that low abundance of exotic warm water species (e.g. sunfish and bass, catfish) was because these species could spawn successfully only in the relatively scarce warm backwater areas of the reservoirs. They also stated that fall–winter water temperatures for mountain whitefish reproduction are now marginal.

Walleye abundance in these reservoirs is based on recruitment from Lake Roosevelt. Short water retention time limit successful spawning.

2.2.2.4 Hanford Reach of the Columbia River

The Hanford Reach extends from the upper portion of McNary Reservoir (Lake Wallula) at about RM 343 to the base of Priest Rapids Dam (RM 393) (Figure 2–10). The Hanford Reach is the only unimpounded section of the Columbia River in Washington State above Bonneville Dam, and as such is an important refuge for native resident fish species. The Hanford Reach is free–flowing in the sense that it is not impounded, but its flow is determined by releases from Priest Rapids Dam, which is sometimes operated for peaking power. Gray and Dauble (1977) reported that 43 species of fish had been sampled from the Hanford Reach since 1943 (Table 2–2); however, this total includes some anadromous species, such as salmon and American shad.

2.2.3 Specific Projects and River reaches – Middle Snake and Clearwater Rivers

2.2.3.1 Brownlee Reservoir

The Brownlee Dam completed at RM 285 (RK 459) on the Snake River in 1958 by the Idaho Power Company, forms a reservoir of about 60 miles in length. Brownlee Reservoir primarily supports a warm–water fishery. Smallmouth bass, channel catfish, and black and white crappie populations are the dominant game species (Rohrer, 1984) (Figure 2–11). 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).

The 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 and sometimes results in localized fish kills. Furthermore, decomposition of organic matter contributes to nutrient cycling and oxygen depletion.

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 depths of 3 to 12 feet (4 to 6 feet preferred) and crappie typically spawn at depths of 4 to 24 feet (7 to 10 feet preferred) may be particularly sensitive to variations in water surface elevation. Smallmouth bass spawn in mid–April through 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, including sunfish and catfish, may be equally affected by the drawdowns. Growth of channel catfish has decreased significantly since the Brownlee Reservoir was impounded. It now takes 12 years to produce a 20–inch fish, compared to 5 years prior to impoundment.

2.2.3.2 Oxbow Reservoir

Oxbow Dam was completed in 1961 at RM 273 (RK 439.3) by the Idaho Power Company (Figure 2–11). At 117 feet (36.1 m) in height, it impounds a reservoir 12 miles (19.3 km) in length which ends at the base of Brownlee Dam (BPA 1985). Because of its

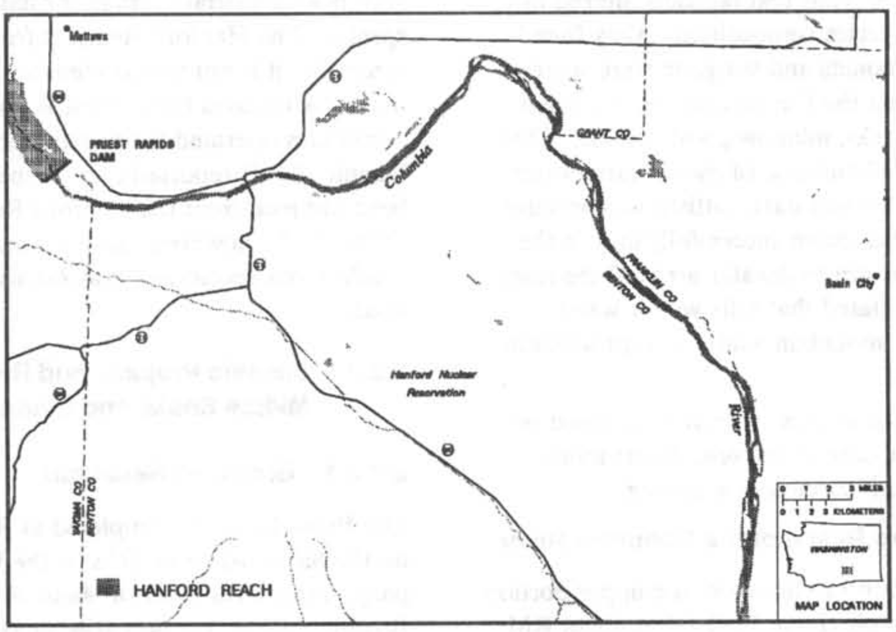


Figure 2–10. Map of Hanford Reach

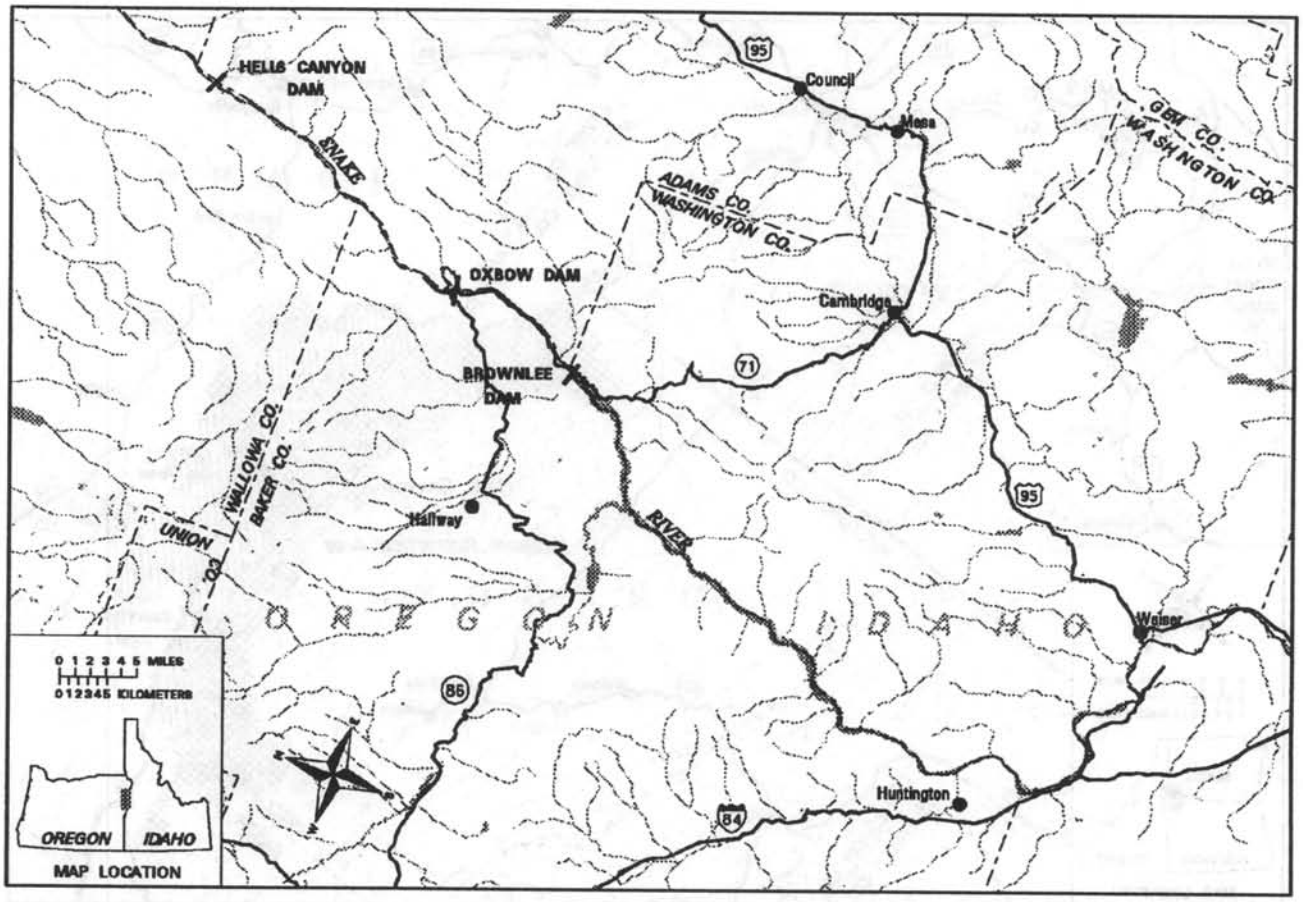


Figure 2–11. Map of Brownlee Oxbow, and Hells Canyon Dam Reservoirs

limited storage capacity (5,520 acre–feet), the water retention time of Oxbow Reservoir is quite short, and this, in combination with cool water temperatures, limits its productivity. This is reflected in the growth rates of the gamefish species. The fishery supports the same species as Brownlee Reservoir, but at lower densities. Numerically, smallmouth bass and bluegill are the most abundant species, while smallmouth bass, carp, chiselmouth, and suckers compose the greatest biomass. Recent sampling by the Oregon Department of Fish and Wildlife (ODFW) suggests that white sturgeon are very rare in Oxbow Reservoir and that opportunities for natural reproduction are probably limited by the lack of available spawning habitat.

2.2.3.3 Hells Canyon Reservoir

Hells Canyon Dam was completed in 1967 at RM 247 (Figure 2–12) by the Idaho Power Company. At 220 feet (67 m) in height, it impounds a reservoir 26 miles (42 km) in length which ends at the base of Oxbow Dam (BPA 1985). Although its storage capacity (98,820 acre–feet) is greater than that of Oxbow Reservoir, the water retention time of Hells Canyon Reservoir is still quite short, and this, in combination with cool water temperatures, limits its productivity. Sampling in Hells Canyon Reservoir by the ODFW has revealed similar fish population characteristics to Oxbow Reservoir.

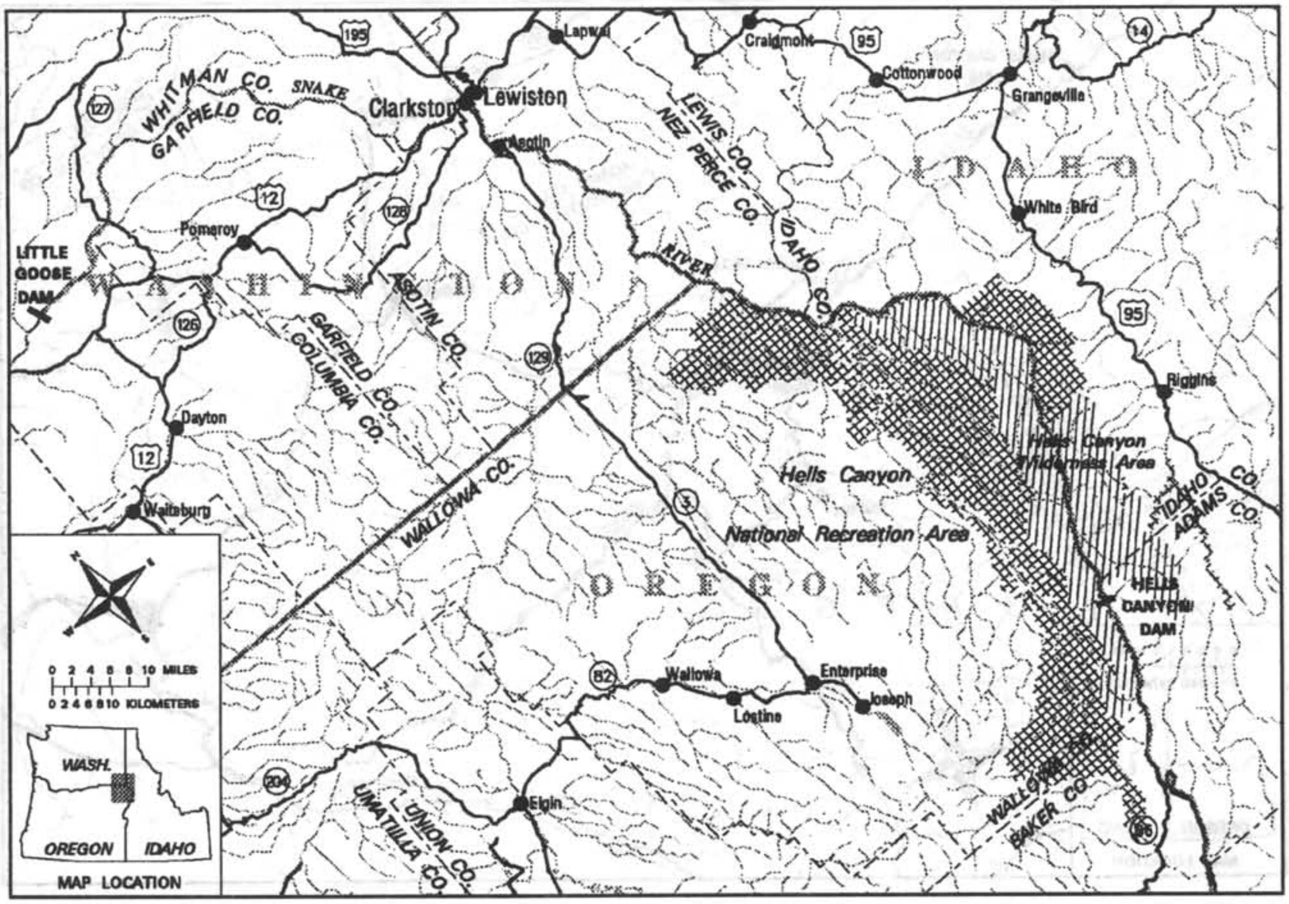


Figure 2–12. Map of Hells Canyon and Snake River

2.2.3.4 Hells Canyon Reach of Snake River

The Hells Canyon Reach extends from the tailrace of Hells Canyon Dam to the upstream edge of Lower Granite Reservoir near Lewiston/Clarkston (Figure 2–12). Although its flow is largely controlled by release from the Hells Canyon Complex dams, it is otherwise the only free–flowing section of the Snake River from its mouth upstream to the top of Brownlee Reservoir, a distance of well over 300 miles (480 km).

Resident gamefish species common in the Hells Canyon Reach include white sturgeon, smallmouth bass, and rainbow trout. Commercial fishing guides are common in this section of the river, targeting the white sturgeon and smallmouth bass populations, with greater effort targeted at the bass. This river section is considered to be very productive, with aquatic insects and crayfish forming the prey base for fish.

2.2.3.5 Dworshak Reservoir

Dworshak Dam, a Corps of Engineers storage project, is located on the North Fork of the Clearwater River, about 2 miles (3.2 km) upstream from its confluence with the mainstem (Figure 2–13). The dam is about 3 miles (4.8 km) northeast of Orofino in Clearwater County, Idaho. At 718 feet (218.8 m) in height, it is the largest straight–axis concrete dam in the United States. Three turbines within the dam have a total operating capacity of 450 megawatts and a hydraulic capacity of 10,000 cubic feet per second (cfs)(283 cubic meters per second [cms]). Water can

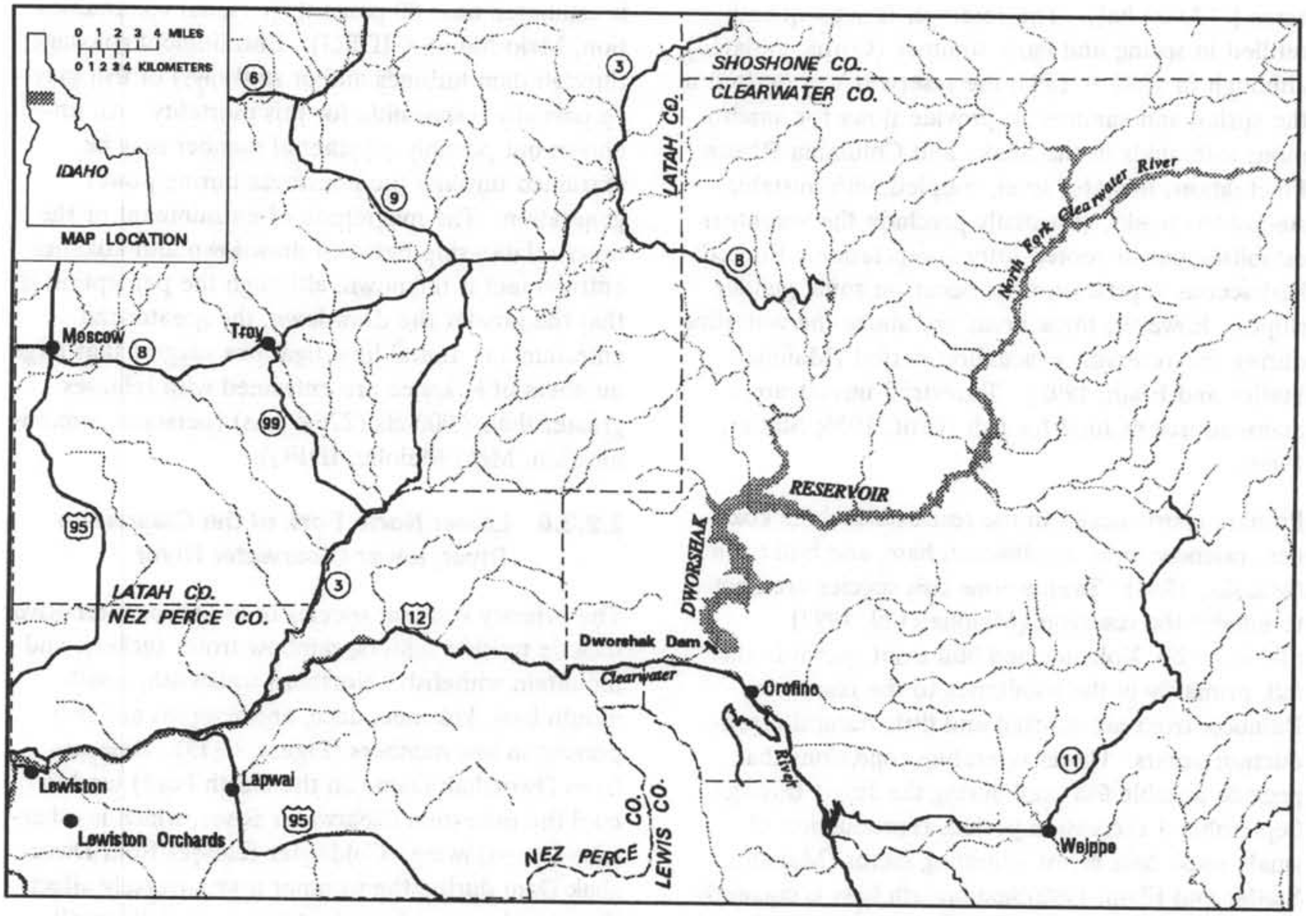


Figure 2–13. Map of Dworshak Project and Lower Clearwater River

be discharged from the reservoir through the turbines, outlet gates, or tainter gates on the spillway.

Dworshak Reservoir is about 54 miles (87 km) long and has about 180 (290 km) miles of generally steep shoreline. Maximum depth is about 636 feet (193.9 m) with a corresponding volume of about 3.4 million acre–feet at full pool. Surface area when full is about 16,400 acres (6,637 ha) and mean depth is about 184 feet (56 m). It contains over 13,300 acres (5,383 ha) of kokanee habitat (defined as area over 50 feet [15.2 m] deep). Mean annual ouflow is about 5,700 cfs (161.3 cms). The reservoir has a mean retention time of 10.2 months, although retention time is variable, depending on precipitation and has ranged from 22 months in 1973 to 6 months during 1974 (Falter 1982). Dworshak Reservoir initially reached full pool in July 1973.

Dworshak Reservoir is deep and characterized as oligomesotorphic in the lower section and mesoeutrophic in the Elk Creek arm (Maiolie et al, 1992). 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 (uppermost water layer), which generally extends over the upper 40 feet (12.2 m) of the reservoir (Corps, undated). Drawdowns of up to 155 feet (47.2 m)(Maiolie, 1988) in the fall and winter reduce surface area as much as 50 percent (~9,000 acres [~3,600 ha]). The reservoir is subsequently refilled in spring and early summer (Corps, undated), although in 1992 – 1995, the reservoir was drafted in the spring and summer to provide flows for anadromous salmonids in the Snake and Columbia Rivers. Fluctuations in water level, coupled with unstable steepsided banks, essentially preclude the volunteer establishment of rooted littoral vegetation. Rooted herbaceous vegetation does occur on some gentler slopes; however, these areas are above the waterline during the reservoir evacuation period (Maiolie, Statler and Elam, 1992). Terrestrial insects are a major source of food for fish (Petit, 1976; Statler, 1989).

Primary sport species in the reservoir include kokanee, rainbow trout, smallmouth bass, and bull trout (Maiolie, 1988). Twenty–one fish species are known to inhabit the reservoir (Maiolie et al, 1992) (Table 2–2). Kokanee and bull trout spawn in the fall, primarily in the tributaries to the reservoir. Rainbow trout are stocked and little natural reproduction occurs. Under operating conditions that provide a stable full pool during the July 1 through September 1 recreation period, reproduction of smallmouth bass is not a limiting factor (Maiolie, Statler and Elam, 1992)Smallmouth bass is currently the most abundant naturally–producing littoral–based game fish species in Dworshak Reservoir (Maiolie, Statler and Elam, 1992). The resident bass population appears to be healthy and has increased in abundance over time (Statler, 1990), but effects of recent spring and summer drafting are unknown.

The reservoir has a regionally important fishery and is approximately 1.5 hours' drive from the population centers of Lewiston, Idaho and Clarkston, Washington. Kokanee are currently the most sought–after species and are known for their large size in Dworshak Reservoir relative to other Idaho lakes and reservoirs.

Maximum spawning habitat for smallmouth bass exists at full pool. It is presumed that mountain whitefish also spawn in the streams or in the North Fork of 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, IDFG). Entrainment (passage through dam turbines and/or spillways) 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 (226.4 cms) (personal communication, Melo Maiolie, IDFG).

2.2.3.6 Lower North Fork of the Clearwater River, lower Clearwater River

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 (Figure 2–13). Releases from Dworshak Dam (on the North Fork) tend to cool the mainstem Clearwater River, which is otherwise free–flowing. Coldwater releases from Dworshak Dam during the summer may adversely affect the growth rates of resident fish, especially smallmouth bass, in the lower Clearwater.

2.2.4 Lower Columbia and Snake River Run–of–River Reservoirs

2.2.4.1 General Conditions

Fish species in the FCRPS reservoirs of the lower Snake and Columbia rivers (Figures 2–14––2–18; 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 in abundance 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 open−water 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 Rasmussen, 1981). Fish normally spawn in shallow water less than 6.5 feet (2 m) deep. Spawning and incubation times vary between species; however, most of these backwater species spawn from May through mid−July.

Shad, minnows, 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 small fry (Hjort et al., 1981). The greatest abundance of fry are generally found in the backwaters and nearshore areas. Only yellow perch and prickly sculpin fry 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 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 suckers and minnows. White sturgeon 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 waterhas 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 relatively 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).

2.2.4.2 Lower Snake River

Lower Granite Reservoir

Lower Granite Reservoir was impounded by Lower Granite Dam in 1975 at Snake RM 107.5 (RK 173) and extends upstream approximately 44 miles (70.8 km) to the vicinity of Lewiston, Idaho (Figure 2–14, map of lower Snake Reservoirs). The reservoir also extends a few miles up the lower Clearwater River at Lewiston. The run–of–river reservoir surface elevation normally fluctuates over a 5–foot (1.5 m) range, but in recent years has been operated at or near Minimum Operating Pool (MOP) during the spring and summer in an attempt to minimize juvenile salmonid travel time through the reservoir.

Lake Bryan (Little Goose Reservoir)

Lake Bryan was impounded by Little Goose Dam in 1970 at Snake RM 70.3 (RK 113.1) and extends upstream approximately 37 miles (59.5 km) to the tailwater of Lower Granite Dam (Figure 2–14). Like Lower Granite, the run–of–river reservoir surface elevation normally fluctuates over a 5–foot (1.5 m) range, but in recent years has been operated at or near (MOP) during the spring and summer.

Lake Herbert G. West (Lower Monumental Reservoir)

Lake Herbert G. West was impounded by Lower Monumental Dam in 1969 at Snake RM 41.6 (RK 66.9) and extends upstream approximately 28.7 miles (46.2 km) to the tailwater of Little Goose Dam (Figure 2–14). The run–of–river reservoir surface elevation normally fluctuates over a 3–foot (0.9 m) range, but like the rest of the lower Snake reservoirs, has been operated at or near Minimum Operating Pool (MOP) during the spring and summer.

Lake Sacajawea (Ice Harbor Reservoir)

Lake Sacajawea was impounded by Ice Harbor Dam in 1969 at Snake RM 9.7 (15.6 km) and extends upstream approximately 31.9 miles (51.3 km) to the tailwater of Lower Monumental Dam (Figure 2–15). Like Lower Monumental, the run–of–river reservoir surface elevation normally fluctuates over a 3–foot (0.9 m) range, but in recent years has been operated at or near MOP during the spring and summer.

General Conditions in the Lower Snake River

Reservoirs in the lower Snake River (Lower Granite, Little Goose, Lower Monumental, and Ice Harbor, Figure 2–10) 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.

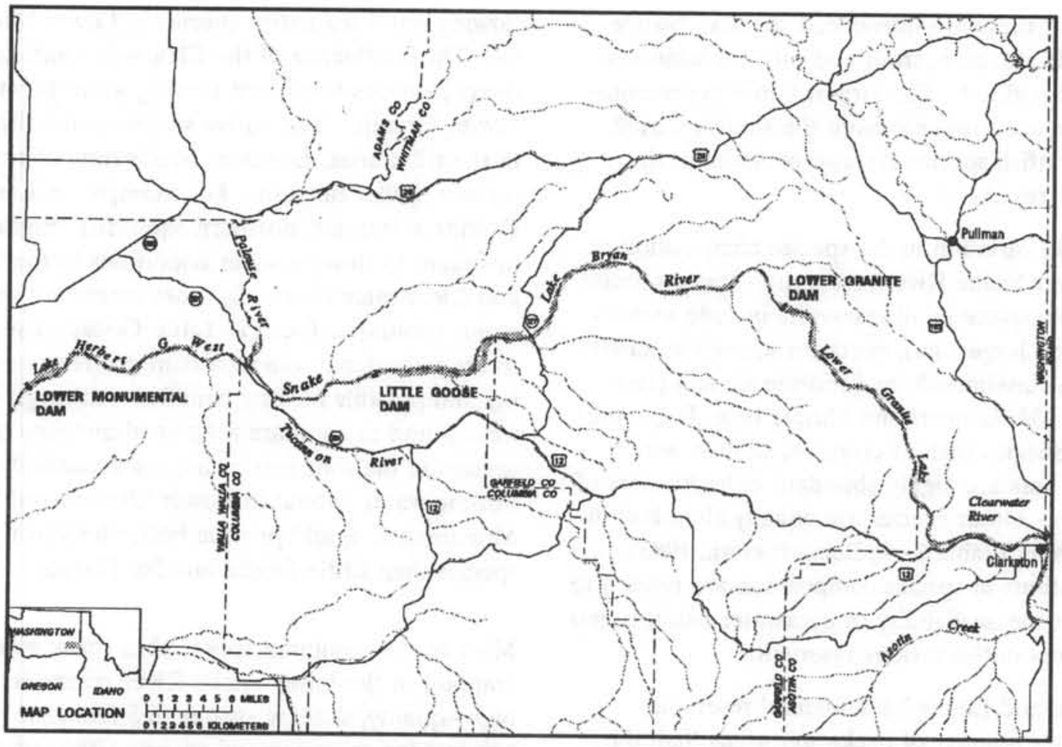


Figure 2–14. Map of Lower Snake Projects

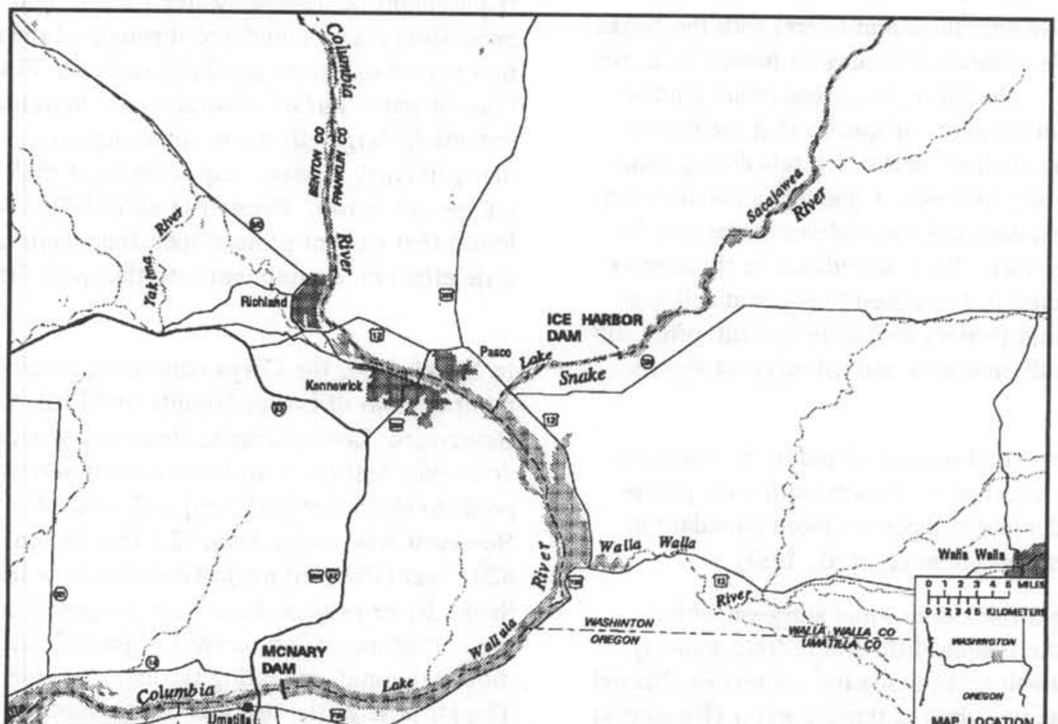


Figure 2–15. Map of the McNary Project

About half of these are introduced species. Native fishes include sturgeon, trout and salmon, minnows, suckers, and sculpins. The largest family representation of introduced fishes is from the sunfish family. Numerous catfish species are also common in the Snake River reservoirs.

There is little variation 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 (Table 2−2; 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 on 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 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 (bass, sunfish, and crappie) in the lower Snake River reservoirs require high−quality, shallow−water (6.5 feet [2 m] 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.

In March 1992, the Corps conducted an experimental drawdown of Lower Granite and Little Goose Reservoirs. Lower Granite Reservoir was drawn down 36.5 feet (11.1 m) from minimum operating pool (to 696.5 feet [221.3 m] msl) and Little Goose Reservoir was drawn down 12.5 feet (3.8 m) (to 620.5 feet [189.1 m] msl). Drawdowns of the lower Snake River projects have been proposed as a method of increasing survival of juvenile anadromous salmonids migrating through the reservoirs. The purpose of the test was to measure the effects of drawdowns on water velocity, water quality, physical structures, and dam operation.

The drawdown test caused the mortality of many resident fish (incomplete estimates ranged from about 15,000–35,000 individuals of at least a dozen species) in the two reservoirs (Corps 1992). Most of the fish killed by the drawdowns were stranded and in embayments or pools left dry by the retreating reservoirs. In addition to direct mortality of resident fish caused by stranding, it is likely that a large percentage of the invertebrates within the drawdown zone perished. Because these invertebrates (chiefly midge larvae, worms, crayfish, and amphipods) are prey organisms for fish, the growth and survival of resident fish may have been adversely affected by the drawdown. Additionally, many fish may have been spilled from Lower Granite and Little Goose Reservoirs into the next reservoir downstream.

2.2.5 Specific Projects and River Reaches – lower Columbia River

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. 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 warmwater 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. Beamesderfer and Ward (1994), however, found that year class strength of smallmouth bass in John Day Reservoir was not consistently correlated with physical variables measured. Nonetheless, habitat manipulation has the potential to affect the quality and quantity of fish habitat, with subsequent potential effects on fish population characteristics. Most fish in the lower Columbia River reservoirs spawn from June to mid–July.

2.2.5.1 Lake Wallula (McNary Reservoir)

McNary Dam impounds the Columbia River at RM 292 and the impounded reach extends to RM 345, at the lower boundary of the Hanford Reach (Figure 2–15). Lake Wallula filled in 1953 and extends up the lower portions of the Walla Walla and Yakima rivers and up the Snake River to Ice Harbor Dam. The normal operating pool of this run–of–river reservoir fluctuates between 335 and 340 feet msl. The area on the east side of Lake Wallula between the Snake and Walla Walla River confluences has extensive shallow–water habitat. Little information is available on the resident fisheries of Lake Wallula, but Table 2–2 provides a list of fish species found in the reservoir. The chief resident fisheries in Lake Wallula are for walleye, smallmouth bass, and white sturgeon.

2.2.5.2 Lake Umatilla (John Day Reservoir)

John Day Dam impounds the Columbia River at RM 215.6 (RK 347.0) and extends to McNary Dam at RM 292 (RK 558.4) (Figure 2–16). Lake Umatilla filled in 1968 and extends up the lower portions of the Umatilla and John Day rivers and several smaller tributaries. The normal operating pool normally fluctuates between 265 feet (80.8 m) and 268 feet (81.7 m) msl during the irrigation season and between 260 feet (79.2 m) and 265 feet (80.8 m) msl at other times of the year. Although it is usually operated as a run–of–river project, the reservoir has some flood control capacity and is technically a storage project. In 1993, the Corps operated the pool at near 262.5 feet (80 m) msl during the spring and summer to increase water particle travel time through the reservoir. This operation would be

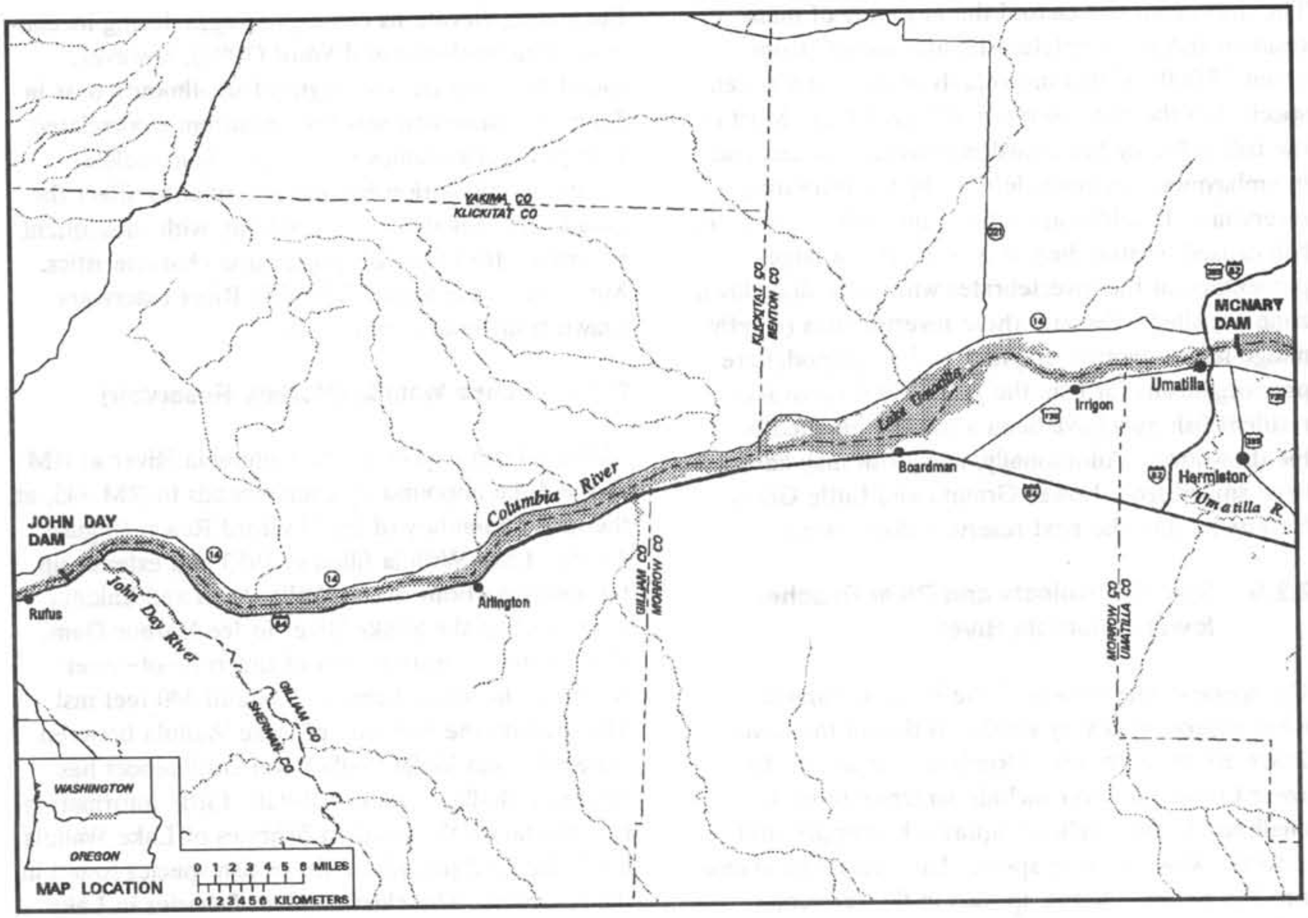


Figure 2–16. Map of John Day Pool

dependent upon the ability of irrigators to pump at this level. Extensive shallow–water habitat exists in the Willow Creek embayment and in the Paterson and McCormack Sloughs.

Hjort et al. (1981) conducted an extensive investigation of the resident fish community and limnology of Lake Umatilla. They found that 1) nearshore areas are important for the larval and juvenile lifestages as well as for the adults of some species; 2) the tailrace open–water area is the main spawning area for native minnows and suckers; 3) the McNary Dam tailrace is the only area of the reservoir with water velocities sufficient for white sturgeon spawning; 4) backwater areas support the greatest diversity of introduced species; 5) nongame fishes, especially sculpin and suckers, are an important food source for game fishes; and 6) June and July may be critical months in determining year–class size of many species because of large changes in water temperature and flow when fish eggs and larvae are present.

The ODFW (1990) reported that creel surveys in the early 1980's showed that 44 percent of angler effort in Lake Umatilla was directed at white sturgeon, 29 percent at smallmouth bass, 11 percent for walleye, and 16 percent for other fish, including American shad, black crappie, and channel catfish. More recent information (Beamesderfer and Ward, 1994; Tivos and Beamesderfer, 1994) indicates increases in smallmouth bass numbers and angling effort.

2.2.5.3 Lake Celilo, Lake Bonneville (The Dalles and Bonneville Reservoirs)

The Dalles Dam was completed in 1960 at RM 191.7 (RK 308.5) and the reservoir extends about 24 miles (39 km) up to John Day Dam (Figure 2–17).

Under normal operation, the run–of–river reservoir fluctuates about 5 feet (1.5 m) in water surface elevation. Bonneville Dam was completed in 1938 at RM 145 (RK 234.2) and the reservoir extends about 46 miles (74 km) up to The Dalles Dam. Under normal operation, the run–of–river reservoir fluctuates about 5 feet (1.5 m) in water surface elevation.

The fish communities of the two reservoirs are thought to be similar. Hjort et al. (1981), in their resident fish survey of Lake Umatilla, also sampled Lakes Bonneville and Celilo but did not note any differences in the resident fish community.

2.2.5.4 The Columbia River below Bonneville Dam

The Columbia River flows for 146 miles below Bonneville Dam to its estuary confluence with the Pacific Ocean (Figure 2–18). Farr and Ward (1993) in a survey of fishes of the lower Willamette River, found 37 species of fish (Table 2–2). This species list probably also reflects the fish community in the Columbia River in the vicinity of Portland. A number of chiefly estuarine and marine fish species also inhabit the river below Bonneville Dam. The most sought–after non–salmonid gamefish species in this section of the Columbia River is white sturgeon, although this species is considered to be anadromous below Bonneville Dam.

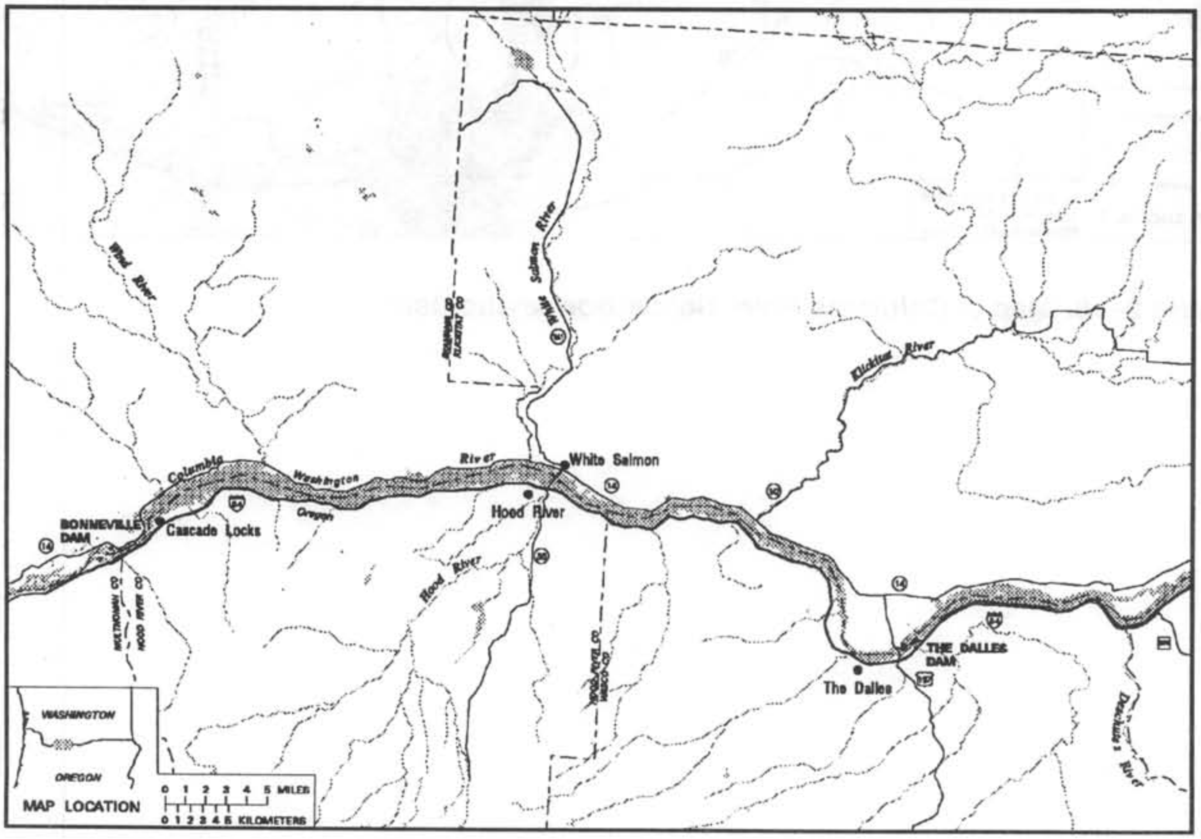


Figure 2–17. Map of the Dalles and Bonneville Projects

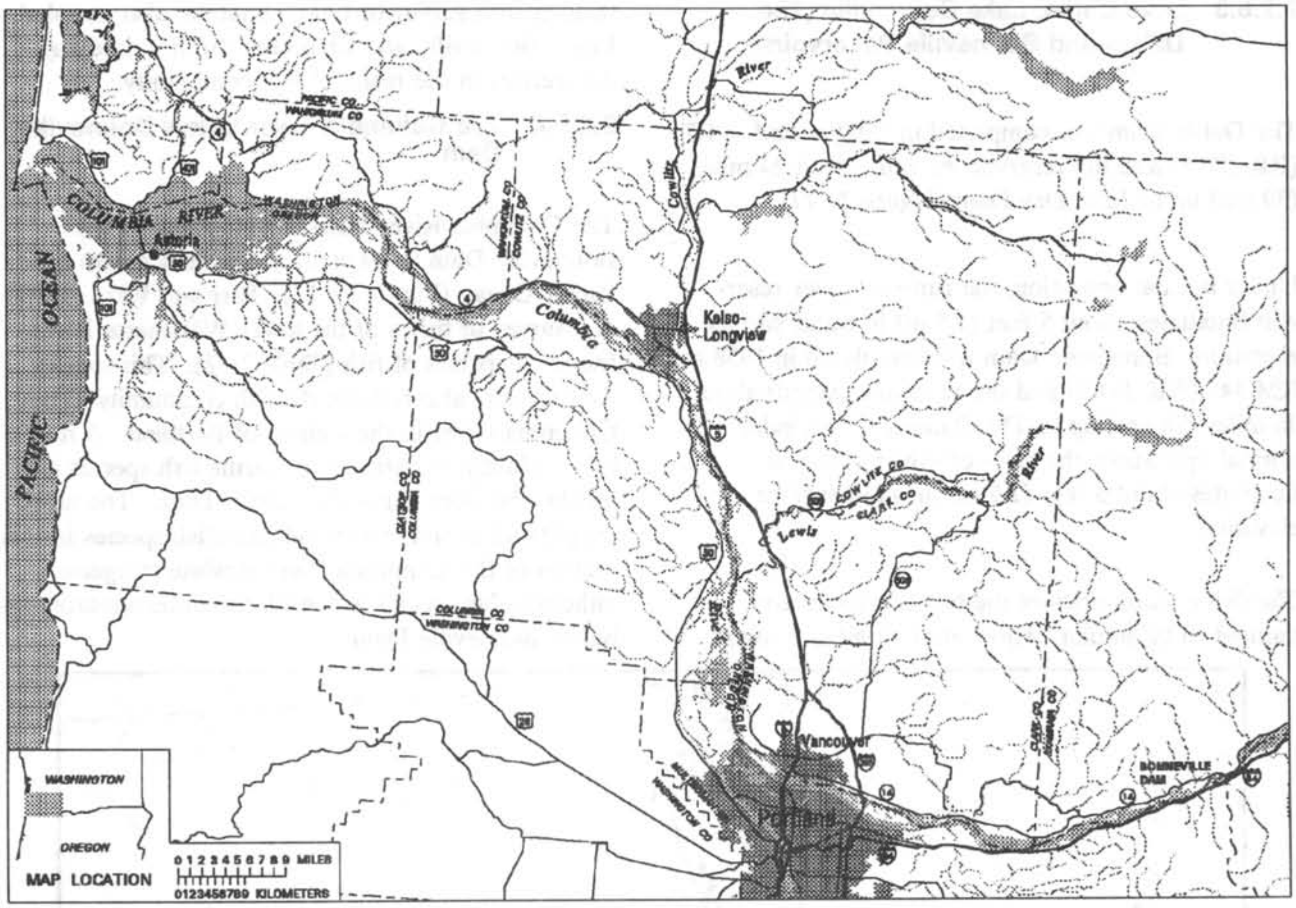


Figure 2–18. Map of Columbia River Below Bonneville Dam

CHAPTER 3

STUDY METHODS

This chapter briefly describes the development of the models that the Resident Fish Work Group (RFWG) used in evaluating the seven Full–Scale operating strategies, gives a general description of the models, and details important assumptions and parameters for the modeled projects.

During the study phase of the System Operation Review, the RFWG progressed from: (1) developing and testing study methods (Pilot Analysis); to (2) developing operating alternatives beneficial to resident fish, and analyzing the impacts to resident fish from alternatives developed by the other technical work groups (Screening Analysis); to (3) refining RFWG study methods and analyzing the seven system operating strategies (SOSs), including 21 options, that emerged from the Screening Analysis into the Full–Scale Analysis.

The results of Full Scale Analysis for Resident Fish were reported on in the Draft EIS, the Draft Technical Appendix K, and the Draft Supplimental Appendix. Based upon public comment, the seven SOSs totaling 21 alternatives were condensed to seven SOSs, with a total of 12 alternatives, plus the prefered alternative.

The models used during the final analysis were used to analyze impacts from hydroregulated pool elevations and flows. Where appropriate, models were updated with any new information from field investigations.

The RFWG is assessing the impacts of system operation to resident fish through the use of life–cycle models. Nature, both physical and biological, is infinitely complex. When attempting to plan for and around natural phenomena, it is impossible to take into account all of nature's variety. For that reason, we build models to represent reality so that we may look at the pieces that most concern us. In building those models, we include details that interest us while excluding others that are not important to our analysis. In cases where the details are incompletely understood, we document our uncertainties with assumptions. If these uncertainties are critical, we may decide that we can not successfully construct a model until the uncertainty is reduced.

For purposes of the System Operation Review, two natural phenomena are being modeled: the hydrology of the Columbia River under different operating strategies, (devised by the technical work groups), and the relative health of selected resident fish populations in selected projects, particularly as their health relates to the habitat requirements of the populations.

In the first modeling process, the Reservoir Operation Simulation Experts (ROSE) model how the river reacts hydrologically to each operating alternative. The hydrological models provide output in terms of pool elevations, discharge, and fish–related spills. This information is then given to each work group, who apply it to their area of expertise. For the RFWG, that meant running the hydrological output through resident fish life–cycle/habitat models. The life–cycle/habitat models the RFWG utilized contain sub–models which connect habitat (e.g., the production of fish food in the projects, the condition of spawning areas, access to spawning tributaries, etc.) to the relative health of the fisheries.

The link between the two modeling efforts is the response of fish habitat to hydrology. If, for instance, a strategy calls for drawing down a reservoir below a certain elevation, the habitat response may be that the shoreline is left dry. If the shoreline is a spawning area, that habitat will no longer support that particular life–cycle activity of the resident fish population; the habitat becomes unsuitable.

For modeling purposes, the connection between hydrology and habitat is represented by indices of habitat suitability (Figure 3–1). Habitat suitability indices portray how the quality of fish habitat changes as a function of reservoir operation.

Habitat suitability indices are combined together to form what is known as value measures. When modelers want to assess the impacts of hydrologic operations to resident fish, it is the value measures at which they look, because these composites of habitat suitability indices are significant indicators of resident fish health. A value measure can either represent a habitat requirement, or a crucial life–cycle activity as a function of a habitat requirement.

For instance, in Lake Pend Oreille, kokanee thrive when fish food is present in the reservoir above a certain amount, when a certain amount of eggs incubate successfully, and when shoreline spawning areas are available above a certain acreage. The value measure for kokanee at Lake Pend Oreille, then, is calculated from the habitat suitability indices which represent two habitat requirements (food production, spawning area) and a life–cycle activity as a function of a habitat requirement (egg incubation as a function of spawning beds left unperturbed by fluctuations in elevations and flows). As with all value measures assigned during the study phase, resident fish value measures are based on empirical data gathered by regional and project experts.

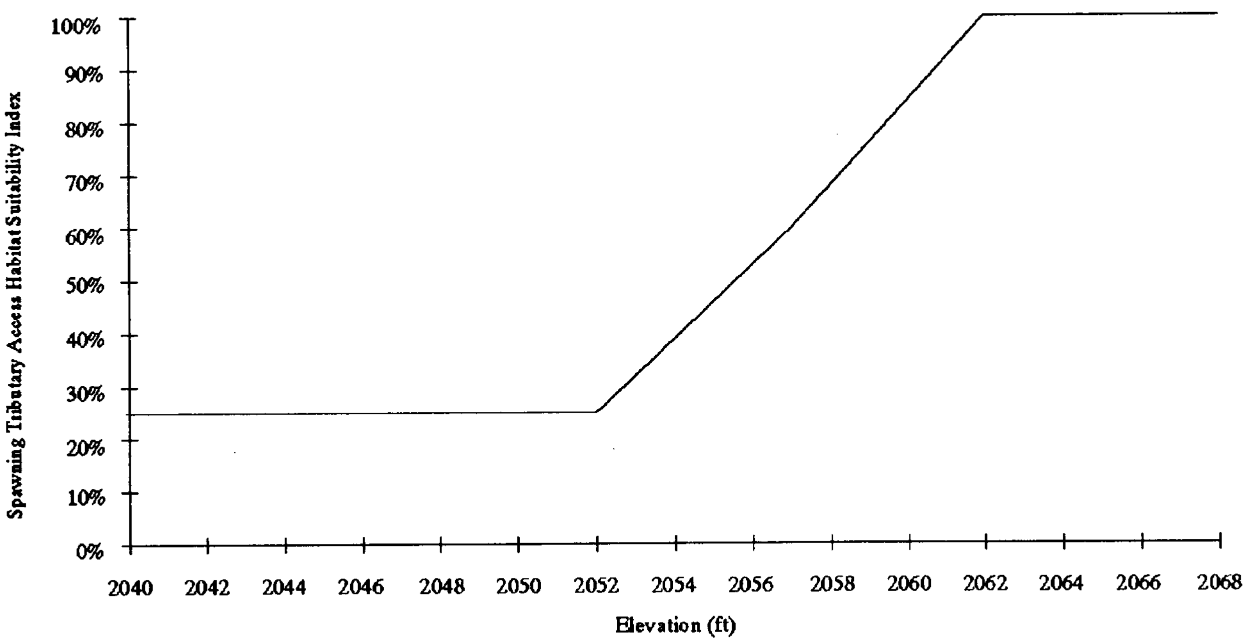


Figure 3–1. An example of a habitat suitability index based on reservoir elevations for a species of resident fish. The life cycle/habitat models read in reservoir elevations and make a relative assessment of the "quality" of spawning tributary access based on the elevation during critical time periods (i.e., spawning season). This relative assessment is the habitat suitability index. In this example, access to tributary streams during the spawning season is excellent (index = 100% or 1.0) when the reservoir elevation is at or above 2062 feet. Reservoir elevations below 2062 feet result in lower and lower indices. Habitat suitability indices from various reservoir operation – habitat relationships can then be combined into a cumulative value measure for each species at each reservoir.

Thus, the models answer questions about the relative health of populations indirectly. While it may be impossible to tell directly whether sufficient fish are actually spawning or getting enough food, by using the models it is possible to see whether the hydrology is degrading the spawning areas or interfering with fish food production.

Two important considerations about the study methods are that (1) the RFWG is studying models of hydrology and fish health relative to habitat suitability, rather than studying actual populations; and (2) the models indirectly measure resident fish health by referring to indicators known as value measures. Because we are using indirect measurements of fish health rather than a study of actual fish populations and this assessment is done using indices of habitat suitability, our value measures are reported as indices.

For each project and each key species we report a value measure. The value measures actually represent a group of indices since there is no single value measure that captures the entire impact. A value measure (i.e., fish index) works to suggest how local hydrology impacts the population in about the same way that a stock index works. The Dow–Jones Index of industrial blue–chip stocks, for instance, is a single number – a weighted average of the value of the stock prices of 30 companies in the index. The number goes up or down on any given day, and is designed to indicate more about the condition of the market environment in which the stocks live than about individual stocks in the index. If the market is not good, the Dow number indicates that by 'declining,' and vice versa. The single number assigned a fish index (also a weighted average) indicates the degree to which the environment (habitat) satisfies the needs of the fish.

When the habitat suitability indices are combined into a value measure, they can be weighted depending upon their relative importance to fish health. For example, for a given species, spawning access may be the limiting factor for the success of that species. Food production in the reservoir may not be as critical to overall species health. Even under 'bad' hydrologic operations adequate food supply may be available. However, if spawning habitat is critical, a higher weight may be placed on its value in calculating overall health. This weighting is done at each project by local and regional experts.

Finally, it is extremely important to note that the value measures are not comparable across locations. An 80 percent fish index at Hungry Horse Reservoir under the base case alternative, for instance, is not necessarily good for fish at Hungry Horse. Nor would a 50 percent value measure at Lake Roosevelt necessarily be bad. At some reservoirs, such as Lake Roosevelt, the existing reservoir conditions are such that a 70 percent index may be the upper end of the achievable scale, and 100 percent may never be attainable. At other reservoirs, such as Hungry Horse, 100 percent is attainable and 80 percent represents the lower end of the scale of what has been experienced historically. Also, the RFWG models are constructed for the explicit purpose of comparing anticipated impacts from the proposed operating strategies. Population estimates predicted by all models are useful only as an index, and do not necessarily represent actual populations that would exist under a particular strategy.

In summary, reservoir operations determine hydrology which impacts habitat. This impact can be quantified in the models with an index of habitat suitability. These indices of habitat suitability are weighted and combined into a single value measure which is a weighted index of fish health at a particular project for a particular species.

3.1 THE PILOT ANALYSIS

Since the early Pilot Analysis phase when the RFWG began developing its methods, those methods have been refined from one analytical phase to the next. For the Pilot Analysis, the RFWG adapted a model developed by the Montana Department of Fish, Wildlife, and Parks for Libby and Hungry Horse Reservoirs (model names, respectively, LRMOD and HRMOD; see section 3.3.1 for a detailed description of LRMOD and HRMOD).

LRMOD and HRMOD measure food production in the reservoirs as a function of hydrology. Each model uses a three–dimensional digitized model of its respective basin to capture hydrologic conditions resulting from operating strategies. Relationships are analyzed between hydrologic conditions and tropic levels in the reservoirs. The relationships between physical factors and biological trophic levels that serve as fish food are:

reservoir volume	*vs.*	*phytoplankton production*
reservoir volume	*vs.*	*zooplankton production*
reservoir elevation	*vs.*	*terrestrial insect deposition*
area wetted bottom	*vs.*	*benthic insect production*

Inputs to the models were streamflow, pool elevation, and discharge. The output from the Pilot Models was a 'generic' fish index which assessed whether the index value measure responded credibly to the inputs (i.e., the hydrology). Once the generic fish index proved promising, the RFWG moved on to the Screening Analysis.

3.2 THE SCREENING ANALYSIS

We provide a brief description of the Screening Analysis here. For a detailed description of the Screening Analysis, please refer to the 'Columbia River System Operation Review, Screening Analysis, Volumes 1 and 2', available from the Bonneville Power Administration, Portland, Oregon.

For the Screening Analysis, the RFWG advanced the Pilot models by modeling specific projects and resident fish populations. The group assigned value measures as indicators of the health of those populations, and combined the indices of habitat suitability into the value measures.

The Screening Analysis considered only selected reservoirs and stream reaches. The selections were not intended to be all–inclusive, but to provide a manageable set of index projects for the large number of screening alternatives. The selected locations were:

- Dworshak Reservoir and the Clearwater River
- Albeni Falls Dam/Lake Pend Oreille
- Lake Roosevelt
- Libby Reservoir and the Kootenai River
- Hungry Horse Reservoir and the Flathead River
- Lower Granite Reservoir
- John Day Reservoir
- Brownlee Reservoir

For the Screening Analysis, the RFWG developed eight operating alternatives that provided greater or lesser benefits to resident fish populations in the modeled projects. The following provides a summary of their purposes. (*The numbers in parentheses appearing after each alternative corresponds to its order in the 'Columbia River System Operation Review, Screening Analysis, Volumes 1 and 2'.*) Details of all the alternatives submitted by the RFWG for the Screening Analysis can be found in technical exhibit 'RFWG Screening Alternatives'.

RES–FULPL (56)

Provides full, stable pool elevations at storage and run–of–river reservoirs year–round with no power peaking. All reservoirs pass inflows. The purpose is to more closely approximate natural lake and river conditions.

RES–WRT (57)

Requires the upper reservoirs to manage water flows to ensure that water retention time through Grand Coulee does not drop below minimum water retention time and elevations. Minimizes resident fish loss through Grand Coulee due to low water retention times at inappropriate times of the year. Also, allows for high water flows downstream for anadromous fish passage. Optimizes fish growth within Grand Coulee by preventing the loss of zooplankton throughout the reservoir.

RES–IRRFLO (65)

Assumes current irrigated acreage and similar distribution in the Columbia River Basins, but with 1) an extensive water conservation program, 2) new upstream storage, 3) use of uncontracted storage space, 4) buybacks of existing storage rights, 5) acquisition of natural flow rights and/or 6) a lease option program during low water years. The water acquired from these potential sources is made available for downstream beneficial uses for fish and wildlife. Brownlee and Grand Coulee Reservoirs pass new inflow regimen resulting from the water made available. An additional 500 thousand acre feet (KAF) passes through Grand Coulee and an additional 1 million acre feet (MAF) passes through Brownlee. All reservoirs are kept full and pass natural inflows, including Canadian projects.

RES–SWAP (90)

Attempts to provide water required by resident fish and anadromous fish, while maintaining flood control and cheap hydropower energy. Operates Hungry Horse and Libby Reservoirs to specific criteria, but retains more water during fall and winter explicitly for release during the critical salmon migration period. Drafts reservoirs only to the assured refill curve and attempts to refill by July 1. Operates all other storage reservoirs similarly to retain water for later release. Maximizes water retention time in Grand Coulee from May through September by increasing reservoir elevations during spring runoff, then releases water gradually until the end of the critical juvenile salmon migration period.

RES–COMP (71)

Attempts to maximize the biological balance in Hungry Horse Reservoir and Flathead River yet operates the project within the hydrologic constraints for the project and drainage basin. Using a quantitative biological model called LRMOD, the alternative also tries to maximize the biological balance above and below Libby Dam. Incorporates flood control within the Flathead System and the Kootenai System downstream to Corra Linn Dam at the outlet of Kootenay Lake. However, no attempt is made to control flooding in offsite areas, caused by offsite waters. Losses to power production and associated revenues are also minimized within the range of operations needed to protect or enhance resident fish. Attempts to increase stability in pool elevations for resident fish at Lake Roosevelt, Brownlee, Dworshak, and Pend Oreille, while allowing for high flows downstream for anadromous fish passage.

RES–FLD (72)

Strives for stable reservoir elevations in the summer and fall by keeping pools as high as possible for as long as possible while providing storage space for local flood control protection during the high runoff conditions. Any stored water above the desired elevation which is caught during flooding conditions is evacuated as quickly as possible without flooding downstream portions of the system.

RES–PECT (73)

Each storage project is operated to specific elevation and flow targets during the year. Attempts to provide the best environmental conditions for resident fish at the storage projects while providing flows for more desirable power production, anadromous fish and other uses. Also attempts to achieve reservoir elevations that provide flood protection and recreational opportunities during the summer season.

RES–IRRFLO2

Similar to RES–IRRFLO, which strives to reshape the hydrograph, reduce consumptive water use of acquire additional water supplies. However, RES–IRRFLO2 includes an additional 1 million acre feet (MAF) available through water conservation efforts for a total of 2 MAF passed through Brownlee.

The RFWG analyzed the impacts of these alternatives, as well as 81 alternatives developed by the other technical work groups. Input into the screening models consisted of average monthly reservoir elevations, discharges and streamflows at selected stations. These inputs were obtained from hydroregulation model output for each of the 90 alternatives analyzed to characterize the operation of the river system.

Some alternatives in the Screening Analysis looked good for one reservoir or location, but showed no effect over the base case for other bodies of water.

Lake Roosevelt's consistent lack of high value measures resulted from the difficulty in operating to maximize water retention time, a goal that is opposite to the goal at run–of–river projects where outmigration of anadromous juveniles is desired. This occurred because the water released from upriver storage projects to help anadromous fish must pass through Lake Roosevelt, thereby reducing the time water remains in this reservoir before flowing downstream.

In the Screening Analysis, almost all the alternatives violated flow requirements currently considered necessary for sturgeon in the Kootenai River at some time during the year. These violations occurred in most of the five water years evaluated but were especially critical in low water conditions. Flow violations with the most serious sturgeon effects occurred in the spring (April through July) where a range of minimum to maximum streamflows was necessary to stimulate successful reproduction.

Biological Rule Curves for resident fish will likely be a more useful tool for developing system operating strategies than would power–driven specifications for pool levels and flows. A biological rule curve is a reservoir operating curve that provides benefit to resident fish by recognizing relationships between water elevation and food production requirements and other life history needs of a particular species.

The results of the Screening Analysis suggest that the operating strategy most beneficial to resident fish entails stable pool elevations in the storage projects, and near–natural flow regimens in the run–of–river projects. This hydrology recreates habitat conditions closest to the life history of the resident fish species modeled.

3.3 THE FULL–SCALE ANALYSIS

For the Full–Scale Analysis, the RFWG examined seven operating strategies, with 21 options total, derived from the 90 Screening Analysis alternatives. A complete description of the Full–Scale System Operating Strategies (SOS) may be found in Chapter 4.0.

Modeling efforts were focused on 1) representative projects 2) locations where data were available 3) locations where we were able to gather information. Quantitative modeling was generally possible only for the storage reservoirs. It was impossible to model all projects and all stretches of river for all species. RFWG members evaluated those species that were felt important and/or representative of the overall health of the system.

To analyze the seven operating strategies, the RFWG used three general types of models. For most projects and most species, improved versions of the models from the Screening Analysis were used. These models were refined by incorporating additional data into the habitat suitability indices which improved the value measure index. These models are described in sections 3.32 to 3.37. At Hungry Horse and Libby reservoirs, two FORTRAN models (HRMOD and LRMOD) were used that were constructed from physical and biological data collected for approximately 10 years from each reservoir. These were the models that formed the foundation for the Pilot Analysis (see section 3.1) that were later incorporated into the food production component of the models used during the Screening Analysis and Full–Scale Analysis. Although HRMOD and LRMOD are very empirical, they represented a significant improvement over the models that were used in the Screening Analysis for

Hungry Horse and Libby reservoirs. They are described in detail in section 3.31.

Finally, during the Full–Scale Analysis, the RFWG added a multistage stock–recruitment model (Moussalli and Hilborn, 1986) for kokanee at Dworshak Reservoir and Lake Pend Oreille. Stock–recruitment data analysis is a standard fisheries management tool (Savidge et al, 1988; Lawler, 1988; Christensen et al, 1977; Parrish, 1973). The underlying concept of a stock–recruitment approach is that kokanee populations respond differently to environmental perturbations either because of factors dependent on density (e.g., growth, cannibalism, food exhaustion), or independent of density (e.g., extreme temperatures, floods, droughts, pollution) (Beverton and Holt, 1957). The stock–recruitment model attempts to determine how survival from one age–class to the next age–class will be affected by these density dependent and density independent factors.

Analysis of the stock recruitment model at Lake Pend Oreille during Full Scale Analysis demonstrated a lack of model sensitivity of kokanee population to the habitat indexes used to ajust its parameters. For the FEIS, actual habitat index values used in the kokanee model are reported in addition to the actual population values.

Over the entire life–cycle of a population, the model recognizes distinct age–classes. Each of these age–classes is said to be populated by an existing stock, and new members are recruited into that age–class from the preceding life–stage. The model assesses the potential rate (productivity) of recruitment from one life–stage to the next, given the effects of an operating strategy on the potential recruits. By breaking out the age–classes of a kokanee population, the modelers can examine how reservoir operational changes potentially affect the population at each life–stage. Treating the population as a continuous spectrum from birth to death gives a truer picture than assuming the population is static. The intention is to add duration and cumulation of impacts to the entire kokanee population over a long time scale.

While the concept sounds simple, estimating how density dependent and density independent factors change the survival rates (and consequently the population) of each age–class is extremely difficult. The first step is to determine what the survival rates for each age–class would be if the reservoir was operated in a stable, full pool strategy. In order to estimate these survival rates, the RFWG relied on research conducted on other north Idaho lakes.

Next, estimates of pool elevations and outflows resulting from each potential operating strategy are used to 'adjust' the survival rates, based on the relationships between reservoir operation and survival or habitat suitability created during the Screening Analysis. If a particular reservoir operation strategy affects the factors dependent on density (e.g., growth, cannibalism, food exhaustion, etc.), this is used to estimate the capacity parameter for that age–class. If a particular operating strategy of a reservoir affects the factors independent of density (e.g., extreme temperatures, floods, droughts, pollution, etc.), this is used to estimate the productivity parameter for that age–class. The capacity and productivity parameters are input into the stock–recruitment equation to estimate the resulting population index value. Reservoir–specific issues related to the stock–recruitment approach are discussed below.

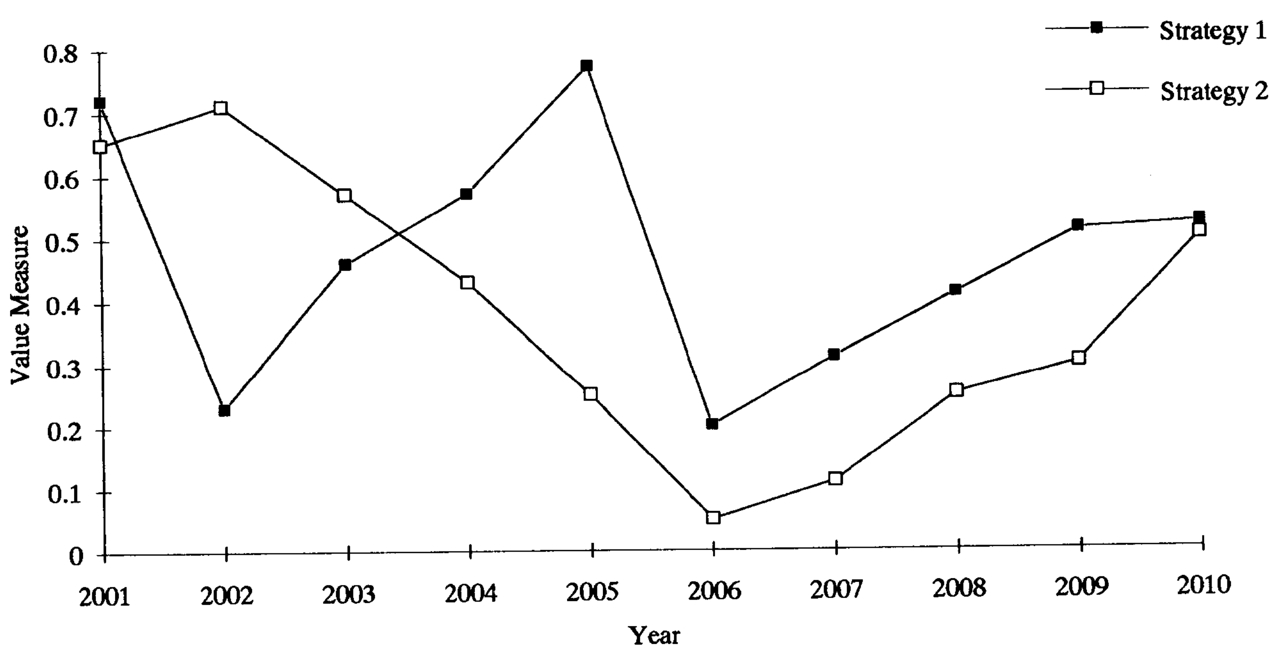
The models we have constructed are project specific, and attempt to model the important relationships between representative resident fish species and their environment. Because the hydroregulation output is meant to represent system–wide hydrology, our assumption is that by documenting potential impacts (both positive and negative) project by project, we will generally identify the relative system–wide impacts for each alternative. However, we recognize there are broader ecosystem concerns which this approach will not adequately represent. The ecological processes of the Columbia Basin are very complex. Since our understanding of these processes is limited, we did not attempt to model the entire basin as one ecosystem. Although we recognize the Columbia River Basin as one ecosystem, we feel that taking a holistic approach at this point would necessarily be so general that specific impacts at individual projects would be missed.

Each model (except HRMOD and LRMOD) is designed to output 50 years of value measures that are expressed either as a growth index or a population estimate index for each SOS for each key species. The value measures can be plotted over time for the 50 years, but because of the dynamic nature of most indices, it is difficult to compare the output of multiple strategies in order to compare each alternative's relative worth. To simplify the analysis, the RFWG looked at the distribution of the value measures at different occurrence intervals, rather than the 50 years of record. We chose to examine the value measures that would most likely occur, on average, every 2, 4, and 10 years. These intervals were chosen because these time periods typically covered the life span of most resident fish and gave us a measure of temporally distributed impacts under different operating strategies.

The following example illustrates our data analysis methods. Let's assume we are interested in evaluating the impacts from two different operating strategies on smallmouth bass at Big Fish Reservoir. We use a computer model that is capable of relating outflows and elevations to habitat suitability and provides as output 10 years of value measures (in this case growth index values) for each of the operating strategies as follows:

Year	Value Measures for Strategy 1	Value Measures for Strategy 2
2001	0.72	0.65
2002	0.23	0.71
2003	0.46	0.57
2004	0.57	0.43
2005	0.77	0.25
2006	0.20	0.05
2007	0.31	0.11
2008	0.41	0.25
2009	0.51	0.30
2010	0.52	0.50

If we plotted each of these strategies over time, it would look something like this:



We could end our analysis here but it is difficult to see which of these two strategies is better for smallmouth bass at Big Fish Reservoir. Optimally we would like to know what the value measure would be, on average, at different intervals of time. For example, perhaps we believe that two occurrence intervals are important for smallmouth bass: 2 and 6 years. Over the next 10 years, what would the value measure for each of the strategies be at 2 years and 6 years?

We can determine this by looking at the distribution of the value measures across the 10 years we predicted. The first thing we do is order the value measures from 0 to 1 (this is the range of the index) and count the number of years (i.e., the number of occurrences) the value measure is at or below a given index value. This is shown below:

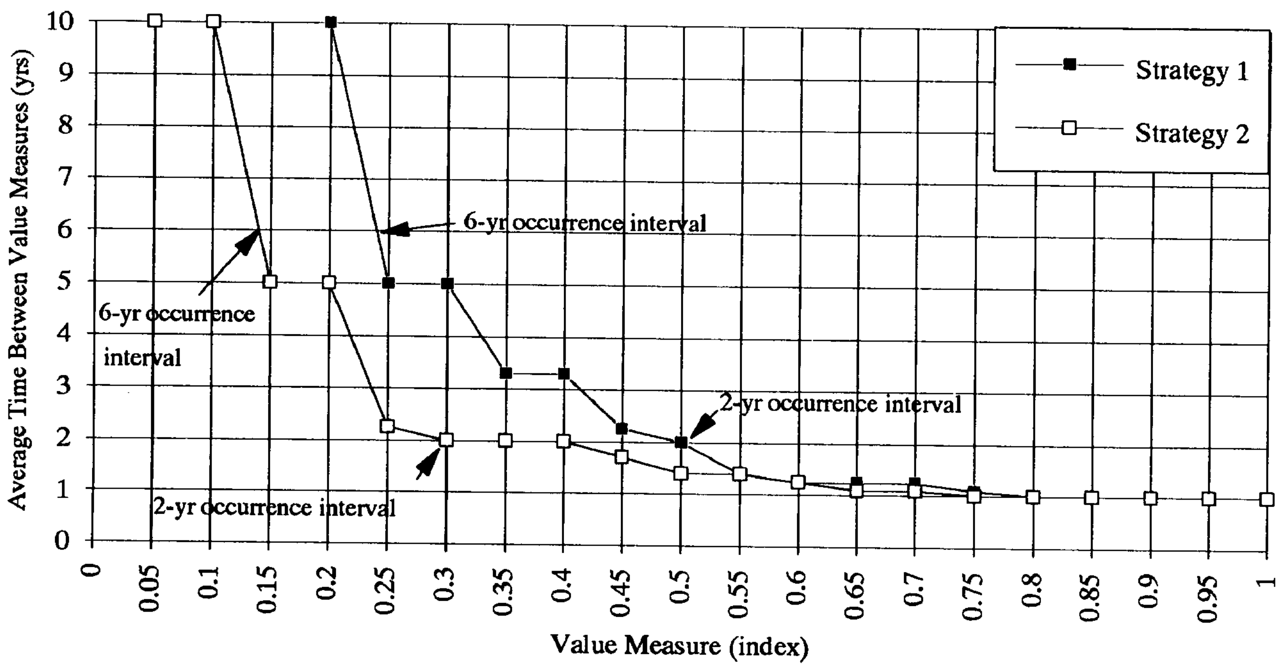
Value Measures	Strategy 1 Number of Years At or Below Respective Value Measure	Strategy 2 Number of Years At or Below Respective Value Measure
0.00	0	0
0.05	0	1
0.10	0	1
0.15	0	2
0.20	1	2
0.25	2	4
0.30	2	5
0.35	3	5
0.40	3	5
0.45	4	6
0.50	5	7
0.55	7	7
0.60	8	8
0.65	8	9
0.70	8	9
0.75	9	10
0.80	10	10
0.85	10	10
0.90	10	10
0.95	10	10
1.00	10	10

In this example, we can see that in strategy 1 over the 10 years we modeled, the value measure was at or below 0.20 at least 1 time while in strategy 2 it was at or below 0.20 at least 2 times. Continuing on, we see that in strategy 1 the value measure was at or below 0.50 at least 5 times while in strategy 2 it was at or below 0.50 at least 7 times. Intuitively, we begin to see that strategy 1 is better than strategy 2. This is because nearly 70% of the value measures (7 times out of 10) are at or below 0.50 in strategy 2, while in strategy 1 only 50% of the value measures (5 times out of 10) are at or below 0.50.

But again, it is still difficult to see the comparison between the temporal distribution of each strategy. Thus, our final step is to determine the average amount of time which would pass before we would expect to see a particular value measure at or below a given index value. So, using the same ordered value measures, we calculate the average time between occurrences by dividing the total number of years (i.e., 10 years) by the number of years the value measure was at or below a given index value. In other words, for the value measure 0.20, in strategy 1 the average number of years which would pass before we would expect to see this index would be 10 (total number of years) divided by 1 (the number of years at or below 0.20, from previous table) which equals 10 years. This can be done for the same value measure for strategy 2: 10 divided by 2 (from previous table) which equals 5 years. These are shown below, along with the other value measures:

Value Measures	Strategy 1 Average Number of Years Between Respective Value Measure	Strategy 2 Average Number of Years Between Respective Value Measure
0.00	NA	NA
0.05	NA	10
0.10	NA	10
0.15	NA	5
0.20	10	5
0.25	5	2.25
0.30	5	2
0.35	3.3	2
0.40	3.3	2
0.45	2.25	1.7
0.50	2	1.4
0.55	1.4	1.4
0.60	1.25	1.25
0.65	1.25	1.1
0.70	1.25	1.1
0.75	1.1	1
0.80	1	1
0.85	1	1
0.90	1	1
0.95	1	1
1.00	1	1

We can plot the values in the table on the following page:



So, in order to complete the analysis of impacts to smallmouth bass in Big Fish Reservoir, we can examine the above table and graph and see which strategy is better. Under strategy 1 we would expect to see the value measure at or below 0.20 every 10 years, while in strategy 2 it would occur every 5 years; more frequently and hence, less desirable. Under strategy 1, we would expect to see the value measure at or below 0.50 every 2 years while in strategy 2, it would again occur more frequently at 1.4 years.

If our occurrence intervals of interest are 2 and 6 years, we can look at the plot and see that in strategy 1, the value measure at 2 years would be 0.50 and at 6 years it would be 0.24. In strategy 2 the value measure at 2 years would be 0.30 and at 6 years it would be 0.14. Therefore, strategy 1 is better since the value measures at those particular occurrence intervals are greater than the value measures at the same occurrence intervals in strategy 2. In chapter 4.0, we derive value measures for each species at occurrence intervals of 2, 4, and 10 years exactly as was shown in this example and present them in a table for each reservoir.

Following are the assumptions and parameters for the individual projects.

3.3.1 Libby and Hungry Horse Reservoirs

Field data from 1983 through 1992 were used to develop biological computer models for Libby and Hungry Horse reservoirs (LRMOD and HRMOD, respectively). The two models have three main components: physical hydrology, thermal dynamics and biological responses. The top–level results of these models characterize fish growth as a measure of reservoir health (specifically using kokanee for Lake Koocanusa, and westslope cutthroat trout for Hungry Horse Reservoir. It is important to note that no density dependence was incorporated into the fish growth estimates, nor in fact was any population measure modelled at all at these two projects.

Physical Hydrology Model Component

Physical hydrology is modeled based on a three–dimensional representation of the reservoir topography, daily inflow volumes since 1928, the physical capacities of the dam structure, and empirical water balance in the reservoir basin.

The Thermal Dynamics Model Component

The reservoir thermal model was modified by the MDFWP and Montana State University as part of the biological models from Flaming Gorge thermal modeling performed by Adams (197?) and later published by the USGS (1990).

During modeling, thermal profiles were measured twice monthly at intervals along the reservoir from April through November 1983 through 1991. Sampling was terminated during ice formation. Thermal models were calibrated to monthly temperature profiles measured along the reservoir length from 1983 to 1989, and 11 years of corresponding meteorological data recorded at the projects.

Data describing the reservoir thermal structure were used to calibrate a modified version of a predictive mathematical model for the behavior of thermal stratification in Hungry Horse Reservoir.

Thermal predictions were calibrated to 11 years of daily climatological records (U.S. Weather Service, Kalispell, Montana), corrected to measured atmospheric conditions at Hungry Horse Dam; long–term inflowing tributary temperatures; the physical properties of water, and a digitized three–dimensional basin topography. Annual schedules of meteorological variables input to the model, included: relative humidity, solar aspect, air temperature, cloud cover, and wind speed. These inputs were smoothed to long–term trends.

The model assumes horizontal homogeneity, and thus generates a single thermal profile for each day of the year. The model accounts for the measured absorption and transmission of solar radiation, solar aspect, surface convention due to cooling and advention due to inflow and outflow. Time lags between inflow and outflow were also accounted for. The thermal model begins on January 1, works with a calendar year, and starts after ice is off the reservoir. The top part of each daily thermal profile (21 values representing a depth of 45m) is stored for later use.

Output from the model includes several tables of temperature accumulation by depth and volume, and the user may view individual temperature profiles for each day of the water year. Several modeling techniques were used to estimate the discharge water temperature based on the reservoir thermal structure at the dam. Based on a comparison of model estimates and observed field measurements, the outflow temperature was assumed to be equivalent to the temperature at the depth of withdrawal.

The Hungry Horse model predicts discharge from unregulated North and Middle forks of the Flathead River based on a regression between daily inflows to Hungry Horse Reservoir and flows in the other two forks. Outflow limits for Hungry Horse Reservoir were then constructed so that when the outflow of Hungry Horse is added to the discharge from the two unregulated river forks, the resulting flow is limited by immediate downstream flood constraints in the main stem of the Flathead River at Columbia Falls. The temperature in the unregulated forks of the Flathead River was established as a fixed schedule closely approximating the observed temperature in the North Fork of the Flathead River for water years 1976 through 1988, explaining 94.8 percent of the total variation. The temperature of the South Fork was provided by the thermal model as the outflow temperature. The temperature in the combined flows at Columbia Falls was calculated as the average temperature in the forks, weighted by flow volume.

For HRMOD only, alternative operational and design strategies for the proposed temperature control structure at Hungry Horse Dam were analyzed using duplicate simulation comparing biological influences with selective withdrawal to equivalent simulations with fixed hypolimnetic withdrawal. Simulations utilized historic daily inflow data from 1928 through 1992. Real data simulations incorporated actual daily elevations from 1954, when Hungry Horse first filled, through 1992. Hypothetical surface elevations based on current power and flood constraints were used for the period 1928 through 1952, when the dam began to regulate flows. Results indicated that thermal control could be implemented with little effect on dam operations. For LRMOD, simulations utilized hypothetical data from 1928 through 1973, and real data simulations from 1974 through the present.

Biological Response Model Components

Primary Production. Carbon fixation was modeled on field measurements, using light– and dark–bottle C^{14} liquid scintillation techniques. Incident light was measured continuously from sun–up to sun–down while the bottle arrays were incubating. Light attenuation was sampled individually at the three sampling areas. Monthly data were used to calibrate daily estimates of primary production along the length of the reservoir. Daily estimates were summed across reservoir areas, then totaled over the ice free period. During ice cover, primary production was assumed to be reduced by 99 percent from values observed immediately before and after ice formation. Reservoir surface area, volume, and seasonality are the primary factors influencing solar aspect, attenuation and carbon fixation. The model outputs an annual schedule of primary production.

Loss of algal production through the dam was calculated based on a negative exponential curve representing the vertical distribution of carbon fixation, and dam discharge volume. Losses were most sensitive to the relationship between the surface elevation and discharge depth and discharge volume. Model results were calibrated by chlorophyll–a and organic carbon measurements in the tailwater. The model produces an annual schedule of downstream loss.

Zooplankton Production. Zooplankton production was first calculated using female fecundity and cohort analyses. However, neither technique provided appropriate results for use with the dynamic hydraulic model. Instead, gross zooplankton production was estimated as a function of primary production using a loss factor developed for phytoplankton and zooplankton communities in low nutrient, temperate waters.

Gross zooplankton production was subdivided in the Hungry Horse model based on the relative biomasses of zooplankton genera in Wisconsin net surveys conducted every three weeks from 1983 through 1991. Few samples were collected during ice formation. The model produces an annual schedule of zooplankton production and monthly and annual estimates by genera.

Zooplankton washout was calibrated to drift net samples in the tailwater. Washout was most significant when the reservoir became isothermal and the reservoir surface approached the outlet depth. The model calculates a daily schedule of zooplankton washout. The Hungry Horse model calculates downstream loss of each genera during each month, and annual totals.

Benthic Insect Emergence. Peterson dredge samples defined the relationship between larval densities of aquatic diptera and water depth. Surface emergence traps provided rates of emergence per unit larval biomass at each depth. Results revealed an inverse relationship between larval densities and the frequency of sediment dewatering. Few larvae inhabit the areas most frequently effected by drawdown, whereas permanently flooded areas contained many larvae and generally supported larger, long–lived varieties. Emergence data, however, indicated that shallow areas produced more pupae and adults (which are available to fish as prey) than did deeper sediment overlain by colder water. Insect life cycles ranged from five weeks to three years. Thus, one deep drawdown can dewater and kill larvae in vast areas of the reservoir bottom; the population does not recover for at least two years. The model calculates benthic emergence based on the area of wetted reservoir bottom and drawdown schedule, then outputs an annual schedule of insect production.

Terrestrial Insect Deposition. Insects from the land that become trapped in the surface film provide the most important food supply for insectivorous fish during summer and fall. These insects were sampled nearshore and offshore using surface tows. Two insect orders were mainly deposited on the surface nearshore, whereas the other two dominant orders were more evenly dispersed at both reservoirs. For this reason, shoreline and open–water deposition was calculated separately by the models. The seasonality of insect activity was statistically distinct between the four main orders. Surface area and seasonal dam operations schedules were the most important factors influencing the number and type of terrestrial insects captured by the reservoir surface and thus available to fish as food The rate at which insects are deposited on the reservoir could not be determined with surface netting. Therefore, the model calculates the percentage of the maximum possible deposition of each insect order that can occur under the various dam operation scenarios. If the reservoir is near full pool when the insects are active, the effect is small. However, if the reservoir deviates from full pool, fewer insects are captured in the surface film. The model then stores an unscaled index of food available for use in the fish growth calculations.

Fish Growth Calculations

HRMOD Flathead River Fish Growth. Trout growth potential was first calculated relative to temperature unit accumulation in the affected river reach. A simple linear, additive model was applied to enumerate the number of days above each temperature within the range of maximal trout growth. Degree days within this temperature range were itemized by month, then summed to arrive at the annual total of trout growth units. This was used to describe potential growth.

Trout growth efficiency was later evaluated by incorporating curvilinear temperature/growth relationships and food ration effects. The latter increased the accuracy of the estimates and inserted, for the first time, thermal influences on riverine insect production. The model calculates increments of growth relative to a pair of curvilinear equations with two different temperature optima for different levels of food ration. Two curves were required because trout under conditions of reduced caloric intake have increased growth efficiency at lower temperatures. Without selective withdrawal, any reduction in production caused by summertime cooling is partially offset by this phenomenon, so the model was designed to compensate for this.

All of the species making up the invertebrate fauna probably display a growth temperature relationship similar to that of trout, namely, an optimum temperature range beyond which growth diminishes as temperature deviates in either direction.

Although the fish growth model was founded on numerical values derived from controlled laboratory experiments, the model output needed to be verified with field data so that the numerical coefficients could be adjusted if necessary. Estimates of actual river growth were difficult because some fish may have resided in Flathead Lake or their natal tributary during portions of their third year of growth. Empirical data provided the average long–term timing and size at emigration. The model therefore estimates the resulting growth for migrant Class III fish under the various operating scenarios.

HRMOD Hungry Horse Reservoir Fish Growth. HRMOD evaluates the first three years of reservoir growth (Ages III+, IV+ and V of cutthroat trout) in migrant class III individuals. Migrant class refers to the age at which juveniles emigrate from their natal tributaries to the reservoir. Migrant class was identified by rapid growth rate immediately upon emigration from the natal tributary as recorded by scale annulus formation. Annual growth between Age III and IV represents the first year of reservoir life. The model assumes identical operation for two and three years to estimate growth at Age IV and V, respectively. The trout growth component was calibrated using scale and otolith aging techniques. Scales provided annual growth increments at each age and otoliths provided the seasonal distribution of growth. Tributary and reservoir cutthroat were aged from samples collected during the 1983 through 1989 field seasons.

Model validation was conducted using age information from 1983 through 1992. Validation of the model is confounded by factors other than dam operation that also influence growth. Cutthroat growth may be dependent on population size. Thus, if cutthroat numbers are high, growth may be reduced. Also, growth effects in the natal tributary may affect the maximum growth in the reservoir. The model assumes a static population size and is not capable of adjusting for growth effects in tributary streams. Instead, we have focused only on growth effects in the reservoir. The Weisberg (1986) technique was used to calibrate the model. The technique assumes a common intercept for length calculations on individual fish.

Results were separated by year–class and the mean length at age and confidence intervals were calculated for each cohort.

Empirical growth data were used to calibrate the reservoir growth model based on reservoir volume, temperature structure, and previously calculated values of food availability. Prey items were included based on their occurrence in stomach content analyses. Food items which were not found in the fishes' diet were not included in the multivariate analysis of growth effects.

LRMOD Lake Koocanusa Fish Growth. At Libby Reservoir, kokanee salmon were selected as the target fish species because of their importance to the recreational fishery. Kokanee respond to reservoir volume and zooplankton production. A few benthic insect pupae were also identified in kokanee stomach contents. Conversely, analysis of field samples shows that rainbow and westslope cutthroat trout respond to food availability (zooplankton, hymenoptera and benthos) similarly to westslope cutthroat trout in Hungry Horse.

Although the kokanee growth model was based on empirical field data from 1983 through 1986, model simulation of kokanee growth potential was not intended for verification through field measurement of kokanee growth. In reality, kokanee growth is strongly density dependent. Three–year cycles of low to high population size have been identified in Libby Reservoir since kokanee first became established. Corresponding growth has similarly fluctuated, with highest annual growth associated with low population size and visa versa. For modeling purposes, we attempted to isolate operational effects from density effects by assuming a static population size. This technique allowed us to focus on operational effects for the purpose of comparing one operational strategy.

LRMOD Kootenai River White Sturgeon. Requirements for white sturgeon in the Kootenai River were assessed using recently developed subroutines in LRMOD. Very few juvenile sturgeon have been recruited to the population since Libby Dam began impounding water in 1972. The last significant spawning run was observed in 1974 when flow and temperature conditions were conducive to reproduction. Evidence suggests that reduced spring flows due to dam operation and unnatural water temperatures are primary factors influencing natural reproduction. Factors limiting the population are not fully understood. Experimental recovery actions have included controlled releases of reservoir storage to enhance sturgeon reproduction. A multi–agency recovery team has recommended that Libby Dam should release water to achieve specific flow volumes in the Kootenai River at Bonners Ferry. These flow targets were dependent on water availability so that high flows would be met during high runoff years and little flow augmentation would occur when runoff was limited. Figure 3–2 shows target sturgeon spawning flows for Bonners Ferry. Idaho, as discussed by the Kootenai River White Sturgeon Technical Committee. Flows were keyed to runoff forecasts. These targets were used as evaluation criteria by the Resident Fish Work Group.

The model was designed to incorporate inflows from unregulated tributaries between Libby Dam and Bonners Ferry. These sideflows were calculated based on a regression between inflows to Libby Dam and flows at Port Hill (minus Libby Dam discharge). The regression was corrected for a one day time lag between the sites. Sideflows were then added to dam releases to calculate the combined flow at Bonners Ferry. This link allowed the meeting of the target flows, while minimizing flow releases from Libby Dam. Specific flow releases were developed each year of record. Some of this resolution was lost when the data were transformed from the daily model for use in the monthly system models. The shape, duration and volume of the sturgeon flow targets are currently being debated and are subject to change as spawning requirements become better defined. Therefore, the model assumed a tiered approach to flow augmentation similar to those recommended by the sturgeon recovery team. Temperature effects were assumed to be correctable through the use of the selective withdrawal structure at Libby Dam.

3.3.2 Brownlee Reservoir

Species modeled in Brownlee Reservoir include crappie, channel catfish, smallmouth bass, and rainbow trout. These species were chosen because of their importance to anglers. Data limitations at Brownlee Reservoir precluded the development of a refined model over what was used in the Screening Analysis. Within the model we used, there is uncertainty in the assumptions regarding the relationship between reservoir elevation and resident fish spawning/incubation suitability. However, we do not believe the uncertainty is critical and assume the model captures the general impacts. As new data are made available, this uncertainty can be reduced. Specific model components include:

- The food production index is estimated for all species.
- In addition to food production, the relative change in reservoir elevation from April 15, averaged over April, May, and June, is used to estimate spawning/incubation habitat suitability for crappie and smallmouth bass.
- In addition to food production, the change in reservoir elevation from July 30 averaged over August and September is used to estimate spawning/incubation habitat suitability for channel catfish.
- Food production only was used to model rainbow trout.

STURGEON FLOW TARGETS

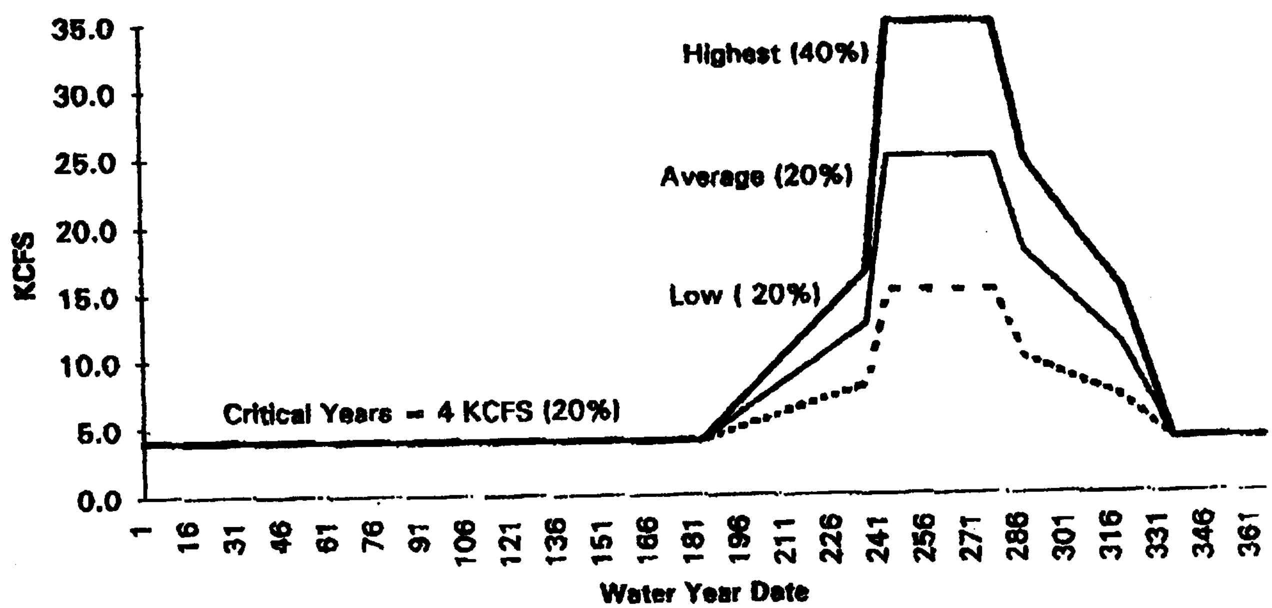


Figure 3–2. Target spawning flows (as measured at Bonners Ferry, Idaho) for Kootenai River white sturgeon, used by Resident Fish Work Group in SOS evaluations.

3.3.3 Lake Roosevelt

Key fish species in Lake Roosevelt include kokanee, walleye, and rainbow trout. Because few data exist for many species and because kokanee salmon, a plankton feeder, are sensitive to reservoir conditions and operations, they were selected as the indicator species to model. We assumed that reservoir operations that were favorable to kokanee would be beneficial to other reservoir species for reasons as follows. Under suitable reservoir conditions, zooplankton density should be sufficient to support a significantly larger population of kokanee than what presently exists. We assume that entrainment of kokanee is the primary limiting factor and that a water retention time (WRT) of greater than 30 days will provide good conditions for kokanee production.

Because water retention time incorporates elevation and outflow, it is a good overall indicator of the biology of Lake Roosevelt and reservoir health as a function of reservoir operation.

Therefore, two value measures were selected to represent the impacts at Lake Roosevelt: kokanee growth and the percentage of kokanee left in the reservoir (i.e., the percentage of kokanee not entrained which remains at the end of a year). These value measures are described below:

- The proportion of kokanee left is determined by relating seasonal water retention times to a measurement of entrainment (an index) and taking the reciprocal (1 minus the entrainment index). Water retention times are calculated by the model as a function of reservoir storage divided by the monthly outflow, with storage a function of monthly reservoir elevation. These estimates of entrainment are summed over the 14 time steps to calculate an annual loss of kokanee. When the reciprocal is taken, this gives the annual proportion of fish left in the reservoir. We make the assumption in this relationship that decreased water retention times below approximately 30 days will negatively impact kokanee by flushing them and their food supply from the reservoir. We also assume that the relationship between water retention time and reservoir operation is correct.

- Kokanee growth is determined by calculating the water retention time (see above) and relating this to a measurement of zooplankton growth: the result is a habitat suitability index. This is done by season. The zooplankton growth index by season is then adjusted to estimate the weighted zooplankton growth by season. Zooplankton growth is then used to calculate kokanee growth. We assume that the food production – reservoir operation relationships developed for Hungry Horse Reservoir generally depict these same relationships in Lake Roosevelt and that the relationship between water retention time and zooplankton abundance is correct.

3.3.4 Albeni Falls Dam/Lake Pend Oreille

Species modeled at Lake Pend Oreille include bull trout, cutthroat trout, warmwater fish (smallmouth and largemouth bass, perch, crappie), and kokanee salmon. Kokanee and rainbow trout are included as representative of the two main sportfish in the lake. Bull trout is an Idaho State sensitive species, and Lake Pend Oreille supports the largest bull trout fishery in Idaho. Warmwater fish are important because they provide a significant low–tech, near–shore fishery which could be greatly expanded. Most of the data available for Lake Pend Oreille focuses on the kokanee population. Data limitations for some of the other species injected varying amounts of uncertainty into the models.

The relationship between small tributary spawning access and reservoir elevation (averaged from August through October) and kokanee habitat was used to model bull trout. Kokanee were included in the bull trout index since bull trout feed heavily on kokanee. When the lake elevation is below 2052 feet msl in the fall of the year, access to spawning tributaries is severely restricted. As the lake elevation increases from 2052 feet msl to 2062 feet msl, access is significantly improved; we assume a linear relationship exists between habitat suitability and elevation at this point.

Cutthroat trout are modeled using the same access to spawning relationships used in the bull trout index except an average from May though June is used instead. Food production is not used in modeling cutthroat trout. We assume that access to tributaries to spawn is also the primary factor limiting production.

Warmwater fish are modeled using the food production model, the fingerling to adult survival rate as a function of elevation (February through April minimum), the overwintering survival as a function of elevation, thought to be limiting (February through April minimum), the relationship between elevation and spawning (May through July average), and the relationship between elevation and incubation success (June and July average). In each relationship, an elevation of 2052 feet msl or less is assumed to be deleterious to warmwater fish for all life stages. Considerable improvement in the habitat suitability index value for each life stage occurs as the pool level is increased above this level. In the case of spawning/incubation, this improvement is not realized until the pool reaches 2056 feet msl.

Kokanee were initially modeled using the stock–recruitment model. Important relationships in the stock–recruitment model include:

- food production,
- available shoreline area,
- egg incubation success, and
- exploitation.

Food production is a function of reservoir elevation and the availability of prey to kokanee at all life–stages. It is based on the food production model used in the Pilot and Screening Analysis.

Lake Pend Oreille kokanee spawn primarily at age–3 and age–4 on the lake shoreline and in tributaries. For modeling purposes, the RFWG assumes that 35 percent of age–3 and 100 percent of age–4 kokanee will potentially spawn. Lake elevation in November through December will determine available spawning habitat. Therefore, spawning habitat to elevation relationships are included in the model and used to estimate the capacity values for the spawner population.

Once kokanee spawn, downward fluctuations from December through the winter in lake elevations can dewater and desiccate eggs, reducing egg incubation success. Therefore, egg incubation success versus lake elevation relationships are used to estimate the productivity value for the age–0 class.

The exploitation rate of age–2 kokanee is estimated to be approximately 1.4 percent; of age–3 kokanee approximately 11 percent; and of age–4 kokanee approximately 25 percent. The RFWG adjusted the above harvest rates as a function of density. The relative exploitation rates from Lake Pend Oreille for each age–class were used to adjust the population level after the productivity and parameter values were estimated.

RFWG model assumes that the estimated average number of eggs per individual kokanee is 400 per female.

Egg incubation and spawning habitat are reported in addition to actual spawner population. These values are sensitive to changes in hydrology and are useful for analysis purposes.

3.3.5 Dworshak Reservoir

Species modeled include kokanee, bull trout, westslope cutthroat trout, smallmouth bass, and redside shiner. The Clearwater River was not modeled because accurate hydroregulated data were not available downstream of Dworshak Dam. Species modeled (models are described below) were selected because of their ecological and/or recreational importance. For example, kokanee is a major self–sustaining fishery, the health of which is dependent on pool and flow management. Smallmouth bass are the most abundant self–sustaining littoral–based species in Dworshak Reservoir and support a fishery. Redside shiner is an important native forage fish species, especially for bull trout and smallmouth bass. The redside shiner is incorporated in the smallmouth bass portion of the model as a food source. The bull trout and westslope cutthroat trout are native species of special concern. Rainbow trout is an important 'put and take' recreational fishery.

In developing the fish index value for Dworshak Reservoir, the RFWG made assumptions about those factors which potentially limit each of the above–named species. These assumptions were then incorporated into the following habitat suitability indices:

- Smallmouth bass spawning/incubation success can be affected by downward fluctuations in pool elevations, potentially causing dewatering of nests during the period lasting from May 15 to August 15. Upward fluctuations in pool elevation can reduce water temperatures at nest sites, causing nest abandonment or interruption of embryo development.
- Redside shiner is an important native forage species and is highly sensitive to pool fluctuations during its spawning period (May 1 to July 15). Thus, its spawning success is an important measure.
- Low water levels may limit the number of streams which kokanee can access for spawning. However, the biggest factor limiting angling success is losses of kokanee through the dam (entrainment). Both of these relationships are incorporated into the model representation of effects to kokanee.

Bull trout and cutthroat trout are modeled using a food production model only. Access to spawning tributary streams does not limit production of cutthroat or bull trout; therefore, this aspect of their life history was not included in the model. Because of their dependence on an adequate food supply in the reservoir, this was the only key variable used.

Smallmouth bass are modeled using spawning/incubation success as a function of elevation fluctuation (maximum of any two–month minimum index values from May through August 15), the availability of rearing habitat as a function of elevation (April 15 through October average), and a food availability component which includes the food production (25%) and the redside shiner availability (75%). Redside shiner availability is a function of spawning success determined by the elevation fluctuation in May and June, and the food production model.

Kokanee were modeled using the stock–recruitment model and incorporated important relationships between reservoir operations and kokanee habitat availability and survival, including:

- food production,
- entrainment,
- access to spawning areas,
- fishing mortality, and
- reservoir elevation as it relates to adult habitat availability.

Food production is a function of reservoir elevation and the availability of prey to kokanee for all life–stages. The food production 'code' within the Dworshak model is based on relationships taken from HRMOD and LRMOD. In that model, lower elevations reduce reservoir surface area and volume, and consequently impact zooplankton, benthic insect and terrestrial insect production.

Entrainment losses are a function of reservoir elevation and discharge. Entrainment of age–1, age–2, and age–3 kokanee appears to be significant. The stock recruitment model incorporates the relationship between average annual discharge and entrainment, and estimates the productivity parameter values for each affected life–stage.

In terms of spawning access, Dworshak kokanee spawn primarily at age–2 in tributaries to Dworshak Reservoir, and very few fish survive to age–3 to spawn. For modeling purposes, the RFWG assumed that 90 percent of age–2 and 100 percent of age–3 kokanee potentially will spawn. Shore spawners are thought to be extirpated from the system due to severe water level fluctuations. Low reservoir elevation in September potentially blocks access to spawning tributaries. Therefore, spawning habitat to elevation relationships were included in the model and used to estimate the capacity values for the spawner population accordingly.

Losses due to exploitation by fisheries would be expected to change relative to kokanee density. At very low densities, the kokanee exploitation rate would be low because of low angler interest and reduced encounter. As densities increase, the exploitation rate would increase, but only to the point that higher densities began to produce smaller fish. Therefore, a 30 percent harvest rate was used to scale exploitation rates as a function of density.

Adult kokanee habitat availability was determined using the relationship between reservoir elevation and pelagic area. The assumption is that adults concentrate primarily in the pelagic zone (defined as open water in that area of the reservoir where the water is deeper than 50 feet). A relative habitat suitability index was used to adjust the capacity value for the adult age–classes.

The estimated average number of eggs per individual kokanee is assumed to be 400 per female.

3.3.6 Lower Granite Reservoir

In Lower Granite Reservoir, the key resident fish species of interest are smallmouth bass, white sturgeon, and northern squawfish. Developing a quantitative model for Lower Granite Reservoir was made difficult because most of the impacts to resident fish occur on a temporal scale much shorter in duration than the temporal scale used in the hydroregulation analysis. In order to best model the Lower Granite Reservoir, sub–monthly information is required. Therefore, the RFWG used two temporal scales in our analysis.

First, we estimated the habitat available to key species, as well as how habitat changed from one month to the next, as a function of end–of–month elevations. The amount of available habitat was estimated using a database developed with a geographical information system (GIS). The GIS was able to tell us the reservoir surface area at one–foot depth contours over the full range of reservoir elevations.

Second, the impact on resident fish from sub–monthly fluctuations in reservoir elevation was estimated using four categories of reservoir fluctuations: 2.5 – 4.9 feet (low variability), 5.0 – 7.4 feet (moderate variability), 7.5 – 9.9 feet (high variability), and greater than 10 feet (very high variability). The sub–monthly model was then used to portray how impacts would be worsened if the reservoir were to be fluctuated within the month.

Smallmouth bass were modeled using the end of month model and the sub–monthly model. Model elements include:

- relative available spawning habitat based on depth requirements averaged over June and July;
- relative available fry rearing habitat based on depth requirements averaged over May through December;
- relative available juvenile overwintering habitat based on depth requirements averaged over November through March;
- spawning/incubation success as a function of elevation changes in elevations from May through August 14;
- early fry rearing success as a function of elevation fluctuation from August 15 through October; and
- juvenile overwintering success as a function of elevation fluctuations from October through March.

White sturgeon were modeled using the end–of–month model only. Model elements include:

- relative available habitat based on preference for depth averaged over all 14 time periods.

Northern squawfish were modeled using the end–of–month model and the sub–monthly models. Model elements include:

- rearing success as a function of elevation fluctuations from May through October.

3.3.7 John Day Reservoir

In John Day Reservoir, the key resident species of interest are smallmouth bass, northern squawfish, and walleye. Development of a quantitative model for John Day was made more difficult because most of the impacts to resident fish occur on a temporal scale (daily and hourly) much shorter in duration than the temporal scale used in the hydroregulation analysis (monthly).

In order to best model John Day Reservoir, sub–monthly information is required. Therefore the RFWG used two temporal scales in our analysis, similar to how it was done at Lower Granite Reservoir. First, habitat changes from one month to the next, as a function of end of month elevation, were evaluated. Next, the impact on resident fish from sub–monthly fluctuations in reservoir elevation was estimated using 4 categories of sub–monthly variability: 2.5–4.9 feet (low variability), 5.0–7.4 feet (moderate variability), 7.5–9.9 feet (high variability), and greater than 10.0 feet (very high variability). The sub–monthly variability model was used to portray how impacts would be worsened if the reservoir pool elevation was allowed to fluctuate during a given month while still maintaining end of month elevation constraints.

Smallmouth bass were modeled using both the end of month model and the sub–monthly model. Model elements included:

- spawning success as a function of changes in elevation from June through July;
- fry rearing success as a function of changes in elevation from April 15 through October; and
- juvenile overwintering success as a function of changes in elevation from November to March.

Northern squawfish were modeled using both the end of month model and the sub–monthly model. Model elements included:

- fry rearing success as a function of changes in elevation from June through July.

Walleye were modeled using the end of month model only. Model elements included:

- percentage of fish left based upon entrainment as a function of monthly water – retention times over the entire year.

3.3.8 Qualitative Analysis – Non–modeled Projects

The RFWG expanded the geographic scope for the Full–scale Analysis to include additional locations which were not included in the Screening Analysis. These locations are:

- Arrow and Mica Reservoirs
- Kootenay Lake
- Flathead Lake
- Cabinet Gorge Reservoir
- Clark Fork River
- Box Canyon
- Pend Oreille River
- Chief Joseph Reservoir and the Columbia River below
- mid–Columbia River, including Wells, Rock Island, Wanapum, Rocky Reach, and Priest Rapids Reservoirs, and the Hanford Reach
- Hells Canyon Reach of the Snake River
- Columbia River below Bonneville Dam

Some resident fish concerns within these additional locations were addressed. Unfortunately, there were not adequate data to develop detailed quantitative models for each project.

Therefore, qualitative surveys were conducted of potential impacts to the resident fish at these locations. Within each of the locations, a resident fish expert was identified as a contact person. This person was interviewed to provide thoughts on resident fish concerns within their areas of expertise, and to acquire a list of reports and journal articles which RFWG could review.

During the interviews and subsequent report review, the focus was on three main areas of resident fish management: biodiversity, species–specific concerns, and sport fisheries.

Biodiversity was chosen to represent those species of importance which do not fall into a sensitive category, or the category of fish considered economically important to the sport fishery. Even falling outside these categories, many of these species of fish are important as prey, or for other requirements within the ecosystem.

Species–specific areas of management include such issues as whether the species is petitioned for listing under the ESA, is a state–sensitive species, or if the species has some other unique characteristic which makes it important in a particular location.

Sport fishery areas of management represent those fish which support a healthy, revenue–generating sport fishery.

To determine if the existing models could be used to assess impacts in this expanded geographic area, RFWG compared the biology and hydrology of each with other projects for which models existed. If a location had a similar biology and hydrology, and hydroregulated output for each SOS existed, RFWG used the output as input to the model and used the model as a relative assessment tool. If the biology and hydrology of the two projects were similar, but hydroregulated output was not available, RFWG used the results from the modeled project and adjusted the results based on interpretations of the similarities. If the biology and/or hydrology was not consistent, the assessment of impacts was made strictly by visually inspecting the hydroregulated output for that location (if available), or by interpolation using as close as possible a project.

RFWG assessment was then provided to the regional experts for their concurrence and adjustments were made accordingly.

3.3.9 Qualitative Analysis – Non–modeled Species

We chose representative fish species at each project for which to construct a quantitative model. We attempted to model potential federal threatened or endangered species (see section 2.1.4) and state threatened, endangered, or species of special concern (see section 2.1.5). However, this was not always possible. Where a model was not constructed, we provide a qualitative discussion of potential impacts to these species from each alternative. Often this was difficult because many of these species are found in river reaches where the hydroregulated data is limited.

However, in general, operations that benefit modeled species would do so because they move closely approximate natural conditions. Thus other species would be expected to benefit as well.

CHAPTER 4

ALTERNATIVES AND THEIR IMPACTS

In this chapter we present the results from our analysis of the full scale alternatives and their impacts to resident fish within the Columbia River Basin. We have grouped our discussion of the alternatives and their impacts by alternative, and discuss these impacts specific to each project. As we described in Chapter 3, quantitative models were used to evaluate alternatives at Hungry Horse and Libby reservoirs in Montana: Lake Pend Oreille. Dworskak, and Brownlee reservoirs in Idaho: and Lower Granite, John Day, and Grand Coulee reservoirs in Washington and Oregon. Describing the impacts from the alternatives to resident fish project by project and species by species necessarily produced an overwhelming amount of information. Therefore, we provide only summary results here. A Technical Exhibit ("Detailed Descriptions of Resident Fish Models and Results of Model Analysis", hereinafter referred to as "Results Exhibit") contains a detailed description of the model results for each of the projects for key resident fish species for each of the alternatives. This technical exhibit is over 500 pages in length and because of its large size, it is not included as an attachment to this document. If the reader would like a copy of the Results Exhibit, they should contact Mr. Jeff Laufle, U.S. Army Corps of Engineers, Post Office Box 3755, Seattle, Washington, 98124.

In addition to the projects where quantitative models were used to assess the impacts, we also evaluated potential impacts from the alternatives to resident fish in a broader geographic scope. This included numerous projects in Canada and elsewhere in Montana, Idaho, Washington, and Oregon. These results are presented in a separate section following the specific modeled projects.

4.1 GENERAL DESCRIPTION OF ALTERNATIVES

Seven alternative System Operating Strategies (SOS) were considered in the Draft EIS. Each of the 7 SOSs contained several options, bringing the total number of alternatives considered to 21. This Final EIS also evaluates 7 operating strategies, with a total of 13 alternatives now under consideration when accounting for options. Section 4.1 of this chapter describes the 13 alternatives and provides the rationale for including these alternatives in the Final EIS. Operating elements for each alternative are summarized in Table 4–1. Later sections of this chapter describe the effects of these alternatives on resident fish.

The 13 final alternatives represent the results of the third analysis and review phase completed since SOR began. In 1992, the agencies completed an initial effort, known as "Screening" which identified 90 possible alternatives. Simulated operation for each alternative was completed for five water year conditions ranging from dry to wet years, impacts to each river use area were estimated using simplified analysis techniques, and the results were compared to develop 10 "candidate SOSs." The candidate SOSs were the subject of a series of public meetings held throughout the Pacific Northwest in September 1992. After reviewing public comment on the candidate strategies, the SOR agencies further reduced the number of SOSs to seven. These seven SOSs were evaluated in more detail by performing 50–year hydroregulation model simulations and by determining river use impacts. The impact analysis was completed by the SOR workgroups. Each SOS had several options so, in total, 21 alternatives were evaluated and compared. The results were presented in the Draft EIS, published in July, 1994. As was done after Screening, broad public review and comment was sought on the Draft EIS. A series of nine public meetings was held in September and October 1994, and a formal comment period on the Draft EIS was held open for over 4 1/2 months. Following this last process, the SOR agencies have again reviewed the list of alternatives and have selected 13 alternatives for consideration and presentation in the Final EIS.

Table 4–1. SOS Alternative–1

Summary of SOS

SOS 1 Pre-ESA Operation	SOS 2 Current Operations	SOS 4 Stable Storage Project Operation
SOS 1 represents system operations before changes were made as a result of the ESA listing of three Snake River salmon stocks. SOS 1a represents operations from 1983 through the 1990–91 operating year, influenced by Northwest Power Act; SOS 1b represents how the system would operate without the Water Budget and related operations to benefit anadromous fish. Short-term operations would be conducted to meet power demands while satisfying nonpower requirements.	SOS 2 reflects operation of the system with interim flow improvement measures in response to the ESA salmon listings. It is consistent with the 1992–93 operations described in the Corps' 1993 Interim Columbia and Snake River Flow Improvement Measures Supplemental EIS. SOS 2c represents the operating decision made as a result of the 1993 Supplemental EIS and is the no action alternative for the SOS. Relative to SOS 1a, primary changes are additional flow augmentation in the Columbia and Snake Rivers and modified pool levels at lower Snake and John Day reservoirs during juvenile salmon migration. SOS 2d represents operations of the 1994-98 Biological Opinion issued by NMFS, with additional flow aumentation measures compared to SOS 2c.	SOS 4 would coordinate operation of storage reservoirs to benefit recreation, resident fish, wildlife, and anadromous fish, while minimizing impacts to power and flood control. Reservoirs would be managed to specific elevations on a monthly basis; they would be kept full longer, while still providing spring flows for fish and space for flood control. The goal is to minimize reservoir fluctuations while moving closer to natural flow conditions. SOS 4c attempts to accommodate anadromous fish needs by shaping mainstem flows to benefit migrations and would modify the flood control operations at Grand Coulee.

Actions by Project

	SOS 1	SOS 2	SOS 4
LIBBY	**SOS 1a**	**SOS 2c**	**SOS 4c**
	Normal 1983–1991 storage project operations	Operate on system proportional draft as in SOS 1a	• Meet specific elevation targets as indicated by Integrated Rule Curves (IRCs); IRCs are based on storage content at the end of the previous year, determination of the appropriate year within the critical period, and runoff forecasts beginning in January • IRCs seek to keep reservoir full (2,459 feet) June-Sept; minimum annual elevation ranges from 2,399 to 2,327 feet, depending on critical year determination • Meet variable sturgeon flow targets at Bonners Ferry during May 25-August 16 period; flow targets peak as high as 35 kcfs in the wettest years
	SOS 1b	**SOS 2d**	
	• Minimum project flow 3 kcfs • No refill targets • Summer draft limit of 5–10 feet	• Provide flow augmentation for salmon and sturgeon when Jan. to July forecast is greater than 6.5 MAF • Meet sturgeon flows of 15, 20, and 12.5 kcfs in May, June, and July, respectively, in at least 3 out of 10 years	

KAF = 1.234 million cubic meters MAF = 1.234 billion cubic meters

Table 4–1. SOS Alternative–1

SOS 5 Natural River Operation	SOS 6 Fixed Drawdown	SOS 9 Settlement Discussion Alternatives	SOS PA
SOS 5 would aid juvenile salmon by increasing river velocity. The four lower Snake River projects would have new outlets installed, allowing the reservoirs to be drawn down to near the original river elevation. The "natural river" operation would be done for 4 1/2 months in SOS 5b and year-round in SOS 5c. John Day would also be operated at MOP for 4 months, and flow augmentation measures on the Columbia River portion of the basin would continue as in SOS 2c.	SOS 6 involves drawing down lower Snake River projects to fixed elevations below MOP to aid anadromous fish. SOS 6b provides for fixed drawdowns for all four lower Snake projects for 4 1/2 months; SOS 6d draws down Lower Granite only for 4 1/2 months. John Day would also be operated at MOP for 4 months, and flow augmentation measures on the Columbia River portion of the basin would continue as in SOS 2c.	SOS 9 represents operations suggested by the USFWS, NMFS, the state fisheries agencies, Native American tribes, and the Federal operating agencies during the settlement discussions in response to the *IDFG v. NMFS* court proceedings. This alternative has three options, SOSs 9a, 9b, and 9c, that represent different scenarios to provide increased river velocities for anadromous fish by establishing flow targets during migration and to carry out other actions to benefit ESA-listed species. The three options are termed the Detailed Fishery Operating Plan (9a), Adoptive Management (9b), and the Balanced Impacts Operation (9c).	SOS PA represents the operation recommended by NMFS and the USFWS Biological Opinions issued March 1, 1995. This SOS supports recovery of ESA-listed species by storing water during the fall and winter to meet spring and summer flow targets, and protects other resources by setting summer draft limits to manage negative effects, by providing flood protection, and by providing for reasonable power generation.

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b Operate on system proportional draft as in SOS 1a	**SOS 6b** Operate on system proportional draft as in SOS 1a	**SOS 9a** • Operate on minimum flow up to flood control rule curves year-round, except during flow augmentation period • Provide sturgeon flow releases April-Aug. to achieve up to 35 kcfs at Bonner's Ferry with appropriate ramp up and ramp down rates	**SOS PA** • Operate on minimum flow up to flood control rule curves beginning in Jan., except during flow augmentation period • Strive to achieve flood control elevations in Dec. in all years and by April 15 in 75 percent of years • Provide sturgeon flows of 25 kcfs 42 days in June and July • Provide sufficient flows to achieve 11 kcfs flow at Bonner's Ferry for 21 days after maximum flow period • Draft to meet flow targets, to a minimum end of Aug. elevation of 2,439 feet, unless deeper drafts needed to meet sturgeon flows
SOS 5c Operate on system proportional draft as in SOS 1a	**SOS 6d** Operate on system proportional draft as in SOS 1a	**SOS 9b** • Operate on minimum flow up to flood control rule curves year-round, except during flow augmentation • Provide sturgeon flow releases similar to SOS 2d • Can draft to elevation 2,435 by end of July to meet flow targets	
		SOS 9c • Operate to the Integrated Rule Curves and provide sturgeon flow releases as in SOS 4c	

1 kcfs = 28 cms   1 ft = 0.3048 meter

Table 4–1. SOS Alternative–2
Actions by Project

HUNGRY HORSE

	SOS 1	SOS 2	SOS 4
	SOS 1a	**SOS 2c**	**SOS 4c**
	Normal 1983–1991 storage project operations	Operate on system proportional draft as in SOS 1a	• Meet specific elevation targets as indicated by Integrated Rule Curves (IRCs), similar to operation for Libby • IRCs seek to keep reservoir full (3,560 feet) June-Sept.; minimum annual elevation ranges from 3,520 to 3,450 feet, depending on critical year
	SOS 1b	**SOS 2d**	
	• No maximum flow restriction from mid-Oct. to mid-Nov. • No draft limit; no refill target	Operate on system proportional draft as in SOS 1a	

ALBENI FALLS

	SOS 1	SOS 2	SOS 4
	SOS 1a	**SOS 2c**	**SOS 4c**
	Normal 1983–1991 storage project operations	Operate on system proportional draft as in SOS 1a	Elevation targets established for each month, generally 2,056 feet Oct.–March, 2,058 to 2,062.5 feet April–May, 2,062.5 feet (full) June, 2,060 feet July–Sept. (but higher if runoff high); Oct.–March drawdown to 2,051 feet every 6th year
	SOS 1b	**SOS 2d**	
	No refill target	Operate on system proportional draft as in SOS 1a	

KAF = 1.234 million cubic meters

MAF = 1.234 billion cubic meters

Table 4–1. SOS Alternative–2

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b Operate on system proportional draft as in SOS 1a	**SOS 6b** Operate on system proportional draft as in SOS 1a	**SOS 9a** • Operate on minimum flow up to flood control rule curves year-round, except during flow augmentation period	**SOS PA** • Operate on minimum flow up to flood control rule curves year-round, except during flow augmentation period • Strive to achieve flood control elevations by April 15 in 75 percent of the years • Draft to meet flow targets, to a minimum end-of-August elevation of 3,540 feet
SOS 5c Operate on system proportional draft as in SOS 1a	**SOS 6d** Operate on system proportional draft as in SOS 1a	**SOS 9b** • Operate on minimum flow up to flood control rule curves year-round, except during flow augmentation • Can draft to meet flow targets, to a minimum end-of-July elevation of 3,535 feet	
		SOS 9c • Operate to the Integrated Rule Curves as in SOS 4c	

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b Operate on system proportional draft as in SOS 1a	**SOS 6b** Operate on system proportional draft as in SOS 1a	**SOS 9a** Operate on minimum flow up to flood control rule curves year-round, except during flow augmentation period	**SOS PA** • Operate to flood control elevations by April 15 in 90 percent of the years • Operate to help meet flow targets, but do not draft below full pool through Aug.
SOS 5c Operate on system proportional draft as in SOS 1a	**SOS 6d** Operate on system proportional draft as in SOS 1a	**SOS 9b** • Operate on minimum flow up to flood control rule curves year-round, except during flow augmentation period • Can draft to meet target flows, to a minimum end-of-July elevation of 2,060 feet	
		SOS 9c • Elevation targets established for each month, generally no lower than 2,056 feet Dec.—April, no lower than 2,057 feet end of May, full (2,062.5 feet) June—Aug., 2,056 feet Sept.—Nov.	

1 kcfs = 28 cms 1 ft = 0.3048 meter

Table 4–1. SOS Alternative–3
Actions by Project

	SOS 1	SOS 2	SOS 4
GRAND COULEE	**SOS 1a** • Operate to meet Water Budget target flows of 134 kcfs at Priest Rapids in May 1/ • Meet minimum elevation of 1,240 feet in May **SOS 1b** • No refill target of 1,240 feet in May • Maintain 1,285 feet June–Sept.; minimum 1,220 feet rest of year • No May–June flow target	**SOS 2c** • Storage of water for flow augmentation from January through April • Supplemental releases (in conjunction with upstream projects) to provide up to 3 MAF additional (above Water Budget) flow augmentation in May and June, based on sliding scale for runoff forecasts • System flood control space shifted from Brownlee, Dworshak **SOS 2d** • Contribute, in conjunction with upstream storage projects, up to 4 MAF for additional flow augmentation • Operate in summer to provide flow augmentation water and meet downstream flow targets, but draft no lower than 1,280 feet	**SOS 4c** • Operate to end-of-month elevation targets, as follows: 1,288 Sept.-Nov 1,287 Dec. 1,270 Jan. 1,260 Feb. 1,270 Mar. 1,272 Apr. 15 1,275 Apr. 30 1,280 May 1,288 Jun.-Aug. • Meet flood control rule curves only when Jan.-June runoff forecast exceeds 68 MAF

	SOS 1	SOS 2	SOS 4
PRIEST RAPIDS	**SOS 1a** • Meet May-June flow targets 1/ • Maintain minimum flows to meet Vernita Bar Agreement 2/ **SOS 1b** • No May flow target • Meet Vernita Bar Agreement	**SOS 2c** Operate as in SOS 1a **SOS 2d** Operate as in SOS 1a	**SOS 4c** Operate as in SOS 1a

1/ Flow targets are weekly averages with weekend and holiday flows no less than 80 percent of flows over previous 5 days.
2/ 55 kcfs during heavy load hours October 15 to November 30; minimum instantaneous flow 70 kcfs December to April
KAF = 1.234 million cubic meters MAF = 1.234 billion cubic meters

Table 4–1. SOS Alternative–3

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b	**SOS 6b**	**SOS 9a**	**SOS PA**
Operate on system proportional draft and provide flow augmentation as in SOS 2c	Operate on system proportional draft and provide flow augmentation as in SOS 2c	• Operate to meet flood control requirements and Vernita Bar agreement • Provide flow augmentation releases to help meet targets at The Dalles of 220-300 kcfs April 16-June 15, 200 kcfs June 16-July 31, and 160 kcfs Aug. 1-Aug.31, based on appropriate critical year determination • In above average runoff years, provide 40% of the additional runoff volume as flow augmentation	• Operate to achieve flood control elevations by April 15 in 85% of years • Draft to meet flow targets, down to minimum end-of-Aug. elevation of 1,280 feet • Provide flow augmentation releases to meet Columbia River flow targets at McNary of 220-260 kcfs April 20-June 30, based on runoff forecast, and 200 kcfs July-Aug.
SOS 5c	**SOS 6d**	**SOS 9b**	
Operate on system proportional draft and provide flow augmentation as in SOS 2c	Operate on system proportional draft and provide flow augmentation as in SOS 2c	• Operate on minimum flow up to flood control rule curves year-round, except during flow augmentation period • Can draft to meet flow targets, bounded by SOS 9a and 9c targets, to a minimum end-of-July elevation of 1,265 feet	
		SOS 9c	
		• Operate to meet McNary flow targets of 200 kcfs April 16-June 30 and 160 kcfs in July • Can draft to meet flow targets, to a minimum end-of-July elevation of 1,280 feet • Contribute up to 4 MAF for additional flow augmentation, based on sliding scale for runoff forecasts, in conjunction with other upstream projects • System flood control shifted to this project	

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b	**SOS 6b**	**SOS 9a**	**SOS PA**
Operate as in SOS 1a	Operate as in SOS 1a	Operate as in SOS 1a	Operate as in SOS 1a
SOS 5c	**SOS 6d**	**SOS 9b**	
Operate as in SOS 1a	Operate as in SOS 1a	Operate as in SOS 1a	
		SOS 9c	
		Operate as in SOS 1a	

1 kcfs = 28 cms 1 ft = 0.3048 meter

Table 4–1. SOS Alternative–4

Actions by Project

	SOS 1	SOS 2	SOS 4
SNAKE RIVER ABOVE BROWNLEE	**SOS 1a** Normal 1990—91 operations; no Water Budget flows	**SOS 2c** Release up to 427 KAF (190 KAF April 16—June 15; 137 KAF Aug.; 100 KAF Sept.) for flow augmentation	**SOS 4c** Same as SOS 1a
	SOS 1b Same as SOS 1a	**SOS 2d** • Release up to 427 KAF, as in SOS 2c • Release additional water obtained by purchase or other means and shaped per Reclamation releases and Brownlee draft requirements; simulation assumed 927 KAF available	

	SOS 1	SOS 2	SOS 4
BROWNLEE	**SOS 1a** • Draft as needed (up to 110 KAF in May) for Water Budget, based on target flows of 85 kcfs at Lower Granite • Operate per FERC license • Provide system flood control storage space	**SOS 2c** Same as SOS 1a except for additional flow augmentation as follows: • Draft up to 137 KAF in July, but not drafting below 2,067 feet; refill from the Snake River above Brownlee in August • Draft up to 100 KAF in Sept. • Shift system flood control to Grand Coulee • Provide 9 kcfs or less in November; fill project by end of month • Maintain November monthly average flow December through April	**SOS 4c** Same as SOS 1a except slightly different flood control rule curves
	SOS 1b • No maximum flow restriction from mid-Oct. to mid-Nov. • No draft limit; no refill target	**SOS 2d** Same as SOS 2c, plus pass additional flow augmentation releases from upstream projects	

KAF = 1.234 million cubic meters

MAF = 1.234 billion cubic meters

Table 4–1. SOS Alternative–4

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b Same as SOS 1a **SOS 5c** Same as SOS 1a	**SOS 6b** Same as SOS 1a **SOS 6d** Same as SOS 1a	**SOS 9a** Provide up to 1.927 MAF through Brownlee for flow augmentation, as determined by Reclamation **SOS 9b** Provide up to 927 KAF through Brownlee as determined by Reclamation **SOS 9c** Provide up to 927 KAF through Brownlee as determined by Reclamation	**SOS PA** Provide 427 KAF through Brownlee for flow augmentation, as determined by Reclamation

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b Same as SOS 4c **SOS 5c** Same as SOS 4c	**SOS 6b** Same as SOS 4c **SOS 6d** Same as SOS 4c	**SOS 9a** • Draft up to 110 KAF in May, 137 KAF in July, 140 KAF in Aug., 100 KAF in Sept. for flow augmentation • Shift system flood control to Grand Coulee **SOS 9b** • Draft up to 190 KAF April-May, 137 KAF in July, 100 KAF in Sept. for flow augmentation • Shift system flood control to Grand Coulee • Provide an additional 110 KAF in May if elevation is above 2,068 feet and 110 KAF in Sept. if elevation is above 2,043.3 feet **SOS 9c** Same as SOS 9b	**SOS PA** Draft to elevation 2,069 feet in May, 2,067 feet in July, and 2,059 feet in Sept., passing inflow after May and July drafts

1 kcfs = 28 cms   1 ft = 0.3048 meter

Table 4–1. SOS Alternative–5

Actions by Project

	SOS 1	SOS 2	SOS 4
DWORSHAK	**SOS 1a** • Draft up to 600 KAF in May to meet Water Budget target flows of 85 kcfs at Lower Granite • Provide system flood control storage space **SOS 1b** • Meet minimum project flows (2 kcfs, except for 1 kcfs in August); summer draft limits; maximum discharge requirement Oct. to Nov. (1.3 kcfs plus inflow) • No Water Budget releases	**SOS 2c** Same as SOS 1a, plus the following supplemental releases: • 900 KAF or more from April 16 to June 15, depending on runoff forecast at Lower Granite • Up to 470 KAF above 1.2 kcfs minimum release from June 16 to Aug. 31 • Maintain 1.2 kcfs discharge from Oct. through April, unless higher required • Shift system flood control to Grand Coulee April–July if runoff forecasts at Dworshak are 3.0 MAF or less **SOS 2d** • Operate on 1.2 kcfs minimum discharge up to flood control rule curve, except when providing flow augmentation (April 10 to July 31) • Provide flow augmentation of 1.0 MAF plus 1.2 kcfs minimum discharge, or 927 KAF and 1.2 kcfs, from April 10-June 20, based on runoff forecasts, to meet Lower Granite flow target of 85 kcfs • Provide 470 KAF from June 21 to July 31 to meet Lower Granite flow target of 50 kcfs • Draft to 1,520 feet after volume is expended, if Lower Granite flow target is not met; if volume is not expended, draft below 1,520 feet until volume is expended	**SOS 4c** Elevation targets established for each month: 1,599 feet Sept.-Oct.; flood control rule curves Nov.-April; 1,595 feet May; 1,599 feet June-Aug.;

KAF = 1.234 million cubic meters

MAF = 1.234 billion cubic meters

Table 4–1. SOS Alternative–5

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b • Operate to local flood control rule curve • No proportional draft for power • Shift system flood control to lower Snake projects • Provide Water Budget flow augmentation as in SOS 1a • Draft to refill lower Snake projects if natural inflow is inadequate	**SOS 6b** Same as SOS 5b	**SOS 9a** • Remove from proportional draft for power • Operate to local flood control rule curves, with system flood control shifted to Grand Coulee • Maintain flow at 1.2 kcfs minimum discharge, except for flood control or flow augmentation discharges • Operate to meet Lower Granite flow targets (at spillway crest) of 74 kcfs April 16-June 30, 45 kcfs July, 32 kcfs August	**SOS PA** • Operate on minimum flow-up to flood control rule curve year-round, except during flow augmentation period • Draft to meet flow targets, down to min. end-of-Aug. elevation of 1,520 feet • Sliding-scale Snake River flow targets at Lower Granite of 85 to 100 kcfs April 10-June 20 and 50 to 55 kcfs June 21-Aug. 31, based on runoff forecasts
SOS 5c • Operate to flood control during spring • Refill in June or July and maintain through August • Draft for power production during fall	**SOS 6d** Same as SOS 5b	**SOS 9b** • Similar to SOS 9a, except operate to meet flow targets at Lower Granite ranging from 85 to 140 kcfs April 16-June 30 and 50-55 kcfs in July • Can draft to meet flow targets to a min. end-of-July elevation of 1,490 feet	
		SOS 9c • Similar to SOS 9a, except operate to meet Lower Granite flow target (at spillway crest) of 63 kcfs April-June • Can draft to meet flow targets to a min. end-of-July elevation of 1,520 feet	

1 kcfs = 28 cms   1 ft = 0.3048 meter

Table 4–1. SOS Alternative–6

Actions by Project

	SOS 1	SOS 2	SOS 4
LOWER SNAKE	**SOS 1a** • Normal operations at 4 lower Snake River projects (within 3 to 5 feet of full pool, daily and weekly fluctuations) • Provide maximum peaking capacity of 20 kcfs over daily average flow in May **SOS 1b** Same as 1a, except: • No minimum flow limit (11,500 cfs) during fall and winter • No fish-related rate of change in flows in May	**SOS 2c** • Operate reservoirs within 1 foot above MOP from April 16 to July 31 • Same as SOS 1a for rest of year **SOS 2d** Same as SOS 2c	**SOS 4c** Same as SOS 2c
LOWER COLUMBIA	**SOS 1a** • Normal operations at 4 lower Columbia projects (generally within 3 to 5 feet of full pool, daily and weekly fluctuations) • Restricted operation of Bonneville second powerhouse **SOS 1b** Same as 1a, except no restrictions on Bonneville second powerhouse	**SOS 2c** Same as SOS 1a except: lower John Day to minimum irrigation pool (approx. 262.5 feet) from April 15 to Aug. 31; operate within 1.5 feet of forebay range, unless need to raise to avoid irrigation impacts **SOS 2d** Same as SOS 2c	**SOS 4c** Same as SOS 2c, except operate John Day within 2 feet of elevation 263.5 feet Nov. 1 through June 30

KAF = 1.234 million cubic meters   MAF = 1.234 billion cubic meters

Table 4–1. SOS Alternative–6

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b • Draft 2 feet per day starting Feb. 18 • Operate at natural river level, approx. 95 to 115 ft below full pool, April 16-Aug. 31; drawdown levels by project as follows, in feet: Lower Granite 623 Little Goose 524 L. Monumental 432 Ice Harbor 343 • Operate within 3 to 5 ft of full pool rest of year • Refill from natural flows and storage releases	**SOS 6b** • Draft 2 feet per day starting April 1 • Operate 33 feet below full pool April 16-Aug. 31; drawdown levels by project as follows, in feet: Lower Granite 705 Little Goose 605 L. Monumental 507 Ice Harbor 407 • Operate over 5-foot forebay range once drawdown elevation reached • Refill from natural flows and storage releases • Same as SOS 1a rest of year	**SOS 9a** • Operate 33 feet below full pool (see SOS 6b) April 1-Aug. 31 to meet L. Granite flow targets (see Dworshak); same as SOS 1a rest of year • Spill to achieve 80/80 FPE up to total dissolved gas cap of 120% daily average; spill cap 60 kcfs at all projects	**SOS PA** • Operate at MOP with 1 foot flexibility between April 10 - Aug. 31 • Refill three lower Snake River pools after Aug. 31, Lower Granite after Nov. 15 • Spill to achieve 80% FPE up to total dissolved gas cap of 115% 12-hour average; spill caps range from 7.5 kcfs at L. Monumental to 25 kcfs at Ice Harbor
SOS 5c Same as SOS 5b, except drawdowns are permanent once natural river levels reached; no refill	**SOS 6d** • Draft Lower Granite 2 feet per day starting April 1 • Operate Lower Granite near 705 ft for 4 1/2 months, April 16-Aug. 31	**SOS 9b** • Operate at MOP, with 1 foot flexibility April 1-Aug. 31; same as SOS 1a rest of year • Spill to achieve 80/80 FPE up to total dissolved gas cap of 120% daily average; spill caps range from 18 kcfs at L. Monumental to 30 kcfs at L. Granite	
		SOS 9c • Operate 35 to 45 feet below full pool April 1-June 15 to meet L. Granite flow targets (see Dworshak), refill by June 30; same as SOS 1a rest of year • Spill to achieve 80/80 FPE, as in SOS 9b	

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b Same as SOS 2, except operate John Day within 1.5 feet above elevation 257 feet (MOP) from May 1 through Aug. 31; same as SOS 2c rest of year	**SOS 6b** Same as SOS 5	**SOS 9a** • Same as SOS 5, except operate John Day within 1 foot above elevation 257 feet April 15-Aug. 31 • McNary flow targets as described for Grand Coulee • Spill to achieve 80/80 FPE, up to total dissolved gas cap of 120% daily average, as derived by agencies	**SOS PA** • Pool operations same as SOS 2c, except operate John Day at 257 feet (MOP) year-round, with 3 feet of flexibility March-Oct. and 5 feet of flexibility Nov.-Feb. • Spill to achieve 80% FPE up to total dissolved gas cap of 115% 12-hour average; spill caps range from 9 kcfs at John Day to 90 kcfs at The Dalles
SOS 5c Same as SOS 5b	**SOS 6d** Same as SOS 5	**SOS 9b** • Same as SOS 2, except operate John Day at minimum irrigation pool or 262.5 feet with 1 foot of flexibility from April 16-Aug. 31 • McNary flow targets as described for Grand Coulee • Spill to achieve 80/80 FPE, up to total dissolved gas cap of 120% daily average, as derived by Corps	
		SOS 9c Same as SOS 9b, except operate John Day at minimum operating pool	

1 kcfs = 28 cms

1 ft = 0.3048 meter

Six options for the alternatives remain unchanged from the specific options considered in the Draft EIS. One option (SOS 4c) is a revision to a previously considered alternative, and the rest represent replacement or new alternatives. The basic categories of SOSs and the numbering convention remains the same as was used in the Draft EIS. However, because some of the alternatives have been dropped, the final SOSs are not numbered consecutively. There is one new SOS category, Settlement Discussion Alternatives, which is labeled SOS 9 (see Section 4.1.6 for discussion).

The 13 alternatives have been evaluated through the use of a computerized model known as HYDROSIM. Developed by BPA, HYDROSIM is a hydroregulation model that simulates the coordinated operation of all projects in the Columbia River system. It is a monthly model with 14 total time periods. April and August are split into two periods each, because major changes can occur in streamflows in the first and second half of each of these months. The model is based on hydrologic data for a 50–year period of record from 1928 through 1978. For a given set of operating rule inputs and other project operating requirements, HYDROSIM will simulate elevations, flows, spill, storage content and power generation for each project or river control point for the 50–year period. For more detailed information, please refer to Appendix A, River Operation Simulation.

The following section describes the final alternatives and reviews the rationale for their inclusion in the Final EIS.

4.1.1 SOS 1-Pre–ESA Operation

This alternative represents one end of the range of the SOR strategies in terms of their similarity to historical system operations. This strategy reflects Columbia River system operations before changes were made as a result of the ESA listing of three Snake River salmon stocks. This SOS has two options:

- **SOS 1a (Pre–Salmon Summit Operation)** represents operations as they existed from 1983 through the 1990–91 operating year, including Northwest Power Act provisions to restore and protect fish populations in the basin. Specific volumes for the Water Budget would be provided from Dworshak and Brownlee reservoirs to attempt to meet a target flow of 85 kcfs (2,380 cms) at Lower Granite Dam in May. Sufficient flows would be provided on the Columbia River to meet a target flow of 134 kcfs (3,752 cms) at Priest Rapids Dam in May. Lower Snake River projects would operate within 3 to 5 feet (0.9 to 1.5 m) of full pool. Other projects would operate as they did in 1990–91, with no additional water provided from the Snake River above Brownlee Dam.
- **SOS 1b (Optimum Load–Following Operation)** represents operations as they existed prior to changes resulting from the Northwest Power Act. It is designed to demonstrate how much power could be produced if most flow–related operations to benefit anadromous fish were eliminated including: the Water Budget; fish spill requirements; restrictions on operation of Bonneville's second powerhouse; and refill targets for Libby, Hungry Horse, Grand Coulee, Dworshak, and Albeni Falls. It assumes that transportation would be used to the maximum to aid juvenile fish migration.

4.1.2 SOS 2-Current Operations

This alternative reflects operation of the Columbia River system with interim flow improvement measures made in response to ESA listings of Snake River salmon. It is very similar to the way the system operated in 1992 and reflects the results of ESA Section 7 consultation with NMFS then. The strategy is consistent with the 1992–93 operations described in the Corps' *1993 Interim Columbia and Snake Rivers Flow Improvement Measures Supplemental EIS* (SEIS). SOS 2 also most closely represents the recommendations issued by the NMFS Snake River Salmon Recovery Team in May 1994. Compared to SOS 1, the primary changes are additional flow augmentation in the Columbia and Snake Rivers and modified pool levels at lower Snake and

John Day reservoirs during juvenile salmon migration. This strategy has two options:

- **SOS 2c (Final SEIS Operation- No Action Alternative)** matches exactly the decision made as a result of the 1993 SEIS. Flow augmentation water of up to 3.0 MAF (3.7 billion m^3) on the Columbia River (in addition to the existing Water Budget) would be stored during the winter and released in the spring in low–runoff years. Dworshak would provide at least an additional 300 KAF (370 million m^3) in the spring and 470 KAF (580 million m^3) in the summer for flow augmentation. System flood control shifts from Dworshak and Brownlee to Grand Coulee would occur through April as needed. It also provides up to 427 KAF (527 million m^3) of additional water from the Snake River above Brownlee Dam.

- **SOS 2d (1994–98 Biological Opinion)** matches the hydro operations contained in the 1994–98 Biological Opinion issued by NMFS in mid–1994. This alternative provides water for the existing Water Budget as well as additional water, up to 4 MAF, for flow augmentation to benefit the anadromous fish migration. The additional water of up to 4 MAF would be stored in Grand Coulee, Libby and Arrow, and provided on a sliding scale tied to runoff forecasts. Flow targets are established at Lower Granite and McNary.

In cases such as the SOR, where the proposed action is a new management plan, the No Action Alternative means continuing with the present course of action until that action is changed (46 FR 13027). Among all of the strategies and options, SOS 2c best meets this definition for the No Action Alternative.

4.1.3 SOS 4-Stable Storage Project Operation

This alternative is intended to operate the storage reservoirs to benefit recreation, resident fish, wildlife, and anadromous fish while minimizing impacts of such operation to power and flood control. Reservoirs would be kept full longer, but still provide spring flows for fish and space for flood control. The goal is to minimize reservoir fluctuations while moving closer to natural flow conditions. For the Final EIS, this alternative has one option:

- **SOS 4c (Stable Storage Operation with Modified Grand Coulee Flood Control)** applies year–round Integrated Rule Curves (IRCs) developed by the State of Montana for Libby and Hungry Horse. Other reservoirs would be managed to specific elevations on a monthly basis; they would be kept full longer, while still providing spring flows for fish and space for flood control. The goal is to minimize reservoir fluctuations while moving closer to natural flow conditions. Grand Coulee would meet elevation targets year–round to provide acceptable water retention times; however, upper rule curves would apply at Grand Coulee if the January to July runoff forecast at the project is greater than 68 MAF (84 billion m^3).

4.1.4 SOS 5-Natural River Operation

This alternative is designed to aid juvenile salmon migration by drawing down reservoirs (to increase the velocity of water) at four lower Snake River projects. SOS 5 reflects operations after the installation of new outlets in the lower Snake River dams, permitting the lowering of reservoirs approximately 100 feet (30 m) to near original riverbed levels. This operation could not be implemented for a number of years, because it requires major structural modifications to the dams. Elevations would be: Lower Granite – 623 feet (190 m); Little Goose – 524 feet (160 m); Lower Monumental – 432 feet (132 m); and Ice Harbor – 343 feet (105 m). Drafting would be at the rate of 2 feet (0.6 m) per day beginning February 18. The reservoirs would refill again with natural inflows and storage releases from upriver projects, if needed. John Day would be lowered as much as 11 feet (3.3 m) to minimum pool, elevation 257 feet (78.3 m), from May through August. All other projects would operate essentially the same as in SOS 1a, except that up to 3 MAF (3.7 billion m^3) of water (in addition to the Water Budget) would be provided to augment flows on the Columbia River in

May and June. System flood control would shift from Brownlee and Dworshak to the lower Snake River projects. Also, Dworshak would operate for local flood control. This alternative has two options:

- **SOS 5b (Four and One–half Month Natural River Operation)** provides for a lower Snake River drawdown lasting 4.5 months, beginning April 16 and ending August 31. Dworshak would be drafted to refill the lower Snake River projects if natural inflow were inadequate for timely refill.

- **SOS 5c (Permanent Natural River Operation)** provides for a year–round drawdown, and projects would not be refilled after each migration season.

4.1.5 SOS 6-Fixed Drawdown

This alternative is designed to aid juvenile anadromous fish by drawing down one or all four lower Snake River projects to fixed elevations approximately 30 to 35 feet (9 to 10 m) below minimum operating pool. As with SOS 5, fixed drawdowns depend on prior structural modifications and could not be instituted for a number of years. Draft would be at the rate of 2 feet (0.6 m) per day beginning April 1. John Day would be lowered to elevation 257 feet (78.3 m) from May through August. All other projects would operate essentially the same as under SOS 1a, except that up to 3 MAF (3.7 billion m^3) of water would be provided to augment flows on the Columbia River in May and June. System flood control would shift from Brownlee and Dworshak to the lower Snake projects. Also, Dworshak would operate for local flood control. This alternative has two options:

- **SOS 6b (Four and One–half Month Fixed Drawdown)** provides for a 4.5–month drawdown at all four lower Snake River projects beginning April 16 and ending August 31. Elevations would be: Lower Granite – 705 feet (215 m); Little Goose – 605 feet (184 m); Lower Monumental – 507 feet (155 m); and Ice Harbor – 407 feet (124 m).

- **SOS 6d (Four and One–half Month Lower Granite Fixed Drawdown)** provides for a 4.5–month drawdown to elevation 705 feet at Lower Granite beginning April 16 and ending August 31.

4.1.6 SOS 9-Settlement Discussion Alternatives

This SOS represents operations suggested by USFWS and NMFS (as SOR cooperating agencies), the State fisheries agencies, Native American tribes, and the Federal operating agencies during the settlement discussions in response to a court ruling in the *IDFG v. NMFS* lawsuit. The objective of SOS 9 is to provide increased velocities for anadromous fish by establishing flow targets during the migration period and by carrying out other actions that benefit ESA–listed species. The specific options were developed by a group of technical staff representing the parties in the lawsuit. The group was known as the Reasonable and Prudent Alternatives Workgroup. They developed three possible operations in addition to the 1994–98 Biological Opinion. This strategy has three options:

- **SOS 9a (Detailed Fishery Operating Plan [DFOP])** establishes flow targets at The Dalles based on the previous year's end–of–year storage content, similar to how PNCA selects operating rule curves. Grand Coulee and other storage projects are used to meet The Dalles flow targets. Specific volumes of releases are made from Dworshak, Brownlee, and upper Snake River to try to meet Lower Granite flow targets. Lower Snake River projects are drawn down to near spillway crest level for 4 1/2 months. Specific spill percentages are established at run–of–river projects to achieve no higher than 120 percent daily average total dissolved gas. Fish transportation is assumed to be eliminated.

- **SOS 9b (Adaptive Management)** establishes flow targets at McNary and Lower Granite based on runoff forecasts. Grand Coulee and other storage projects are used to meet the McNary flow targets. Specific volumes of releases are made from Dworshak, Brownlee, and the upper Snake River to try to meet Lower Granite flow targets. Lower Snake River projects are drawn down to minimum operating pool levels and John Day is at minimum irrigation pool level. Specific spill percentages are established at run–of–river projects to achieve no higher than 120 percent daily average for total dissolved gas.

- **SOS 9c (Balanced Impacts Operation)** draws down the four lower Snake River projects to near spillway crest levels for 2 1/2 months during the spring salmon migration period. Full drawdown level is achieved on April 1. Refill begins after June 15. This alternative also provides 1994–98 Biological Opinion flow augmentation (as in SOS 2d), IRC operation at Libby and Hungry Horse, a reduced flow target at Lower Granite due to drawdown, limits on winter drafting at Albeni Falls, and spill to achieve no higher than 120 percent daily average for total dissolved gas.

4.1.7 SOS PA-Preferred Alternative

This SOS represents the operation recommended by NMFS and USFWS in their respective Biological Opinions issued on March 1, 1995. SOS PA is intended to support recovery of ESA–listed species by storing water during the fall and winter to meet spring and summer flow targets, and to protect other resources by managing detrimental effects through maximum summer draft limits, by providing public safety through flood protection, and by providing for reasonable power generation. This SOS would operate the system during the fall and winter to achieve a high confidence of refill to flood control elevations by April 15 of each year, and use this stored water for fish flow augmentation. It establishes spring flow targets at McNary and Lower Granite based on runoff forecasts, and a similar sliding scale flow target at Lower Granite and a fixed flow target at McNary for the summer. It establishes summer draft limits at Hungry Horse, Libby, Grand Coulee, and Dworshak. Libby is also operated to provide flows for Kootenai River white sturgeon. Lower Snake River projects are drawn down to minimum operating pool levels during the spring and summer. John Day is operated at minimum operating pool level year–round. Specific spill percentages are established at run–of–river projects to achieve 80–percent FPE, with no higher than 115–percent 12–hour daily average for total dissolved gas measured at the forebay of the next downstream project.

4.1.8 Rationale for Selection of the Final SOSs

Table 4–2 summarizes the changes to the set alternatives from the Draft EIS to the Final EIS.

SOS 1a and 1b are unchanged from the Draft EIS. SOS 1a represents a base case condition and reflects system operation during the period from passage of the Northwest Power Planning and Conservation Act until ESA listings. It provides a baseline alternative that allows for comparison of the more recent alternatives and shows the recent historical operation. SOS 1b represents a limit for system operation directed at maximizing benefits from development–oriented uses, such as power generation, flood control, irrigation and navigation and away from natural resources protection. It serves as one end of the range of alternatives and provides a basis for comparison of the impacts to power generation from all other alternatives. Public comment did not recommend elimination of this alternative because it serves as a useful milepost. However, the SOR agencies recognize it is unlikely that decisions would be made to move operations toward this alternative.

In the Draft EIS, SOS 2 represented current operation. Three options were considered. Two of these options have been eliminated for the Final EIS and one new option has been added. SOS 2c continues as the No Action Alternative. Maintaining this option as the No Action Alternative allows for consistent comparisons in the Final EIS to those made in the Draft EIS. However, within the current practice category, new operations have been developed since the original identification of SOS 2c. In 1994, the SOR agencies, in consultation

Table 4–2. Summary of Alternatives in the Draft and Final EIS

Draft EIS Alternatives	Final EIS Alternatives
SOS 1 Pre–ESA Operation	SOS 1 Pre–ESA Operation
SOS 1a Pre–Salmon Summit Operation	SOS 1a Pre–Salmon Summit Operation
SOS 1b Optimum Load Following Operation	SOS 1b Optimum Load Following Operation
SOS 2 Current Practice	SOS 2 Current Practice
SOS 2a Final Supplemental EIS Operation	SOS2c Final Supplemental EIS Operation – No–Action Alternative
SOS 2b Final Supplemental EIS with Sturgeon Operations at Libby	**SOS 2d 1994–98 Biological Opinion Operation**
SOS2c Final Supplemental EIS Operation – No–Action Alternative	
SOS 3 Flow Augmentation	
SOS 3a Monthly Flow Targets	
SOS 3b Monthly Flow Targets with additional Snake River Water	
SOS 4 Stable Storage Project Operation	SOS 4 Stable Storage Project Operation
SOS 4a1 Enhanced Storage Level Operation	**SOS 4c Enhanced Operation with modified Grand Coulee Flood Control**
SOS 4a3 Enhanced Storage Level Operation	
SOS 4b1 Compromise Storage Level Operation	
SOS 4b3 Compromise Storage Level Operation	
SOS 4c Enhanced Operation with modified Grand Coulee Flood Control	
SOS 5 Natural River Operation	SOS 5 Natural River Operation
SOS 5a Two Month Natural River Operation	SOS 5b Four and One Half Month Natural River Operation
SOS 5b Four and One Half Month Natural River Operation	**SOS 5c Permanent Natural River Operation**
SOS 6 Fixed Drawdown	SOS 6 Fixed Drawdown
SOS 6a Two Month Fixed Drawdown Operation	SOS 6b Four and One Half Month Fixed Drawdown Operation
SOS 6b Four and One Half Month Fixed Drawdown Operation	SOS 6d Four and One Half Month Lower Granite Drawdown Operation
SOS 6c Two Month Lower Granite Drawdown Operation	
SOS 6d Four and One Half Month Lower Granite Drawdown Operation	
SOS 7 Federal Resource Agency Operations	**SOS 9 Settlement Discussion Alternatives**
SOS 7a Coordination Act Report Operation	**SOS 9a Detailed Fishery Operating Plan**
SOS 7b Incidental Take Statement Flow Targets	**SOS 9b Adaptive Management**
SOS 7c NMFS Conservation Recommendations	**SOS 9c Balance Impacts Operation**
	SOS Preferred Alternative

Bold indicates a new or revised SOS alternative with the NMFS and USFWS, agreed to an operation, which was reflected in the 1994–98 Biological Opinion. This operation (SOS 2d) has been modeled for the Final EIS and represents the most "current" practice. SOS 2d also provides a good baseline comparison for the other, more unique alternatives. SOS 2a and 2b from the Draft EIS were eliminated because they are so similar to SOS 2c. SOS 2a is identical to SOS 2c except for the lack of an assumed additional 427 KAF of water from the upper Snake River Basin. This additional water did not cause significant changes to the effects between SOS 2a and 2c. There is no reason to continue to consider an alternative that has impacts essentially equal to another alternative. SOS 2b is also similar to SOS 2c, except it modified operation at Libby for Kootenai River white sturgeon. Such modifications are included in several other alternatives, namely SOS 2d, 9a, 9c, and the Preferred Alternative.

SOS 3a and 3b, included in the Draft EIS, have been dropped from consideration in the Final EIS. Both of these alternatives involved anadromous fish flow augmentation by establishing flow targets based on runoff forecast on the Columbia and Snake Rivers. SOS 3b included additional water from the upper Snake River Basin over what was assumed for SOS 3a. This operation is now incorporated in several new alternatives, including SOS 9a and 9b. Public comment also did not support continued consideration of the SOS 3 alternatives.

SOS 4 originally included 5 options in the Draft EIS. They were similar in operation and impact. In SOS 4a and 4b, the primary feature was the use of Biological Rule Curves for Libby and Hungry Horse reservoirs. SOS 4c also included these rule curves but went further by optimizing the operation of the other storage projects, particularly Grand Coulee and Dworshak. For the Final EIS, the SOR agencies have decided to update the alternative by substituting the IRC for the Biological Rule Curves and by eliminating SOS 4a and 4b. The IRCs are a more recent, acceptable version of minimum elevations for Libby and Hungry Horse. Significant public comment in support of this alternative with IRCs was received. Similar to SOS 2 above, SOS 4a and 4b were not different enough in operation or impacts to warrant continued consideration.

The Natural River (SOS 5) and the Spillway Crest Drawdown (SOS 6) alternatives in the Draft EIS originally included options for 2 months of drawdown to the appropriate pool level and 4 1/2 months of drawdown. The practicality of 2–month drawdowns was questioned during public review, particularly for the natural river. It did not appear that the time involved in drawing down the reservoirs and later refilling them provided the needed consideration for other uses. Flows are restricted to refill the reservoirs at a time when juvenile fall chinook are migrating downstream and various adult species are returning upstream. The 2 1/2 month drawdown strategies (SOS 5a, 6a, and 6c) have been dropped from the Final EIS. However, 2 1/2 month spillway crest drawdown at all four lower Snake projects is still an element in SOS 9c, so the impacts associated with this type of operation are assessed in the Final EIS.

A new option was added to SOS 5, namely SOS 5c. This option includes natural river drawdown of the lower Snake River projects on a permanent, year–round basis. The Corps received comment on this type of alternative during the review of Phase I of the SCS, a reconnaissance assessment of potential physical modifications for the system to enhance fish passage. Many believe the cost for such modification would be less than that required for periodic, temporary drawdowns, which would require specialized facilities to enable the projects to refill and operate at two different pool elevations.

SOS 7 Federal Resource Agencies Operations, which included 3 options in the Draft EIS, has been dropped from the Final EIS and replaced with an alternative now labeled as SOS 9 that also has 3 options. SOS 7a was suggested by the USFWS and represented the State fishery agencies and tribes' recommended operation. Since the issuance of the Draft EIS, this particular operation has been revised and replaced by the DFOP (SOS 9a). The SOR agencies received comment that the DFOP was not evaluated, but should be. Therefore, we have included this alternative exactly as proposed by these agencies; it is SOS 9a. SOS 7b and 7c were suggested by NMFS through the 1993 Biological Opinion. This opinion suggested two sets of flow targets as a way of increasing flow augmentation levels for anadromous fish. The flow targets came from the Incidental Take Statement and the Conservation Recommendation sections of that Biological Opinion. The opinion was judged as arbitrary and capricious as a result of legal action, and these operational alternatives have been replaced with other alternatives that were developed through settlement discussions among the parties to this lawsuit. SOS 7b and 7c have been dropped, but SOS 9b and 9c have been added to represent operations stemming from NMFS or other fishery agencies. In particular, SOS 9b is like DFOP but has reduced flow levels and forgoes drawdowns. It is a modification to DFOP. SOS 9c incorporates elements of operation supported by the State of Idaho in its "Idaho Plan." It includes a 2 1/2–month spillway crest drawdown on the lower Snake River projects and several other elements that attempt to strike a balance among the needs of anadromous fish, resident fish, wildlife and recreation.

Shortly after the alternatives for the Draft EIS were identified, the Nez Perce Tribe suggested an operation that involved drawdown of Lower Granite, significant additional amounts of upper Snake River water, and full pool operation at Dworshak (i.e., Dworswak remains full year round). It was labeled as SOS 8a. Hydroregulation of that operation was completed and provided to the Nez Perce Tribe. No technical response has been received from the Nez Perce Tribe regarding the features or results of this alternative. However, the elements of this operation are generally incorporated in one or more of the other alternatives, or impose requirements on the system or specific projects that are outside the range considered reasonable. Therefore, this alternative has not been carried forward into the Final EIS.

The Preferred Alternative represents operating requirements contained in the 1995 Biological Opinions issued by NMFS and USFWS on operation of the FCRPS. These opinions resulted from ESA consultation conducted during late 1994 and early 1995, which were a direct consequence of the lawsuit and subsequent judgement in *Idaho v. NMFS*. The SOR agencies are now implementing this operating strategy and have concluded that it represents an appropriate balance among the multiple uses of the river. This strategy recognizes the importance of anadromous fish and the need to adjust river flows to benefit the migration of all salmon stocks, as well as the needs of resident fish and wildlife species at storage projects.

4.2 DESCRIPTION OF IMPACTS OF SYSTEM OPERATING STRATEGIES

4.2.1 PRE–ESA OPERATIONS (SOS 1a and SOS 1b) for Upper Columbia River and tributaries

4.2.1.1 Lake Pend Oreille

Description of alternative specific to Lake Pend Oreille

There are no specific operational requirements mentioned in the alternative description for Lake Pend Oreille. A review of the flows and elevations indicates there is little difference in this SOS from current operations. The average annual end–of–month elevations at Albeni Falls Dam since 1984 have been approximately at elevation 2056 feet with fluctuations of approximately 12 feet from minimum end of month elevation to maximum end of month elevation (Figure 4–1). The average annual monthly discharge at Albeni Falls Dam since 1984 has been approximately 2–3 kcfs (Figure 4–2). It appears this alternative results in nearly the same average monthly elevation and elevation fluctuations (see the Technical Exhibit for a complete set of yearly flows and elevations). Therefore, we make the assumption that operations under this SOS are similar to current operations.

Short–term impacts

This alternative does not alter the present operational strategy of Lake Pend Oreille; therefore, kokanee abundance would be expected to continue to decline under this alternative. Using as input the simulated end–of–month water surface elevations and flows, the Lake Pend Oreille kokanee model predicts a spawner index level of approximately

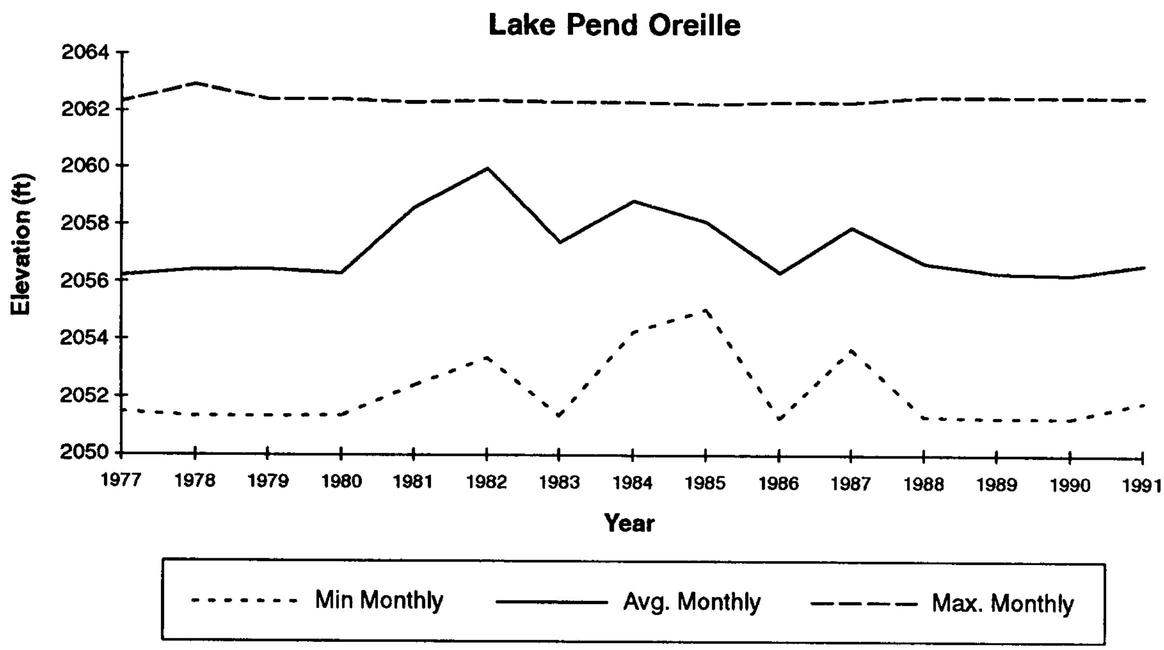


Figure 4–1. Annual summary of monthly elevations based on actual hydrologic data taken at Albeni Falls Dam (1977–1991).

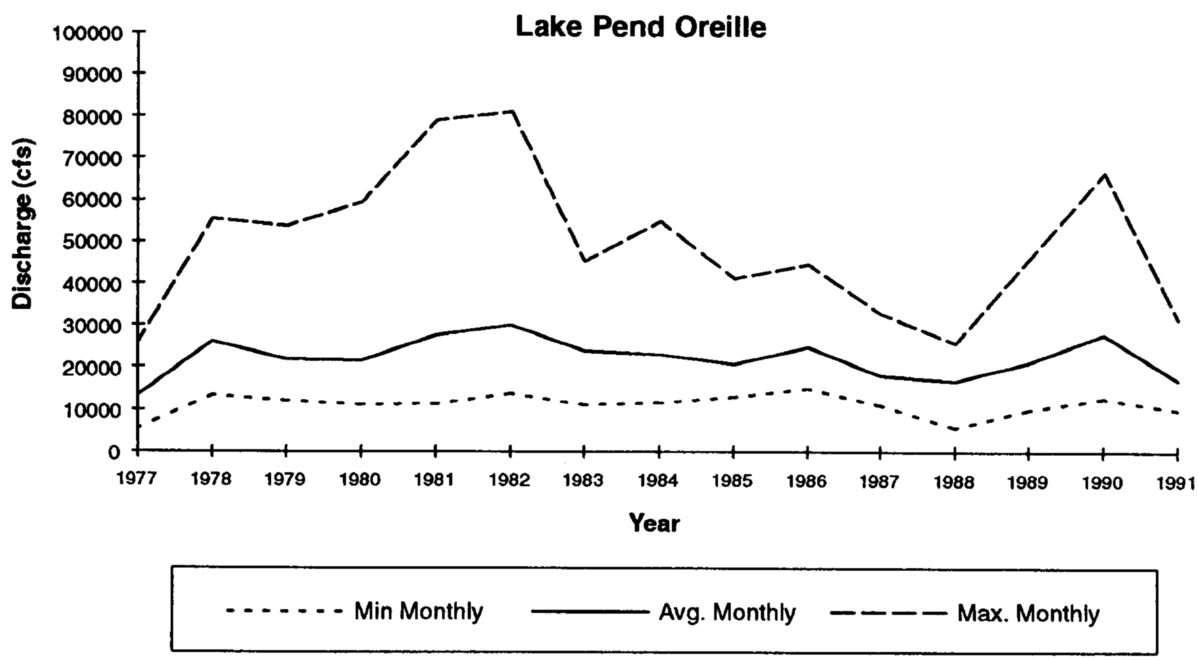


Figure 4–2. Annual summary of monthly discharge based on hydrologic data taken at Albeni Falls Dam (1977–1991).

150,000 kokanee at 2, 4, and 10 year occurrence intervals (Table 4–3; see the Results Exhibit for a complete set of spawner index predictions).

In both cases, the long–term population predictions stabilize at an index level of 150,000. This is misleading and not indicative of the potential long–term impacts to kokanee from this operational strategy, but rather an indication of the limitations in the input data. Two aspects of water management appear to be important in predicting kokanee population fluctuations in Lake Pend Oreille. Lake–shore spawning kokanee are forced to spawn in inferior quality substrate when lake elevations are reduced prior to spawning. We have attempted to account for this in the model by adjusting the amount of habitat available to kokanee spawners based on water surface elevation averaged from September through November (Figure 4–3). Average end of month water surface elevations may not represent actual operating conditions. Second, and probably more important, deep drawdowns in water surface elevation after kokanee have spawned severely reduce egg incubation success and the production of fry. Again, our model attempts tc capture this relationship by reducing the egg to fall–fry survival based on the relationship of ha suitability to lake elevation from November thro May (Figure 4–4). Because the input to the m are end–of–month elevations, significant opera tional variation may be occurring during the mo which would not be represented by end–of–mc elevations. In fact, looking at Figure 4–1 we se that annual average end–of–month elevations e 1983 have remained relatively constant, althoug] is may not necessarily be true if we looked at the fluctuations from November through May each r. Unless input is redefined to include daily eleva s, our model in its present form may not capture t variability in kokanee egg incubation success. N e- theless, it is fair to say that kokanee population Lake Pend Oreille will probably not improve ab existing conditions under this alternative.

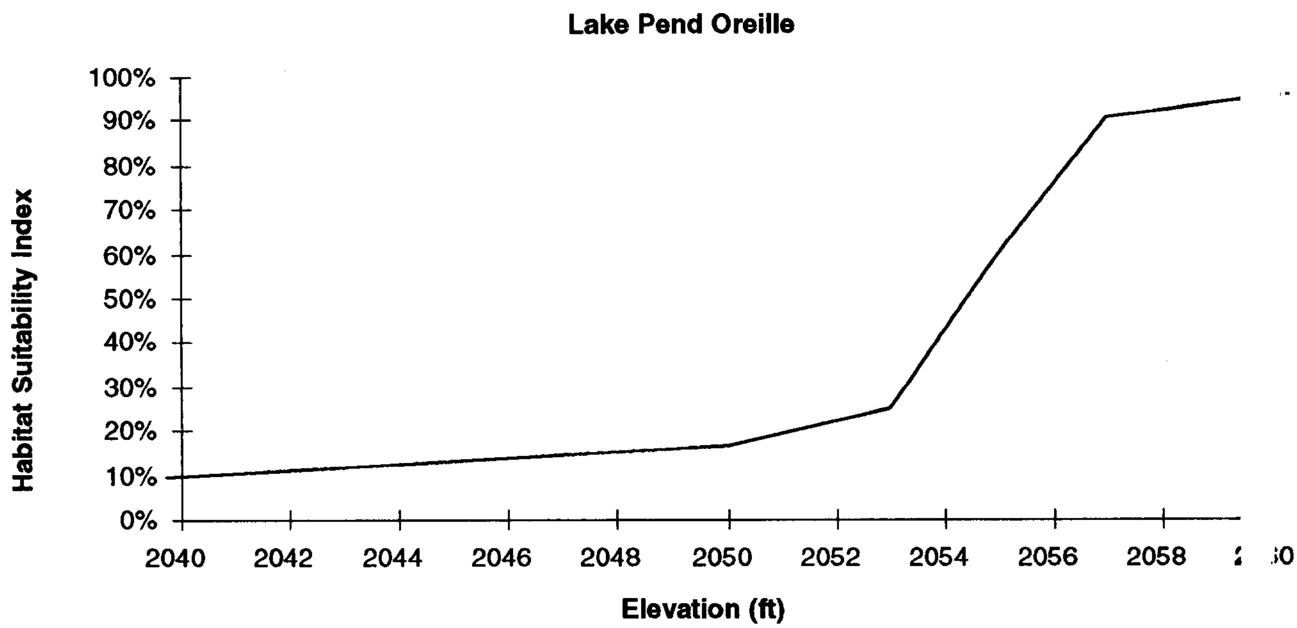


Figure 4–3. Kokanee spawning habitat suitability index values (September – Novemb). The habitat suitability index values represent the relative quality of the spawning habitat at each water surface elevation. This index value was u ed in combination with other habitat suitability index values to estimate the l- ue measures (spawner population index values) for kokanee.

Table 4–3. Value measures for Lake Pend Oreille predicted by the model at occurrence intervals of 2, 4, and 10 years. Value measures represent a compilation of habitat suitability indices that incorporate the physical and biological key variables into a relative index of fish health that ranges between 0 (bad) and 1 (good). Within each species, vertical comparisons can be made by reviewing the value measures for each SOS; higher value measures represent better conditions for resident fish. Horizontal comparisons between species can be misleading because the key variables which comprise the habitat suitability indices which are combined to form the value measures differ between species. Temporal assessments can be made by reviewing the value measures in each occurrence interval. The occurrence intervals were selected from the 50 years of record to represent the effects of each operating strategy within the life span of key resident fish species. Value measures at an occurrence interval of 2 years represent the index of fish health we would expect to occur, on average, every 2 years; the value measure at an occurrence interval of 4 years represents the index of fish health we would expect to see every 4 years, and so on. Section 3.3 of Chapter 3 contains a detailed description of how these values were calculated.

Lake Pend Oreille																		
	Occurrence Interval = 2 years						Occurrence Interval = 4 years						Occurrence Interval = 10 years					
	Min. Egg Incubation	Avg. Spawning	Kokanee	Cutthroat Trout	Warm Water	Bull Trout	Min. Egg Incubation	Avg. Spawning	Kokanee	Cutthroat Trout	Warm Water	Bull Trout	Min. Egg Incubation	Avg. Spawning	Kokanee	Cutthroat Trout	Warm Water	Bull Trout
SOS 1a	0.250	0.525	284385	0.932	0.106	0.104	0.250	0.525	284351	0.932	0.106	0.104	0.250	0.525	284248	0.932	0.105	0.104
SOS 1b	0.250	0.525	284385	0.932	0.106	0.104	0.250	0.525	284351	0.932	0.106	0.104	0.250	0.525	284248	0.932	0.106	0.104
SOS 2c	0.25	0.525	284385	0.933	0.106	0.104	0.25	0.525	284351	0.933	0.106	0.104	0.25	0.525	284248	0.933	0.106	0.104
SOS 2d	0.250	0.525	284385	0.933	0.106	0.104	0.250	0.525	284351	0.933	0.106	0.104	0.250	0.525	284248	0.933	0.106	0.104
SOS 4c	1.000	0.817	283995	1.000	0.293	0.608	0.999	0.817	283722	0.999	0.244	0.551	0.726	0.455	283188	0.921	0.113	0.299
SOS 5b	0.250	0.525	284385	0.932	0.106	0.104	0.250	0.525	284351	0.932	0.106	0.104	0.250	0.525	284248	0.932	0.106	0.104
SOS 5c	0.129	0.250	284385	0.932	0.106	0.104	0.129	0.250	284351	0.932	0.106	0.104	0.129	0.250	284248	0.932	0.106	0.104
SOS 6b	0.250	0.525	284385	0.932	0.106	0.104	0.250	0.525	284351	0.932	0.106	0.104	0.250	0.525	284248	0.932	0.106	0.104
SOS 6d	0.250	0.525	284385	0.932	0.106	0.104	0.250	0.525	284351	0.932	0.106	0.104	0.250	0.525	284248	0.932	0.106	0.104
SOS 9a	0.230	0.875	282204	0.965	0.168	0.128	0.208	0.667	279706	0.819	0.053	0.079	0.205	0.624	277420	0.537	0.002	0.056
SOS 9b	0.231	0.887	285579	0.959	0.319	0.176	0.228	0.887	284825	0.808	0.137	0.173	0.209	0.887	284122	0.721	0.085	0.159
SOS 9c	0.209	0.889	286786	0.933	0.249	0.175	0.209	0.889	286751	0.933	0.249	0.175	0.209	0.889	286649	0.933	0.249	0.175
SOS PA	0.250	0.525	284391	0.933	0.106	0.104	0.250	0.525	284356	0.933	0.106	0.104	0.250	0.525	284252	0.933	0.106	0.104

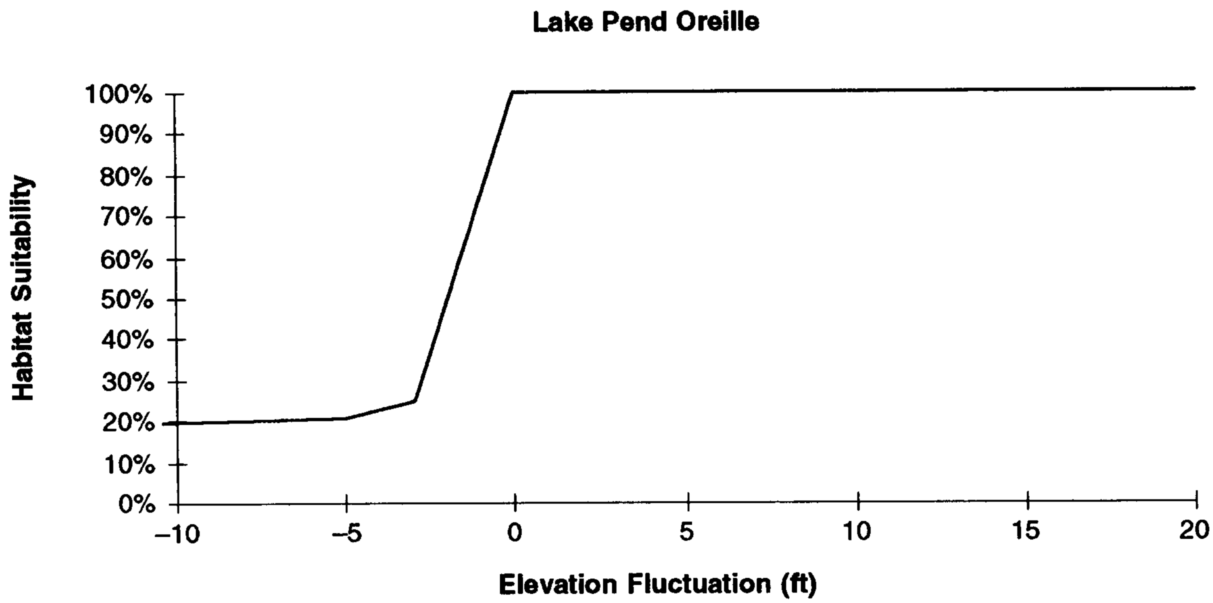


Figure 4–4. Egg to fry survival habitat suitability index values (November – May). The habitat suitability index values represent the relative quality of kokanee incubation habitat at varying degrees of water surface elevation fluctuations from full pool (0). This index value was used in combination with other habitat suitability index values to estimate the value measures (spawner population index values) for kokanee.

The value measures at 2, 4, and 10 year occurrence intervals for bull trout and cutthroat trout are shown in Table 4–3 (see the Results Exhibit for additional results). Again, the similarity in index values from each occurrence interval suggests the temporal scale in the model input values is not sensitive enough to capture all the impacts to these species. Bull trout and rainbow trout (not modeled), both predators which feed on kokanee, would be expected to decline with the declining kokanee population. The relative low values for bull trout associated with this alternative agree with this assumption. Cutthroat trout would also be expected to decline because access to spawning tributaries in the spring would be blocked by low reservoir elevation, although the impact to this species may not be as severe as the impact to kokanee and bull trout.

The value measures at 2, 4, and 10 year occurrence intervals for warmwater fish are presented in Table 4–3 (see the Results Exhibit for additional results). Warmwater fisheries habitat, including largemouth bass, is degraded under present operational scenarios. Elevation fluctuations within the lake reduce spawning success, rearing habitat availability, and food production. About 25 miles of the Pend Oreille River upstream of Albeni Falls Dam remains out of production for warmwater species because of the elevation fluctuations. It is not expected this alternative would change operational conditions which impact warmwater species; therefore, this alternative would not be favorable.

Flow/habitat relationships are unavailable for the Pend Oreille River below Albeni Falls Dam, nor are any short–term water fluctuations discernible from available data. It is possible that operations under SOS 1 would dewater shallow habitat stranding or killing fish and food organisms.

Long–term impacts

Lake Pend Oreille is Idaho's largest natural lake and attracts recreationalists from all over Idaho and the rest of the northwest. Fisheries for kokanee, rainbow trout, and bull trout are extremely popular, although these fisheries have been declining over the last 40 years. This alternative is not expected to change this decline and would be expected to contribute to the continual deterioration of these important fisheries.

Cumulative impacts

Fluctuating water levels reduce access to spawning tributaries, eliminate quality shoreline spawning habitat for kokanee, which reduces kokanee and other salmonid fry production. With a reduction in the prey base, higher order predators such as rainbow trout, bull trout, and bass would also decline. Because many of these impacts occur at a time step less than one month, the resident fish life history models are not able to accurately depict this impact given monthly hydroregulator data as input. However, since the overall operation of this alternative is not different than that under present conditions, we would not expect this alternative to mitigate present impacts.

Unavoidable impacts

Unavoidable impacts to all fisheries in Lake Pend Oreille will occur under this operational strategy. These would include a continual decline in the reproductive and incubation success of nearly all resident fish species.

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain higher and stable reservoir elevations.

4.2.1.2 Box Canyon Reservoir

Description of alternatives specific to Box Canyon Reservoir

SOS 1a represents operations from 1983 through the 1990–91 operating year, influenced by Northwest Power Act. SOS 1b represents how the system would operate without the Water Budget and related operations to benefit anadromous fish. Short–term operations would be conducted to meet power demands while satisfying nonpower requirements.

Short and long–term, cumulative, and unavoidable impacts

Every one of these SOS alternatives is very similar in their outflow during the months of May and June. This is the critical time for bass spawning. SOS 1a, 1b, 2d, 5b, 6b and 6d would allow releases from Albeni Falls to rise from nearly 47,000 cfs in May to a peak of 59,000 cfs in June. Minimum outflow from Albeni Falls for bass productions would be at 40,000 cfs. Maximum outflow for bass production would be at 45,000 cfs. Fluctuating water levels in reservoirs can adversely affect spawning success of largemouth bass that rely on shallow water or nearshore areas for nest construction. Rapidly receding water levels may also result in desertion of nest, poor egg survival, and disrupted spawning (Ploskey 1986).

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations. Mitigation may also include supplementation in a largemouth bass hatchery.

4.2.1.3 Hungry Horse Reservoir

Description of alternative specific to Hungry Horse Reservoir

This alternative, based on operational years 1983 through 1990–91, results in an average reservoir drawdown greater than the observed average historic drawdown to 3,477.4 feet msl (82.6 feet below full pool). The frequency of refill failure is greater than occurred during the historic record since 1954 when the reservoir first filled. This "base case" is worse for biological production in the reservoir than historic operation practices. The two scenarios differ only slightly. Alternative 1b is worse for the reservoir biology than 1a during low water years.

Short–term impacts

Failure to refill the reservoir in a given year impacts biological production (Table 4–4). This alternative causes refill failure in about 40 percent of all years. During a deep drawdown, aquatic resources are confined within a diminished environment. This results in an overall loss in aquatic production and an increase in potential for high predation rates on juvenile fish as they become concentrated in a smaller pool.

Production of phytoplankton (suspended algae), the base of the aquatic food web, is reduced when the reservoir surface area shrinks during the peak growing season from June through September. Production of zooplankton (tiny water fleas), an important food supply for young and older fish during the winter, varies proportionally with phytoplankton production. In addition, downstream loss of zooplankton through the dam is increased as the surface approaches the outlet depth and reservoir water is replaced at a faster rate; the result is less food for fish.

Reduction in surface area results in less food during summer and fall as fewer insects from the surrounding (and more distant with drawdown) shoreline vegetation are deposited on the smaller surface. Terrestrial insects presently provide the greatest biomass consumed by fish during their peak growth period. Conversely, food availability is maximized when the reservoir fills and remains near full pool during the months of peak insect activity.

Deep drawdown exposes vast expanses of reservoir bottom to desiccation and freezing which kills aquatic insect larvae. Aquatic insects provide the main food supply for insect eating fish during spring and early summer. Cutthroat trout growth in Hungry Horse Reservoir would be affected by the reduced volume of water at optimal temperatures and the reduced food availability (Table 4–4).

Long–term impacts

Reservoir. The increased frequency of deep drawdown and refill failure would cause a further decline in the health of the reservoir fishery as compared to historic conditions. Recovery of the aquatic insect community takes at least two years after a single, deep drawdown event. Frequent deep drawdowns would decrease the spring food supply for insect–eating fish (e.g. westslope cutthroat trout, mountain whitefish) during about 80 percent of all years. Decreased spring growth combined with poor fall growth due to frequent refill failure would decrease the maximum attainable size of fish.

Field sampling has shown evidence of size selective mortality in juvenile westslope cutthroat trout. Reduced growth in young trout has been linked to reduced survival, increased losses to predation, decreased fecundity and poor reproductive success. Although trout populations can recover with time after adverse operational events, frequent deep drawdowns and refill failures strongly influence fisheries health. Genetically pure westslope cutthroat trout have been reduced to less than ten percent of their historic range, making Hungry Horse populations an important genetic resource.

Impacts on prey availability for bull trout, leading to lower survival and growth, ultimately result in decreased bull trout growth and abundance in the reservoir. Although fish concentrations caused by reduced reservoir volumes benefit bull trout initially, the effect is short lived. When the reservoir ultimately refills, prey species redistribute in the larger pool, at lower prey densities. Hungry Horse

Table 4–4. Examination of trophic responses caused by SOS alternatives at Hungry Horse Reservoir. The 50 year record was subdivided into quintiles based on water availability, drought (00) to flood (80). Gross PP is primary production in metric tons of carbon fixed. PP loss is new production lost through the dam turbines. Zooplankton is reported only for Daphnia production and loss. Terrestrial insect deposition of flying ants (Hymenoptera [Hymen]) is represented as an unscaled index of the percent of total possible deposition. Benthic production is metric tons of emergent insects (Chironomidae). Westslope cutthroat (WCT) growth (reported as weight (WT) in grams) was calculated based on water temperature and food availability for ages III, IV and V. Westslope cutthroat trout growth is also reported for the Flathead River for age III (WCT III FHR).

Group	Gross PP	PP Loss	Gross Daphnia	Daphnia Loss	Hymen % Max	Benthic Prod	WCT III WT	WCT IV WT	WCT V WT	Min Elev.	Min Vol.	Refill Elev.	WCT III FHR
SOS 1a													
%ile = 80	2138.6	10.3	140.2	51.8	98.7	139.4	234	386	453	3448.2	1452.1	3560.0	193
%ile = 60	2241.7	12.4	147.9	68.0	97.4	170.1	261	439	518	3475.2	1819.1	3558.5	200
%ile = 40	2045.8	8.4	127.1	57.2	93.9	131.8	216	352	412	3451.8	1496.4	3550.9	198
%ile = 20	2057.2	11.9	125.1	75.1	89.2	149.5	222	365	427	3463.0	1643.7	3544.7	207
%ile = 00	1589.9	17.7	77.3	92.6	59.3	127.8	154	235	270	3426.9	1206.7	3492.8	225
SOS 1b													
%ile = 80	2133.2	9.7	139.6	50.9	98.5	139.4	233	385	452	3448.2	1452.1	3560.0	199
%ile = 60	2245.9	12.5	148.3	65.8	97.1	170.1	261	439	518	3473.9	1799.5	3558.3	201
%ile = 40	2028.0	8.2	124.4	57.3	92.4	133.0	213	347	406	3447.6	1444.3	3548.1	202
%ile = 20	2042.0	11.4	123.7	75.3	89.3	145.1	219	358	418	3462.1	1631.9	3545.1	206
%ile = 00	1422.8	16.9	65.7	98.2	54.0	94.3	127	187	212	3394.7	892.9	3480.8	230
SOS 2c													
%ile = 80	2170.1	11.2	142.2	60.7	98.4	165.3	253	423	499	3462.1	1631.7	3560.0	194
%ile = 60	2224.9	12.2	145.5	66.5	96.8	176.0	262	442	522	3475.9	1828.9	3557.0	197
%ile = 40	2024.2	9.8	125.1	54.3	93.3	136.9	216	353	413	3454.8	1534.7	3550.0	198
%ile = 20	2064.6	12.5	125.4	73.6	88.9	152.4	225	369	432	3466.5	1692.9	3545.4	212
%ile = 00	1725.9	19.9	88.2	98.2	63.2	145.2	173	272	314	3444.7	1410.0	3506.0	219

Table 4–4. Examination of trophic responses caused by SOS alternatives at Hungry Horse Reservoir. The 50 year record was subdivided into quintiles based on water availability, drought (00) to flood (80). Gross PP is primary production in metric tons of carbon fixed. PP loss is new production lost through the dam turbines. Zooplankton is reported only for Daphnia production and loss. Terrestrial insect deposition of flying ants (Hymenoptera [Hymen]) is represented as an unscaled index of the percent of total possible deposition. Benthic production is metric tons of emergent insects (Chironomidae). Westslope cutthroat (WCT) growth (reported as weight (WT) in grams) was calculated based on water temperature and food availability for ages III, IV and V. Westslope cutthroat trout growth is also reported for the Flathead River for age III (WCT III FHR). – CONT

Group	Gross PP	PP Loss	Gross Daphnia	Daphnia Loss	Hymen % Max	Benthic Prod	WCT III WT	WCT IV WT	WCT V WT	Min Elev.	Min Vol.	Refill Elev.	WCT III FHR
SOS 2d													
%ile = 80	2141.1	11.5	139.3	58.7	97.6	158.7	244.1	407.0	478.7	3456.4	1559.7	3558.1	193.2
%ile = 60	2233.0	12.1	146.8	68.9	97.3	171.3	261.0	439.6	518.7	3472.3	1781.6	3559.3	202.3
%ile = 40	2086.0	10.0	132.9	59.9	94.2	137.6	227.9	377.0	442.2	3448.7	1569.0	3552.3	205.8
%ile = 20	2030.1	15.1	123.4	81.1	85.5	147.8	222.2	366.0	429.0	3455.6	1632.5	3539.6	209.0
%ile = 00	1770.0	18.6	96.5	90.0	66.8	121.6	172.9	272.9	315.9	3432.9	1350.5	3513.1	221.2
SOS 4c/9c													
%ile = 80	2326.5	12.6	159.0	66.9	99.9	181.1	280.2	477.2	564.6	3473.6	1799.1	3560.1	205.5
%ile = 60	2372.5	14.1	162.1	70.0	99.8	192.1	291.1	499.0	591.3	3490.9	2075.5	3560.1	193.7
%ile = 40	2385.3	14.0	162.6	66.9	99.5	184.6	285.0	486.5	576.0	3497.3	2181.6	3560.0	198.9
%ile = 20	2391.4	14.0	161.0	65.2	98.4	179.5	281.3	479.4	567.2	3500.7	2240.5	3558.5	201.7
%ile = 00	2381.0	12.2	160.2	58.9	97.3	154.5	257.9	433.6	511.1	3505.8	2328.9	3556.9	221.8
SOS 5c													
%ile = 80	2125.4	10.6	139.1	53.0	98.6	140.9	233.3	385.8	452.6	3448.0	1454.0	3559.9	195.4
%ile = 60	2219.3	10.6	146.5	60.5	97.9	161.0	253.2	424.3	499.6	3468.2	1723.4	3559.5	199.9
%ile = 40	2077.3	9.7	132.3	58.1	94.2	139.1	229.0	379.0	445.1	3448.9	1581.6	3551.8	204.6
%ile = 20	1963.1	13.7	119.2	79.9	84.3	135.1	211.3	345.9	404.8	3445.2	1518.0	3535.8	204.3
%ile = 00	1686.0	17.7	90.1	88.5	64.2	113.4	163.8	257.0	297.2	3420.1	1240.8	3502.7	228.7

Table 4–4. Examination of trophic responses caused by SOS alternatives at Hungry Horse Reservoir. The 50 year record was subdivided into quintiles based on water availability, drought (00) to flood (80). Gross PP is primary production in metric tons of carbon fixed. PP loss is new production lost through the dam turbines. Zooplankton is reported only for Daphnia production and loss. Terrestrial insect deposition of flying ants (Hymenoptera [Hymen]) is represented as an unscaled index of the percent of total possible deposition. Benthic production is metric tons of emergent insects (Chironomidae). Westslope cutthroat (WCT) growth (reported as weight (WT) in grams) was calculated based on water temperature and food availability for ages III, IV and V. Westslope cutthroat trout growth is also reported for the Flathead River for age III (WCT III FHR). – CONT

Group	Gross PP	PP Loss	Gross Daphnia	Daphnia Loss	Hymen % Max	Benthic Prod	WCT III WT	WCT IV WT	WCT V WT	Min Elev.	Min Vol.	Refill Elev.	WCT III FHR
SOS 5b/6b/6d													
%ile = 80	2137.4	10.4	139.9	50.7	98.6	140.9	234	387	454	3448.9	1460.1	3560.0	193
%ile = 60	2224.2	11.8	146.3	64.8	97.4	161.6	254	425	501	3469.8	1738.1	3558.4	194
%ile = 40	2025.4	8.4	124.9	52.0	93.6	135,2	216	352	411	3451.8	1496.4	3549.2	196
%ile = 20	2045.5	12.0	123.9	73.3	89.0	149.8	221	362	424	3463.0	1643.7	3543.9	206
%ile = 00	1589.9	17.7	77.3	92.5	59.3	127.8	154	235	270	3426.9	1206.7	3492.8	225
SOS 9a													
%ile = 80	1936.4	16.1	117.0	67.8	87.6	165.0	225.6	371.7	435.8	3444.9	1459.0	3540.8	197.5
%ile = 60	2032.0	18.5	121.6	78.4	83.3	206.2	252.9	424.5	500.1	3473.5	1813.8	3536.4	191.3
%ile = 40	1814.3	18.1	100.8	82.5	73.1	159.5	205.1	333.8	389.8	3434.3	1399.3	3524.2	200.2
%ile = 20	1846.7	20.4	103.2	92.3	70.3	152.3	204.5	332.9	389.3	3435.2	1438.8	3525.4	206.0
%ile = 00	1264.3	29.4	55.4	117.7	38.0	78.6	110.8	160.1	180.5	3360.9	662.7	3469.5	207.1
SOS 9b													
%ile = 80	2238.6	15.2	147.8	64.1	97.4	193.8	277.9	472.5	559.0	3476.1	1840.8	3559.3	188.3
%ile = 60	2266.8	16.7	147.0	69.0	93.5	211.4	287.2	490.8	581.4	3487.9	2023.9	3552.3	186.6
%ile = 40	2312.1	18.9	150.4	76.3	93.3	221.9	299.1	514.7	610.8	3499.6	2217.2	3556.4	193.9
%ile = 20	2292.8	20.0	146.7	79.3	90.4	213.3	287.3	491.1	581.6	3502.7	2275.9	3551.3	198.6
%ile = 00	2269.9	18.7	142.9	70.5	89.7	196.3	269.1	455.8	538.3	3501.9	2265.1	3545.9	213.4

Table 4–4. Examination of trophic responses caused by SOS alternatives at Hungry Horse Reservoir. The 50 year record was subdivided into quintiles based on water availability, drought (00) to flood (80). Gross PP is primary production in metric tons of carbon fixed. PP loss is new production lost through the dam turbines. Zooplankton is reported only for Daphnia production and loss. Terrestrial insect deposition of flying ants (Hymenoptera [Hymen]) is represented as an unscaled index of the percent of total possible deposition. Benthic production is metric tons of emergent insects (Chironomidae). Westslope cutthroat (WCT) growth (reported as weight (WT) in grams) was calculated based on water temperature and food availability for ages III, IV and V. Westslope cutthroat trout growth is also reported for the Flathead River for age III (WCT III FHR). – CONT

Group	Gross PP	PP Loss	Gross Daphnia	Daphnia Loss	Hymen % Max	Benthic Prod	WCT III WT	WCT IV WT	WCT V WT	Min Elev.	Min Vol.	Refill Elev.	WCT III FHR
SOS PA													
%ile = 80	2215.8	16.5	143.7	74.2	93.4	206.0	281.3	479.4	567.4	3475.8	1836.3	3559.0	190.4
%ile = 60	2268.8	17.8	147.2	73.8	92.9	213.1	289.8	496.1	587.8	3488.1	2027.9	3557.1	188.8
%ile = 40	2300.3	20.0	148.5	79.8	91.9	227.4	300.9	517.9	614.7	3499.6	2217.2	3557.1	191.5
%ile = 20	2297.1	20.2	146.8	75.7	91.0	216.7	290.1	496.7	588.7	3503.6	2292.2	3554.0	196.6
%ile = 00	2296.6	19.3	146.3	69.7	91.0	198.4	274.6	466.4	551.6	3508.6	2387.2	3552.7	213.4

provides one of two remaining fishable bull trout populations in Montana. The apparently stable population is one of the strongest anywhere, increasing the importance of the remaining population as a genetic reserve for the species. Bull trout were petitioned for listing under ESA. The USFWS determined that listing is warranted and a status review is scheduled for completion in October 1994.

Long–term effects of large reservoir fluctuations have affected species assemblages and relative abundance of species in the aquatic community. Aquatic insect diversity has been reduced. Now chironomidae (midges) comprise nearly the entire assemblage. Stoneflies, mayflies, caddis flies and other more desirable fish food organisms are rare in the reservoir pool. Northern squawfish, an important predator on young fish, have benefited from impoundment and are now the most abundant species in the reservoir.

Flathead River. Spring discharges are much reduced as compared to natural spring conditions under this alternative. Spring flows provide the cue for spawning migrants, and they resort the river sediments and thus maintain channel integrity. Natural, unregulated discharges from the North and Middle forks of the Flathead River partially mitigate the effects of flow regulation. However, flow fluctuations from Hungry Horse Dam have increased sediment inputs to the Flathead River as streambanks de–stabilize and collapse. Modified Flathead Lake elevations caused by Kerr Dam operation affect Flathead River stage and velocity for as much as 22 river miles upstream from the inlet to Flathead Lake. Reduced velocities in the semi–impounded reach of the river allow fine sediments to accumulate, filling interstices between river cobble. Sediment buildup damages insect habitat and juvenile fish security cover. This problem could be partially mitigated by increasing river velocities during spring run–off. Higher flows at the correct time would flush fine sediments from the gravels, improving conditions. Alternatives 1A and 1B, however, would perpetuate and exacerbate the sedimentation problem.

Peaking and load factoring operations intermittently inundate and dewater the river margins. This "varial" zone is nearly devoid of insect life and is unproductive. When recolonization of aquatic life occurs, a rapid flow reduction can cause widespread stranding and desiccation of insects, small fish and fish eggs. Stable flows, conversely, promote biological production. Intermittent high discharges can scour portions of the main channel, dislodging insects and their habitat. Annual flood events performed the same function, although conditions became stable for the remainder of the year. Frequent scour events, however, limit production in the zone protected by minimum flow requirements.

Cumulative and unavoidable impacts

Seventy–seven miles of low gradient river and tributaries were permanently lost when the reservoir first filled. Tributary segments above full pool elevation were further limited by man–caused barriers to fish passage at road crossings around the reservoir. Recruitment of juvenile fish to the reservoir has been reduced by the elimination of spawning and rearing habitat. Growth and survival of young fish is further influenced upon emigration from their natal tributaries into the fluctuating reservoir. Recovery of lost habitat area is only partially mitigatable. The reduction in juvenile recruitment and suitable habitat will continue to limit tributary spawning by adfluvial species.

The lack of temperature control facilities at Hungry Horse Dam allows rapid fluctuations in the Flathead River, creating shock to fish and prey organisms. Furthermore, water is released for extended periods from deeper strata in the reservoir, and is of a temperature below that required for insect production and for normal metabolism of trout in the growing season. Thus, trout growth is suboptimal.

Northern squawfish have apparently benefited from impoundment. Although native to the river system, this species has disproportionally expanded their abundance. Predation by northern squawfish contributes to significant losses of juvenile trout and whitefish.

Mitigation

An ongoing mitigation program for the construction and operation of Hungry Horse Dam began in 1992. The loss statement and mitigation criteria assumed that reservoir operation would not change from historic conditions. Additional mitigation is being negotiated for excessive drawdowns in recent years. This alternative, if selected, would necessitate additional mitigative actions and reduce the effectiveness of mitigation actions taken to date.

Implementation of the Hungry Horse mitigation plan involves habitat enhancement, fish passage improvement, fisheries improvements in associated offsite areas, hatchery supplementation and monitoring. Measures directed at the reservoir basin will include: fish passage at human–caused barriers, reconstruction of spawning and rearing areas to increase natural recruitment of juvenile fish and shoreline revegetation. Options to improve conditions in the reservoir are limited unless operational limits can be enforced.

The primary mitigation objective for the Flathead River is the installation and operation of a selective withdrawal structure on Hungry Horse Dam to control discharge temperatures. Natural temperatures can be mimicked with minimal effects on power generation. Rapid thermal fluctuations and long–term cooling effects can be greatly reduced through the use of selective withdrawal, benefiting fish growth and aquatic insect production. Flow fluctuation should be reduced to promote biological production in the varial zone downstream of Hungry Horse Dam. Selective withdrawal was partially funded in 1993. Contracts for construction will be let in spring 1994.

4.2.1.4 Lake Koocanusa

Description of alternative specific to Lake Koocanusa

This alternative, based on operational years 1983 through 1990–91, results in an average reservoir drawdown greater than the observed average historic drawdown to 2,342.5 feet (116.5 feet below full pool). The frequency of refill failure is greater than occurred during the historic record since 1974 when the reservoir first filled. This "base case" is worse for biological production than historic operations. The two scenarios differ only slightly. Alternative 1b is worse for the reservoir biology than 1a during low water years.

Short–term impacts

Deep drawdowns and failure to refill the reservoir in a given year impacts biological production (Table 4–5). This alternative causes refill failure in about 25 percent of all years. The depth of refill failure is extreme ten percent of the time. The reservoir falls short of refill by over 70 feet during some years. The biological effects of refill failure are similar to those of Hungry Horse Reservoir, resulting in lost aquatic production and lost terrestrial insect production.

Kokanee growth is highly dependent on population density; growth declines as densities increase. Growth also responds to the volume of optimal water temperature and the availability of their primary food item, zooplankton. As the reservoir volume shrinks, phytoplankton (suspended algae) production diminishes, which in turn reduces zooplankton production. The combined effects of reduced food availability and increased fish density on kokanee growth is magnified by refill failure during the warm months of peak biological activity.

Insect–eating species, including cutthroat trout, rainbow trout, and mountain whitefish, are impacted by the dewatering and desiccation of aquatic insect larvae during reservoir drawdown. Refill failure results in a smaller surface area, with pool margins further from terrestrial vegetation which is the source for terrestrial insect deposition, thus limiting the summer and fall food supply. Aquatic insect production is temporarily enhanced by reservoir refill failure. Refill failure brings warm water layers in contact with zones of higher larval densities, enhancing aquatic insect emergence. These benefits to food availability are short–lived. Future aquatic insect production is damaged. The net result is slower annual growth in gamefish and prey species.

Table 4–5. Examination of trophic responses caused by SOS alternatives at Lake Koocanusa. The 50 year record was subdivided into quintiles based on water availability, drought (00) to flood (80). Gross PP is primary production in metric tons of carbon fixed. PP loss is new production lost through the dam turbines. Zooplankton (Zoop) is reported as production and loss for all genera. Terrestrial insect deposition of flying ants (Hymenoptera [Hymen]) is represented as an unscaled index of the percent of total possible deposition. Benthic production is metric tons of emergent insects (Chironomidae). Kokanee salmon growth (reported as weight [WT] in grams) was based on water temperature and food availability for ages I+ and II+.

Group	Gross PP	PP Loss	Gross Zoop	Hymen % Max	Benthic Prod	Kokanee WT I+	Kokanee WT II+	Min Elev.	Min Vol.	Refill Elev.
SOS 1a										
%ile=80	11503.7	46.7	1314.7	99.1	178.1	221	582	2296.2	1028.1	2458.3
%ile=60	11525.7	36.8	1318.3	99.4	188.7	223	590	2301.5	1115.4	2459.0
%ile=40	11257.5	27.1	1288.7	98.9	228.3	213	550	2329.5	1647.0	2459.0
%ile=20	12206.5	36.5	1396.5	96.9	330.2	233	628	2370.7	2621.9	2455.1
%ile=00	10796.6	32.1	1235.2	82.5	262.9	199	498	2352.1	2154.1	2425.5
SOS 1b/6b/6d										
%ile=80	11483.6	48.1	1312.2	99.1	179.6	222	588	2296.2	1028.1	2458.2
%ile=60	11413.3	38.0	1305.3	99.3	183.7	222	587	2301.5	1115.4	2459.0
%ile=40	11238.8	28.1	1286.4	98.7	228.5	213	553	2328.9	1634.2	2459.0
%ile=20	12020.1	37.5	1375.0	96.3	320.5	229	614	2365.1	2476.4	2453.7
%ile=00	10346.5	33.6	1183.4	81.4	237.2	190	465	2336.4	1796.5	2423.3
SOS 2c										
%ile=80	11539.6	49.0	1318.5	99.1	205.4	223	591	2297.7	1051.1	2458.6
%ile=60	11579.9	38.4	1324.4	99.3	215.7	224	593	2311.0	1282.7	2459.0
%ile=40	11476.1	34.7	1312.9	98.7	253.2	227	605	2322.8	1510.9	2458.0
%ile=20	12141.4	33.2	1389.4	97.6	318.1	231	624	2359.4	2331.6	2455.8
%ile=00	11661.1	33.4	1334.3	88.2	317.8	223	593	2370.1	2606.2	2437.1
SOS 2d										
%ile=80	1165.1	48.4	1331.4	99.1	207.1	224.5	597.0	2307.2	1231.3	2459.0
%ile=60	11716.6	38.7	1340.0	98.5	213.9	227.7	609.4	2315.6	1380.3	2457.8
%ile=40	11330.4	36.5	1296.0	97.5	264.1	221.3	586.4	2326.7	1660.9	2455.6
%ile=20	12016.1	36.1	1374.7	95.3	299.0	230.8	622.1	2353.4	2247.7	2455.5
%ile=00	11293.3	34.8	1291.9	84.9	301.2	219.2	579.4	2350.5	2222.0	2438.6
SOS 4c										
%ile=80	12352.4	53.2	1411.3	99.5	345.4	237.6	649.6	2348.1	2069.7	2458.9
%ile=60	12360.7	45.5	1413.2	96.8	341.2	237.3	647.9	2355.4	2258.1	2455.8
%ile=40	12530.2	43.8	1432.8	95.6	352.5	242.1	667.1	2369.2	2607.6	2451.1
%ile=20	13088.9	34.9	1498.0	99.0	366.6	254.4	716.7	2386.3	3064.7	2456.3
%ile=00	13104.1	24.0	1500.9	99.2	370.4	256.2	723.6	2394.2	3292.7	2458.0

Table 4–5. Examination of trophic responses caused by SOS alternatives at Lake Koocanusa – CONT

Group	Gross PP	PP Loss	Gross Zoop	Hymen % Max	Benthic Prod	Kokanee WT I+	Kokanee WT II+	Min Elev.	Min Vol.	Refill Elev.
SOS 5b										
%ile=80	11499.5	46.6	1314.2	99.1	177.3	221	581	2296.2	1028.1	2458.3
%ile=60	11461.7	36.6	1311.0	99.4	179.1	222	587	2296.6	1034.2	2459.0
%ile=40	11241.0	33.1	1286.1	98.8	235.0	219	574	2316.2	1381.4	2458.3
%ile=20	11939.1	35.1	1366.0	96.7	ND	227	605	2354.3	2208.5	2453.6
%ile=00	10791.7	32.8	1234.6	82.5	263.4	198	496	2351.6	2141.5	2425.5
SOS 5c										
%ile=80	11820.0	48.3	1328.1	99.5	193.2	224.3	598.8	2297.8	1083.7	2459.0
%ile=60	11852.7	38.4	1333.0	98.8	182.8	228.2	803.7	2301.8	1128.5	2457.9
%ile=40	11329.7	33.3	1298.3	98.7	231.5	221.1	584.1	2315.0	1381.9	2458.5
%ile=20	12029.2	34.2	1378.4	96.5	300.7	233.0	830.5	2353.8	2238.8	2454.3
%ile=00	11053.9	33.3	1284.8	81.8	284.1	213.8	558.8	2344.8	2045.2	2430.1
SOS 9a										
%ile=80	10710.5	48.8	1223.7	89.3	222.7	200.3	504.3	2311.9	1326.4	2443.8
%ile=60	9920.7	48.2	1133.1	75.5	247.7	185.2	449.0	2310.8	1307.9	2423.8
%ile=40	9491.3	47.2	1083.7	70.8	259.3	173.7	408.0	2323.2	1582.2	2410.4
%ile=20	10611.0	52.2	1211.8	54.5	384.7	200.1	508.8	2357.9	2351.0	2410.8
%ile=00	8885.1	48.8	1011.7	44.7	370.0	185.1	384.2	2323.9	1809.4	2378.8
SOS 9b										
%ile=80	11880.8	45.0	1335.2	97.1	238.4	225.5	800.5	2313.8	1382.3	2455.4
%ile=60	11580.9	38.8	1324.5	94.0	255.3	221.9	587.0	2319.4	1485.4	2448.4
%ile=40	11852.2	38.8	1332.8	92.4	288.9	222.5	589.7	2334.8	1817.2	2444.5
%ile=20	12238.7	38.8	1399.7	90.9	343.4	233.8	832.8	2370.0	2857.8	2442.2
%ile=00	12804.9	33.0	1442.8	89.7	386.3	243.2	871.7	2395.1	3323.7	2438.4
SOS 9c										
%ile=80	12388.5	53.5	1412.9	99.5	347.8	238.2	851.1	2348.2	2071.9	2458.9
%ile=60	12358.2	45.8	1412.8	98.7	341.2	237.0	848.5	2355.7	2288.8	2455.8
%ile=40	12500.7	43.5	1429.5	95.8	347.5	240.8	882.2	2389.3	2811.2	2451.1
%ile=20	13088.9	34.9	1498.0	99.0	388.8	254.4	718.7	2388.3	3084.7	2458.3
%ile=00	13104.1	24.0	1501.0	99.2	370.4	258.2	723.8	2394.2	3292.7	2458.0
SOS PA										
%ile=80	11418.2	48.2	1304.7	94.8	228.9	218.0	583.9	2310.2	1301.8	2452.8
%ile=60	11040.8	37.7	1282.8	91.3	281.8	207.9	533.4	2315.8	1401.3	2442.9
%ile=40	11078.3	40.0	1288.4	89.3	289.5	208.0	534.5	2335.0	1823.3	2441.8
%ile=20	·12041.2	38.4	1377.4	88.4	359.3	231.5	625.4	2389.3	2845.7	2438.2
%ile=00	12139.9	33.1	1389.2	88.3	370.3	232.0	828.7	2393.1	3289.0	2432.1

Long–term impacts

Reservoir. The aquatic insect community contains species having life cycles from five weeks to three years. One extreme drawdown event can limit the spring food supply for at least two years.

Long–term effects of reservoir fluctuation have resulted in shifts in the species assemblage. Aquatic insect diversity has been reduced. Chironomidae (midges) now compose nearly the entire aquatic insect assemblage. Stoneflies, mayflies, caddis flies and other more desirable fish food organisms, are rare in the reservoir pool.

Long–term monitoring has shown that rainbow, cutthroat and bull trout have stabilized at low populations in the reservoir. Growth impacts have been linked to decreased survival, poor reproductive success, reduced fecundity and shifts in species relative abundance. Columbia River chubs have benefited from impoundment and are now the most abundant fish in Lake Koocanusa.

Kootenai River. Spring releases under these alternatives would not approach the levels associated with successful natural reproduction of the Kootenai River white sturgeon. Only one year class (1974) of white sturgeon has been recruited to the population in any number since Libby Dam became operational. Spring flows are believed to be a major factor in the reproductive success of these fish. The species is proposed for listing under the Endangered Species Act. If this alternative were selected, natural reproduction of white sturgeon would be unlikely. Table 4–6 shows SOS flows compared to targets for wet, medium and dry years.

Sediment accumulation and loss of interstitial habitat in the river substrate of the Kootenai River has been linked to a gradual reduction in trout growth downstream of the tailwater area. The fishery immediately below the dam, however, is benefiting from zooplankton, fish and other food items entrained through the turbines from the reservoir. Entrainment can be partially controlled regardless of the operational alternative selected. Conversely, sedimentation can be addressed only through flow velocity manipulation. This alternative has no provision for channel maintenance flows.

Cumulative and unavoidable impacts

Impoundment has apparently benefited native Columbia River chubs and northern squawfish. Chubs, because of their large numbers, consume a huge portion of the zooplankton biomass. Kokanee must compete for the available zooplankton supply. Squawfish are effective predators on juvenile fish.

Approximately 200 miles of low gradient, primary spawning and rearing areas in the river and tributary streams were permanently lost when the reservoir first filled. High gradient stream segments, migration barriers and human–caused stream degradation have further limited critical habitat in areas above full pool elevation, reducing natural recruitment of juvenile fish to the reservoir. Growth and survival of young trout has been further reduced by biological interactions caused by extreme reservoir fluctuation.

Mitigation

Current mitigation for construction of Libby Dam consists of fish stocking in Lake Koocanusa and nearby waters from Murray Springs Trout Hatchery. A selective withdrawal system regulates release temperatures in the Kootenai River downstream.

A public scoping process will begin during spring of 1994 to develop a mitigation plan to repair anticipated fisheries losses caused by the operation of Libby Dam. The scoping procedure will be similar to the Hungry Horse mitigation planning process. Mitigation for excessive reservoir drawdowns is currently being negotiated. Mitigation measures include habitat enhancement in tributaries, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring. Additional mitigation measures could include operational constraints on the existing 3–foot river level fluctuations on the Kootenai River below Libby Dam.

Table 4–6 . Examination of SOS capability to meet sturgeon spawning flow targets at Bonners Ferry for wet, medium and dry years. Shaded areas indicate where average flows met or exceeded targets. Note that within–month variations (eg, load following and natural runoff patterns), which may be significant, could not be accounted for with available data. Targets for May, June and July, for the driest 10% of years are the 4,000 cfs base flow out of Libby, plus available local inflow.

SOS	WET YR (1956)			MED. YR (1957)			DRY YR (1940)		
	MAY	JUNE	JULY	MAY	JUNE	JULY	MAY	JUNE	JULY
	Sturgeon Spawning Criteria: Minimum Flow Targets at Bonners Ferry								
	17000	35000	28000	12500	25000	20000	7000	15000	13000
	Modeled Average Monthly Flows at Bonners Ferry by SOS								
1a	33048	19210	28374	31759	14893	12425	12400	14782	10030
1b	33047	19210	28374	31759	14893	12425	11400	11472	7263
2c	33047	19210	28374	25134	18199	13115	20005	7620	11181
2d	30200	20000	27610	29486	11986	13115	12400	7620	4867
4c	27811	38383	28374	24383	29276	15173	12400	12184	10917
5b	33047	19210	28374	26915	14893	12425	12400	14782	10030
5c	33047	19210	28374	26915	14893	12425	12400	14782	10030
6b	33047	19210	28374	26915	14893	12425	12400	14782	10030
6d	33047	19210	28374	26915	14893	12425	12400	14782	10030
9a	30200	35000	31771	26000	35000	23000	26000	35000	23000
9b	30200	35000	23000	23933	33516	15173	12400	26528	10197
9c	27811	38383	28374	24383	29276	15173	12400	12184	10917
PA	35940	36927	9100	29959	24829	15173	21502	15120	10917

There are short–term recovery activities under consideration for Kootenai River white sturgeon which include the release of reservoir storage during May, June and July to provide the stimulus for spawning as well as protection for egg incubation and for rearing of larval sturgeon. The intent is to store water during the fall through spring period, specifically for sturgeon flow enhancement. This strategy can provide the necessary release without compromising refill probability. Flow augmentation varies with water availability. No water would be released during critically low water years. Furthermore, alternatives under System Operating Strategies 2 and 4 would provide in the long term for rule curve–driven spring flow provisions for sturgeon.

4.2.2 PRE–ESA Operations (SOS 1a and 1b) for Lake Roosevelt and mid–Columbia River

4.2.2.1 Lake Roosevelt

Description of alternative specific to Lake Roosevelt

Water budget flows are provided for at Grand Coulee under SOS 1a. Under SOS 1b, Grand Coulee operational requirements call for elimination of the 1240 feet target elevation in May, a new target elevation of 1285 feet from July through September, and a 1220 feet minimum elevation limit. There are significant changes from average annual end–of–month elevations and average annual maximum elevations under SOS 1 (see the Results Exhibit for a complete set of yearly flows and elevations). In some years, maximum and minimum end of month pool elevations change over 85 feet while outflow jumps from approximately 60 kcfs to over 180 kcfs. Average annual end–of–month elevations and average outflow from one year to the next year also fluctuate significantly.

Short–term impacts

Short term impacts at Lake Roosevelt from the operations of SOS 1a and 1b are similar and will be discussed together (Table 4–7; see the Results Exhibit for additional results). Both operations offer deep drawdowns for extended periods of time. Combined with high outflows these drawdowns result in water retention times that are 30 days or less from January to May for approximately 90% of the 50 water years examined. Low water retention times at Coulee have a two fold impact. The first impact is a loss of nutrients from the reservoir as a result of high water speeds. This loss of nutrients results in less phytoplankton production which is a primary food source for zooplankton (Beckman et al. 1985). Additionally, low water retention times continued through the late spring/early summer decrease the growing season of zooplankton. Low nutrient availability and a decreased growing season result in low zooplankton density and biomass values (Beckman et al. 1985; Peone et al. 1990; Griffith and Scholz 1991; Griffith et al. 1993; Thatcher et al. 1993). High zooplankton density and biomass are important because zooplankton provide the forage base for the salmonid and juvenile walleye populations within the reservoir. If the zooplankton population is "healthy" the result will be reflected in high fish growth rates. However, if the zooplankton population is poor the growth rates of the fish will be low. The second impact of low water retention time is loss of fish via entrainment through the dam (Peone et al. 1990; Griffith and Scholz 1991; Griffith et al. 1993; Thatcher et al. 1993). The salmonids of Lake Roosevelt tend to congregate in the forebay of the reservoir in the late winter/early spring months. Increased water speeds (low water retention times) lead to entrainment of the fish through the turbines resulting in decreased fish populations. The value measures for the percentage of fish left in the reservoir at occurrence intervals of 2, 4, and 10 years demonstrate these concepts (Table 4–7; see the Results Exhibit for a complete set of results). At an occurrence interval of 2 years, the value measure representing the proportion of kokanee left in the reservoir is relatively high (approximately 0.40) while the value measure representing growth is relatively low (approximately 0.26). At a 10 year occurrence interval both value measures (the proportion left in the reservoir and the growth index) are very low (0.25 and 0.09, respectively). What this may imply is that in any given 2 year time period, you may be able to observe reduced populations of kokanee and increased growth, but over the long term, both kokanee growth and population levels would be expected to decrease, most likely because food supplies are washed out of the reservoir along with kokanee.

In summary, these operational strategies would lead to low densities of zooplankton, reduced fish growth, and high annual fish entrainment.

Spring spawners such as yellow perch and smallmouth bass may be impacted by spring pool elevation increases, if eggs are inundated by cold water.

Long–term impacts

Lake Roosevelt is currently a destination fishery for kokanee, rainbow trout, and walleye. All fish exhibit good growth and have fairly high catch–per–unit–effort (CPUE) rates when compared to other northwest waters (Peone et al. 1990; Griffith and Scholz 1991; Griffith et al. 1993; Thatcher et al. 1993). However, these same studies have shown that fish growth and entrainment levels have been inconsistent due to yearly changes in dam operation strategies. Prolonged studies have also found steady decreases in fish growth while entrainment has increased under certain yearly operations. It is for these reasons that it is believed that if the operations of SOS 1a and 1b are continued it could result in have an adverse effect on fisheries due to low food resources and fish numbers. If the reservoir is continually operated in a manner that results in a continual loss of nutrients and reduced growing season for the zooplankton, the resultant impact will be poor fish growth. Increased fish entrainment losses will decrease the population size of rainbow, kokanee and, to a smaller degree, walleye. Smaller fish populations lead to decreased catch rates.

Limited information is available for sturgeon, whitefish and burbot. Primary impacts to these species would be growth–related as benthic or other food items may be exposed and killed by drawdowns.

It is for these reasons that it is believed that if the operations of SOS1a and 1b are continued it could have an adverse effect on the fisheries due to low food resources and fish numbers

Cumulative impacts

Low water retention times lead to decreased food production which results in poor fish growth. Monthly fluctuations in water levels decrease spawning success of many spring spawning resident fish of Lake Roosevelt (Beckman et al. 1985). Due to the limited capability of the hydroregulator models these impacts could not be documented but would most certainly be an important impact to the survivability of eggs and fry and ultimately to fish population success.

Unavoidable impacts

Unavoidable impacts due to Grand Coulee operations are loss of nutrients, loss of zooplankton, loss of benthic invertebrates, decreases in fish spawning and feeding habitats, and entrainment losses.

Mitigation

Potential mitigation measures for these alternatives include stream and riparian zone improvements, benthic invertebrate structure placement, and sonic avoidance mechanisms. Stream and riparian improvements would create more usable shoreline and tributary habitat for fish population utilization thereby potentially decreasing entrainment numbers. Riparian improvements and benthic invertebrate structure placement would increase the number of terrestrial and benthic insects within the reservoir thereby creating an alternative food source. Sonic avoidance structures in the forebay might decrease the number of salmonids congregating in the area and lead to entrainment reductions.

Additionally, monitoring systems should be set up to aid in determining impacts that could not be predicted based upon current models and output data. Mitigation measures should focus on on–site development; however, in the event that on–site mitigation is not possible, off–site mitigation should occur on the Spokane and Colville Indian Reservations.

Table 4–7. Value measures predicted by the model for Lake Roosevelt at occurrence intervals of 2, 4, and 10 years. Value measures represent a compilation of habitat suitability indices that incorporate the physical and biological key variables into a relative index of fish health that ranges between 0 (bad) and 1 (good). Within each species, vertical comparisons can be made by reviewing the value measures for each SOS; higher value measures represent better conditions for resident fish. Horizontal comparisons between species can be misleading because the key variables which comprise the habitat suitability indices which are combined to form the value measures differ between species. Temporal assessments can be made by reviewing the value measures in each occurrence interval. The occurrence intervals were selected from the 50 years of record to represent the effects of each operating strategy within the life span of key resident fish species. Value measures at an occurrence interval of 2 years represent the index of fish health we would expect to occur, on average, every 2 years; the value measure at an occurrence interval of 4 years represents the index of fish health we would expect to see every 4 years, and so on. Section 3.3 of Chapter 3 contains a detailed description of how these values were calculated.

Lake Roosevelt	Occurrence Interval = 2 Years		Occurrence Interval = 4 Years		Occurrence Interval = 10 Years	
	Proportion kokanee left	Growth	Proportion kokanee left	Growth	Proportion kokanee left	Growth
SOS 1a	0.402	0.262	0.304	0.097	0.249	0.087
SOS 1b	0.404	0.272	0.309	0.096	0.257	0.086
SOS 2c	0.431	0.272	0.313	0.096	0.257	0.086
SOS 2d	0.473	0.216	0.354	0.096	0.271	0.087
SOS 4c	0.543	0.207	0.342	0.094	0.267	0.086
SOS 5b	0.433	0.289	0.315	0.096	0.256	0.086
SOS 5c	0.433	0.289	0.315	0.096	0.256	0.086
SOS 6b	0.433	0.289	0.315	0.096	0.256	0.086
SOS 6d	0.433	0.289	0.315	0.096	0.256	0.086
SOS 9a	0.373	0.085	0.324	0.081	0.232	0.070
SOS 9b	0.418	0.095	0.322	0.090	0.241	0.086
SOS 9c	0.414	0.099	0.301	0.091	0.257	0.085
SOS PA	0.437	0.099	0.359	0.091	0.284	0.085

4.2.3 PRE–ESA Operations (SOS 1a and SOS1b) Middle Snake and Clearwater Rivers

4.2.3.1 Dworshak Reservoir

Description of alternative specific to Dworshak Reservoir

SOS 1a requires Dworshak Reservoir to provide up to 600 KAF of water in May for the Water Budget and assumes there is no transfer of system flood control from Dworshak to Grand Coulee. SOS 1b requires that Dworshak meet minimum project flows (i.e., 2000 cfs, except in August, 1000 cfs), meet summer draft limits, and meet maximum discharge requirements October through November (i.e., 1300 cfs plus inflow).

The average annual end–of–month elevations at Dworshak under this SOS range between 1505 and 1570 feet (see the Results Exhibit for flows and elevations). Drawdown to minimum pool (1445) may occur in any given hydrology (i.e., wet through dry), but is less likely during a medium low (3.0–3.4 MAF flow volume per year) and low (<3.0 MAF) water year. Although annual maximum monthly elevations of approximately 1600 feet are reached with this alternative, failure to refill the reservoir under this alternative is likely during medium low and low water years There is very little difference between the two SOSs. SOS 1a draws the reservoir down approximately 15 feet more in some years based on average annual end–of–month elevations. Average annual discharge (based on monthly flows) under this SOS ranges from 3,000 cfs to 9,000 cfs. Monthly discharge goes as high as 25,000 cfs and as low 1,000 cfs (see the Results Exhibit for flows and elevations). Discharge under this SOS is essentially identical for 1a and 1b.

Short and long–term impacts

Both options in SOS 1 result in relatively good conditions for kokanee, with SOS 1b slightly better than 1a (Table 4–8; see the Results Exhibit for additional results). This is most likely because water budget flows under SOS 1a result in slightly higher entrainment than in 1b. Entrainment ranges from high in wet years (0.10 on an index scale of 0 to 1 with 0 being high entrainment and 1 representing low entrainment) to very low in dry years (an index value near 1). The average entrainment, over 50 years of water records, was fairly moderate (an index value of 0.6). Access to spawning tributary streams under this SOS is good. Under this alternative, the amount of adult kokanee habitat (pelagic area greater than 50 feet deep) is relatively low during the winter, but full pool is reached most summers.

This alternative is designed to represent operating requirements as they existed from approximately 1983 through the 1991 water year (prior to the listing of Snake River stocks of salmon under the ESA). In an attempt to place a reference on the model's predictions, we used the actual end–of–month elevations (Figure 4–5) and average monthly flows (Figure 4–6) from 1976 through 1992 to generate a kokanee population index value at Dworshak Reservoir using the stock–recruitment model (Figure 4–7). Direct comparisons between the simulations using the actual hydrology and the simulations using the 50 year record are not valid. This is because the 50 years of record used in the hydroregulator analysis covers a different time period and hydrology than the period 1976 through 1992. However, it is useful to note that the kokanee population index estimates using the simulated hydrology generally fall into the range observed when actual data were used. Further, comparisons between the individual index values used in the model to predict the kokanee population index values for SOS 1a also indicates general agreement. Over the time period from 1976 through 1992, the entrainment index is approximately 0.65. This is a similar value, although indicating slightly less entrainment, than when we ran the same model using the 50–year record for SOS 1a (Figure 4–8). Considering the period between 1976 and 1992 contained several drought years, it is not surprising that entrainment would appear to be slightly less.

Table 4–8. Value measures predicted by the model for Dworshak at occurrence intervals of 2, 4, and 10 years. Value measures represent a compilation of habitat suitability indices that incorporate the physical and biological key variables into a relative index of fish health that ranges between 0 (bad) and 1 (good). Within each species, vertical comparisons can be made by reviewing the value measures for each SOS; higher value measures represent better conditions for resident fish. Horizontal comparisons between species can be misleading because the key variables which comprise the habitat suitability indices which are combined to form the value measures differ between species. Temporal assessments can be made by reviewing the value measures in each occurrence interval. The occurrence intervals were selected from the 50 years of record to represent the effects of each operating strategy within the life span of key resident fish species. Value measures at an occurrence interval of 2 years represent the index of fish health we would expect to occur, on average, every 2 years; the value measure at an occurrence interval of 4 years represents the index of fish health we would expect to see every 4 years, and so on. Section 3.3 of Chapter 3 contains a detailed description of how these values were calculated.

Dworshak Reservoir

	Critical Occurrence = 2 Years				Critical Occurrence = 4 Years				Critical Occurrence = 10 Years			
	Kokanee	Small Mouth	Bull Trout	Cut-throat	Kokanee	Small Mouth	Bull Trout	Cut-throat	Kokanee	Small Mouth	Bull Trout	Cut-throat
SOS 1a	37804	0.154	0.813	0.813	26106	0.072	0.755	0.755	8367	0.027	0.621	0.621
SOS 1b	41404	0.207	0.813	0.813	26665	0.078	0.770	0.770	9967	0.024	0.692	0.692
SOS 2c	19804	0.030	0.761	0.761	6906	0.026	0.727	0.727	3167	0.023	0.653	0.653
SOS 2d	21804	0.013	0.618	0.618	10906	0.009	0.544	0.544	5967	0.006	0.409	0.409
SOS 4c	35004	0.266	0.911	0.911	21306	0.240	0.877	0.877	8367	0.177	0.856	0.856
SOS 5b	30706	0.232	0.809	0.809	20106	0.214	0.792	0.792	7967	0.137	0.772	0.772
SOS 5c	35804	0.254	0.867	0.867	20906	0.227	0.841	0.841	7967	0.145	0.812	0.812
SOS 6b	32604	0.252	0.859	0.859	20906	0.226	0.843	0.843	8367	0.149	0.818	0.818
SOS 6d	32604	0.252	0.859	0.859	20906	0.226	0.843	0.843	8367	0.149	0.818	0.818
SOS 9a	20906	0.024	0.754	0.754	13306	0.012	0.673	0.673	7567	0.007	0.554	0.554
SOS 9b	14106	0.009	0.493	0.493	6041	0.007	0.419	0.419	4220	0.006	0.376	0.376
SOS 9c	19404	0.032	0.763	0.763	8906	0.015	0.710	0.710	3567	0.013	0.602	0.602
SOS PA	1804	0.013	0.621	0.621	400	0.010	0.598	0.598	400	0.008	0.536	0.536

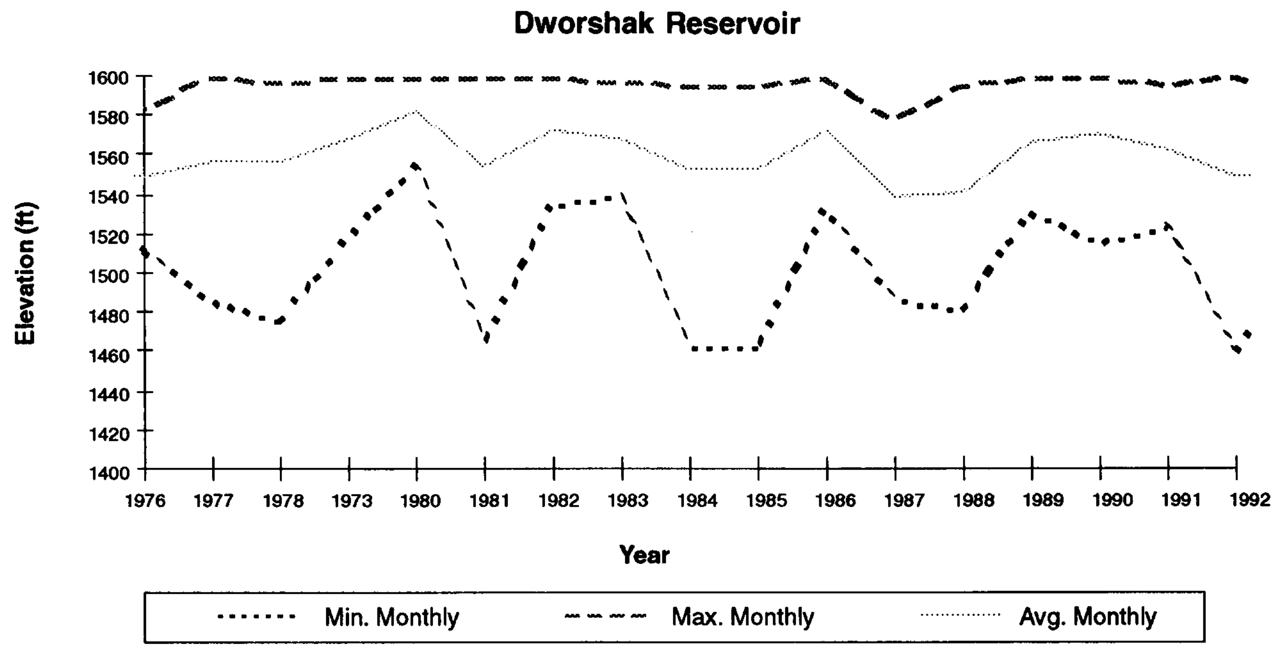


Figure 4–5. Annual summary of monthly elevations based on actual hydrologic data taken at Dworshak Dam (1976–1992).

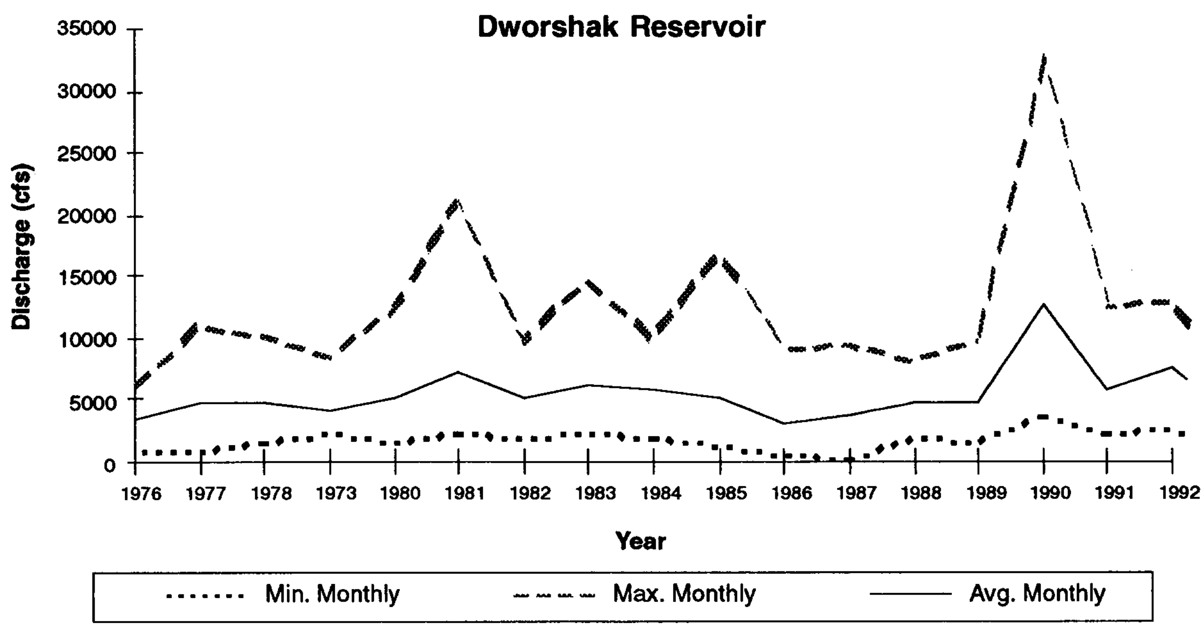


Figure 4–6. Annual summary of monthly discharges based on actual hydrologic data taken at Dworshak Dam (1976–1992).

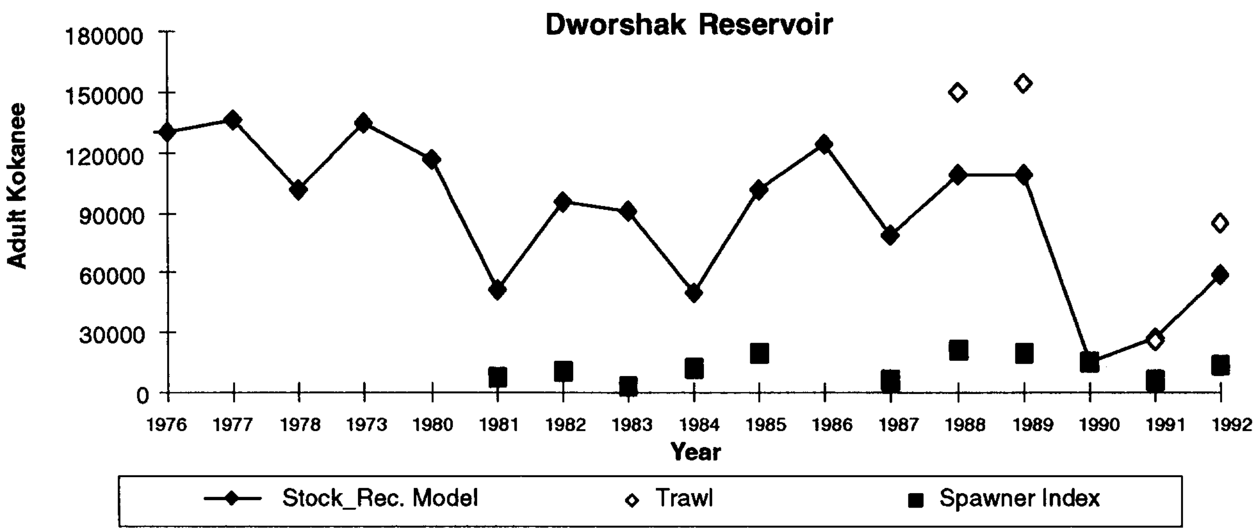


Figure 4–7. Simulated adult kokanee population index values using the stock–recruitment model with actual monthly flows and elevations as input (1976–1992). Comparisons are made between the stock–recruitment model predictions and spawner indices and trawl estimates.

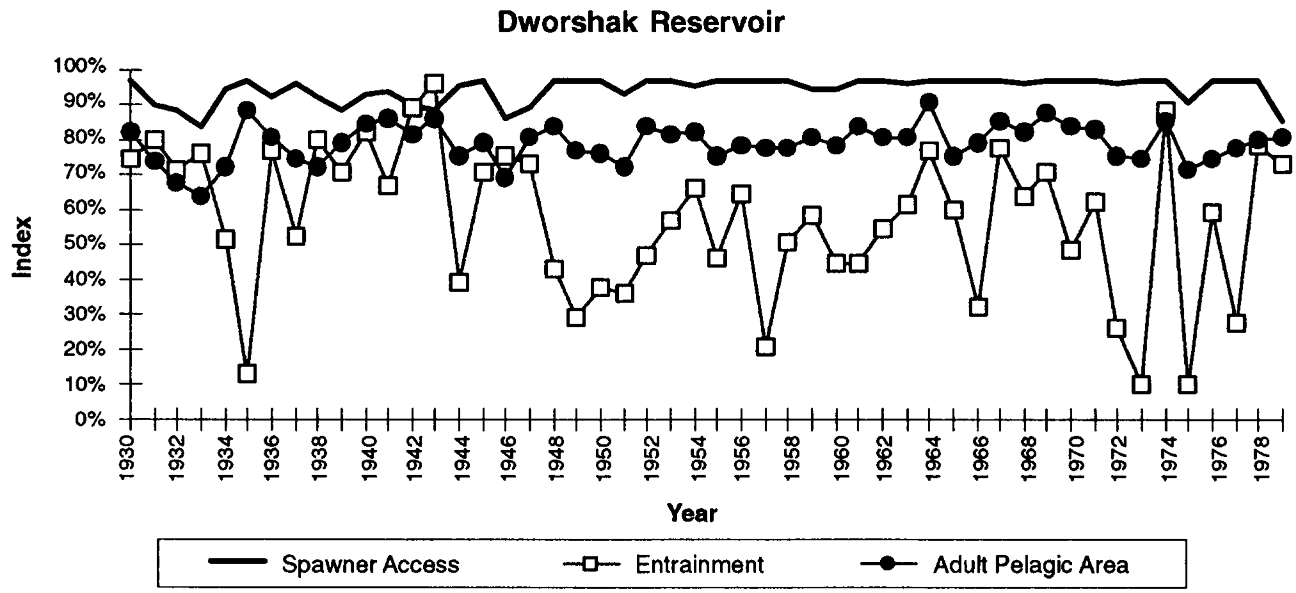


Figure 4–8. Annual kokanee habitat suitability indices under SOS 1a. Each index is generated by the stock–recruitment model. Input to the model consists of monthly flows and elevations over the 50–year record as simulated by the HYDROSIM model for SOS 1a. The individual index values are combined to form the value measure (adult kokanee population index values) for kokanee at Dworshak Reservoir (see Figure 4–7).

Smallmouth bass, cutthroat trout, and bull trout are negatively impacted from this alternative (Table 4–8; see the Results Exhibit for additional results). Annual drawdowns of the magnitude and frequency observed in this SOS preclude the voluntary establishment of permanent shoreline vegetation. This severely limits the diversity of shoreline habitat and food production potential. Food limitations are captured in the food production index values, which drop as low as 0.45 (minimum of 0 to a maximum of 1) under this alternative. In the later part of the 50–year record the food production index increases to values slightly greater than 0.80.

Increasing pool levels in June, and associated decreasing temperatures at smallmouth bass spawning nest sites, can abort smallmouth bass spawning and/or interfere with egg and larvae development. For SOS 1b, pool elevations in July and August are generally stable, although pool levels fluctuate downward in early August under SOS 1a. During medium and low water years, late active smallmouth bass nests may be impacted from the lower pool levels associated with SOS 1a.

Cumulative and unavoidable impacts

Routine annual drawdowns of 100–150 feet under both options of SOS 1 restrict the long–term reservoir productivity due to a lack of macrophytes in the littoral zone, the dewatering of shoreline benthic production, and the increased distance from the permanent upland vegetation and the reservoir water surface. Drawdown operations render the littoral zone unsuitable for spawning of redside shiner, which is a native forage species. This constitutes a cumulative and long–term loss of available food for bull trout, cutthroat trout, and smallmouth bass.

Mitigation

Certain measures could be taken to lessen the effect of this alternative, including:

- Revegetation of the drawdown zone along the more gently sloping banks. Aerial photography and a digitized reservoir contour map could aid in the identification of suitable candidate areas. Shoreline revegetation could partly offset the food and habitat deficits caused by pool level fluctuations. Follow–up on the effectiveness of this program would be required.
- Small sub–impoundments near full pool elevation could provide a permanently wetted, relatively stable environment to promote the production of aquatic and semi–aquatic vegetation. This would provide food and substrate for aquatic insect production and could also provide a nursery area for forage fish. The sub–impoundments would also partly offset the food and habitat deficits caused by pool level fluctuations. Follow–up on the effectiveness of this program would be required.

4.2.3.2 Brownlee Reservoir

Description of alternative specific to Brownlee Reservoir

SOS 1a requires up to 110 KAF of water to be drafted from Brownlee Reservoir for the water budget and assumes there is no transfer of flood control from Brownlee to Grand Coulee. Operations would be similar to how they existed in 1990–1991 at Brownlee. SOS 1b assumes an additional 1.427 MAF of water can be found in the upper Snake River. The annual hydrology for the two alternatives is identical in the hydroregulated output (see the Results Exhibit for flows and elevations). Average annual monthly flows range between 10 and 30 kcfs while monthly maximum flows reach 70 kcfs in some years and minimum flows approximately 6 kcfs. Elevations fluctuate between 2080 and 1980 feet and average end–of–month elevations are generally near 2060 feet.

Short and long–term, cumulative, and unavoidable impacts

SOS 1 results in food production indices which fluctuate between 0.6 and 0.95 (scale 0 to 1; see the Results Exhibit for additional results). The fluctuation in end–of–month reservoir elevations dewaters shoreline habitat, which in turn impacts food production. Rainbow trout are modeled using the food production index only, and consequently this alternative results in poor conditions for rainbow trout (Table 4–9). The other resident fish species in Brownlee are modeled using food production and the relationship between elevation fluctuation and spawning and egg incubation success (see the Results Exhibit for additional results). Channel catfish appear to be impacted more by this alternative because they spawn later than smallmouth bass and other warmwater species. Apparently the reservoir is fluctuating over a greater range of elevations during this time period. The value measure index values for this SOS range between 0.45 and 0.7 for channel catfish; 0.3 and 0.92 for smallmouth bass; and 0.6 and 0.9 for other warmwater species (Table 4–9; see the Results Exhibit for additional results). Even with this range of fluctuations, this alternative is still one of the better ones for smallmouth bass.

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.2.4 PRE–ESA Operations (SOS 1a and SOS 1b) for Lower Snake River

4.2.4.1 Lower Granite Reservoir

Description of alternative specific to Lower Granite Reservoir

SOS 1a calls for operating the four Lower Snake River projects within 3–5 feet of full pool. However, hydroregulation model results indicate that elevations fluctuate as much as 50 feet during some years (see the Results Exhibit for flows and elevations for this and other SOSs). (Please note that the RFWG believes that the output from the HYDROSIM hydroregulation model is incorrect for SOS 1a; however, this mistake was not corrected and our resident fish model results reflect the extreme elevation fluctuations. In reality, SOS 1a is most likely very similar to SOS 1b.) SOS 1b maintains the pool elevation at 736 feet over all 50 years and removes the minimum flow requirements of 11,500 cfs during the fall and winter and allows a maximum peaking capacity of 20 kcfs over the daily average flow during May. However, monthly average, maximum, and minimum flows in SOS 1b are similar to SOS 1a.

Short and long–term impacts

Growth index values at 2, 4, and 10 year occurrence intervals for smallmouth bass, white sturgeon, and northern squawfish for all SOSs can be found in Tables 4–10 – 4–12 (additional detail can be found in the Results Exhibit). Without hydroregulated input at a time scale finer than 1 month, it is impossible to make highly accurate predictions of the impacts to resident fish in Lower Granite Reservoir. The model predictions based on the end–of–month pool elevations and our qualitative assessment of the impacts when fluctuations in the pool levels occur at a time scale finer than 1 month are presented in the following tables. Table 4–10 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of no variability in within–month pool levels; i.e., the growth index values predicted by the model based on end–of–month elevations. Table 4–11 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of minimal within–month pool fluctuations (2.5 – 4.9 feet); i.e., a qualitative estimate of the impacts should the pool be fluctuated between 2.5 and 4.9 feet within any given month. Table 4–12 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of high within–month pool fluctuations (7.5 – 9.9 feet); i.e., a qualitative estimate

Table 4-9. Value measures predicted by the model for Brownlee at occurrence intervals of 2, 4, and 10 years. Value measures represent a compilation of habitat suitability indices that incorporate the physical and biological key variables into a relative index of fish health that ranges between 0 (bad) and 1 (good). Within each species, vertical comparisons can be made by reviewing the value measures for each SOS; higher value measures represent better conditions for resident fish. Horizontal comparisons between species can be misleading because the key variables which comprise the habitat suitability indices which are combined to form the value measures differ between species. Temporal assessments can be made by reviewing the value measures in each occurrence interval. The occurrence intervals were selected from the 50 years of record to represent the effects of each operating strategy within the life span of key resident fish species. Value measures at an occurrence interval of 2 years represent the index of fish health we would expect to occur, on average, every 2 years; the value measure at an occurrence interval of 4 years represents the index of fish health we would expect to see every 4 years, and so on. Section 3.3 of Chapter 3 contains a detailed description of how these values were calculated.

Brownlee Reservoir	Occurrence Interval = 2 Years				Occurrence Interval = 4 Years				Occurrence Interval = 10 Years			
	Crappie	Small Mouth	Channel Catfish	Rainbow Trout	Crappie	Small Mouth	Channel Catfish	Rainbow Trout	Crappie	Small Mouth	Channel Catfish	Rainbow Trout
SOS 1a	0.568	0.648	0.848	0.852	0.468	0.600	0.761	0.801	0.280	0.459	0.641	0.718
SOS 1b	0.568	0.648	0.848	0.852	0.468	0.600	0.761	0.801	0.280	0.459	0.641	0.718
SOS 2c	0.614	0.647	0.816	0.831	0.397	0.521	0.789	0.802	0.259	0.384	0.773	0.785
SOS 2d	0.614	0.647	0.814	0.831	0.397	0.521	0.789	0.802	0.259	0.384	0.773	0.785
SOS 4c	0.652	0.723	0.824	0.838	0.596	0.603	0.803	0.815	0.264	0.433	0.781	0.786
SOS 5b	0.614	0.647	0.815	0.831	0.397	0.520	0.790	0.802	0.260	0.385	0.774	0.786
SOS 5c	0.614	0.647	0.816	0.831	0.397	0.521	0.789	0.802	0.259	0.384	0.773	0.785
SOS 6b	0.614	0.647	0.815	0.831	0.397	0.520	0.790	0.802	0.260	0.385	0.774	0.786
SOS 6d	0.614	0.647	0.815	0.831	0.397	0.520	0.790	0.802	0.260	0.385	0.774	0.786
SOS 9a	0.404	0.522	0.543	0.767	0.302	0.429	0.464	0.723	0.244	0.344	0.449	0.709
SOS 9b	0.439	0.520	0.431	0.681	0.342	0.438	0.412	0.651	0.216	0.307	0.399	0.629
SOS 9c	0.439	0.521	0.431	0.681	0.342	0.438	0.412	0.651	0.216	0.307	0.399	0.629
SOS PA	0.492	0.584	0.742	0.762	0.382	0.496	0.709	0.729	0.244	0.363	0.715	0.696

Table 4–10. Value measures predicted by the model for Lower Granite at occurrence intervals of 2, 4, and 10 years under conditions of no variability in reservoir pool elevations. Value measures represent a compilation of habitat suitability indices that incorporate the physical and biological key variables into a relative index of fish health that ranges between 0 (bad) and 1 (good). Within each species, vertical comparisons can be made by reviewing the value measures for each SOS; higher value measures represent better conditions for resident fish. Horizontal comparisons between species can be misleading because the key variables which comprise the habitat suitability indices which are combined to form the value measures differ between species. Temporal assessments can be made by reviewing the value measures in each occurrence interval. The occurrence intervals were selected from the 50 years of record to represent the effects of each operating strategy within the life span of key resident fish species. Value measures at an occurrence interval of 2 years represent the index of fish health we would expect to occur, on average, every 2 years; the value measure at an occurrence interval of 4 years represents the index of fish health we would expect to see every 4 years, and so on. Section 3.3 of Chapter 3 contains a detailed description of how these values were calculated.

Lower Granite Reservoir									
	Occurrence Internal = 2 years			Occurrence Internal = 4 years			Occurrence Internal = 10 years		
	Small-mouth	White Sturgeon	Northern Squawfish	Small-mouth	White Sturgeon	Northern Squawfish	Small-mouth	White Sturgeon	Northern Squawfish
SOS 1a	0.270	0.795	1.000	0.130	0.789	0.101	0.128	0.771	0.101
SOS 1b	0.270	0.795	1.000	0.270	0.795	1.000	0.270	0.795	1.000
SOS 2c	0.316	0.790	0.713	0.316	0.790	0.713	0.316	0.790	0.713
SOS 2d	0.316	0.790	0.713	0.316	0.790	0.713	0.316	0.790	0.713
SOS 4c	0.316	0.790	0.713	0.316	0.790	0.713	0.316	0.790	0.713
SOS 5b	0.303	0.341	0.101	0.303	0.341	0.101	0.303	0.341	0.101
SOS 5c	0.550	0.001	1.000	0.550	0.001	1.000	0.550	0.001	1.000
SOS 6b	0.293	0.704	0.101	0.293	0.704	0.101	0.293	0.704	0.101
SOS 6d	0.293	0.704	0.101	0.293	0.704	0.101	0.293	0.704	0.101
SOS 9a	0.294	0.694	0.101	0.294	0.694	0.101	0.294	0.694	0.101
SOS 9b	0.320	0.788	0.713	0.320	0.788	0.713	0.320	0.788	0.713
SOS 9c	0.120	0.726	0.101	0.120	0.726	0.101	0.120	0.726	0.101
SOS PA	0.335	0.785	1.000	0.335	0.785	1.000	0.335	0.785	1.000

Table 4–11. Value measures predicted by the model for Lower Granite at occurrence intervals of 2, 4, and 10 years under conditions of low variability (2.5–4.9 feet) in reservoir pool elevations. Value measures represent a compilation of habitat suitability indices that incorporate the physical and biological key variables into a relative index of fish health that ranges between 0 (bad) and 1 (good). Within each species, vertical comparisons can be made by reviewing the value measures for each SOS; higher value measures represent better conditions for resident fish. Horizontal comparisons between species can be misleading because the key variables which comprise the habitat suitability indices which are combined to form the value measures differ between species. Temporal assessments can be made by reviewing the value measures in each occurrence interval. The occurrence intervals were selected from the 50 years of record to represent the effects of each operating strategy within the life span of key resident fish species. Value measures at an occurrence interval of 2 years represent the index of fish health we would expect to occur, on average, every 2 years; the value measure at an occurrence interval of 4 years represents the index of fish health we would expect to see every 4 years, and so on. Section 3.3 of Chapter 3 contains a detailed description of how these values were calculated.

Lower Granite Reservoir

	Occurrence Internal = 2 years			Occurrence Internal = 4 years			Occurrence Internal = 10 years		
	Small-mouth	White Sturgeon	Northern Squawfish	Small-mouth	White Sturgeon	Northern Squawfish	Small-mouth	White Sturgeon	Northern Squawfish
SOS 1a	0.242	0.795	0.601	0.118	0.789	0.060	0.117	0.771	0.060
SOS 1b	0.243	0.793	0.601	0.243	0.795	0.601	0.243	0.795	0.601
SOS 2c	0.284	0.790	0.428	0.284	0.790	0.428	0.284	0.790	0.428
SOS 2d	0.284	0.790	0.428	0.284	0.790	0.428	0.284	0.790	0.428
SOS 4c	0.284	0.790	0.428	0.284	0.790	0.428	0.284	0.790	0.428
SOS 5b	0.269	0.341	0.060	0.269	0.341	0.060	0.269	0.341	0.060
SOS 5c	0.495	0.001	0.601	0.495	0.001	0.601	0.495	0.001	0.601
SOS 6b	0.259	0.704	0.060	0.259	0.704	0.060	0.259	0.704	0.060
SOS 6d	0.259	0.704	0.060	0.259	0.704	0.060	0.259	0.704	0.060
SOS 9a	0.260	0.694	0.060	0.260	0.694	0.060	0.260	0.694	0.060
SOS 9b	0.288	0.788	0.428	0.288	0.788	0.428	0.288	0.788	0.428
SOS 9c	0.110	0.726	0.060	0.110	0.726	0.060	0.110	0.726	0.060
SOS PA	0.301	0.785	0.601	0.301	0.785	0.601	0.301	0.785	0.601

Lower Granite low variability
June 8 1995

Table 4–12. Value measures predicted by the model for Lower Granite at occurrence intervals of 2, 4, and 10 years under conditions of high variability (7.5–9.9 feet) in reservoir pool elevations. Value measures represent a compilation of habitat suitability indices that incorporate the physical and biological key variables into a relative index of fish health that ranges between 0 (bad) and 1 (good). Within each species, vertical comparisons can be made by reviewing the value measures for each SOS; higher value measures represent better conditions for resident fish. Horizontal comparisons between species can be misleading because the key variables which comprise the habitat suitability indices which are combined to form the value measures differ between species. Temporal assessments can be made by reviewing the value measures in each occurrence interval. The occurrence intervals were selected from the 50 years of record to represent the effects of each operating strategy within the life span of key resident fish species. Value measures at an occurrence interval of 2 years represent the index of fish health we would expect to occur, on average, every 2 years; the value measure at an occurrence interval of 4 years represents the index of fish health we would expect to see every 4 years, and so on. Section 3.3 of Chapter 3 contains a detailed description of how these values were calculated.

Lower Granite Reservoir

	Occurrence Internal = 2 years			Occurrence Internal = 4 years			Occurrence Internal = 10 years		
	Small-mouth	White Sturgeon	Northern Squawfish	Small-mouth	White Sturgeon	Northern Squawfish	Small-mouth	White Sturgeon	Northern Squawfish
SOS 1a	0.062	0.795	0.101	0.035	0.789	0.010	0.034	0.771	0.010
SOS 1b	0.063	0.795	0.101	0.063	0.795	0.101	0.063	0.795	0.101
SOS 2c	0.073	0.790	0.071	0.073	0.790	0.071	0.073	0.790	0.071
SOS 2d	0.073	0.790	0.071	0.073	0.790	0.071	0.073	0.790	0.071
SOS 4c	0.073	0.790	0.071	0.072	0.790	0.071	0.072	0.790	0.071
SOS 5b	0.063	0.341	0.010	0.063	0.341	0.010	0.063	0.341	0.010
SOS 5c	0.128	0.001	0.101	0.127	0.001	0.101	0.127	0.001	0.101
SOS 6b	0.060	0.704	0.010	0.060	0.704	0.010	0.060	0.704	0.010
SOS 6d	0.060	0.704	0.010	0.060	0.704	0.010	0.060	0.704	0.010
SOS 9a	0.061	0.694	0.010	0.061	0.694	0.010	0.061	0.694	0.010
SOS 9b	0.073	0.788	0.071	0.073	0.788	0.071	0.073	0.788	0.071
SOS 9c	0.033	0.726	0.010	0.033	0.726	0.010	0.033	0.726	0.010
SOS PA	0.078	0.785	0.101	0.078	0.785	0.101	0.078	0.785	0.101

Lower Granite high variability
June 8 1955

of the impacts should the pool level be fluctuated between 7.5 and 9.9 feet within any given month.

SOS 1a negatively impacts smallmouth bass (Figures 4–9 and 4–10 see the Results Exhibit for additional results). Growth index values drop from 0.27 to 0.12 in some years. SOS 1b appears to be slightly worse than present conditions. Elevations are constant and steady based on end–of–month elevations. Hence, the index value is constant at 0.27. Any fluctuations of the pool levels within the month would drive the index down, with fluctuations greater than 10 feet driving the index to zero. Maximum peaking capability for SOS 1b is 20 kcfs over daily average flows in May; thus, short term fluctuations may occur which would be detrimental to all resident fish resources in Lower Granite reservoir, including smallmouth bass.

White sturgeon are modeled solely using their preference for deep water habitat. Water velocities for successful spawning are likely more important than deep water habitat. Spawning habitat was qualitatively evaluated. These alternatives appear to provide adequate deep water habitat similar to present conditions (Figures 4–11 and 4–12; see the Results Exhibit for additional results). Short term fluctuations in pool elevations could pose problems for young sturgeon rearing in nearshore areas.

Northern squawfish are modeled using the elevation fluctuation. We assume that constant pool elevations will provide optimal habitat for northern squawfish, but fluctuations in pool elevations either within or between months will decrease available habitat. This is evident with SOS 1a. Extreme fluctuations in reservoir elevations cause the index value to drop substantially; from approximately 1 to 0.1 in some years (Figures 4–13 and 4–14; see the Results Exhibit for additional results). Since reservoir elevations are constant in SOS 1b, the index value for squawfish is at 1. In both alternatives, within month fluctuations would lower the index values.

Cumulative and unavoidable impacts

Under SOS 1a, smallmouth bass and northern squawfish would be expected to decline. This alternative, as modeled, results in a loss of spawning habitat, reduction in food production from the dewatering of shoreline benthos and crayfish habitat, and stranding of fry in near–shore environments. SOS 1b, if pools are maintained at constant elevations within the month, will reduce losses seen in SOS 1a. Under both alternatives, white sturgeon do not seem to be affected.

Mitigation

Mitigation measures may include, but not be limited to offsite fisheries improvements, including project site selection and monitoring.

4.2.5 PRE–ESA Operations (SOS 1a and 1b) Lower Columbia River

4.2.5.1 John Day Reservoir

Description of alternative specific to John Day Reservoir

There are no specific operational requirements mentioned in the alternative description for John Day Reservoir. A review of the flows and elevations indicates there is little difference between SOS 1a and SOS 1b. In each case, the average annual elevation is approximately 265 feet msl and fluctuates over 2 feet (264 – 266 feet msl). The average annual flow ranges from approximately 100,000 to 230,000 cfs with the maximum ranging from 200,000 to 500,000 cfs. The average minimum discharge under SOS 1a is slightly lower (0 – 80,000 cfs) than under SOS 1b (90,000 – 110,000 cfs). See the Results Exhibit for a complete set of yearly flows and elevations.

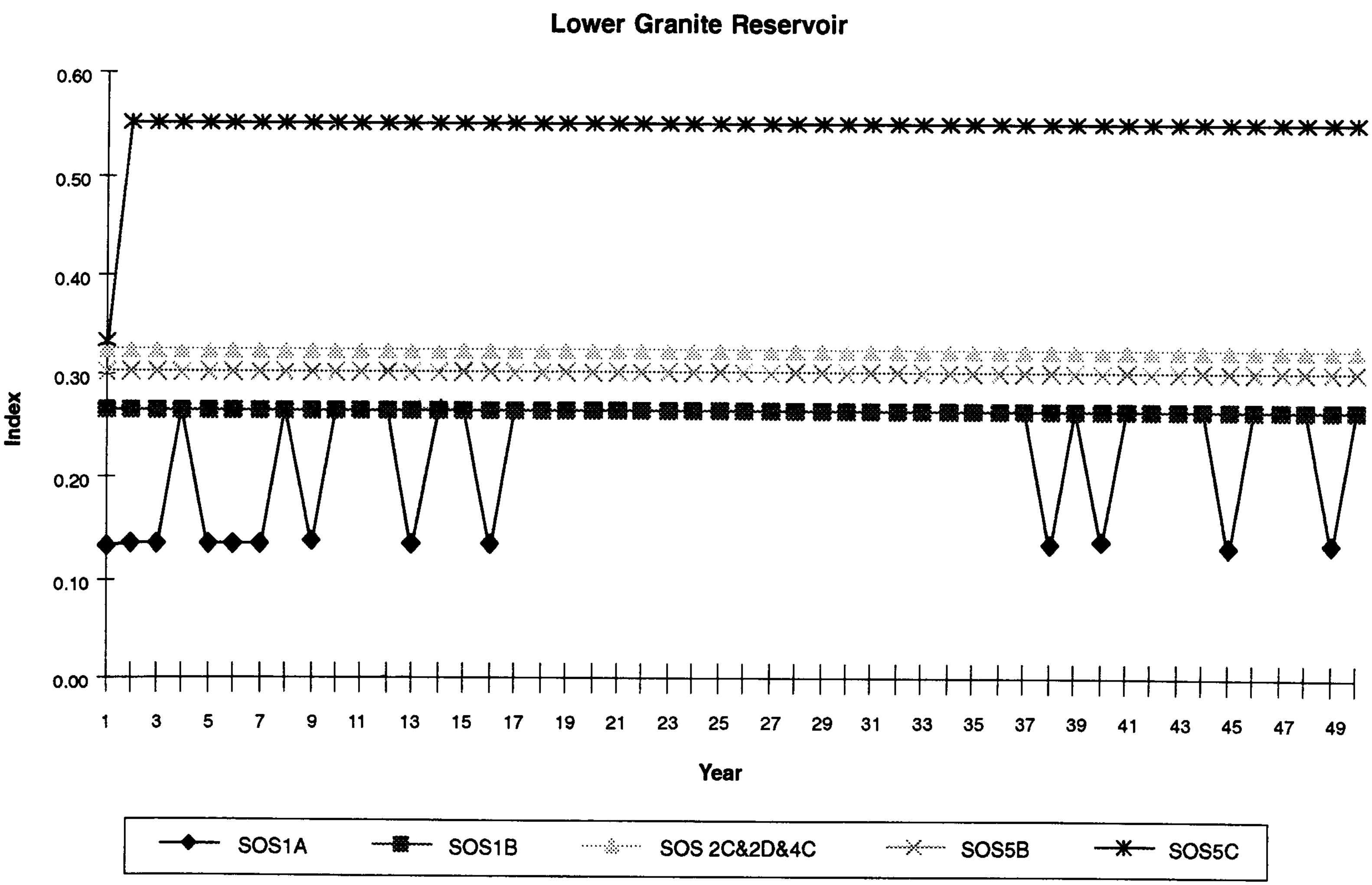


Figure 4–9. Smallmouth bass value measures for Lower Granite (reported as indices of growth) for each of the system operation strategies.

Lower Granite Reservoir

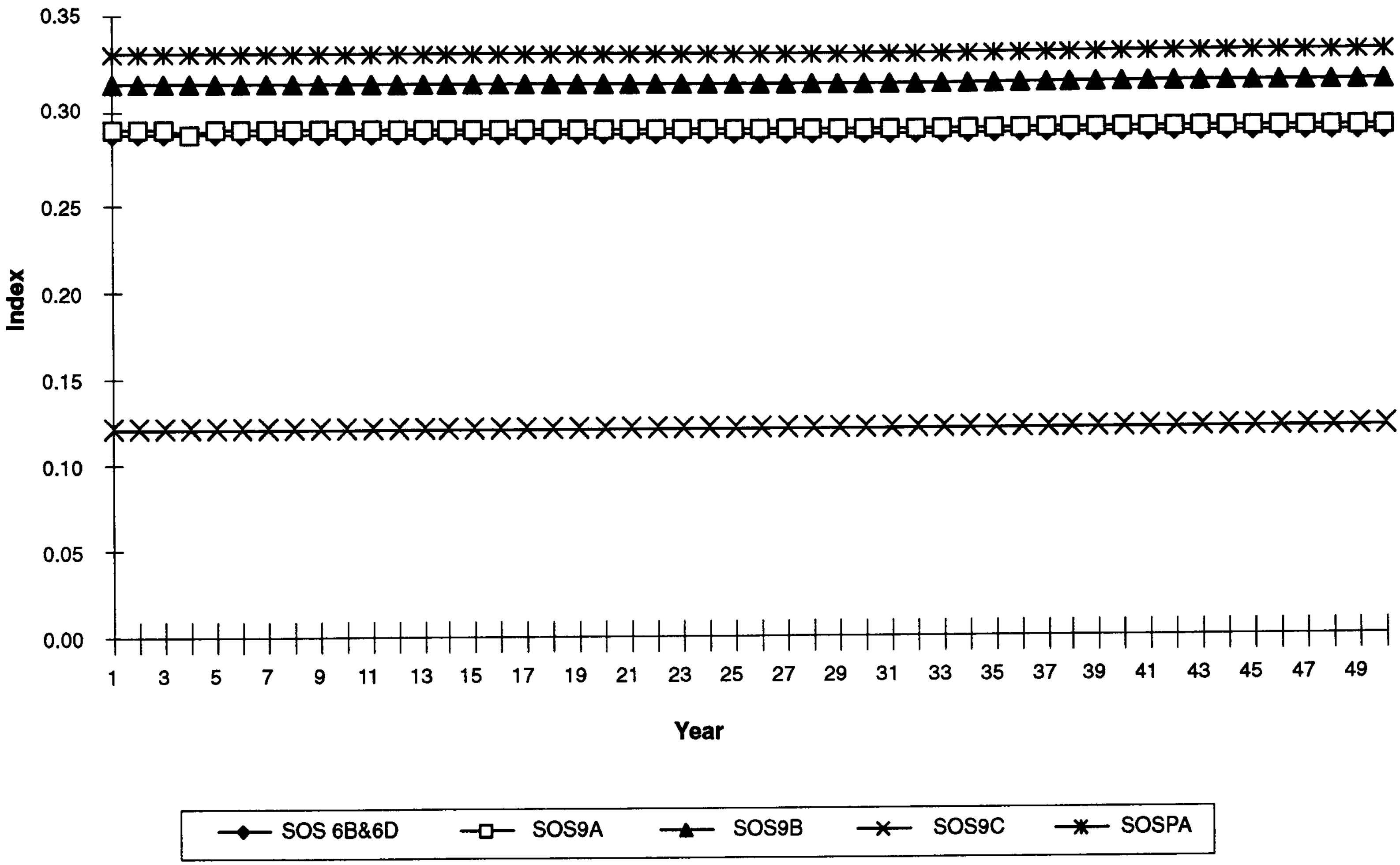


Figure 4–10. Smallmouth bass value measures for Lower Granite (reported as indices of growth) for each of the system operation strategies.

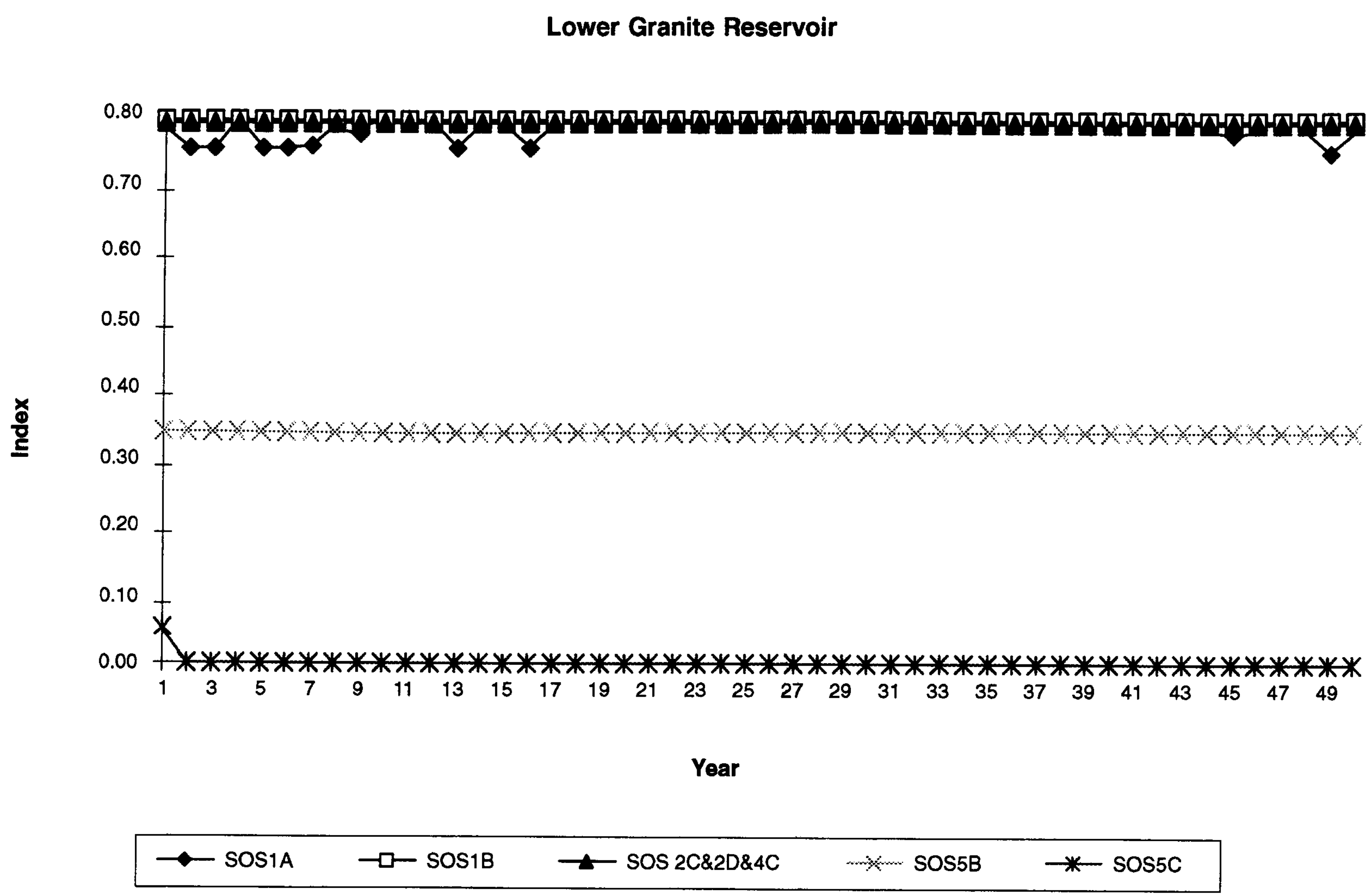


Figure 4–11. White sturgeon value measures for Lower Granite (reported as indices of growth) for each of the system operation strategies.

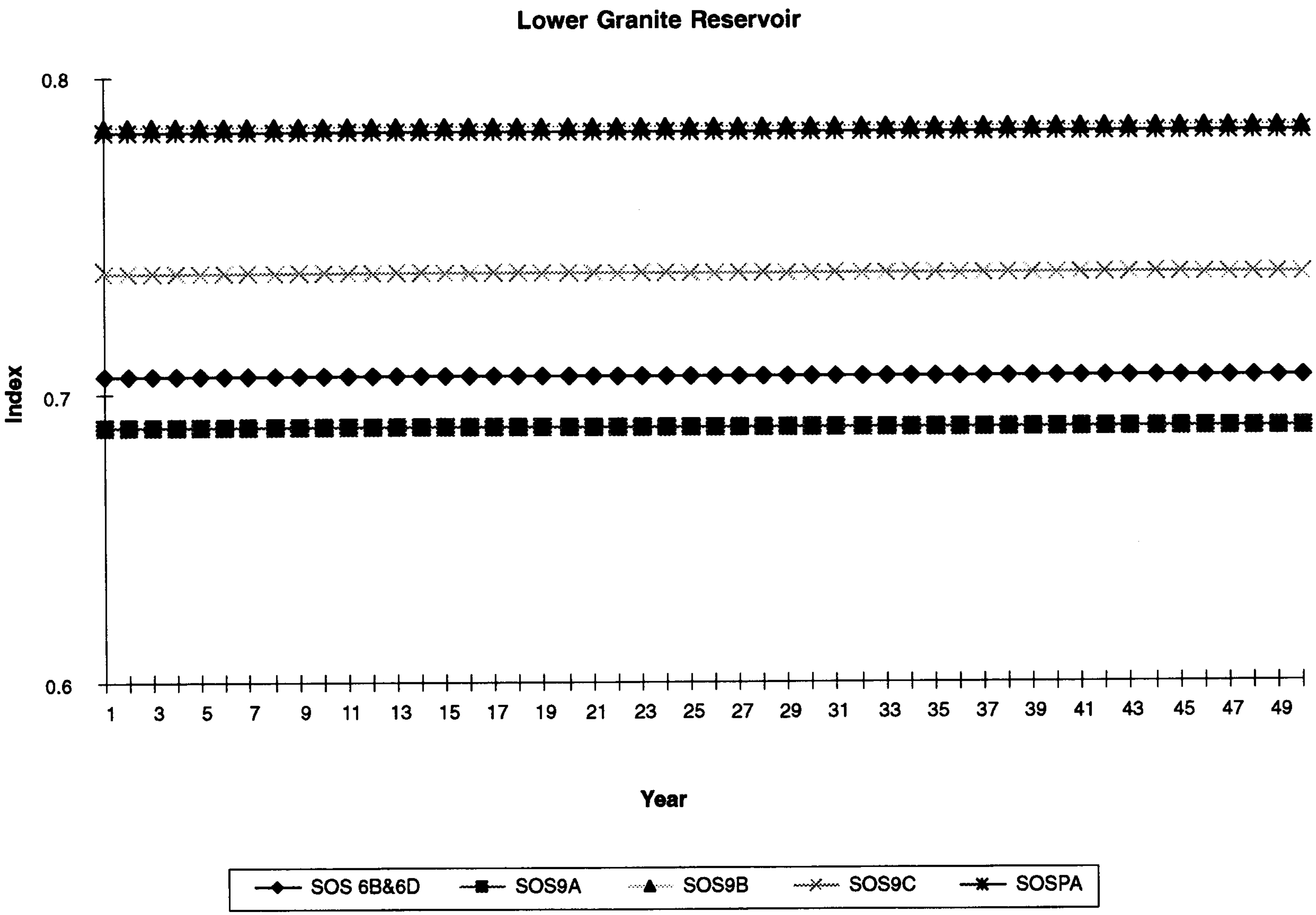


Figure 4–12. White sturgeon value measures for Lower Granite (reported as indices of growth) for each of the system operation strategies.

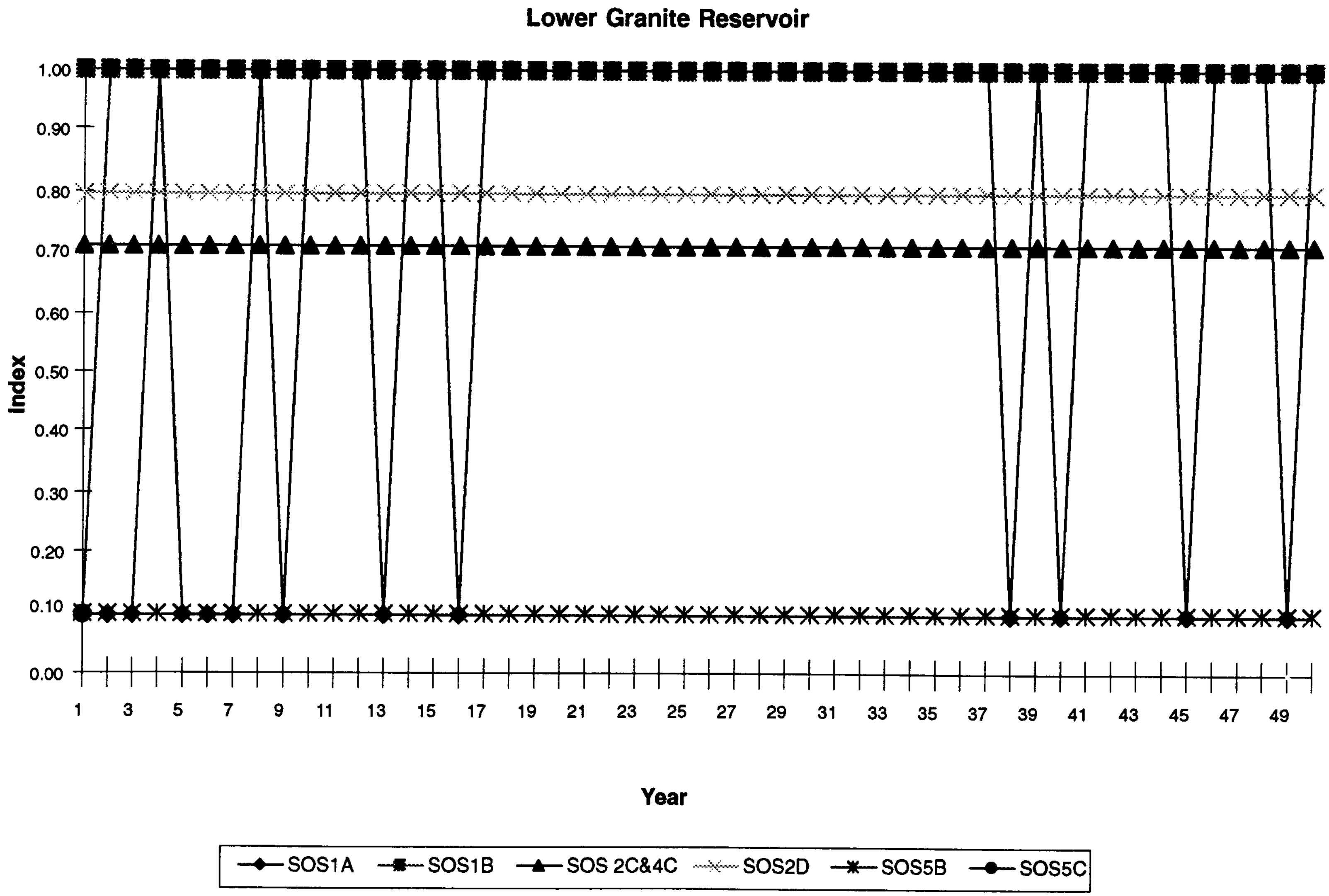


Figure 4–13. Northern squawfish value measures for Lower Granite (reported as indices of growth) for each of the system operation strategies.

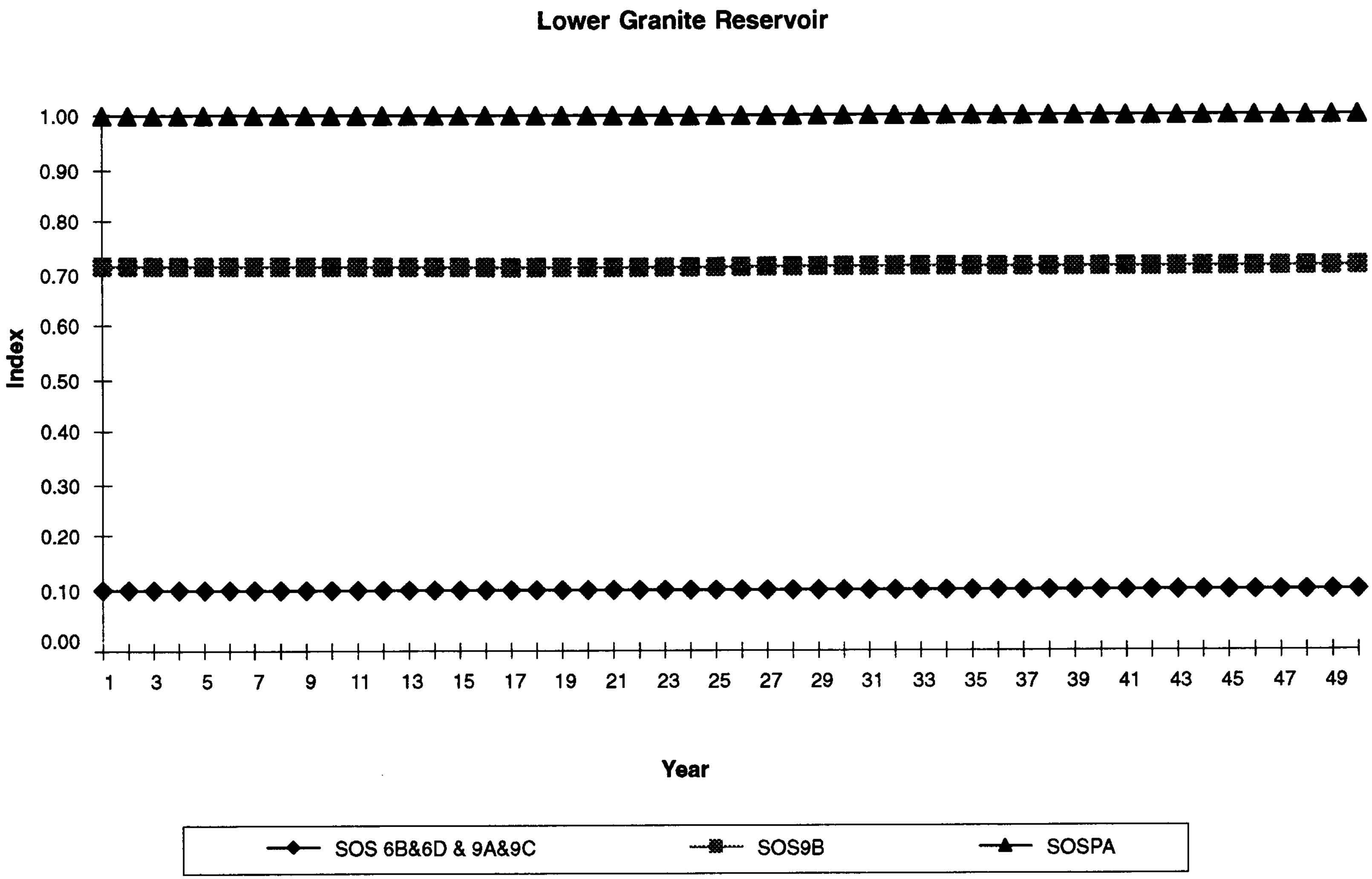


Figure 4–14. Northern squawfish value measures for Lower Granite (reported as indices of growth) for each of the system operation strategies.

Table 4–13 shows growth index values at 2, 4, and 10 year occurance intervals for each species with no pool fluctuation. Table 4–14 gives growth indices a 2, 4, and 10 year occurance intervals for species under conditions of minimal within–month pool fluctuations (2.5 – 4.9 feet); i.e., a qualitative estimate of the impacts should the pool be fluctuated between 2.5 and 4.9 feet within any given month. Table 4–15 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of high within–month pool fluctuations (7.5 – 9.9 feet); i.e., a qualitative estimate of the impacts should the pool level be fluctuated between 7.5 and 9.9 feet within any given month.

SOS 1 appears to be good for smallmouth bass since there are minimal fluctuations in end–of–month pool elevation and spawning success, fry rearing, and over wintering survival should be good. However, within month fluctuations cause the growth index to drop from approximately 0.95 (fluctuation of less than 2.5 feet) to 0.88 (2.5 – 4.9 feet fluctuation); 0.7 (5 – 7.4 feet fluctuation); 0.22 (7.5 – 9.9 feet fluctuation); and 0 (fluctuations greater than 10 feet).

Apparently there are no fluctuations of the end–of–month pool level in June and July in SOS 1 since the index value for northern squawfish is approximately equal to 1.0 (Table 4–13). However, within–month fluctuations in the pool levels cause the index to be reduced substantially (Tables 4–14 and 4–15).

SOS 1a is slightly better for walleye than SOS 1b (Tables 4–13 – 4–15). This is because the annual minimum discharge under SOS 1b is slightly higher, resulting in slightly higher entrainment. In both SOSs the index values are generally less than 0.3 (range 0.19 – 0.3), indicating this alternative is not very good for walleye.

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.3 DESCRIPTION OF IMPACTS OF SYSTEM OPERATING STRATEGIES

4.3.1 Current Operations (SOS 2c and SOS 2d) for Upper Columbia River and tributaries

4.3.1.1 Lake Pend Oreille

Description of alternative specific to Lake Pend Oreille

Similar to SOS 1, there are no specific operational requirements mentioned in the alternative description for Lake Pend Oreille. A review of the flows and elevations indicates there is little difference in this SOS from current operations (see the Results Exhibit for flows and elevations). Therefore, we make the assumption that operations under this SOS are similar to current operations.

Short and long–term, cumulative, and unavoidable impacts

This alternative does not alter the present operational strategy of Lake Pend Oreille and contains the exact same hydrology as in SOS 1. Therefore, impacts to all resident fish species from this alternative are exactly as they were described in SOS 1 (Table 4–3).

Short–term, long–term impacts, cumulative, and unavoidable impacts

Growth index values at 2, 4, and 10 year occurrence intervals for smallmouth bass, northern squawfish, and walleye for all SOSs can be found in Tables 4–13 – 4–14 (additional detail can be found in the Results Exhibit). Without hydroregulated input at a time scale finer than 1 month, it is impossible to make highly accurate predictions of the impacts to resident fish in John Day Reservoir. The model predictions based on the end–of–month pool elevations and our qualitative assessment of the impacts when fluctuations in the pool levels occur at a time scale finer than 1 month are presented in the following tables. Table 4–13 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of no variability in within–month pool levels; i.e., the growth index values predicted by the model based on end–of–month elevations.

Table 4–13. Value measures predicted by the model for John Day at occurrence intervals of 2, 4, and 10 years under conditions of no variability in reservoir pool elevations. Value measures represent a compilation of habitat suitability indices that incorporate the physical and biological key variables into a relative index of fish health that ranges between 0 (bad) and 1 (good). Within each species, vertical comparisons can be made by reviewing the value measures for each SOS; higher value measures represent better conditions for resident fish. Horizontal comparisons between species can be misleading because the key variables which comprise the habitat suitability indices which are combined to form the value measures differ between species. Temporal assessments can be made by reviewing the value measures in each occurrence interval. The occurrence intervals were selected from the 50 years of record to represent the effects of each operating strategy within the life span of key resident fish species. Value measures at an occurrence interval of 2 years represent the index of fish health we would expect to occur, on average, every 2 years; the value measure at an occurrence interval of 4 years represents the index of fish health we would expect to see every 4 years, and so on. Section 3.3 of Chapter 3 contains a detailed description of how these values were calculated.

John Day Reservoir									
	Occurrence Interval = 2 years			Occurrence Interval = 4 years			Occurrence Interval = 10 years		
	Small Mouth	Northern Squawfish	Walleye	Small Mouth	Northern Squawfish	Walleye	Small Mouth	Northern Squawfish	Walleye
SOS 1a	0.963	1.000	0.220	0.963	1.000	0.198	0.963	1.000	0.182
SOS 1b	0.963	1.000	0.199	0.963	1.000	0.179	0.963	1.000	0.166
SOS 2c	0.996	1.000	0.199	0.996	1.000	0.176	0.996	1.000	0.163
SOS 2d	0.996	1.000	0.200	0.996	1.000	0.178	0.996	1.000	0.164
SOS 4c	0.980	1.000	0.203	0.980	1.000	0.179	0.980	1.000	0.167
SOS 5b	0.984	1.000	0.194	0.984	1.000	0.175	0.984	1.000	0.162
SOS 5c	0.984	1.000	0.193	0.984	1.000	0.172	0.984	1.000	0.160
SOS 6b	0.984	1.000	0.194	0.984	1.000	0.173	0.984	1.000	0.161
SOS 6d	0.984	1.000	0.193	0.984	1.000	0.172	0.984	1.000	0.160
SOS 9a	0.938	1.000	0.203	0.938	1.000	0.187	0.938	1.000	0.168
SOS 9b	0.996	1.000	0.204	0.996	1.000	0.189	0.996	1.000	0.171
SOS 9c	0.949	1.000	0.193	0.949	1.000	0.177	0.949	1.000	0.163
SOS PA	1.000	1.000	0.179	1.000	1.000	0.164	1.000	1.000	0.152

Table 4–14. Value measures predicted by the model for John Day at occurrence intervals of 2, 4, and 10 years under conditions of low variability (2.5–4.9 feet) in reservoir pool elevations. Value measures represent a compilation of habitat suitability indices that incorporate the physical and biological key variables into a relative index of fish health that ranges between 0 (bad) and 1 (good). Within each species, vertical comparisons can be made by reviewing the value measures for each SOS; higher value measures represent better conditions for resident fish. Horizontal comparisons between species can be misleading because the key variables which comprise the habitat suitability indices which are combined to form the value measures differ between species. Temporal assessments can be made by reviewing the value measures in each occurrence interval. The occurrence intervals were selected from the 50 years of record to represent the effects of each operating strategy within the life span of key resident fish species. Value measures at an occurrence interval of 2 years represent the index of fish health we would expect to occur, on average, every 2 years; the value measure at an occurrence interval of 4 years represents the index of fish health we would expect to see every 4 years, and so on. Section 3.3 of Chapter 3 contains a detailed description of how these values were calculated.

John Day Reservoir	Occurrence Interval = 2 years			Occurrence Interval = 4 years			Occurrence Interval = 10 years		
	Small Mouth	Northern Squawfish	Walleye	Small Mouth	Northern Squawfish	Walleye	Small Mouth	Northern Squawfish	Walleye
SOS 1a	0.886	0.601	0.220	0.886	0.601	0.198	0.886	0.601	0.182
SOS 1b	0.886	0.601	0.199	0.886	0.601	0.179	0.886	0.601	0.166
SOS 2c	0.868	0.601	0.199	0.868	0.601	0.176	0.868	0.601	0.163
SOS 2d	0.898	0.601	0.200	0.898	0.601	0.178	0.898	0.601	0.164
SOS 4c	0.884	0.601	0.203	0.884	0.601	0.179	0.884	0.601	0.167
SOS 5b	0.868	0.601	0.194	0.868	0.601	0.175	0.868	0.601	0.162
SOS 5c	0.886	0.601	0.193	0.886	0.601	0.172	0.886	0.601	0.160
SOS 6b	0.898	0.601	0.194	0.898	0.601	0.173	0.898	0.601	0.161
SOS 6d	0.886	0.601	0.193	0.886	0.601	0.172	0.886	0.601	0.160
SOS 9a	0.844	0.601	0.203	0.844	0.601	0.187	0.844	0.601	0.168
SOS 9b	0.898	0.601	0.204	0.898	0.601	0.189	0.898	0.601	0.171
SOS 9c	0.854	0.601	0.193	0.854	0.601	0.177	0.854	0.601	0.163
SOS PA	0.901	0.601	0.179	0.901	0.601	0.164	0.901	0.601	0.152

Table 4–15. Value measures predicted by the model for John Day at occurrence intervals of 2, 4, and 10 years under conditions of high variability (7.5–9.9 feet) in reservoir pool elevations. Value measures represent a compilation of habitat suitability indices that incorporate the physical and biological key variables into a relative index of fish health that ranges between 0 (bad) and 1 (good). Within each species, vertical comparisons can be made by reviewing the value measures for each SOS; higher value measures represent better conditions for resident fish. Horizontal comparisons between species can be misleading because the key variables which comprise the habitat suitability indices which are combined to form the value measures differ between species. Temporal assessments can be made by reviewing the value measures in each occurrence interval. The occurrence intervals were selected from the 50 years of record to represent the effects of each operating strategy within the life span of key resident fish species. Value measures at an occurrence interval of 2 years represent the index of fish health we would expect to occur, on average, every 2 years; the value measure at an occurrence interval of 4 years represents the index of fish health we would expect to see every 4 years, and so on. Section 3.3 of Chapter 3 contains a detailed description of how these values were calculated.

John Day Reservoir	Occurrence Interval = 2 years			Occurrence Interval = 4 years			Occurrence Interval = 10 years		
	Small Mouth	Northern Squawfish	Walleye	Small Mouth	Northern Squawfish	Walleye	Small Mouth	Northern Squawfish	Walleye
SOS 1a	0.230	0.101	0.220	0.230	0.101	0.198	0.230	0.101	0.182
SOS 1b	0.230	0.101	0.199	0.230	0.101	0.179	0.230	0.101	0.166
SOS 2c	0.226	0.101	0.199	0.226	0.101	0.176	0.226	0.101	0.163
SOS 2d	0.234	0.101	0.200	0.234	0.101	0.178	0.234	0.101	0.164
SOS 4c	0.230	0.101	0.203	0.230	0.101	0.179	0.230	0.101	0.167
SOS 5b	0.226	0.101	0.194	0.226	0.101	0.175	0.226	0.101	0.162
SOS 5c	0.230	0.101	0.193	0.230	0.101	0.172	0.230	0.101	0.160
SOS 6b	0.234	0.101	0.194	0.234	0.101	0.173	0.234	0.101	0.161
SOS 6d	0.230	0.101	0.193	0.230	0.101	0.172	0.230	0.101	0.160
SOS 9a	0.218	0.101	0.203	0.218	0.101	0.187	0.218	0.101	0.168
SOS 9b	0.234	0.101	0.204	0.234	0.101	0.189	0.234	0.101	0.171
SOS 9c	0.220	0.101	0.193	0.220	0.101	0.177	0.220	0.101	0.163
SOS PA	0.235	0.101	0.179	0.235	0.101	0.164	0.235	0.101	0.152

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.3.1.2 Box Canyon Reservoir

Description of alternatives specific to Box Canyon Reservoir

SOS 2c represents the no action alternative. Relative to SOS 1a, primary changes are additional flow augmentation on the Columbia and Snake Rivers and modified pool levels at lower Snake and John Day reservoirs during juvenile salmon migration.

SOS 2d matches the hydro operations contained in the 1994–98 Biological Opinion issued by the National Marine Fisheries Service in mid–1994. Requirements for this alternative is to use synthetic forecasts designed to replicate actual forecasts instead of observed runoff for those actions based on forecasts and to establish flood control elevations. This would be similar to current operations.

Short and long–term, cumulative, and unavoidable impacts

Every one of these SOS alternatives is very similar in their outflow during the months of May and June. This is the critical time for bass spawning. SOS 1a, 1b, 2d, 5b, 6b and 6d would allow releases from Albeni Falls to rise from nearly 47,000 cfs in May to a peak of 59,000 cfs in June. Minimum outflow from Albeni Falls for bass production would be at 40,000 cfs. Maximum outflow for bass production would be at 45,000 cfs. Fluctuating water levels in reservoirs can adversely affect spawning success of largemouth bass that rely on shallow water or nearshore areas for nest construction. Rapidly receding water levels may also result in desertion of nest, poor egg survival, and disrupted spawning (Ploskey 1986).

This SOS would allow releases from Albeni Falls to increase nearly 33,000 cfs from April 30 to June. This is a substantial increase in flows. Figure 4–15 compares bass spawning requirements to Strategy 2d and current operation.

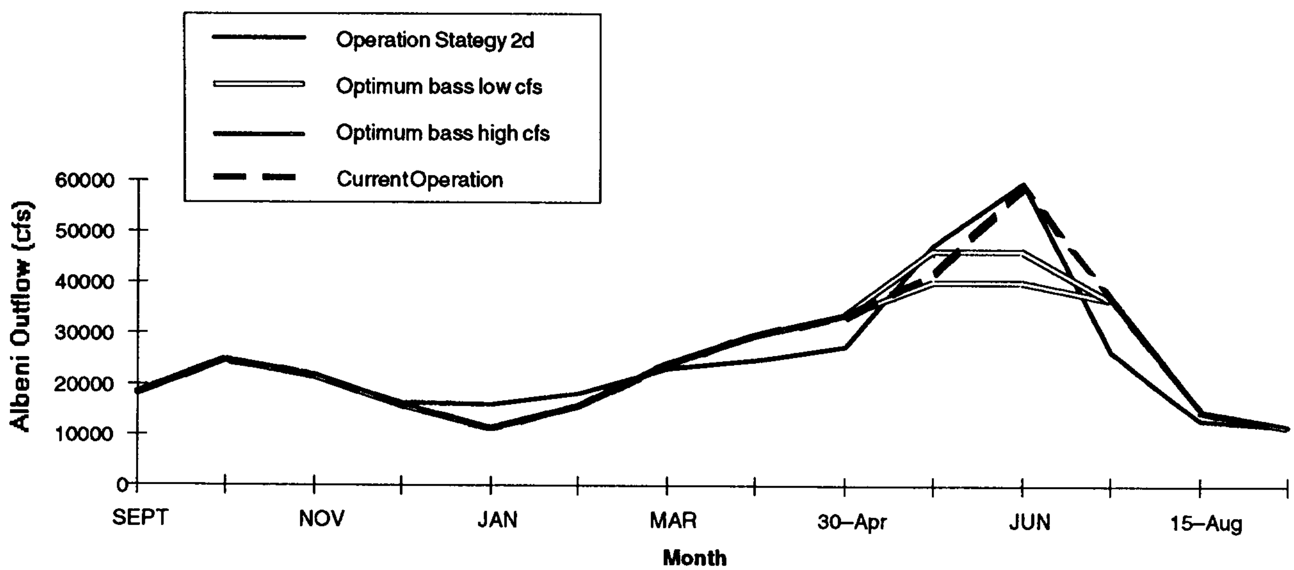


Figure 4–15. Operation at Albeni Falls Dam and Bass Spawning Requirements Under Strategy 2d

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations. Mitigation may also include supplementation in a largemouth bass hatchery.

4.3.1.3 Hungry Horse Reservoir

Description of alternatives specific to Hungry Horse Reservoir

The two scenarios were very similar at Hungry Horse Reservoir and will be discussed together.

Description of SOS2d specific to Hungry Horse Reservoir

Biological production is impacted 30 percent of the time when the reservoir fails to refill by more than 10 feet, and 68 percent of the time when maximum drawdowns exceed 85 feet. Maximum drawdown exceeds 200 feet approximately 6 percent of the time (Figure 4–16). Extreme drawdowns and refill failures would repeatedly damage biological productionat all trophic levels including fish growth and survival.

This alternative is worse for biological production in the reservoir than historic practices.

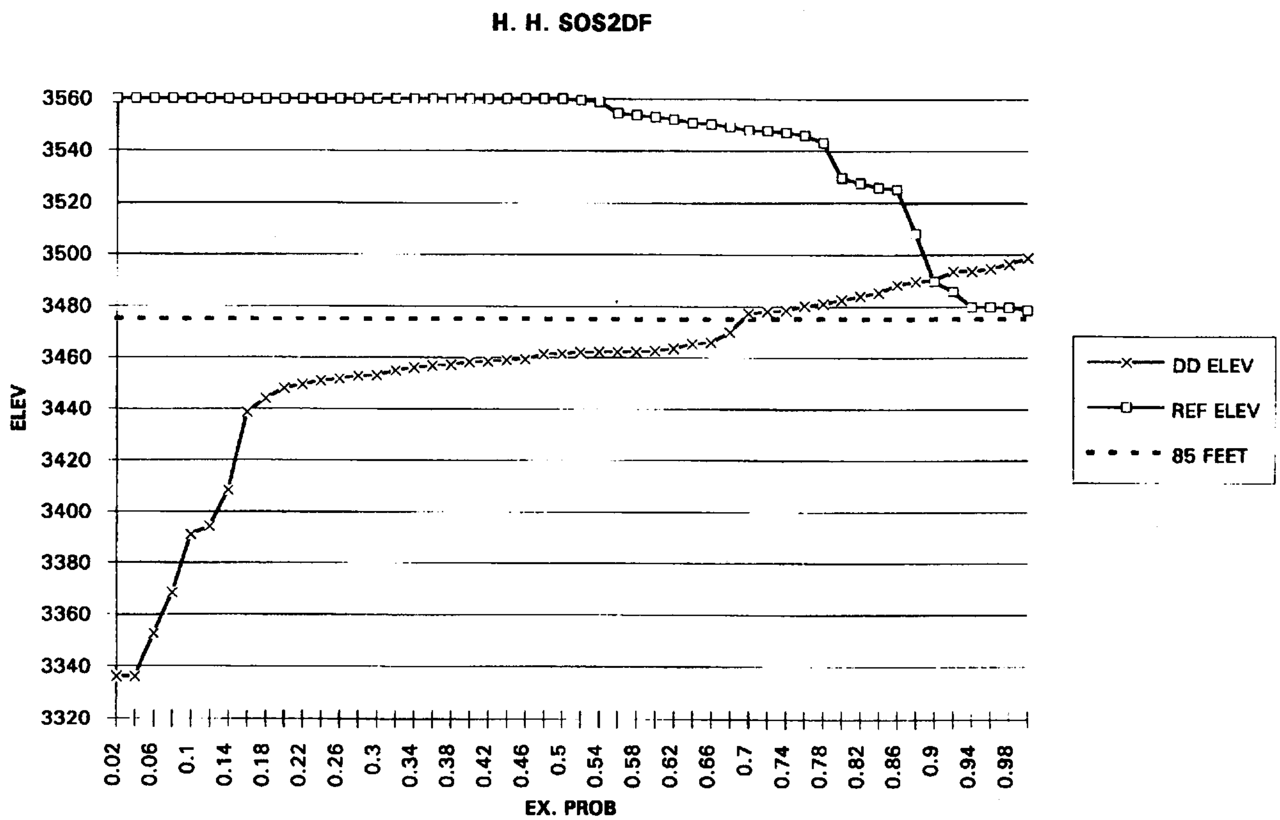


Figure 4–16. Results of a 50–year study showing the maximum elevation during the period June through August (squares), and the minimum elevation ("X") during the period March through May. Existing drawdown limits are shown in horizontal dashed line (at center). Points on the chart represent the probability of refilling or exceeding a given drawdown level.

Short−term impacts

Failure to refill the reservoir in a given year impacts biological production (Table 4−4). Aquatic resources are confined within a diminished environment resulting in an overall loss in aquatic production.

Production of phytoplankton (suspended algae), the base of the aquatic food web, is reduced when the reservoir surface area shrinks during the peak growing season from June through September. Production of zooplankton, an important food supply for young and older fish during the winter, varies proportionally with phytoplankton production. In addition, downstream loss of zooplankton through the dam is increased as the surface approaches the outlet depth and reservoir water is replaced at a faster rate; the result is less food for fish.

Reduction in surface area results in less food during summer and fall as fewer insects from the surrounding (and more distant with drawdown) shoreline vegetation are deposited on the smaller surface.

Terrestrial insects presently provide the greatest biomass consumed by insect−eating fish during their peak growth period. Conversely, food availability is maximized when the reservoir fills and remains near full pool during the months of peak insect activity.

Deep drawdown exposes vast expanses of reservoir bottom to desiccation and freezing which kills aquatic insect larvae. Aquatic insects provide the main food supply for insect eating fish during spring and early summer. Cutthroat trout growth in Hungry Horse Reservoir would be affected by the reduced volume of water at optimal temperatures and the reduced food availability. During a deep drawdown, juvenile gamefish emerge from their natal tributaries into a reduced reservoir volume and are concentrated with predators. This increases the potential for high predation rates.

Reduced food availability and volume of optimal temperature water causes fish to grow less rapidly. Growth reduction during one or more years of the life cycle results in a smaller maximum size at maturity. Female fecundity and egg quality is directly correlated with female size and condition factor. Egg to fry survival is correlated to egg size, larger eggs survive better than small eggs. Given identical conditions in the natal tributary then, it follows that larger, healthier spawners will produce greater recruitment to the reservoir. Given identical conditions in the reservoir, it follows that greater recruitment will result in a larger spawning population to perpetuate the life cycle.

Long−term impacts

Reservoir. The increased frequency of deep drawdown and refill failure would cause a further decline in the health of the reservoir fishery as compared to historic conditions. Recovery of the aquatic insect community takes at least two years after a single deep drawdown event. Frequent deep drawdowns would decrease the spring food supply for insect−eating fish (e.g. westslope cutthroat trout, mountain whitefish). Decreased spring growth combined with poor fall growth due to frequent refill failure would decrease the maximum attainable size of fish and ultimately, population size.

Field sampling has shown evidence of size selective mortality in juvenile westslope cutthroat trout. Reduced growth in young trout has been linked to reduced survival, increased losses to predation, decreased fecundity and poor reproductive success. Although the trout population can recover with time after adverse operational events, frequent deep drawdowns and refill failures strongly influence fisheries health. Genetically pure westslope cutthroat trout have been reduced to less than 10 percent of their historic range, making Hungry Horse populations an important genetic resource.

Impacts on prey availability for bull trout, leading to greater search perimeters, greater energy expenditure and slower growth, ultimately result in decreased bull trout growth and abundance in the reservoir. Although fish concentrations caused by reduced reservoir volumes benefit bull trout initially, the effect is short lived. When the reservoir ultimately refills, prey species redistribute in the larger pool, at lower prey densities. Hungry Horse provides one of two remaining fishable bull trout populations in Montana. The apparently stable population is one of the strongest anywhere, increasing the importance of the remaining population as a genetic reservoir for the species. Bull trout are under consideration for listing under ESA. The USFWS determined that listing is warranted but precluded pending further examination of data.

Long–term effects of large reservoir fluctuations have affected species assemblages and relative abundance of species in the aquatic community. Aquatic insect diversity has been reduced. Now chronomidae (midges) comprise nearly the entire assemblage. Stoneflies, mayflies, caddis flies and other more desirable fish food organisms are rare in the reservoir pool. Northern squawfish, an important predator on young fish, have benefitted from impoundment and are now the most abundant species in the reservoir.

Flathead River. Spring discharges are much reduced as compared to natural spring conditions under this alternative. Spring flows provide the cue for spawning migrants, and resort the river sediments and thus maintain channel integrity. Natural, unregulated discharges from the North and Middle forks of the Flathead River partially mitigate the effects of flow regulation. However, flow fluctuations from Hungry Horse Dam have increased sediment inputs to the Flathead River as streambanks destabilize and collapse. Modified Flathead Lake elevations caused by Kerr Dam operation affect Flathead River stage and velocity for as much as 22 river miles upstream from the inlet to Flathead Lake. Reduced velocities in the semi–impounded reach of the river allow fine sediments to accumulate, filling interstices between river cobble. Sediment buildup damages insect habitat and juvenile fish security cover. This problem could be partially mitigated by increasing river velocities during spring runoff. Higher flows at the correct time would flush fine sediments from the gravels, improving conditions. This SOS alternative, however, would perpetuate and exacerbate the sedimentation problem.

Peaking and load factoring operations intermittently inundate and dewater the river margins. This "varial" zone is nearly devoid of insect life and is unproductive. When recolonization of aquatic life occurs, a rapid flow reduction can cause widespread stranding and desiccation of insects, small fish and fish eggs. Stable flows, conversely, promote biological production. Intermittent high discharges can scour portions of the main channel, dislodging insects and their habitat. Annual flood events performed the same function, although conditions became stable for the remainder of the year. Frequent scour events, however, limit production in the zone protected by minimum flow requirements.

The lack of temperature control facilities at Hungry Horse Dam allows rapid fluctuations in the Flathead River, creating shock to fish and prey organisms. Furthermore, water is released for extended periods from deeper strata in the reservoir, and is of a temperature below that required for insect production and for normal metabolism of trout in the growing season. Thus, trout growth is suboptimal. This problem will be mitigated to a great extent by the construction and operation of a temperature control device called "selective withdrawal." This structure is planned for complete operation by June 1996. A portion may be functional in late summer 1995. The analysis in Table 4–4 assumed that selective withdrawal was fully functional. Therefore, alternatives which discharged large volumes during the summer resulted in enhanced growth of trout in the Flathead River (WCT III FHR). Until selective withdrawal is complete, summer drafts will in reality harm trout growth.

Cumulative and unavoidable impacts

Seventy–seven miles of low gradient river and tributaries were permanently lost when the reservoir first filled. Tributary segments above full pool elevation were further limited by man–caused barriers to fish passage at road crossings around the reservoir. Recruitment of juvenile fish to the reservoir has been reduced by the elimination of spawning and rearing habitat. Growth and survival of young fish is further influenced upon emigration from their natal tributaries into the fluctuating reservoir. Recovery of lost habitat area is only partially mitigatable. The reduction in juvenile recruitment and suitable habitat will continue to limit tributary spawning by adfluvial species.

Northern squawfish have apparently benefitted from impoundment. Although native to the river system, this species has disproportionally expanded their abundance. Predation by northern squawfish contributes to significant losses of juvenile trout and whitefish.

Mitigation

An ongoing mitigation program for the construction and operation of Hungry Horse Dam began in 1992. The loss statement and mitigation criteria assumed that reservoir operation would not become more damaging than historic conditions. Additional mitigation is underway for excessive drawdowns in recent years. This alternative, if selected, would reduce the effectiveness of mitigation actions taken to date and result in significant unmitigatable impacts.

Implementation of the Hungry Horse mitigation plan involves habitat enhancement, fish passage improvement, fisheries improvements in associated off-site areas, hatchery supplementation and monitoring. Mitigation efforts in the full-scale program have been directed to areas downstream of Hungry Horse Dam. The Excessive Drawdown Mitigation Program, begun in 1994, includes measures directed at the reservoir basin: fish passage at human-caused barriers, reconstruction of spawning and rearing areas to increase natural recruitment of juvenile fish and shoreline revegetation. Mitigation options which do not require changes in dam operation (non-operational mitigation) was expected to replace approximately 50 percent of the loss statement. The remaining approximately 50 percent of the loss was to be replaced through operational changes which were deferred to this SOR process. It is important to note that existing funding and mitigative techniques will not fully mitigate for the construction and operation of Hungry Horse Dam. Cumulative impacts have caused irreparable damage to the ecosystem. Options to protect and enhance fish populations in the reservoir are limited unless operation limits (IRCs) can be enforced.

The primary mitigation objective for the Flathead River is the installation and operation of a selective withdrawal structure on Hungry Horse Dam to control discharge temperatures. Natural temperatures can be mimicked with minimal effects on power generation. Rapid thermal fluctuations (up to 15°F) and long-term cooling effects can be greatly reduced through the use of selective withdrawal, benefitting fish growth and aquatic insect production. Selective withdrawal will be partially functional in 1995 and fully operational by summer of 1996. Flow fluctuation should also be reduced to promote biological production in the varial zone downstream of Hungry Horse Dam.

4.3.1.4 Lake Koocanusa

Description of alternatives specific to Lake Koocanusa

SOS 2c and 2d are very similar at this project.

Description of SOS 2D specific to Lake Koocanusa

Biological production is impacted 18 percent of the time when the reservoir fails to refill by more than 10 feet. Refill failure is extreme 8 percent of all years. Extreme drawdowns in excess of 110 feet occur 66 percent of the time (Figure 4-17). Maximum drawdown approaches the bottom of active storage (≈172 feet) 30 percent of the time. Extreme drawdowns and refill failures would repeatedly damage biological production at all trophic levels including fish growth and survival. This alternative is worse for biological production than historic operations.

Short-term impacts

Deep drawdowns and failure to refill the reservoir in a give year impacts biological production (Table 4-5). The biological effects of refill failure are similar to those of Hungry Horse Reservoir, resulting in lost aquatic production and lost terrestrial insect deposition (see text concerning SOS2D and Hungry Horse Dam).

Kokanee growth is highly dependent on population density; growth declines as densities increase. Growth also responds to the volume of optimal water temperature and the availability of their primary food item, zooplankton. As the reservoir volume shrinks, phytoplankton (suspended algae) production diminishes, which in turn reduces zooplankton production. The combined effects of reduced food availability and increased fish density on kokanee growth is magnified by refill failure during the warm months of peak biological activity.

Insect–eating species, including cutthroat trout, inland redband trout and mountain whitefish are impacted by the dewatering and desiccation of aquatic insect larvae during reservoir drawdown. Refill failure results in a smaller surface area, with pool margins further from terrestrial vegetation which is the source for terrestrial insect deposition, thus limiting the summer and fall food supply.

Aquatic insect production is temporarily enhanced by reservoir refill failure. Refill failure brings warm water layers in contact with zones of higher larval densities, enhancing aquatic insect emergence. These benefits to food availability are short–lived. Future aquatic insect production is damaged. The net result is slower annual growth in gamefish and prey species.

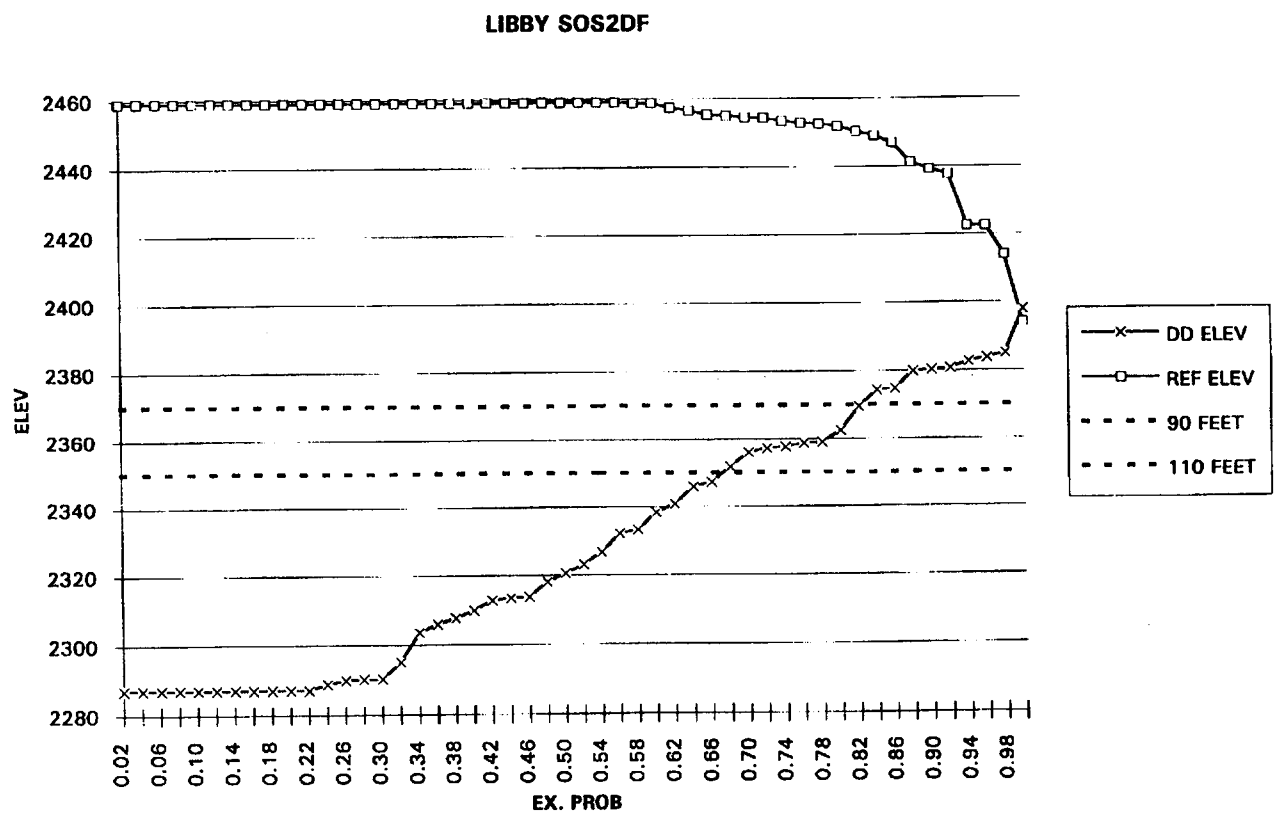


Figure 4–17. Results of a 50–year study showing the maximum elevation during the period June through August (squares), and the minimum elevation ("X") during the period March through May. Existing drawdown limits are shown in horizontal dashed line (at center). Points on the chart represent the probability of refilling or exceeding a given drawdown level.

Peaking and load factoring operations intermittently inundate and dewater the river margins. This "varial" zone is nearly devoid of insect life and in unproductive. When recolonization of aquatic life occurs, a rapid flow reduction can cause widespread stranding and desiccation of insects, small fish and fish eggs. Stable flows, conversely, promote biological production. Intermittent high discharges can scour portions of the main channel, dislodging insects and their habitat. Annual flood events performed the same function, although conditions became stable for the remainder of the year. Frequent scour events, however, limit production in the zone protected by minimum flow requirements.

Long–term impacts

Reservoir. The aquatic insect community contains species having life cycles from five weeks to three years. One extreme drawdown event can limit the spring food supply for at least two years.

Long–term effects of reservoir fluctuation have resulted in shifts in the species assemblage. Aquatic insect diversity has been reduced. Chironomidae (midges) now compose nearly the entire aquatic insect assemblage. Stoneflies, mayflies, caddis flies and other more desirable fish food organisms, are rare in the reservoir pool.

Long–term monitoring has shown that rainbow, cutthroat and bull trout have stabilized at low populations in the reservoir. Growth impacts have been linked to decreased survival, poor reproductive success, reduced fecundity and shifts in species relative abundance. Columbia River chubs and northern squawfish have benefitted from impoundment and are now the most abundant fish in Lake Koocanusa.

Kootenai River. Spring releases under these alternatives would not approach the levels associated with successful natural reproduction of the Kootenai River white sturgeon. If this alternative were selected, natural reproduction of white sturgeon would be unlikely.

Sediment accumulation and loss of interstitial habitat in the river substrate of the Kootenai River has been linked to a gradual reduction in trout growth downstream of the tailwater area. The fishery immediately below the dam, however, is benefitting from zooplankton, fish and other food items entrained through the turbines from the reservoir. Entrainment can be partially controlled regardless of the operational alternative selected. Conversely, sedimentation can be addressed only through flow velocity manipulation. This alternative has no provision for channel maintenance flows.

Cumulative and unavoidable impacts

Impoundment has apparently benefitted native Columbia River chubs and northern squawfish. Chubs, because of their large numbers, consume a huge portion of the zooplankton biomass. Kokanee must compete for the available zooplankton supply. Squawfish are effective predators on juvenile fish.

Approximately 200 miles of low gradient, primary spawning and rearing areas in the river and tributary streams were permanently lost when the reservoir first filled. High gradient stream segments, migration barriers and human–cause stream degradation have further limited critical habitat in areas above full pool elevation, reducing natural recruitment of juvenile fish to the reservoir. Growth and survival of young trout has been further reduced by biological interactions caused by extreme reservoir fluctuation.

Mitigation

Current mitigation for construction of Libby Dam consists of fish stocking in Lake Koocanusa and nearby waters from Murray Springs Trout Hatchery. A selective withdrawal system regulates release temperatures in the Kootenai River downstream.

A public scoping process began during spring of 1995 to develop a mitigation plan to repair fisheries losses caused by the operation of Libby Dam. The scoping procedure is similar to the Hungry Horse mitigation planning process. Mitigation for excessive reservoir drawdowns is currently underway. Mitigation measures include habitat enhancement in tributaries, off–site fisheries improvements, project site selection and monitoring. Additional mitigation measures could include operational constraints on the existing 3–foot river level fluctuations on the Kootenai River below Libby Day.

There are short–term recovery activities under consideration for Kootenai River white sturgeon which include the release of reservoir storage during May, June and July to provide the stimulus for spawning as well as protection for egg incubation and for rearing of larval sturgeon. The intent is to store water during the fall through spring period, specifically for sturgeon flow enhancement. This strategy can provide the necessary release without compromising refill probability. Initial efforts have called for fixed releases from Libby Reservoir, unrelated to water availability. For the long–term, however, flow augmentation should vary with water availability. Volumes should be balanced with reservoir refill. If spring flow provisions are not included in the alternative for sturgeon, reservoir refill probability will be poorer than the hydroregulation study indicates.

Proposed recovery actions submitted by FWP, Idaho Fish and Game (IDFG) and the Kootenai Tribe of Idaho recommend a tiered approach to flow augmentation for sturgeon spawning. This SOS2d does not contain this provision. A provision in the IRCs developed by Montana (SOS4c and 9c) establishes high targets when water availability is ample and specifies no discharge during drought. These alternatives approximate a tiered approach, actual shape and volume of the discharge is under examination by the White Sturgeon Recovery Team. This tiered approach will consider thresholds between conditions resulting in reproductive success and failure, and the needs of other sensitive species in the river and reservoir. The experimental flow event must correspond with the release of optimal water temperatures. Adults marked with sonic transmitters will be monitored enroute to known spawning areas to assure at the spawning que occurs at the appropriate time to simulate natural conditions.

The Recovery Team is also considering hatchery technology to replace missing year classes of juveniles. Cooperating agencies agree that hatchery methods are a valuable recovery took, but stress concern for the long–term genetic health of the species.

A balance of techniques must be examined to conserve the remaining viability of the stock. Recruitment of juveniles to spawning age must be accomplished either naturally or artificially before the existing adults die or become infertile. The near absence of recruitment during the last 20 years must be replaced by conserving year classes of juveniles through careful crosses among mature survivors.

The selected SOS alternatives should avoid impacting other sensitive species. Flow augmentation should be balanced with reservoir refill to protect important fish species above the dam (e.g. bull trout, westslope cutthroat, inland redband trout, and kokanee). The IRCs (SOS4c/9c) were designed to balance resident fish in the reservoir and river with anadromous recovery actions in the lower Columbia Basin. Discharge targets requiring the use of the spillway should also be avoided to eliminate gas supersaturation and associated gas bubble trauma in riverine species. Trout, kokanee, burbot, and whitefish inhabiting the stilling basin are particularly susceptible to gas supersaturation. Use of the spillway may be unnecessary with all five turbines in Libby Dam fully operational.

4.3.2 Current Operations (SOS 2c and SOS 2d) for Lake Roosevelt and mid–Columbia River

4.3.2.1 Lake Roosevelt

Description of alternative specific to Lake Roosevelt

Under SOS 2, up to 3 MAF of water from the upper Columbia River, including Lake Roosevelt, would provide water budget flows for salmonids. In all cases, flood control would be shifted to Grand Coulee. Short term operation requirements would provide flow augmentation at Coulee for downstream needs while not limiting peaking ability of the project or other downstream mid–Columbia projects. There are significant monthly variations in elevation and outflow at Grand Coulee under this alternative (see the Results Exhibit for a complete set of yearly flows and elevations). For example, average annual end–of–month elevations fluctuate over 20 feet from one year to the next while within–year fluctuations in elevation are over 80 feet in some years. Fluctuations in elevation appear to frequent in this SOS while outflows fluctuations similar to other SOSs.

Short–term impacts

Short term impacts at Lake Roosevelt from the operations of SOS 2c and 2d are similar and will be discussed together. Each operation offers deep drawdowns for extended periods of time. Combined with high outflows these drawdowns result in water retention times that are 30 days or less from January to May for roughly 80% of the 50 water years examined. As stated earlier, low water retention times result in low zooplankton density and biomass values and high entrainment of salmonids which are reflected in reduced fish growth and decreased fish population numbers (Table 4–7). Spring spawners may be impacted by drafting in spring.

Long–term impacts

Long term impacts from continued operations of SOS 2c, or 2d could cause adverse effects of the fisheries so they now exist due to low food resources and fish numbers as related to decreased food sources and increased entrainment.

Limited information is available for sturgeon, whitefish and burbot. Primary impacts to these species from this alternative would be food related as benthic or other food items may be impacted and killed by drawdowns.

Cumulative impacts

Low water retention times lead to decreased food production which results in poor fish growth. Monthly fluctuations in water levels decrease spawning success of many spring spawning resident fish of Lake Roosevelt (Beckman et al. 1985). Due to the limited capability of the hydroregulated models these impacts could not be quantified but would most certainly be an important impact to the survivability of eggs and fry and ultimately to fish population success.

Unavoidable impacts

Unavoidable impacts due to Grand Coulee operations under SOS 2 are loss of nutrients, loss of zooplankton, loss of benthic invertebrates, decreases in fish spawning and feeding habitat, and entrainment losses.

Mitigation

Potential mitigation measures for these alternatives include stream and riparian zone improvements, benthic invertebrate structure placement, and sonic avoidance mechanisms. These measures would increase usable fish habitat, increase food sources, and decrease entrainment levels. Monitoring systems to detect unforeseen impacts should be set up to aid in determining on–site and off–site mitigation locations and actions.

4.3.3 Current Operations (SOS 2c and SOS 2d) for Middle Snake and Clearwater Rivers

4.3.3.1 Dworshak Reservoir

Description of alternative specific to Dworshak Reservoir

SOS 2c requires Dworshak Reservoir to provide supplemental releases as follows (1) draft up to 900 KAF (or more) of water from April 16 to June 15 and (2) draft up to 470 KAF above the 1.2 kcfs minimum release from June 16 to August 31. Flood control is shifted from Dworshak to Grand Coulee for the April through July runoff forecasts. SOS 2d results in Dworshak Reservoir being operated on minimum flow (i.e., 1.2 kcfs) up to flood control except when providing flow augmentation (April 10 – July 31). Volume of discharge depends upon the time of the year. For example, from April 10 to June 20, the volume discharged would be 927 KAF plus minimum flow, 470 KAF plus minimum flow during June 21 to July 31, and 1 MAF plus minimum flow all other times of the year. If after the volume is expended and the flow target at Lower Granite Dam is not met, then additional drafting can occur to 1520 feet. If Dworshak drafts to 1520 feet before all the volume is used, then further draft below 1520 is allowed until the volume is expended.

The average annual end–of–month elevations at Dworshak under SOS 2c and SOS 2d range between 1525 and 1570 feet, and 1500 and 1560 feet, respectively. Under both options, the annual minimum monthly elevations reach 1445 feet and annual maximum monthly elevations reach 1600 feet (see the Results Exhibit for flows and elevations). Drawdowns greater than 100 feet below normal full pool (1600 feet) can be expected under this alternative during high (>5.5 MAF flow volume per year) and medium–high (4.5–5.5 MAF) water years. A drawdown of approximately 80 feet would be expected under an average (3.5–4.4 MAF) water year. SOS 2d differs from SOS 2c in that fluctuations in elevation and discharge occur more frequently. Both SOSs fail to refill in all years under most hydrology's. Maximum annual pool levels will occur on or about July 1, and on the average will be 15 feet below full pool.

Average annual discharge (based on monthly flows) for SOS 2d is slightly higher than for SOS 2c. SOS 2d ranges in discharge from approximately 4 kcfs to 10 kcfs, while SOS 2c ranges from 3 kcfs to 10 kcfs (see the Results Exhibit for flows and elevations). Higher peak annual discharges are predicted under SOS 2d with maximum discharge reaching 25 kcfs in most years. Both SOS 2c and SOS 2d appear to have higher average annual discharges than predicted under SOS 1. Evacuation of the reservoir begins after July 1, and continues until the following spring when the next refill cycle begins.

Short and long–term impacts

Each option results in deleterious impacts to kokanee (Table 4–8; see the Results Exhibit for additional results). It appears that the increased flows provided for anadromous fish migration result in high kokanee entrainment. Successive years of increased flows in the mid 1950s reduce the entrainment index in consecutive years and drive the kokanee population lower and lower until it cannot rebound. Failure to refill and long evacuation periods severely affect kokanee spawning and rearing success. Fluctuations in elevation reduce the spawning habitat availability index and potentially block access to kokanee spawning areas.

This SOS will have chronic negative effects on smallmouth bass, cutthroat trout, and bull trout (Table 4–8). Food production indices are generally much worse under SOS 2d than SOS 2c, and both are the same or worse than in SOS 1. Annual drawdowns of this magnitude will preclude the voluntary establishment of shoreline riparian vegetation and littoral zone macrophytes. This will result in poor food production. Seasonal reservoir drawdown also have the potential to limit productivity of resident fish populations in a drawndown reservoir by disrupting shallow–water habitat for benthic invertebrates, which are an important food source for many resident fish species.

Increasing pool levels during June, and the associated decrease in water temperature, under all options of SOS 2 may abort smallmouth bass spawning and/or interfere with egg and larvae development. Declining pool elevations during July and August may dewater smallmouth bass spawning nests. Reproductive failure of smallmouth bass may occur if spawning is aborted during the June refill and if nests are dewatered in July.

Cumulative and unavoidable impacts

This alternative approximates current operating conditions at Dworshak Reservoir. In fact, successively wet years with high discharge under this operating scenario may result in a further decline in the kokanee population. Although food production does not appear to be significantly affected under this operating strategy, we would expect that the overall reservoir productivity would decline at an increased rate under this operating strategy. Routine annual drawdowns of 100–150 feet restrict the long–term reservoir productivity due to the lack of macrophytes in the littoral zone. Redside shiner spawning success would be negatively impacted under this alternative which would reduce the available forage base for bull trout, cutthroat trout, and smallmouth bass.

Mitigation

Certain measures could be taken to lessen the effect of this alternative, including:

- Revegetation of the drawdown zone along the more gently sloping banks. Aerial photography and a digitized reservoir contour map could aid in the identification of suitable candidate areas. Shoreline revegation could partly offset the food and habitat deficits caused by pool level fluctuations. Follow–up on the effectiveness of this program would be required.

- Small sub–impoundments near full pool elevation could provide a permanently wetted, relatively stable environment to promote the production of aquatic and semi–aquatic vegetation. This would provide food and substrate for aquatic insect production and could also provide a nursery area for forage fish. The sub–impoundments would also partly offset the food and habitat deficits caused by pool level fluctuations. Follow–up on the effectiveness of this program would be required.

- More water from the Snake River above Hells Canyon Dam and/or lower pool levels in the Lower Snake River would reduce the drawdown requirements for Dworshak Reservoir, while providing for the migration needs of anadromous salmonids.

- Eliminating prescribed releases for flood control and power production would reduce the drawdown requirements for Dworshak Reservoir and fulfill the need for flow augmentation for anadromous fish (made necessary because of other projects that continue to derive benefits for flood control, power production, and irrigation).

4.3.3.2 Brownlee Reservoir

Description of alternative specific to Brownlee Reservoir

SOS 2 requires Brownlee to draft up to 137 KAF in July and 100 KAF in September with flood control shifted to Grand Coulee. Annual flows for both SOS 2c and SOS 2d based on monthly averages are similar to SOS 1, ranging between 10 – 30 kcfs.

Short and long–term, cumulative, and unavoidable impacts

Food production index values (and hence rainbow trout index values) are nearly identical under SOS 2c and SOS 2d (Table 4–9; see the Results Exhibit for additional results). Smallmouth bass and channel catfish are also affected nearly the same in SOS 2c and SOS 2d as in SOS 1 (Table 4–9; see the Results Exhibit for additional results). Generally, SOS 2c and 2d are not as good for smallmouth bass, causing fluctuations in the spawning and incubation success index from year to year (see the Results Exhibit). SOS 2c and 2d are better alternatives for channel catfish and rainbow trout.

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.3.4 Current Operations (SOS 2c and SOS 2d) for Lower Snake River

4.3.4.1 Lower Granite

Description of alternative specific to Lower Granite Reservoir

At Lower Granite, the end–of–month elevations for SOS 2c, and 2d are all identical. Elevations from April through July are to be held within 1 foot of the minimum operating pool. There is no more than a 1 foot change in elevation from one month to the next. Average monthly flows over the 50 year record appear to be identical for each of the options. The maximum monthly flows in any one year are approximately 120 kcfs; however, flows do reach 180 kcfs in some years. This alternative represents current operating conditions.

Short and long–term, cumulative, and unavoidable impacts

Growth index values at 2, 4, and 10 year occurrence intervals for smallmouth bass, white sturgeon, and northern squawfish for all SOSs can be found in Tables 4–10 to 4–12 (additional detail can be found in the Results Exhibit). Without hydroregulated input at a time scale finer than 1 month, it is impossible to make highly accurate predictions of the impacts to resident fish in Lower Granite Reservoir. The model predictions based on the end–of–month pool elevations and our qualitative assessment of the impacts should fluctuations in the pool levels occur at a time scale finer than 1 month are presented in the following tables. Table 4–10 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of no variability in within–month pool levels; i.e., the growth index values predicted by the model based on end–of–month elevations. Table 4–11 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of minimal within–month pool fluctuations (2.5 – 4.9 feet); i.e., a qualitative estimate of the impacts should the pool be fluctuated between 2.5 and 4.9 feet within any given month. Table 4–12 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of high within–month pool fluctuations (7.5 – 9.9 feet); i.e., a qualitative estimate of the impacts should the pool level be fluctuated between 7.5 and 9.9 feet within any given month.

Each alternative for smallmouth bass is slightly better than SOS 1b, most likely because elevations are held constant, thus improving spawning success (Figure 4–9; see the Results Exhibit for additional results). Assuming there are no within–month elevation changes, this alternative would be expected to result in similar smallmouth bass production as under current operations.

There is very little difference from SOS 1 for white sturgeon (Figure 4–11). All options result in the same index value. As in SOS 1, there are similar concerns with regard to the lack of a velocity component to the model.

The index value for northern squawfish is constant at approximately 0.7 (Figure 4–12). This is less than the index value in SOS 1b, and is due to the slight elevation fluctuation found in each option of SOS 2.

Mitigation

Mitigation measures may include, but not be limited to offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.3.5 Current Operations (SOS 2c and SOS 2c) for Lower Columbia River

4.3.5.1 John Day Reservoir

Description of alternative specific to John Day Reservoir

SOS 2 operates John Day Reservoir at minimum pool (approximate elevation of 262.5 feet msl) from May 1 through August 31. The pool would be held at this level unless it needed to be raised to alleviate irrigation impacts.

A review of the flows and elevations indicates there is little difference between SOS 2c and SOS 2d. In each case, the average annual elevation is approximately 263 feet msl and fluctuates monthly over 5 feet (262 – 267 feet msl). This is a slightly wider range of fluctuation than observed under SOS 1. The average annual flow ranges from approximately 100,000 to 230,000 cfs with the maximum ranging from 200,000 to 500,000 cfs. The average minimum discharge under SOS 2 is approximately 90,000 – 110,000 cfs. See the Results Exhibit for a complete set of yearly flows and elevations.

Short–term, long–term impacts, cumulative, and unavoidable impacts

Growth index values at 2, 4, and 10 year occurrence intervals for smallmouth bass, northern squawfish, and walleye for all SOSs can be found in Tables 4–13 – 4–15 (additional detail can be found in the Results Exhibit). Without hydroregulated input at a time scale finer than 1 month, it is impossible to make highly accurate predictions of the impacts to resident fish in John Day Reservoir. The model predictions based on the end–of–month pool elevations and our qualitative assessment of the impacts should fluctuations in the pool levels occur at a time scale finer than 1 month are presented in the following tables. Table 4–13 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of no variability in within–month pool levels; i.e., the growth index values predicted by the model based on end–of–month elevations. Table 4–14 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of minimal within–month pool fluctuations (2.5 – 4.9 feet); i.e., a qualitative estimate of the impacts should the pool be fluctuated between 2.5 and 4.9 feet within any given month. Table 4–15 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of high within–month pool fluctuations (7.5 – 9.9 feet); i.e., a qualitative estimate of the impacts should the pool level be fluctuated between 7.5 and 9.9 feet within any given month.

4.4 DESCRIPTION OF IMPACTS OF SYSTEM OPERATING STRATEGIES

4.4.1 Stable Storage (SOS 4c) for Upper Columbia River and tributaries

4.4.1.1 Lake Pend Oreille

Description of alternative specific to Lake Pend Oreille

SOSs 4c is intended to meet the following elevation targets by the end of the indicated month at Lake Pend Oreille: September – 2060 feet (2.5 feet below full pool), October through March – 2056 feet, April through May – between 2058 and 2062.5 feet, June – 2062.5 feet, July through August – 2060; every sixth year draft to elevation 2051 in October through March.

Inspection of the average annual end–of–month elevations (see Results Exhibit) reveals SOS 4 is the only alternative which results in any significant differences in operations from current conditions. The total fluctuation in end–of–month elevations throughout the year is typically less than 7 feet; however, every sixth year fluctuations may be as great as 11 feet.

Short–term impacts

Under this SOS, Lake Pend Oreille elevations should remain stable prior to and during the spawning and egg incubation period of kokanee. Also, the winter elevations of the lake will remain higher and make high quality, wave washed gravel available for kokanee spawning. The spawner index values at 2, 4, and 10 year occurrence intervals are approximately 280,000 (Table 4–3; see the Results Exhibit for a complete set of spawner index predictions). This demonstrates a marked improvement over existing conditions; primarily because of the improvements to spawning. This response is consistent with historical changes in the kokanee population, which showed marked declines in kokanee abundance with deeper drawdowns. Elevation drawdowns every sixth year in the model results did not appear to significantly affect the kokanee population. However, this sixth year drawdown will likely cause significant declines in that one age class of kokanee. The effect of a single weak year class of kokanee will be reduced since the fishery encompasses primarily two age classes. Bull trout and cutthroat trout also appear to benefit from this SOS based on the index values at occurrence intervals of 2, 4, and 10 years (Table 4–3).

This SOS also has the potential to improve the habitat for warmwater species in both the lake and the Pend Oreille River. The relative index values at 2, 4, and 10 year occurrence intervals for warm water species improve under this SOS (Table 4–3). The effect of the sixth year drawdown will reduce the available winter habitat to all age groups of warmwater fish. Although this is still a significant improvement over current conditions. With stable elevations, the river environment would remain stable and become more productive under current operations.

Long–term impacts

This SOS should improve the rainbow trout, kokanee, bull trout, and warmwater fisheries, thereby increasing angler interest at Lake Pend Oreille. This will produce a healthier ecosystem, promoting the recovery of bull trout, a sensitive species.

Cumulative impacts

This SOS should improve conditions for kokanee which would be expected to improve conditions for predator species such as rainbow trout, bull trout, and warm water species. Overall production in the river should increase as well.

Unavoidable impacts

Conditions should improve under this SOS.

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations. Should this alternative be implemented, removal of barriers to bull trout access would be recommended for creek mouths.

4.4.1.2 Box Canyon Reservoir

Description of alternative specific to Box Canyon Reservoir

Under SOS 4c, Albeni Falls would meet the following elevation targets by the end of the indicated month: September – 2060 feet (2.5 feet below full pool), October – 2056, November through March – 2056, April through May – between 2058 and 2062.5, June – 2062.5, July through August – 2060 but allow higher levels for flooding for one month. Every 6th year have October through March drawdown to 2051 feet.

Short and long–term, cumulative, and unavoidable impacts

This SOS would allow releases from Albeni Falls to increase around 35,000 cfs from mid–April to June. The peak in June would be higher than current operations. Figure 4–18 compares bass spawning requirements to Strategy 4c and current operation. Minimum outflow from Albeni Falls for bass productions would be at 40,000 cfs. Maximum outflow for bass production would be at 45,000 cfs. Fluctuating water levels in reservoirs can adversely affect spawning success of largemouth bass that rely on shallow water or nearshore areas for nest construction. Rapidly receding water levels may also result in desertion of nest, poor egg survival, and disrupted spawning (Ploskey 1986).

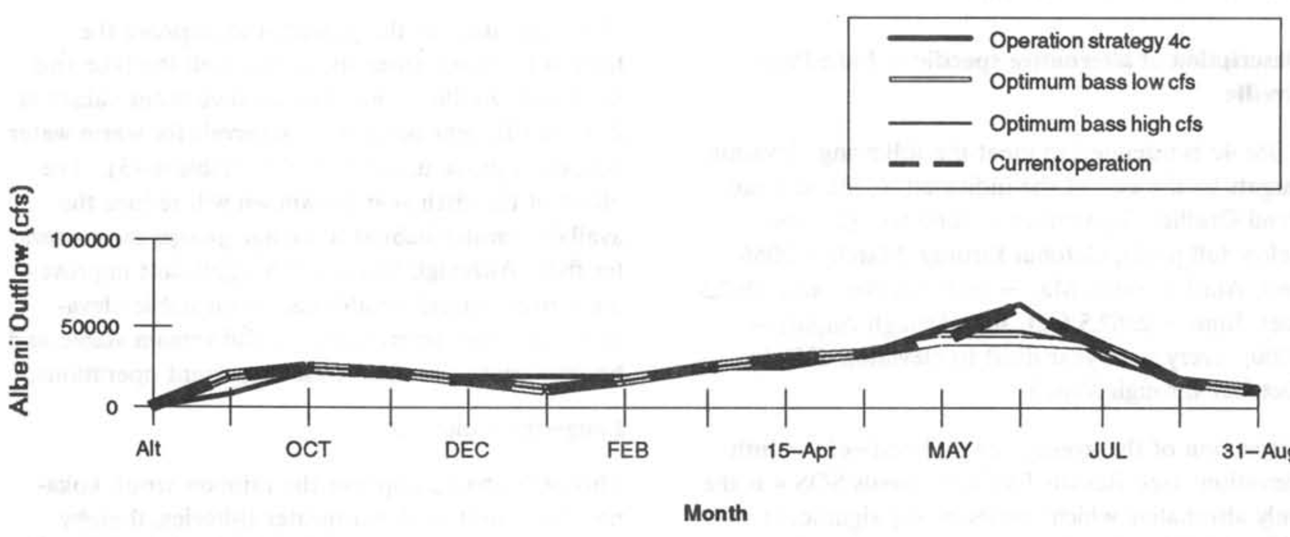


Figure 4–18. Operation at Albeni Falls Dam and Bass Spawning Requirements Under Strategy 4c

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations. Mitigation may also include supplementation in a largemouth bass hatchery.

4.4.1.3 Hungry Horse Reservoir

Description of SOS4C specific to Hungry Horse

Reservoir

This alternative represents the June 1994 version of the Integrated Rule Curves (IRCs) developed by Montana FWP. The reservoir completely refills 90 percent of all years. Refill failure occurs in dry years, but the reservoir fills to within ≈10 feet of full pool in all years. Maximum drawdown exceeds the 85 foot drawdown limit 18 percent of all years. Drawdowns are minimized to protect biological production in the reservoir. River discharges remain within local flood control limits and simulate a natural runoff event for channel maintenance (Figure 4–19).

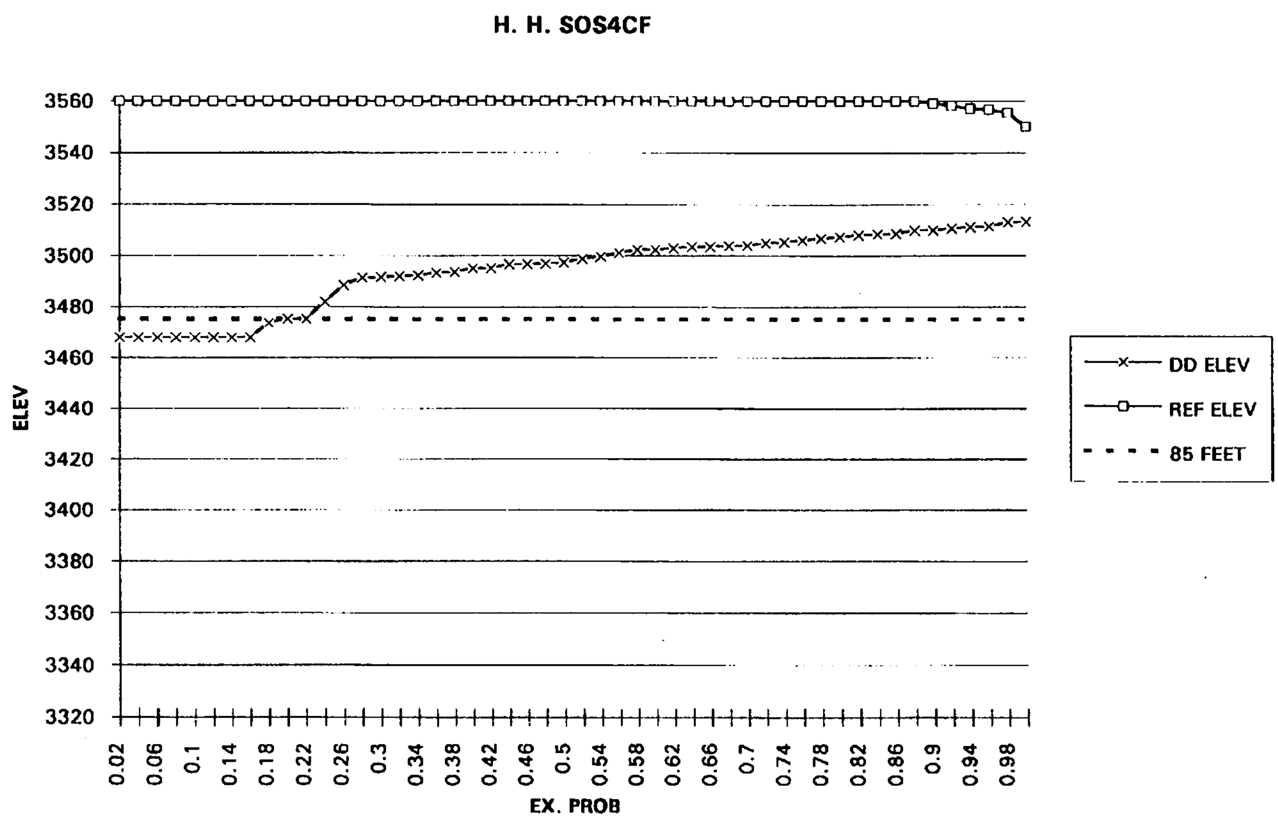


Figure 4–19. Results of a 50–year study showing the maximum elevation during the period June through August (squares), and the minimum elevation ("X") during the period March through May. Existing drawdown limits are shown in horizontal dashed line (at center). Points on the chart represent the probability of refilling or exceeding a given drawdown level.

This alternative was designed to balance the requirements of resident and anadromous fish with power and flood control. As modeled, anadromous benefits are detectable but limited. Benefits for anadromous smolt migrations could be further enhanced by storing water above the IRCs prior to runoff for later release. This "earmarked" water can be released without compromising reservoir refill probability.

IRCs were constructed with two sliding scales. The first allowed for consecutively deeper drawdown in a given year depending on inflow forecasts, drought to flood. This version, which integrates power and flood control requirements, results in less benefits for anadromous smolts than a previous version called Biological Rule Curves (BRCs). BRCs had been modified to store extra water during the fall through early spring period for release during spring (to aid salmon migrations and improve channel conditions in the Flathead River). This strategy remains as a provision in the IRC concept which allows storage of water above the IRCs prior to runoff for release to aid anadromous smolts. This model analysis however, assumes that the IRCs are elevational targets and does not attempt to "earmark" water for salmon flow augmentation.

Our intent was to control local flood waters at the nearest downstream critical flood control center, Columbia Falls, using the IRCs. System flood control was intended to be handled through coordinated releases from storage projects and subsequent reregulation enroute downstream. This strategy is similar to the Army Corps "VARQ" flood control strategy. The flood peaks would be removed, and the runoff protracted, so that discharges remain at maximum tolerable flood stage for an extended period. High spring discharges provide for anadromous passage and interregional power marketing. This intent was not represented by previous modeling analyses.

Short–term impacts

The reduced duration and frequency of deep drawdown and refill failure would improve conditions for biological productivity in the reservoir (Table 4–4). Production would be maintained at higher levels in SOS4c than in any other alternative. Phytoplankton and zooplankton production, which constitute the base of the aquatic food web, benefit from the large surface area and volume in the reservoir pool during the warm months. The moderated pool fluctuation aids aquatic insect production. Reservoir surface area at or near maximum during the warm months increases the biomass of terrestrial insects deposited on the reservoir surface from surrounding shoreline vegetation. Food availability for fish is correspondingly improved during all seasons. Large volumes of optimal temperature water for fish growth, combined with ample food, would enhance fish growth. Refill timing also assures that passage into spawning and rearing habitat in tributaries is maintained. Note that SOSPA also results in relatively fast fish growth (WCT) but this is a short–lived single year phenomenon. Multiple year simulations reveal less stability than SOS4c and 9c.

Long–term impacts

Reservoir. The frequency of adverse growing conditions is reduced. Annual fish growth is enhanced for each year class, so fish can attain a larger size at maturity. The long–term maintenance of species of special concern, westslope cutthroat trout and bull trout, would become more probable under this SOS.

Flathead River. The intent of SOS 4 was to release spring flows to improve channel integrity in the Flathead River. The releases were built into the daily IRCs but became less obvious when the curves were transformed to monthly data for system modeling.

In the Flathead River, flow regulation is causing sediment accumulation, channel braiding and bank erosion. Short–term flow fluctuations from Hungry Horse Dam pulse water into the riverbanks. The water then returns to the river from the saturated banks carrying sediments and causing the banks to collapse. Most sediment deposition is occurring in the lower 22 miles of the river which is influenced by Flathead Lake elevations. These problems could be mitigated by high spring flows (below flood stage). A flushing flow would carry fine sediments will decrease "embeddedness" of the substrate (increase interstitial spaces) to provide insect habitat and hiding cover for juvenile salmonids (e.g., bull trout). At present, the fine sediments accumulating in the lower 22 miles of the Flathead River have shifted the insect biota from a stonefly and mayfly assemblage to a midge–dominated community, affecting food availability.

Spring discharges from Hungry Horse should be released to complement natural spring runoff (late May – early June), yet avoid conflicts with local flood control. Discharge should be less than the channel capacity of the South Fork below Hungry Horse Dam (20 kcfs), yet high enough to re–sort fine materials in the Flathead River bed (less than 5 mm diameter). The flush must happen at a frequency no less than 2.5 years for a duration of at least 48 hours to maintain channel integrity. Flood waters are protracted, with the peaks removed. Channel maintenance will reduce river braiding that threatens adjacent lands.

Cumulative and unavoidable impacts

Northern squawfish have benefitted from impoundment and have expanded their abundance in Hungry Horse Reservoir. Even if conditions in the reservoir become more favorable for westslope cutthroat and bull trout, it is likely that predation by northern squawfish on juvenile trout and whitefish will continue at some level.

Mitigation

See discussion on fisheries mitigation under SOS2d.

This SOS, if implemented correctly, would complement the ongoing mitigation program for Hungry Horse Dam. This plan has two components, non–operational and operational. The ongoing program is directed only at the non–operational mitigation aspects (things that can improve the fishery without changing the operation of Hungry Horse Dam). This component was expected to mitigate approximately 50 percent of the fisheries loss due to the construction and operation of Hungry Horse Dam.

The operational component of the plan (Integrated Rule Curves) was intended to resolve the other 50 percent of the loss statement. Operational mitigation was deferred to the SOR process. The IRC concept has not, as yet, been implemented. Operational changes must be implemented and enforced to recover a healthy fishery in the Flathead Basin.

4.4.1.4 Lake Koocanusa

Description of SOS 4c specific to Lake Koocanusa

This alternative represents the June 1994 version of the Integrated Rule Curves (IRCs) developed by Montana FWP. The reservoir completely refills 78 percent of all years. Refill failure occurs in dry years, but the reservoir fills to within 20 feet of full pool in most years (94 percent). Maximum drawdown exceeds the 90–110 foot drawdown limit on 16 percent of all years. Drawdowns are minimized to protect biological production in the reservoir. River discharges remain within local flood control limits and simulate a natural runoff event for channel maintenance and white sturgeon spawning (Figure 4–20).

Integrated Rule Curves (IRCs) were constructed with two sliding scales. The first allowed for consecutively deeper drawdown in a given year depending on inflow forecasts, drought to flood. The second scale allowed for consecutively deeper drawdowns during a four–year critical period of extended drought. This alternative was designed to balance the requirements of resident and anadromous fish with power and flood control. Benefits for anadromous smolt migrations could be enhanced by storing water above the IRCs prior to runoff for later release. This "earmarked" water can be released without compromising reservoir refill probability.

SOS4c does not benefit anadromous species as much as earlier versions. The BRCs had been previously modified to store extra water during the fall through early spring period for release during June (to aid white sturgeon recovery in the Kootenai River and salmon smolt migrations in the lower Columbia). This intent, although not modeled here, remains as a provision in the IRC concept to further improve conditions for anadromous species without compromising reservoir refill for resident fish. System flood control, however, was intended to be controlled similarly to VARQ by coordinated releases from storage reservoirs and subsequent regulation enroute downstream. The flood peaks would be removed, and the runoff protracted, so that discharges remain at maximum tolerable flood stage for an extended period.

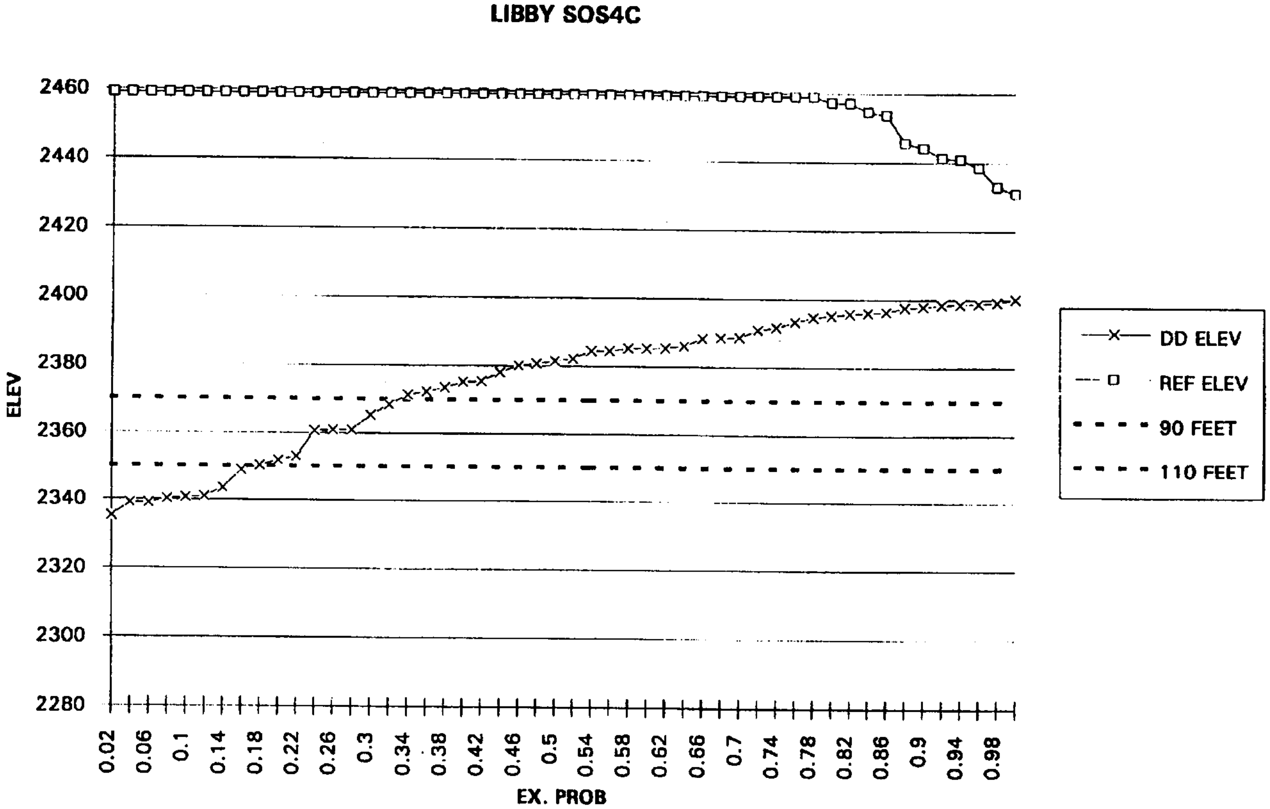


Figure 4–20. Results of a 50–year study showing the maximum elevation during the period June through August (squares), and the minimum elevation ("X") during the period March through May. Existing drawdown limits are shown in horizontal dashed line (at center). Points on the chart represent the probability of refilling or exceeding a given drawdown level.

High spring discharges provide for anadromous passage and interregional power marketing. This intent was not represented by the modeling analysis.

Short–term impacts

The reduced duration and frequency of adverse environmental conditions (deep drawdown and refill failure) would improve conditions for biological productivity in the reservoir (Table 4–5). Production would be maintained at higher levels in SOS4c than in any other SOS. Phytoplankton and zooplankton production, which constitute the base of the aquatic food web, benefit from the large surface area and volume in the reservoir pool during the warm months. The moderated pool fluctuation aids aquatic insect production. Reservoir surface area at or near maximum during the warm months increases the biomass of terrestrial insects deposited on the reservoir surface from surrounding shoreline vegetation. Food availability for fish is correspondingly improved during all seasons. Larger volume of optimal temperature water for fish growth, combined with ample food, would enhance fish growth. Refill timing also assures that passage into spawning and rearing habitat in tributaries is maintained.

Long–term impacts

Reservoir. Conditions for kokanee growth would improve with increased zooplankton production and larger volume of optimal water temperatures. Insect–eating species, cutthroat, rainbow trout and mountain whitefish would benefit from increased aquatic insect production and maximum deposition of terrestrial insects due to the large reservoir surface area. As prey species benefit from enhanced biological productivity, predatory species such as bull trout can find abundant food.

Kootenai River. This SOS was intended to balance the needs of reservoir biota with white sturgeon spawning requirements and anadromous fish migration flows. Discharges for Kootenai River white sturgeon were built into the IRCs on a daily basis. Once the daily criteria were transformed into the monthly format used by the system models, many details were lost.

This SOS meets sturgeon flow targets for May and June in wet and medium years, and for May in dry years (Table 4–6). Some spawning would probably occur in all but the very driest years, but probably would be better in wetter years. Depending on spawning location, flow protection for incubating areas may be inadequate in moderate–to–dry years.

Cumulative or unavoidable impacts

Columbia River chub and northern squawfish have apparently benefitted from impoundment and have disproportionally expanded their relative abundance in Libby Reservoir. It is uncertain whether the improved conditions for targeted fish species will cause a shift in relative abundances toward a more desirable balance, or if all fish will benefit proportionally.

Spawning and rearing habitat in reservoir tributaries will remain limited unless habitat restoration and fish passage projects are completed. Approximately 200 miles of tributary and river habitat were permanently inundated when Libby Dam first filled.

Mitigation

See discussion under SOS2d.

Integrated Rule Curves were incorporated into SOS4c and 9c. Among the purposes of the IRC was provision of flows to benefit Kootenai River white sturgeon. Sturgeon flows which were built into the IRCs varied with water availability. During the highest 40 percent of water years, Libby Dam was to release just enough water to augment natural side flows to achieve a target flow of 35 kcfs at Bonners Ferry. The flow would ramp up to the target beginning june 1 and ramp down to basal flows after the set duration. Flow targets were set relative to inflow conditions. During water years ranging from the 35th to 60th percentile, dam discharges would be adjusted to meet a target flow of 25 kcfs. A 15 kcfs target would be released during the lowest 10th to 35th percentile inflows. During critical drought years, the lowest 10 percent, no sturgeon flows were to be released. Flows released for sturgeon would continue downstream to aid the downstream migration of salmon smolts in the lower Columbia.

Flows released for anadromous smolt migrations during critically low water years could be shaped to benefit white sturgeon enroute.

4.4.2 Stable Storage (SOS 4c) for Lake Roosevelt and mid–Columbia River

4.4.2.1 Lake Roosevelt

Description of alternative specific to Lake Roosevelt

SOS 4c is intended to meet the following elevation targets for the end of the indicated month at Lake Roosevelt: September throught November – 1288 feet (2 feet below full pool), December– 1287 feet, January – 1270 feet, February – 1260 feet, March – 1270 feet, April 1–15 – 1272 feet, April 16–30 – 1275 feet, May 1280 feet, June through August –1288 feet. Flood control rule curves apply only when January through July runoff is greater than 68 MAF.

Short–term impacts

SOS 4c provides for improved water retention times which lead to reduced entrainment of fish and zooplankton relative to other SOSs.

Long–term impacts

The reservoir is held at a minimum elevation of 1260 unless forecast runoff is high. This promotes strong year class strength of many fish species and reduces entrainment levels. In turn, the reservoir can take a "hit" in high–runoff years when water needs to be released for flood control purposes.

Cumulative impacts

Low water retention times lead to decreased food production which results in poor fish growth. Monthly fluctuations in water levels decrease spawning success of many spring spawning resident fish of Lake Roosevelt (Beckman et al. 1985). Due to the limited capability of the hydroregulated models these impacts could not be quantified, but would most certainly be an important impact to the survivability of eggs and fry and ultimately to fish population success.

Unavoidable impacts

Unavoidable impacts due to Grand Coulee operations are loss of nutrients, loss of zooplankton, loss of benthic invertebrates, decreases in fish spawning and feeding habitat, and entrainment losses. The extent of these losses depends on the season and the amount of draw down and flow.

Mitigation

Potential mitigation measures for these alternatives include stream and riparian zone improvements, benthic invertebrate structure placement, and sonic avoidance mechanisms. These measures would increase usable fish habitat, increase food sources, and decrease entrainment levels. Monitoring systems to detect unforeseen impacts should be set up to aid in determining on–site and off–site mitigation locations and actions.

4.4.3 Stable Storage (SOS 4c) for Middle Snake and Clearwater Rivers

4.4.3.1 Dworshak Reservoir

Description of alternative specific to Dworshak Reservoir

SOS 4c intends Dworshak Reservoir to meet the following elevation targets by the end of the indicated month: September through October – 1599 feet (1 foot below full pool), November through April – flood control role curve, May – 1595 feet, and June through August – 1599 feet.

The average annual end–of–month elevations at Dworshak under SOS 4c range between 1550 and 1580 feet with annual minimum monthly elevations of 1445 feet to annual maximum monthly elevations of approximately 1599 feet (see the Results Exhibit for flows and elevations). Drawdowns of about 75–100 feet below normal full pool are expected in any given year. The reservoir will refill in most years. Simulated hydroregulation shows that the full stable pool criterion would not be met for June, and would be violated somewhat during September and October.

Average annual discharge (based on monthly flows) under this SOS ranges from 3,000 cfs to 10,000 cfs. Monthly discharge goes as high as 25,000 cfs and as low 1,000 cfs (see the Results Exhibit for flows and elevations).

Short and long–term impacts

SOS 4c provide excellent conditions for all species of resident fish at Dworshak Reservoir (Table 4–8; see the Results Exhibit for additional results). The pool is maintained at or near full pool (1600 feet) which provides complete access to spawning tributaries (spawning index is always near 1.0). Adult kokanee habitat (pelagic zone) is also significantly better under these SOSs than under all other SOSs. Food production indices under this SOS are consistently good. However, food production is still below optimal because of annual drawdowns. Entrainment under this SOS is slightly higher than was estimated in SOS 1b and about the same as that estimated in SOS 1a. During wet years, entrainment is very high (index drops to as low as 0.1).

Smallmouth bass, cutthroat trout, and bull trout benefit from SOS (Table 4–8; see the Results Exhibit for additional results). The stable pool levels in SOS 4c provide favorable conditions for smallmouth bass spawning and incubation. Stable pool levels allow smallmouth bass adults to successfully spawn and do not force them off the spawning nests. Under SOS 4c, significant drawdowns in the pool level do not occur in most years, although depending on the water year, drawdowns to 1445 feet do occur periodically. This lack of significant drawdown provides a greater opportunity for the establishment of shoreline vegetation and littoral zone macrophytes than under other SOSs.

Cumulative and unavoidable impacts

Under SOS 4c, conditions might be expected to be optimal for redside shiner populations. However, routine annual drawdowns of 75–100 feet may restrict the long–term reservoir productivity if macrophytes are not able to become established in the littoral zone. Annual draw downs of this magnitude would preclude the successful spawning of redside shiners. There may be some long–term benefits to cutthroat trout, bull trout, and smallmouth bass if a healthy forage base developed. These benefits would come from increased food production assuming revegetation takes place.

Mitigation

Certain measures could be taken to lessen the effect of this alternative, including:

- Revegetation of the drawdown zone along the more gently sloping banks. Aerial photography and a digitized reservoir contour map could aid in the identification of suitable candidate areas. Shoreline revegetation could partly offset the food and habitat deficits caused by pool level fluctuations. Follow–up on the effectiveness of this would be necessary..

- Small sub–impoundments near full pool elevation could provide a permanently wetted, relatively stable environment to promote the production of aquatic and semi–aquatic vegetation. This would provide food and substrate for aquatic insect production and could also provide a nursery area for forage fish. The sub–impoundments would also partly offset the food and habitat deficits caused by pool level fluctuations. Follow–up on the effectiveness of this program would be required.

4.4.3.2 Brownlee Reservoir

Description of alternative specific to Brownlee Reservoir

This SOS is designed as a stable pool SOS. However, specific requirements for Brownlee Reservoir were not provided for in hydroregulation analysis. The hydrology of this SOS is similar to current operations as hydroregulated in SOS 2a and 2c (see the Results Exhibit for flows and elevations). There are minimal differences in both elevation and outflow, with minimum monthly elevations not quite as low as in current operations and flows not quite as high.

Short and long–term, cumulative, and unavoidable impacts

Because the hydrology for this alternative is similar for SOS 2, the impacts to the fish species are also similar. This SOS is generally good for rainbow trout and channel catfish; slightly better than under current operations with index values ranging from 0.7 to 0.9 for rainbow trout and channel catfish, respectively (Table 4–9; see the Results Exhibit for additional results). For smallmouth bass and other warmwater species, it is generally good, although not the best alternative reviewed. The index values at 2, 4, and 10 year occurance intervals range between 0.3 and 0.85, with slightly less annual fluctuations (Table 4–9). The lower index values for mallmouth bass are most likely because fluctuations in reservoir elevation occur primarily in the spring when bass spawn, while it is held stable in the late summer and fall when channel catfish are spawning.

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.4.4 Stable Storage (SOS4c) for Lower Snake River

4.4.4.1 Lower Granite Reservoir

Description of alternative specific to Lower Granite Reservoir

This SOS does not set specific requirements for Lower Granite Reservoir as the SOS is designed for storage projects. Short–term operation requirements at Lower Granite require that all lower Snake River reservoirs operate within 1 foot of minimum operating pool from April 16 through July. Inspection of the annual flows and elevations indicates this is generally the case (see the Results Exhibit for flows and elevations).

Short and long–term, cumulative, and unavoidable impacts

Growth index values at 2, 4, and 10 year occurrence intervals for smallmouth bass, white sturgeon, and northern squawfish for all SOSs can be found in Tables 4–10 – 4–12 (additional detail can be found in the Results Exhibit). Without hydroregulated input at a time scale finer than 1 month, it is impossible to make highly accurate predictions of the impacts to resident fish in Lower Granite Reservoir. The model predictions based on the end–of–month pool elevations and our qualitative assessment of the impacts should fluctuations in the pool levels occur at a time scale finer than 1 month are presented in the following tables. Table 4–10 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of no variability in within–month pool levels; i.e., the growth index values predicted by the model based on end–of–month elevations. Table 4–11 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of minimal within–month pool fluctuations (2.5 – 4.9 feet); i.e., a qualitative estimate of the impacts should the pool be fluctuated between 2.5 and 4.9 feet within any given month. Table 4–12 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of high within–month pool fluctuations (7.5 – 9.9 feet); i.e., a qualitative estimate of the impacts should the pool level be fluctuated between 7.5 and 9.9 feet within any given month.

Because this SOS is designed for storage reservoirs, we expected the results for smallmouth bass to be similar to results from SOS 2; the results generally agree with this assumption (figure 4–9; see the Results Exhibit for additional results).

For white sturgeon and northern squawfish, there was little change from previous SOSs (Figures 4–11 and 4–13).

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.4.5 Stable Storage (SOS 4c) for Lower Columbia River

4.4.5.1 John Day Reservoir

Description of alternative specific to John Day Reservoir

There are no specific operational requirements mentioned in the alternative description for John Day Reservoir. The average annual elevation is approximately 264 feet msl and fluctuates over 2 feet (263 – 265 feet msl). This is similar to SOS 1. The average annual flow ranges from approximately 120,000 to 260,000 cfs with the maximum ranging from 180,000 to 500,000 cfs, similar to SOS 2. However, the average minimum discharge under SOS 4c is approximately 60,000 – 110,000 cfs. See the Results Exhibit for a complete set of yearly flows and elevations.

Short–term, long–term impacts, cumulative, and unavoidable impacts

Growth index values at 2, 4, and 10 year occurrence intervals for smallmouth bass, northern squawfish, and walleye for all SOSs can be found in Tables 4–13 – 4–15 (additional detail can be found in the Results Exhibit). Without hydroregulated input at a time scale finer than 1 month, it is impossible to make highly accurate predictions of the impacts to resident fish in John Day Reservoir. The model predictions based on the end–of–month pool elevations and our qualitative assessment of the impacts should fluctuations in the pool levels occur at a time scale finer than 1 month are presented in the following tables. Table 4–13 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of no variability in within–month pool levels; i.e., the growth index values predicted by the model based on end–of–month elevations. Table 4–14 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of minimal within–month pool fluctuations (2.5 – 4.9 feet); i.e., a qualitative estimate of the impacts should the pool be fluctuated between 2.5 and 4.9 feet within any given month. Table 4–15 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of high within–month pool fluctuations (7.5 – 9.9 feet); i.e., a qualitative estimate of the impacts should the pool level be fluctuated between 7.5 and 9.9 feet within any given month.

SOS 4c appears to be good for smallmouth bass since there are minimal fluctuations in pool elevation and spawning success, fry rearing, and over wintering survival should be good. The indexes are similar to SOS 2. Within–month fluctuations cause the index to drop from approximately 0.95 (fluctuation of less than 2.5 feet) to 0.88 (2.5 – 4.9 feet fluctuation); 0.7 (5 – 7.4 feet fluctuation); 0.22 (7.5 – 9.9 feet fluctuation); and 0 (fluctuations greater than 10 feet). Without hydroregulated input at a time scale finer than 1 month, it is impossible to predict where the index would lie within these ranges.

As in all other SOSs, apparently there are no fluctuations of the pool level during June and July since the index value for northern squawfish is approximately equal to 1.0 (Table 4–13). However, within month fluctuations in the pool levels cause the index to be reduced (Tables 4–14 and 4–15).

SOS 4 is essentially the same as SOS 2 for walleye (Tables 4–14 – 4–15). The index values are low (range 0.19 – 0.3), indicating this alternative is not very good for walleye.

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.5 DESCRIPTION OF IMPACTS OF SYSTEM OPERATING STRATEGIES

4.5.1 "Natural River" Option (SOS 5b and SOS 5c) for Upper Columbia River and tributaries

4.5.1.1 Lake Pend Oreille

Description of alternative specific to Lake Pend Oreille

Similar to SOS 2 and SOS 3, there are no specific operational requirements mentioned in the SOS description for Lake Pend Oreille. A review of the flows and elevations indicates there is little difference in this SOS from current operations (see the Results Exhibit for flows and elevations). Therefore, we make the assumption that operations under this SOS are similar to current operations.

Short and long–term, cumulative, and unavoidable impacts

This SOS does not alter the present operational strategy of Lake Pend Oreille and contains the exact same hydrology as in SOS 2 and SOS 3. Therefore, impacts to all resident fish species from this SOS are as they were described in SOS 1 (Table 4–3)

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.5.1.2 Box Canyon Reservoir

Description of alternatives specific to Box Canyon Reservoir

SOS 5b would aid juvenile salmon by increasing river velocity. The four lower Snake River projects would be drawn down to near the original river elevation for 4 1/2 months. SOS 5c assumes the drawdown occurs year round with no refill of the projects to normal operating ranges. The objective is to lower the full pool levels to near river bed with new outlets for the lower four Snake River Projects. This would affect Albeni Falls in providing additional water under low runoff conditions.

Short and long–term, cumulative, and unavoidable impacts

Every one of these SOS alternatives is very similar in their outflow during the months of May and June. This is the critical time for bass spawning. SOS 5b would allow releases from Albeni Falls to rise from nearly 47,000 cfs in May to a peak of 59,000 cfs in June. Minimum outflow from Albeni Falls for bass productions would be at 40,000 cfs. Maximum outflow for bass production would be at 45,000 cfs. Fluctuating water levels in reservoirs can adversely affect spawning success of largemouth bass that rely on shallow water or nearshore areas for nest construction. Rapidly receding water levels may also result in desertion of nest, poor egg survival, and disrupted spawning (Ploskey 1986).

SOS 5c would allow releases from Albeni Falls to increase around 40,000 cfs from mid–April to June. The peak in June would be similar to current operations. Figure 4–21 compares bass spawning requirements to Strategy 5c and current operation. Minimum outflow from Albeni Falls for bass productions would be at 40,000 cfs. Maximum outflow for bass production would be at 45,000 cfs. Fluctuating water levels in reservoirs can adversely affect spawning success of largemouth bass that rely on shallow water or nearshore areas for nest construction. Rapidly receding water levels may also result in desertion of nest, poor egg survival, and disrupted spawning (Ploskey 1986).

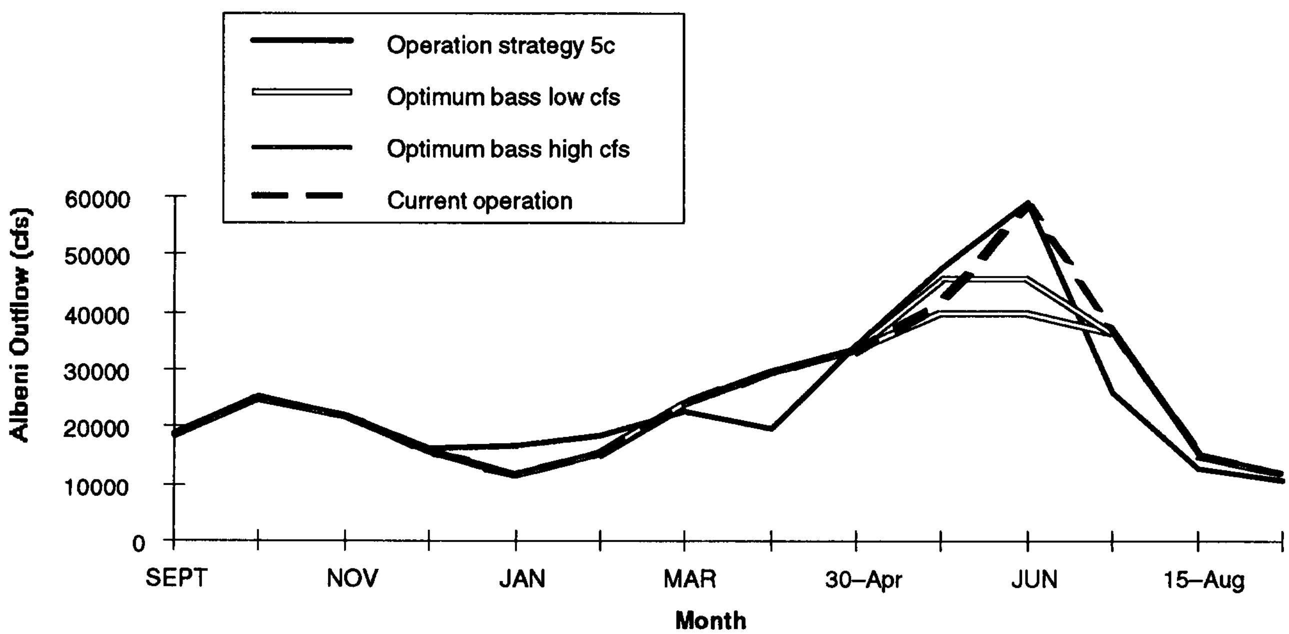


Figure 4–21. Operation at Albeni Falls Dam and Bass Spawning Requirements Under Strategy 5c

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations. Mitigation may also include supplementation in a largemouth bass hatchery.

4.5.1.3 Hungry Horse Reservoir

Description of alternative specific to Hungry Horse Reservoir

There are no specific operational requirements for Hungry Horse Dam under this SOS.

Biological production is harmed by refill failures to within 10 feet, 30 percent of the time. Six percent of the time the reservoir refills below the 85–foot drawdown limit. Drawdown exceeds the 85–foot limit 70 percent of the time further harming biological production. This alternative is worse than historic operations (Figure 4–22).

Short–and long–term, cumulative and unavoidable impacts and mitigation

This SOS is essentially the same as SOS 2d. Please see discussion under Section 4.3.1.2.

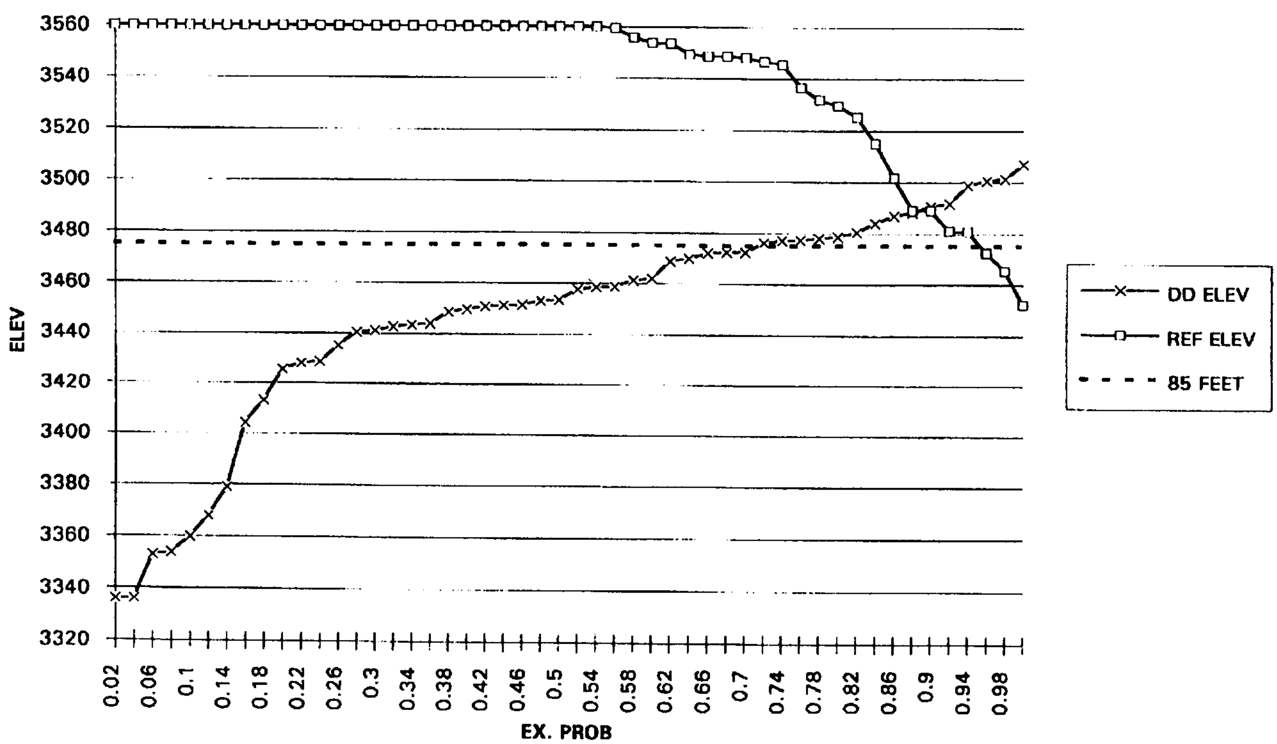


Figure 4–22. Results of a 50–year study showing the maximum elevation during the period June through August (squares), and the minimum elevation ("X") during the period March through May. Existing drawdown limits are shown in horizontal dashed line (at center). Points on the chart represent the probability of refilling or exceeding a given drawdown level.

4.5.1.4 Lake Koocanusa

Description of alternative specific to Lake Koocanusa

There are no specific operational requirements for Libby Dam under this SOS.

Biological production is harmed 20 percent of the time by reservoir refill failures of more than 10 feet, and 76 percent of the time by maximum drawdowns of more than 110 feet. Maximum drawdown to the bottom of active storage (2,287') occurs 26 percent of the time, and approaches the bottom of active storage a farther 8 percent of the time. This alternative is worse for biological production than historic operations (Figure 4–23).

Short–and long–term, cumulative and unavoidable impacts and mitigation

This SOS is essentially the same as SOS 2d. Please see discussion under Section 4.3.1.3.

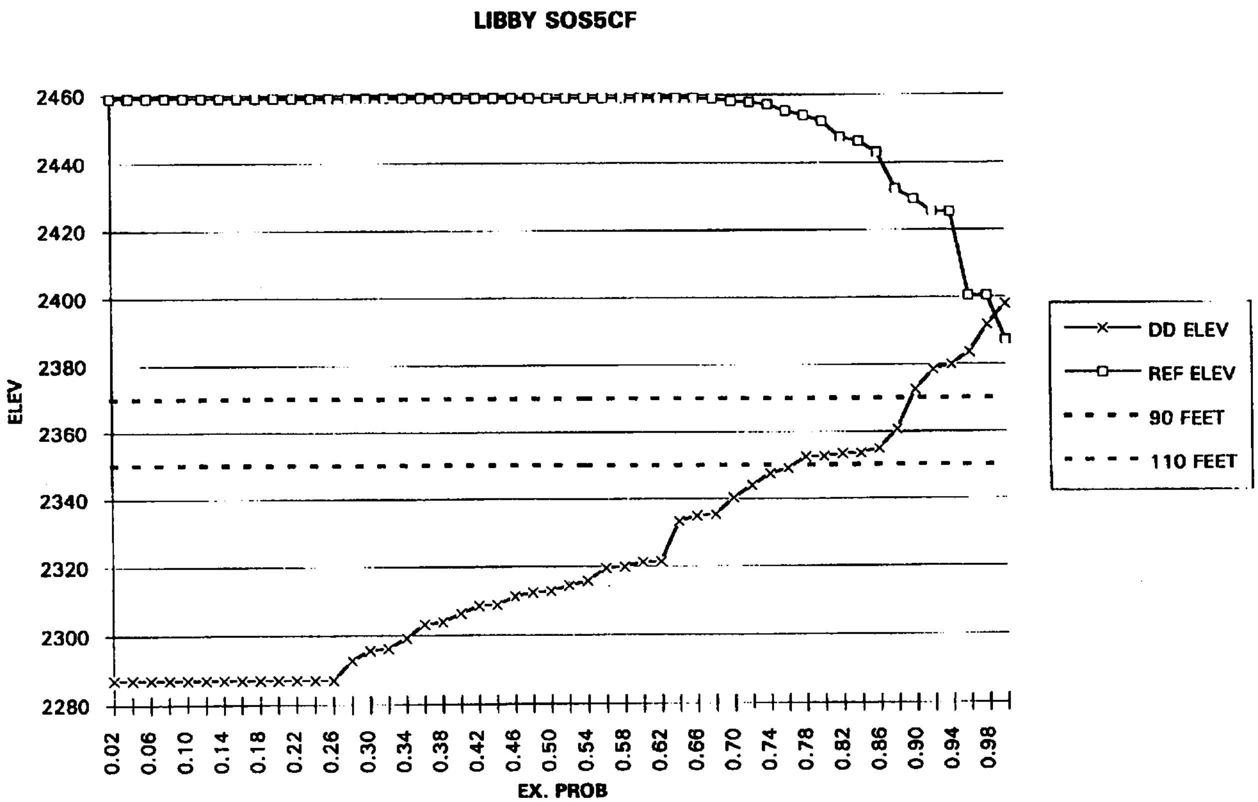


Figure 4–23. Results of a 50–year study showing the maximum elevation during the period June through August (squares), and the minimum elevation ("X") during the period March through May. Existing drawdown limits are shown in horizontal dashed line (at center). Points on the chart represent the probability of refilling or exceeding a given drawdown level.

4.5.2 "Natural River" Option (SOS 5b and SOS 5c) for Lake Roosevelt and mid–Columbia River

4.5.2.1 Lake Roosevelt

Description of alternative specific to Lake Roosevelt

Short term operation at Grand Coulee provides flow augmentation without limiting peaking ability of downstream projects. Inspection of flows and elevations shows that within year variation may not be as significant as in other SOSs, but year to year variations suggest this SOS would result in unstable flows and elevations over the long–term (see the Results Exhibit for a complete set of flows and elevations).

Short–term impacts

Short term impacts at Lake Roosevelt from the operations of SOS 5b and 5c are similar and will be discussed together (Table 4–7). Each operation offers deep drawdowns for extended periods of time. Combined with high outflows these drawdowns result in water retention times that are 30 days or less from January to May for roughly 80% of the 50 water years examined. As stated earlier low water retention times result in low zooplankton density and biomass values and high entrainment of salmonids which are reflected in reduced fish growth and decreased fish population numbers. Spring spawners may be impacted from drafting in spring.

Long–term impacts

Long term impacts from continued operations of SOS 5b or 5c could result in adverse effects on the fisheries as they now exist due to low food resources and fish numbers as related to decreased food sources and increased entrainment. Limited information is available for sturgeon, whitefish and burbot. Primary impacts to these species would be growth–related as benthic or other food items may be exposed and killed by drawdowns. See section 4.2.2.1, Long Term Impacts.

Cumulative impacts

Low water retention times lead to decreased food production which results in poor fish growth. Monthly fluctuations in water levels decrease spawning success of many spring spawning resident fish of Lake Roosevelt (Beckman et al. 1985). Due to the limited capability of the hydroregulator models these impacts could not be documented but would most certainly be an important impact to the survivability of eggs and fry and ultimately to fish population success.

Unavoidable impacts

Unavoidable impacts due to Grand Coulee operations are loss of nutrients, loss of zooplankton, loss of benthic invertebrates, decreases in fish spawning and feeding habitat, and entrainment losses.

Mitigation

Potential mitigation measures for these SOSs include stream and riparian zone improvements, benthic invertebrate structure placement, and sonic avoidance mechanisms. These measures would increase usable fish habitat, increase food sources, and decrease entrainment levels. Monitoring systems to detect unforeseen impacts should be set up to aid in determining on–site and off–site mitigation locations and actions.

4.5.3 "Natural River" Option (SOS 5b and SOS 5c) for Middle Snake and Clearwater Rivers

4.5.3.1 Dworshak Reservoir

Description of alternative specific to Dworshak Reservoir

SOS 5 calls for Dworshak Reservoir to be removed from proportional draft for power generation and operated instead for local flood control with system flood control shifted to the lower Snake projects. Under 5b, if natural inflow at the lower Snake River projects is insufficient for refill, then Dworshak would be drafted accordingly to refill the lower river projects after the completion of drawdown. Under each option, Dworshak would provide instantaneous flows of not less than 1200 cfs or greater than 25,000 cfs. The project would be operated on the flood control rule curve from January through July but would not violate the minimum flow requirements. The project could be used for short periods to meet firm peak loads.

The average annual end-of-month elevations under SOS 5 range between 1500 and 1570 feet with annual minimum monthly elevations of 1445 feet and annual maximum monthly elevations of approximately 1599 feet (see the Results Exhibit for flows and elevations). Under SOS 5, an elevation of 1599 feet is not reached every year. Drawdowns of 75–100 feet below normal full pool would be expected under this alternative. The reservoir will refill by July 1 in most years. During wet years, the reservoir will be stable and at or near full pool during July and August; however, under normal to dry years pool elevations would be expected to decline about 25 feet from July 1 through August 31.

Average annual discharge (based on monthly flows) under this SOS ranges from 3,000 cfs to 10,000 cfs. Monthly discharge goes as high as 25,000 cfs and as low 1,000 cfs.

Short and long–term impacts

This SOS results in generally poor conditions for kokanee (Table 4–8; see the Results Exhibit for additional results). Refill requirements of lower Snake River projects reduces reservoir elevation and increases entrainment of kokanee. This SOS generally results in poor conditions for smallmouth bass, cutthroat trout, and bull trout (Table 4–8). Refill of Lower Granite Reservoir under this SOS occurs in September (a 50 foot drop in reservoir elevation is expected to occur), after smallmouth bass eggs have hatched. Both options result in a general reduction in the food production potential.

Cumulative and unavoidable impacts

Routine annual drawdowns to meet downstream flow requirements and/or power production restrict the long–term reservoir productivity. This is mainly because macrophytes in the littoral zone cannot become established, the shoreline benthos are dewatered, and there is an increase in the distance from the edge of the upland vegetation to the reservoir water surface. The drawdown of the pool in September would reduce the deposition of terrestrial insects into the reservoir.

Mitigation

Certain measures could be taken to lessen the effect of this alternative, including:

- Revegetation of the drawdown zone along the more gently sloping banks. Aerial photography and a digitized reservoir contour map could aid in the identification of suitable candidate areas. Shoreline revegetation could partly offset the food and habitat deficits caused by pool level fluctuations. Follow–up on the effectiveness of this would be necessary.
- Small sub–impoundments near full pool elevation could provide a permanently wetted, relatively stable environment to promote the production of aquatic and semi–aquatic vegetation. This would provide food and substrate for aquatic insect production and could also provide a nursery area for forage fish. The sub–impoundments would also partly offset the food and habitat deficits caused by pool level fluctuations. Follow–up on the effectiveness of this program would be required.
- More water from the Snake River above Hell's Canyon Dam and/or lower pool levels in the lower Snake River would reduce the draw down requirements for Dworshak Reservoir, while providing for the migration needs of anadromous salmonids.
- Eliminating prescribed releases for flood control and power production would reduce the draw down requirements for Dworshak Reservoir and fulfill the need for flow augmentation for anadromous fish (made necessary because of other projects that continue to derive benefits for flood control, power production and irrigation).

4.5.3.2 Brownlee Reservoir

Description of alternative specific to Brownlee Reservoir

This SOS is designed as a natural river alternative for the lower Snake River. The upper Snake River is to be operated as it was operated in 1991. However, the hydrology of this SOS is similar to current operations as hydroregulated in SOS 2a and 2c (see the Results Exhibit for flows and elevations).

Short and long–term, cumulative, and unavoidable impacts

Because the hydrology for this SOS is the same as for SOS 2c and 2d (as well as SOS 3), the impacts to the fish species are the same as well. This SOS is generally good for rainbow trout and channel catfish with index values ranging from 0.8 to 0.9. (Table 4–9; see the Results Exhibit for additional results). However, this alternative is not very good for smallmouth bass and other warmwater species, with large fluctuations in the index values (Table 4–9). As in other SOSs, this is most likely because fluctuations in reservoir elevation occur primarily in the spring when smallmouth bass are spawning, while held stable in the late summer and fall when channel catfish are spawning.

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.5.4 "Natural River" Option (SOS 5b and SOS 5c) for Lower Snake River

4.5.4.1 Lower Granite Reservoir

Description of alternative specific to Lower Granite Reservoir

This alternative will result in significant changes in operations from present conditions for Lower Granite Reservoir. The primary difference between SOS 5b and 5c is the length of drawdown. Both options draw Lower Granite Reservoir down from an elevation of 738 feet in January to 623 feet by mid April. SOS 5b (Figure 4–24) maintains the reservoir at an elevation of 623 feet for 4 months and begins refill on September 1, raising the pool back to an elevation of 738 feet by the end of the month (115 feet in one month or ~ 3.8 ft/day). Under SOS 5c, Lower Granite remains permanently drawn/down at 623 feet (see the Results Exhibit for flows and elevations).

Short and long term impacts

Growth index values at 2, 4, and 10 year occurrence intervals for smallmouth bass, white sturgeon, and northern squawfish for all SOSs can be found in Tables 4–10 – 4–12 (additional detail can be found in the Results Exhibit). Without hydroregulated input at a time scale finer than 1 month, it is impossible to make highly accurate predictions of the impacts to resident fish in Lower Granite Reservoir. The model predictions based on the end–of–month pool elevations and our qualitative assessment of the impacts should fluctuations in the pool levels occur at a time scale finer than 1 month are presented in the following tables. Table 4–10 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of no variability in within–month pool levels; i.e., the growth index values predicted by the model based on end–of–month elevations. Table 4–11 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of minimal within–month pool fluctuations (2.5 – 4.9 feet); i.e., a qualitative estimate of the impacts should the pool be fluctuated between 2.5 and 4.9 feet within any given month. Table 4–12 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of high within–month pool fluctuations (7.5 – 9.9 feet); i.e., a qualitative estimate of the impacts should the pool level be fluctuated between 7.5 and 9.9 feet within any given month.

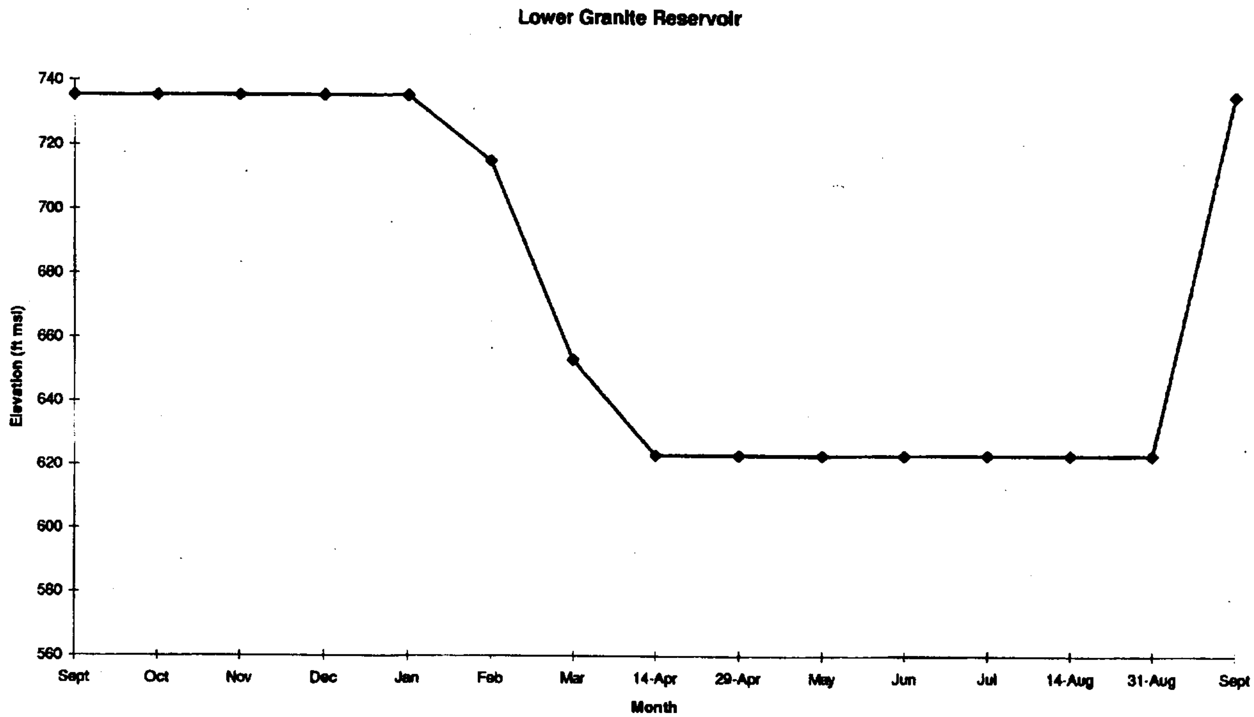


Figure 4–24. Monthly reservoir elevations as simulated by HYDROSIM for SOS 5b. Under SOS 5b, the reservoir is drawn down to elevation 623 feet msl for 4 months.

SOS 5 would generally result in negative impacts to resident fish in Lower Granite Reservoir (Figures 4–9 thru 4–14; see the Results Exhibit for additional results). SOS 5b would provide stable pool levels for spawning in a river—like environment which should be favorable to smallmouth bass. This assessment assumes that the substrate which exists at elevation 623 feet is suitable for spawning. Just as in all SOSs, if the pool is fluctuated more than 2.5 feet during June and July, egg incubation success will be reduced substantially. When the reservoir is refilled in September, a substantial change in the rearing environment will occur. This may force young–of–the–year fry into deep open water where they will have difficulty finding food and will be subjected to predation. Overwintering habitat may be enhanced with increased pool levels.

SOS 5c would provide stable spawning and rearing habitat for smallmouth bass year–round. It is assumed that under a natural river option, fine silt and sediment that has been deposited within Lower Granite Reservoir will be washed downstream. If the reservoir level was not fluctuated, shoreline colonization of vegetation could occur. This would result in organic input to the river reach and stimulate production of invertebrates. Higher velocities under a natural river environment would undoubtedly benefit egg incubation success. It is likely that this option would be very favorable for smallmouth bass in Lower Granite Reservoir.

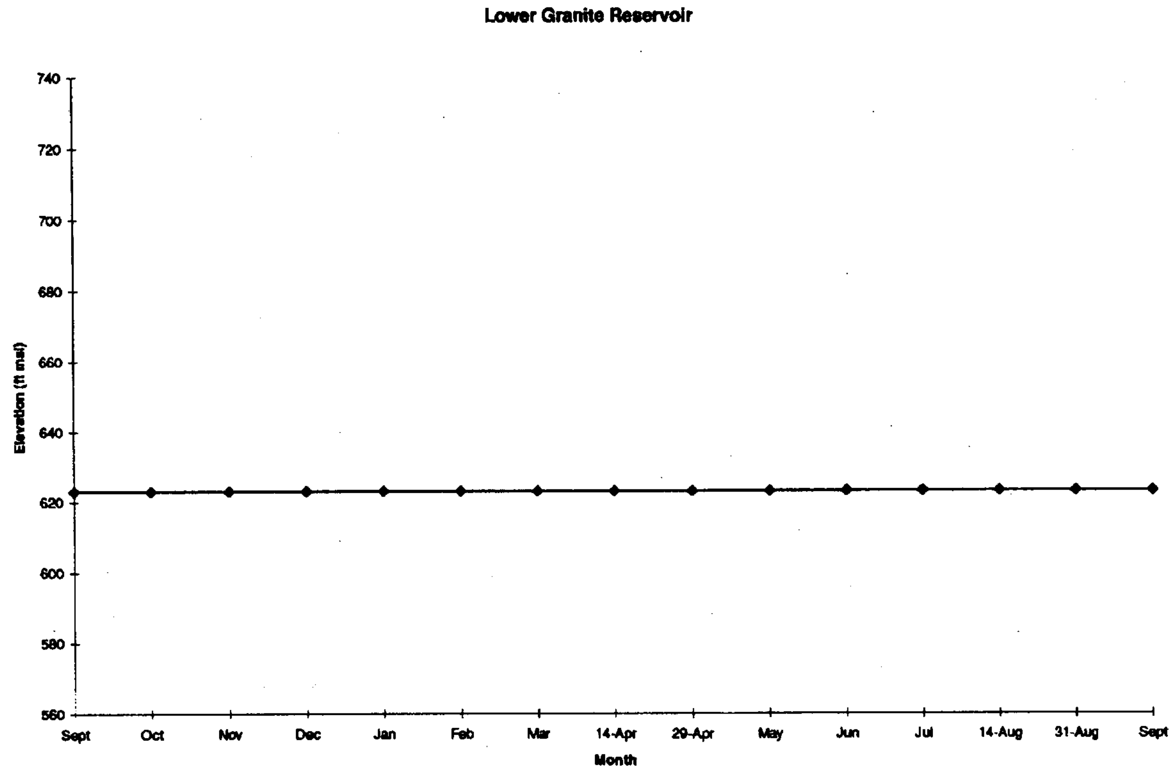


Figure 4–25. Monthly reservoir elevations as simulated by HYDROSIM for SOS 5c. Under SOS 5c, the reservoir is drawn down to elevation 623 feet msl for 4 months.

As part of the Lower Granite Sedimentation Study, dredge fill removed for the Lewiston area has been used to create islands and underwater plateaus at several sites in Lower Granite reservoir. The use of these dredge disposal sites by fish (northern squawfish, smallmouth bass, channel catfish, white sturgeon) has been described in several reports (Bennett et al., 1990). Drawdowns of Lower Granite reservoir have the potential to alter the use of these sites by fish, but the long–tern impacts of these actions are unknown.

As part of the Lower Granite Sedimentation Study, dredge fill removed from the Lewiston area has been used to create islands and underwater plateaus at several sites in Lower Granite reservoir. The use of these dredge disposal sites by fish (northern squawfish, smallmouth bass, channel catfish, white sturgeon) has been described in several reports (Bennett et al., 1990). Drawdowns of Lower Granite reservoir have the potential to alter the use of these sites by fish, but the long–term impacts of these actions are unknown.

Both SOS options would potentially increase the amount of preferred spawning habitat for white sturgeon by increasing the amount of river–like environment. The model is not able to simulate the relationship between velocity preference and velocity changes over different pool levels. When only the amount of deep water habitat is used in the analysis, the result of this SOS is worse than other SOSs; with SOS 5c worse than SOS 5b. However, the fact of an increase in the amount of river–like environment from May through July may override the loss of deep water habitat, thereby making this SOS favorable to white sturgeon.

SOS 5b does not appear to be good for northern squawfish, primarily because of the degradation in fry rearing habitat at lower reservoir elevations. However, reduced reservoir elevations may provide an increase in the potential spawning habitat by forming additional high–velocity habitat. However, if rearing habitat is limiting, then increasing spawning habitat is unlikely to benefit squawfish. SOS 5c apparently results in excellent conditions for northern squawfish from the permanent establishment of high velocity habitat for spawning. The result is high index values under this option.

Cumulative impacts

Shallow water habitat (less than 10 feet deep) appears to be critical for many of the life stages of the resident fish in Lower Granite Reservoir. In an attempt to look at the relative contribution of shallow water habitat to the entire surface area at each water surface elevation, we utilized data from a Geographical Information System GIS) data base for Lower Granite Reservoir. Using the GIS database, we were able to compute the relative amount of habitat at 2, 5, and 8 foot water depths at each elevation based on reservoir bathymetry (Figure 4–26). What we found was that there may be relatively more shallow water habitat at lower reservoir elevations than under existing reservoir conditions. What this implies is that reservoir drawdown alternatives such as SOS 5 and SOS 6 may provide relatively more shallow water habitat than under current conditions, which would be beneficial to resident fish. However, our model results suggest that, overall, this SOS 5b is not very good for resident fish in Lower Granite because of the extreme (> 115 ft) annual fluctuations in pool elevations, but SOS 5c results in favorable conditions. If the pool levels are not held constant, this will have a much higher impact on resident fish, and may result in a long–term loss of some of the fisheries. Food production would be expected to decrease, primarily because of the loss of crayfish and benthic production under reduced reservoir levels.

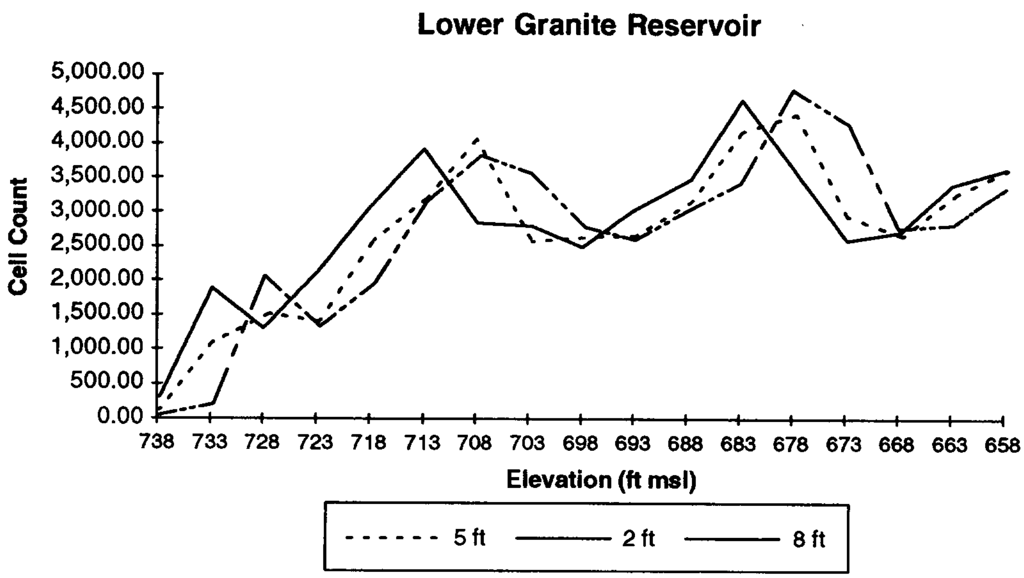


Figure 4–26. The relative surface area (represented as "cell counts") of 2, 5, and 8 foot deep habitat as compared to the total surface area at different reservoir elevations. This analysis was done using a database contained in a Geographical Information System for Lower Granite Reservoir. Based on this analysis, there appears to be relatively more shallow water habitat as the reservoir is drawn down as compared to full–pool. However, this analysis does not indicate the quality of this shallow water habitat.

Unavoidable impacts

SOS 5b results in unavoidable impacts to resident fish and their environment. Impacts could be reduced if the reservoir were held at a constant, albeit lower, elevation (as in SOS 5c). This would allow the system to stabilize; under the fluctuating pool levels this is not possible.

Mitigation

Mitigation measures may include, but not be limited to offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.5.5 "Natural River" Option (SOS 5b and SOS 5c) for Lower Columbia River

4.5.5.1 John Day Reservoir

Description of alternative specific to John Day Reservoir

SOS 5 operates John Day Reservoir at an elevation of 257 feet msl from May through August. A review of the flows and elevations indicates there is little difference between the two options. In each case, the average annual elevation is approximately 261 feet msl and fluctuates over 10 feet (256 – 266 feet msl). This is more fluctuation than was observed in previous SOSs. The average annual flow ranges from approximately 100,000 to 230,000 cfs with the maximum ranging from 200,000 to 500,000 cfs and the average minimum discharge approximately 70,000 – 100,000 cfs, similar to previous SOSs. See the Results Exhibit for a complete set of yearly flows and elevations.

Short–term, long–term impacts, cumulative, and unavoidable impacts

Drawdown of John Day Pool to minimum operating pool (MOP) will reduce the amount of shallow water habitat by approximately 6000 acres (Mark Smith, personal communication). Some new habitat will be created, but based on available information the amount of habitat will be reduced. It is possible that the first year of drawdown may allow dormant seeds (which are at lower elevations) to germinate and give some productivity to the new habitat.

Drawdown has the potential to desiccate eggs and larvae of early spawning fish such as yellow perch. Perch in John Day begin spawning in early April and therefore, may spawn in the drawdown zone. The initial drawdown will undoubtedly reduce or eliminate populations of these early spawning fish. Smallmouth bass and crappie may be able to avoid this problem because they spawn later. Spawning areas at lower elevations have not been analyzed for habitat quality (i.e., cover, substrate, and flow). If the conditions are different from existing conditions, then it is likely that production will be less at the lower elevations.

In summary, a drawdown of John Day Pool to MOP will have a negative effect on resident fish populations. It is unknown at this time the fullest extent of the effects, but the loss of shallow water habitat, resident fish, and primary and secondary productivity will be substantial.

Growth index values at 2, 4, and 10 year occurrence intervals for smallmouth bass, northern squawfish, and walleye for all SOSs can be found in Tables 4–13 – 4–15 (additional detail can be found in the Results Exhibit). Without hydroregulated input at a time scale finer than 1 month, it is impossible to make highly accurate predictions of the impacts to resident fish in John Day Reservoir. The model predictions based on the end–of–month pool elevations and our qualitative assessment of the impacts should fluctuations in the pool levels occur at a time scale finer than 1 month are presented in the following tables. Table 4–13 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of no variability in within–month pool levels; i.e., the growth index values predicted by the model based on end–of–month elevations. Table 4–14 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of minimal within–month pool fluctuations (2.5 – 4.9 feet); i.e., a qualitative estimate of the impacts should the pool be fluctuated between 2.5 and 4.9 feet within any given month. Table 4–15 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of high within–month pool fluctuations (7.5 – 9.9 feet); i.e., a qualitative estimate of the impacts should the pool level be fluctuated between 7.5 and 9.9 feet within any given month.

SOS 5 appears to be slightly worse for smallmouth bass than previous SOSs, however, the index values under stable pool conditions are still relatively high (> 0.90). This SOS is worse because of the greater range in pool elevations and the lower average pool elevation (261 vs. >264 feet), which negatively affects spawning success, fry rearing, and over wintering survival. Within month fluctuations can cause the index to drop from approximately 0.95 (fluctuation of less than 2.5 feet) to 0.90 (2.5 – 4.9 feet fluctuation); 0.70 (5 – 7.4 feet fluctuation); 0.20 (7.5 – 9.9 feet fluctuation); and 0.1 (fluctuations greater than 10 feet). Without hydroregulated input at a time scale finer than 1 month, it is impossible to predict where the index would lie within these ranges.

As in all other SOSs, apparently there are no fluctuations of the pool level during June and July since the index value for northern squawfish is approximately equal to 1.0 (Table 4–13). However, within month fluctuations in the pool levels cause the index to be reduced substantially (Tables 4–14 and 4–15).

SOS 5 is essentially the same as previous SOSs for walleye (Tables 4–10 – 4–13). The index values are usually low (range 0.19 – 0.3), indicating this alternative is not very good for walleye.

Mitigation

A year–round drawdown to MOP would allow habitat to develop at this elevation. It is estimated it would take 3–5 years for aquatic vegetation and a food base to develop in new shallow water areas. This would allow for some re–establishment of resident fish over several years.

It is unknown at this time to what extent habitat would develop or if acreage of shallow water habitat would be comparable to present conditions. From limited available data on pool topography it appears that the amount of shallow water areas (potential habitat development) at elevation 257 feet will be substantially less than current conditions due to configuration of the river channel (M. Smith, US Army Corps of Engineers, Portland District, pers. communication). Current bathymetric information is necessary before this option is considered to determine the type, quality, and size of habitats that may be established.

Further studies are required to more clearly assess the impacts of an annual drawdown of John Day Pool to elevation 257 feet. This would include at least an assessment of habitat in backwaters (including vegetation mapping), substrate mapping, population estimates, spawning use, and bathymetric mapping.

4.6 DESCRIPTION OF IMPACTS OF SYSTEM OPERATING STRATEGIES

4.6.1 Fixed Drawdown (SOS 6b and SOS 6d) for Upper Columbia River and tributaries

4.6.1.1 Lake Pend Oreille

Description of alternative specific to Lake Pend Oreille

Similar to previous SOSs (with the exception of SOS 4), there are no specific operational requirements mentioned in the SOS description for Lake Pend Oreille. A review of the flows and elevations indicates there is little difference from this SOS and current operations (see the Results Exhibit for flows and elevations). Therefore, we make the assumption that operations under this SOS are similar to current operations.

Short and long–term, cumulative, and unavoidable impacts

This SOS does not alter the present operational strategy of Lake Pend Oreille and contains the exact same hydrology as in previous SOSs (with the exception of SOS 4). Therefore, impacts to all resident fish species from this SOS are exactly as they were described in SOS 1 (Table 4–3).

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.6.1.2 Box Canyon Reservoir

Description of alternatives specific to Box Canyon Reservoir

SOS 6 involves drawing down the four lower Snake River projects to fixed elevations below MOP to aid anadromous fish. SOS 6b provides for fixed draw-downs for all four lower Snake projects for 2 and 4 1/2 months. SOS 6d draws down Lower Granite only for 2 and 4 1/2 months.

Short and long–term, cumulative, and unavoidable impacts

These SOS alternatives are very similar in their outflow during the months of May and June. This is the critical time for bass spawning. SOS 6b and 6d would allow releases from Albeni Falls to rise from nearly 47,000 cfs in May to a peak of 59,000 cfs in June. Minimum outflow from Albeni Falls for bass production would be at 40,000 cfs. Maximum outflow for bass production would be at 45,000 cfs. Fluctuating water levels in reservoirs can adversely affect spawning success of largemouth bass that rely on shallow water or nearshore areas for nest construction. Rapidly receding water levels may also result in desertion of nest, poor egg survival, and disrupted spawning (Ploskey 1986).

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations. Mitigation may also include supplementation in a largemouth bass hatchery.

4.6.1.3 Hungry Horse Reservoir

Description of alternative specific to Hungry Horse Reservoir

There are no specific operational requirements for Hungry Horse Dam under this SOS. Apparently, Hungry Horse Dam operations default to conditions very similar to those specified by SOS 1.

Short– and long–term, cumulative and unavoidable impacts and mitigation

This SOS is essentially the same as SOS 1. Please see discussion under Section 4.2.1.2.

4.6.1.4 Lake Koocanusa

Description of alternative specific to Lake Koocanusa

There are no specific operational requirements for Libby Dam under this SOS. Libby Dam operations default to conditions very similar to those specified by SOS 1b.

Short– and long–term, cumulative and unavoidable impacts and mitigation

This SOS is essentially the same as SOS 1b. Please see discussion under Section 4.2.1.3.

4.6.2 Fixed Drawdown (SOS 6b and SOS 6d) for Lake Roosevelt and mid–Columbia River

4.6.2.1 Lake Roosevelt

Description of alternative specific to Lake Roosevelt

No operating conditions were specified for Grand Coulee in the narrative of this SOS. Observation of the flows and elevations reveals the same hydrology as was observed in SOS 5 (see the Results Exhibit for flows and elevations).

Short–term impacts

Short term impacts at Lake Roosevelt from the operations of SOS 6b and 6d are similar and will be discussed together (Table 4–7; see the Results Exhibit for additional results). Each operation offers deep drawdowns for extended periods of time. Combined with high outflows these drawdowns result in water retention times that are 30 days or less from January to May for roughly 80% of the 50 water years examined. Low water retention times result in low zooplankton density and biomass values and high entrainment of salmonids which are reflected in reduced fish growth and decreased fish population numbers. Spawning areas for spring spawners may be impacted by spring drafting.

Long–term impacts

Long term impacts from continued operations of SOS 6b and 6d could cause decline in the fisheries as they now exist due to low food resources and fish numbers as related to decreased food sources and increased entrainment. Limited information is available for sturgeon, whitefish and burbot. Primary impacts to these species would be growth–related as benthic or other food items may be exposed and killed by drawdowns. See section 4.2.2.1 – long term impacts.

Cumulative impacts

Low water retention times lead to decreased food production which results in poor fish growth. Monthly fluctuations in water levels decrease spawning success of many spring spawning resident fish of Lake Roosevelt (Beckman et al. 1985). Due to the limited capability of the hydroregulator models these impacts could not be quantified, but would most certainly be an important impact to the survivability of eggs and fry and ultimately to fish population success.

Unavoidable impacts

Unavoidable impacts due to Grand Coulee operations are loss of nutrients, loss of zooplankton, loss of benthic invertebrates, decreases in fish spawning and feeding habitat, and entrainment losses.

Mitigation

Potential mitigation measures for these alternatives include stream and riparian zone improvements, benthic invertebrate structure placement, and sonic avoidance mechanisms. These measures would increase usable fish habitat, increase food sources, and decrease entrainment levels. Monitoring systems to detect unforeseen impacts should be set up to aid in determining on–site and off–site mitigation locations and actions.

4.6.3 Fixed Drawdown (SOS 6b and SOS 6d) for Middle Snake and Clearwater Rivers

4.6.3.1 Dworshak Reservoir

Description of alternative specific to Dworshak Reservoir

Operations at Dworshak under SOS 6 are essentially the same as required under SOS 5. SOS 6b and 6d calls for Dworshak Reservoir to be removed from proportional draft for power generation and operated instead for local flood control with system flood control shifted to the lower Snake projects. If natural inflow at the lower Snake River projects is insufficient for refill, then Dworshak would be drafted accordingly to refill the lower river projects after the completion of drawdown. Under SOS 6d, Dworshak would provide instantaneous flows of not less than 1,200 cfs or greater than 25,000 cfs. The project would be operated on the flood control rule curve from January through July but would not violate the minimum flow requirements. The project could be used for short periods to meet firm peak loads.

The average annual end–of–month elevations at Dworshak under SOS 6b, range between 1525 and 1580 feet with annual minimum monthly elevations of 1445 feet and annual maximum monthly elevations of approximately 1599 feet (see the Results Exhibit for flows and elevations). The average annual end–of–month elevations under SOS 6d range between 1525 and 1570 feet with annual minimum monthly elevations of 1445 feet and annual maximum monthly elevations of approximately 1599 feet. Under SOS 6d, an elevation of 1599 feet is not reached every year while in SOS 6b, full pool is reached nearly every year. Drawdowns of 75–100 feet below normal full pool would be expected under this alternative. The reservoir would refill by July 1 in most years. The reservoir would be stable and at or near full pool during July and August. However, under normal to dry water years pool elevations would be expected to be as low as 40 feet below full pool. Average end–of–month elevations under SOS 6b is consistently 5 to 20 feet higher than under SOS 6d. Average annual discharge (based on monthly flows) under SOS 6b, ranges from 3,000 cfs to 9,500 cfs. Average annual discharge (based on monthly flows) under SOS 6d ranges from 3,000 cfs to 8,500 cfs. Under SOS 6, monthly discharge goes as high as 25,000 cfs and as low 1,000 cfs (see the Results Exhibit for flows and elevations). However, maximum monthly discharge under SOS 6d is significantly less than SOS 6b in a majority of the 50 years modeled.

Short and long–term impacts

This alternative results in generally poor conditions for kokanee, similar to impacts under SOS 5 (Table 4–8; see the Results Exhibit for additional results). Refill requirements of lower Snake River projects reduces reservoir elevation and increases entrainment of kokanee. Access to spawning tributaries appears to be slightly better under SOS 6 than under SOS 5. This alternative generally results in average conditions for smallmouth bass, cutthroat trout, and bull trout (Table 4–8). Both options alternatives result in a general increase in the food production potential from SOS 5.

Cumulative and unavoidable impacts

Routine annual drawdowns to meet downstream flow requirements and/or power production restrict the long–term reservoir productivity. This is mainly because macrophytes in the littoral zone cannot become established, the shoreline benthos are dewatered, and there is an increase in the distance from the edge of the upland vegetation to the reservoir water surface.

Mitigation

Certain measures could be taken to lessen the effect of this alternative, including:

- Revegetation of the drawdown zone along the more gently sloping banks. Aerial photography and a digitized reservoir contour map could aid in the identification of suitable candidate areas. Shoreline revegetation could partly offset the food and habitat deficits caused by pool level fluctuations. Follow–up on the effectiveness of this would be necessary.

- Small sub–impoundments near full pool elevation could provide a permanently wetted, relatively stable environment to promote the production of aquatic and semi–aquatic vegetation. This would provide food and substrate for aquatic insect production and could also provide a nursery area for forage fish. The sub–impoundments would also partly offset the food and habitat deficits caused by pool level fluctuations. Follow–up on the effectiveness of this program would be required.

- More water from the Snake River above Hell's Canyon Dam and/or lower pool levels in the lower Snake River would reduce the draw down requirements for Dworshak Reservoir, while providing for the migration needs of anadromous salmonids.

- Eliminating prescribed releases for flood control and power production would reduce the draw down requirements for Dworshak Reservoir and fulfill the need for flow augmentation for anadromous fish (made necessary because of other projects that continue to derive benefits for flood control, power production and irrigation).

4.6.3.2 Brownlee Reservoir

Description of alternative specific to Brownlee Reservoir

This SOS is designed as a drawdown alternative for the lower Snake River. The upper Snake River is to be operated as it was operated in 1991. However, the hydrology of SOS 6b, and is similar to current operations as hydroregulated in SOS 2c while

SOS 6d is similar to operations in 1990–1991 (see the Results Exhibit.)

Short and long–term, cumulative, and unavoidable impacts

Because the hydrology for SOS 6b is the same as for SOS 2c, the impacts to the fish species are the same as well (Table 4–9; see the Results Exhibit for additional results). These options are generally good for rainbow trout and channel catfish with index values ranging from 0.8 to 0.9, and 0.55 to 0.65, respectively. However, SOS 6d results in poor conditions for rainbow trout and channel catfish, with values index values fluctuating over a greater range: 0.6 to 0.95, and 0.45 to 0.7 for rainbow trout and channel catfish, respectively.

SOS 6b is not very good for smallmouth bass and other warmwater species, with large fluctuations in the index values (Table 4–8). This is most likely because fluctuations in reservoir elevation occur primarily in the spring when smallmouth bass are spawning. However, in SOS 6d, conditions are generally good for these species, with index values the same as those in SOS 1.

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.6.4 Fixed Drawdown (SOS 6b, and SOS 6d) for Lower Snake River

4.6.4.1 Lower Granite Reservoir

Description of alternative specific to Lower Granite reservoir

For purposes of analysis at Lower Granite reservoir, alternatives 6b and 6d are identical (see the Results Exhibit for flows and elevations). SOS 6b is a 4–month fixed drawdown and all 4 lower Snake River reservoirs while SOS 6d is confined to Lower Granite only. In both options, the pool is drawn down from 735 feet beginning April 1 and reaches 705 feet by April 14. SOS 6b (and 6d), refill begins September 1 and is refilled by September 30 (Figure 4–27). Outflow averaged over the month on an annual basis does not appear to be significantly different from the other SOSs.

Short and long–term impacts

Growth index values at 2, 4, and 10 year occurrence intervals for smallmouth bass, white sturgeon, and northern squawfish for all SOSs can be found in Tables 4–10 – 4–12 (additional detail can be found in the Results Exhibit). Without hydroregulated input at a time scale finer than 1 month, it is impossible to make highly accurate predictions of the impacts to resident fish in Lower Granite Reservoir. The model predictions based on the end–of–month pool elevations and our qualitative assessment of the impacts should fluctuations in the pool levels occur at a time scale finer than 1 month are presented in the following tables. Table 4–10 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of no variability in within–month pool levels; i.e., the growth index values predicted by the model based on end–of–month elevations. Table 4–11 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of minimal within–month pool fluctuations (2.5 – 4.9 feet); i.e., a qualitative estimate of the impacts should the pool be fluctuated between 2.5 and 4.9 feet within any given month. Table 4–12 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of high within–month pool fluctuations (7.5 – 9.9 feet); i.e., a qualitative estimate of the impacts should the pool level be fluctuated between 7.5 and 9.9 feet within any given month.

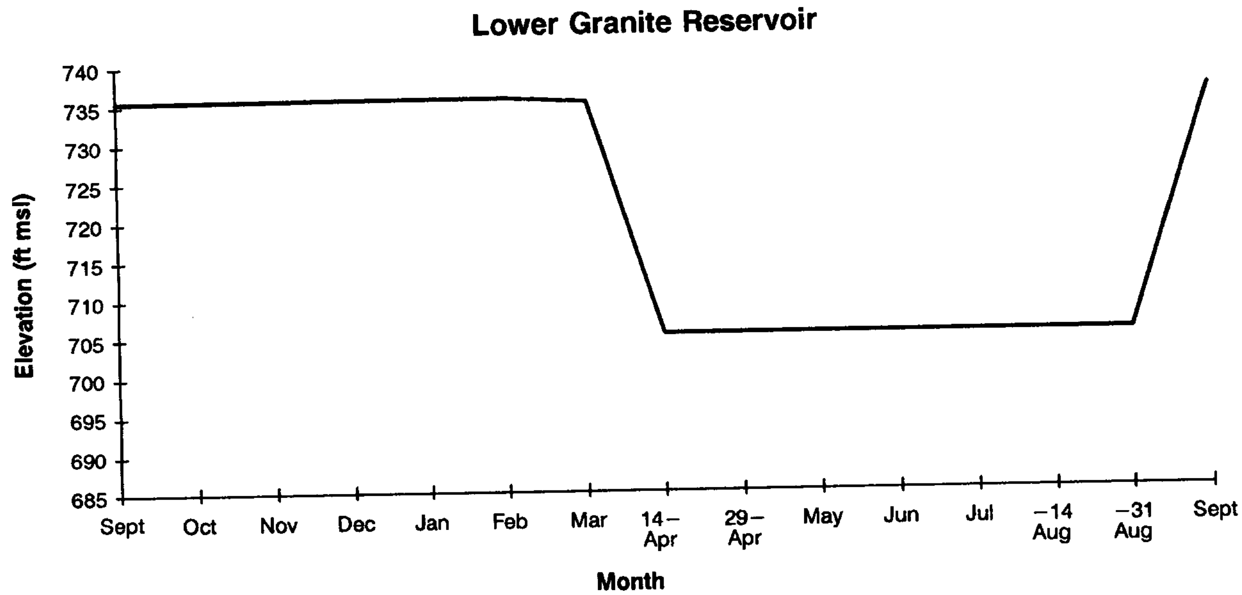


Figure 4–27. Monthly reservoir elevations as simulated by HYDROSIM for SOS 6b and SOS 6d. Under both SOS's, the reservoir is drawn down to elevation 705 feet msl for approximately 4 months.

It is difficult to determine if this alternative will have a significantly different impact than alternative 5. The amount of deep water habitat is reduced under this alternative from base case conditions. However, with an increase in the amount of riverine conditions and increased velocities, white sturgeon reproductive success may actually be higher for this alternative than under current conditions. In fact, this alternative may provide a good compromise for white sturgeon by limiting the depth of the drawdown and maintaining some deep holes for rearing while still providing some high velocity habitat for spawning. Crayfish production may be affected by this SOS which might impact sturgeon feeding. Impacts to northern squawfish from this alternative are similar to SOS 5.

Cumulative impacts

Cumulative impacts from this alternative would be expected to be similar to the cumulative impacts for SOS 5. However, since drawdown in this alternative is actually not as drastic as SOS 5, impacts to the benthos and other food production components may not be as great. White sturgeon may actually benefit from this alternative since an increase in the amount of spawning habitat would be realized.

Unavoidable impacts

Unavoidable impacts to northern squawfish and smallmouth bass will most likely occur under this SOS. Food production for these species may be limited to some degree. White sturgeon may actually benefit from this SOS.

Mitigation

Mitigation measures may include, but not be limited to offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.6.5 Fixed Drawdown (SOS 6b and SOS 6d) for Lower Columbia River

4.6.5.1 John Day Reservoir

Description of alternative specific to John Day Reservoir

SOS 6 operates John Day Reservoir at an elevation of 257 feet msl from May through August. A review of the flows and elevations indicates there is little difference between SOS 6b and 6d. In each case, the average annual elevation is approximately 261 feet msl and fluctuates over 10 feet (256 – 266 feet msl). This is similar to SOS 5 and is more fluctuation than was observed in SOSs previous to SOS 5. The average annual flow ranges from approximately 100,000 to 230,000 cfs with the maximum ranging from 200,000 to 500,000 cfs and the average minimum discharge approximately 70,000 – 100,000 cfs, similar to previous SOSs. See the Results Exhibit for a complete set of yearly flows and elevations.

Short–term, long–term impacts, cumulative, and unavoidable impacts

Impacts to resident fish are similar under this alternative to those in SOS 5. Growth index values at 2, 4, and 10 year occurrence intervals for smallmouth bass, northern squawfish, and walleye for all SOSs can be found in Tables 4–13 – 4–15 (additional detail can be found in the Results Exhibit). Without hydroregulated input at a time scale finer than 1 month, it is impossible to make highly accurate predictions of the impacts to resident fish in John Day Reservoir. The model predictions based on the end–of–month pool elevations and our qualitative assessment of the impacts should fluctuations in the pool levels occur at a time scale finer than 1 month are presented in the following tables. Table 4–13 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of no variability in within–month pool levels; i.e., the growth index values predicted by the model based on end–of–month elevations. Table 4–14 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of minimal within–month pool fluctuations (2.5 – 4.9 feet); i.e., a qualitative estimate of the impacts should the pool be fluctuated between 2.5 and 4.9 feet within any given month. Table 4–15 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of high within–month pool fluctuations (7.5 – 9.9 feet); i.e., a qualitative estimate of the impacts should the pool level be fluctuated between 7.5 and 9.9 feet within any given month.

SOS 6 appears to be similar to SOS 5 for smallmouth bass; worse than previous SOSs. However, the index values under stable pool conditions are still greater than 0.85. As in SOS 5, SOS 6 is not as good because of the greater range in pool elevations and the lower average pool elevation (261 vs. >264 feet), which negatively affects spawning success, fry rearing, and over wintering survival. Within month fluctuations cause the index to drop from approximately 0.90 (fluctuation of less than 2.5 feet) to 0.80 (2.5 – 4.9 feet fluctuation); 0.68 (5 – 7.4 feet fluctuation); 0.20 (7.5 – 9.9 feet fluctuation); and 0 (fluctuations greater than 10 feet). Without hydroregulated input at a time scale finer than 1 month, it is impossible to predict where the index would lie within these ranges.

As in all other SOSs, apparently there are no fluctuations of the pool level during June and July since the index value for northern squawfish is approximately equal to 1.0 (Table 4–13). However, within month fluctuations in the pool levels can cause the index to be reduced substantially (Tables 4–14 and 4–15).

SOS 6 is essentially the same as previous SOSs for walleye (Tables 4–13 – 4–15). The index values are usually less than 0.3 (range 0.19 – 0.3), indicating this alternative is not very good for walleye.

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.7 DESCRIPTION OF IMPACTS OF SYSTEM OPERATING STRATEGIES

4.7.1 Settlement Discussion Alternatives (SOS 9a, SOS 9b, and SOS 9c) for Upper Columbia River and Tributaries

4.7.1.1 Lake Pend Oreille

Description of alternative specific to Lake Pend Oreille

There are no specific operational requirements mentioned in the description of SOS 9a for Lake Pend Oreille. A review of the end–of–month elevations for SOS 9a suggests significant changes in operation at Lake Pend Oreille as compared to previous SOSs (see the Results Exhibit for flows and elevations). Elevation fluctuations under SOS 9a are extreme, and range from 2050 to 2062 feet in a single year. The average annual end–of–month elevations fluctuate between 2055 and 2059, with the maximum as high as 2065 feet and the minimum as low as 2049 feet in any given year. The average monthly flows for SOS 9a do not appear much different than under previous SOSs.

Under SOS 9b, Albeni Falls Dam is to operate on minimum flow up to the flood control rule curves year round except during the flow augmentation period (April through August). Lake Pend Oreille can be drafted to meet flow targets down to a minimum end of July elevation of 2060 feet. A review of the end–of–month elevations shows that the average elevations range between 2058 and 2059 feet each year with maximum elevations reaching as high as 2067 feet (note that full pool is 2062.5) and minimum as lows as 2052 feet in any given year. Usually the maximum is somewhere around 2063 feet and the minimum near 2055 feet under this option. Again, average monthly flows tend to be similar to previous SOSs.

Under SOS 9c, Albeni Falls Dam is to operate to the following elevations: no lower than 2056 feet from December through April, no lower than 2057 feet by the end of May, full pool (i.e., 2062.5 feet) from June through August, and down to 2056 feet by December from September through November. A review of the end–of–month elevations shows that the average elevations are near 2058 feet with maximum elevations reaching 2065 feet in some years, and minimum elevations dropping as low as 2054 feet in some years. Average monthly flows tend to be similar to previous SOSs.

Short and long–term, cumulative, and unavoidable impacts

This SOS is one of the worst alternatives for kokanee, with SOS 9a especially bad for kokanee (Table 4–3). The egg incubation success indices for all options of SOS 9 range between 0.2 and 0.7, with most years at 0.2. The spawning habitat indices for SOS 9a range between 0.6 and 0.9, and average about 0.9 for SOS 9b and SOS 9c. Based on these two indices, the following conclusions can be drawn. First, under SOS 9b and SOS 9c, the reservoir appears to be operated in the fall to provide suitable shoreline spawning habitat for kokanee. However, under SOS 9a this does not appear to be the case. Evidently the kokanee are being forced to spawn in inferior quality substrate at a reduced lake elevation. This is reflected in the low spawning habitat indices for SOS 9a. Second, under all the options the lake levels apparently are being reduced in the winter by deep drawdowns. This is occurring after the kokanee have spawned, and the result is poor egg incubation success in each of the options.

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.7.1.2 Box Canyon Reservoir

Description of alternatives specific to Box Canyon Reservoir

SOS 9a (Detailed Fishery Operating Plan) establishes flow targets at The Dalles based the previous years end–of–year storage content similar to how PNCA selects operating rule curves. This would affect Albeni Falls by providing additional water earlier (late April to June) than current operation.

SOS 9b (Adaptive Management) establishes flow targets at McNary and Lower Granite based on runoff forecasts. Albeni Falls would operate on minimum flow up to flood control rule curves year round except during the flow augmentation period. The project can be drafted to meet flow target down to a minimum end of July elevation of 2060 feet.

SOS 9c (Balanced Impacts Operation) draws down the four lower Snake River projects to near spillway crest levels for two and one-half months during the spring salmon migration periods. Albeni Falls would operate to the following elevations – no lower than 2056 feet from December through April, no lower than 2057 feet by the end of may, full (i.e., 2062.5 feet) from June through August, and down to 2056 feet by December from September through November.

Short and long-term, cumulative, and unavoidable impacts

SOS 9a, 9b, and 9c each would have increased discharge at Albeni Falls during June than current operations. Strategy 9a and 9b are similar. Figures 4-28 and 4-29 compare these strategies to bass spawning requirements and current operation. Figure 4-30 compares SOS 9c to bass spawning requirements and current operation. Minimum outflow from Albeni Falls for bass production would be at 40,000 cfs.

Maximum outflow for bass production would be at 45,000 cfs. Fluctuating water levels in reservoirs can adversely affect spawning success of largemouth bass that rely on shallow water or nearshore areas for nest construction. Rapidly receding water levels may also result in desertion of nest, poor egg survival, and disrupted spawning (Ploskey 1986).

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations. Mitigation may also include supplementation in a largemouth bass hatchery.

4.7.1.3 Hungry Horse Reservoir

Description of SOS9a specific to Hungry Horse Reservoir

Biological production is devastated under this plan. Refill failure occurs 80 percent of the time with 20 percent of refills at or below the 85-foot drawdown limit. Drawdowns exceed the 85-foot limit 82 percent of the time with the bottom of active storage (3,336') reached 18 percent of the time. Refill to within 20 feet occurs only 32 percent of the time. This plan is worse for biological production than historic operations (Figure 4-31).

Short- and long-term impacts

See discussion under SOS2d.

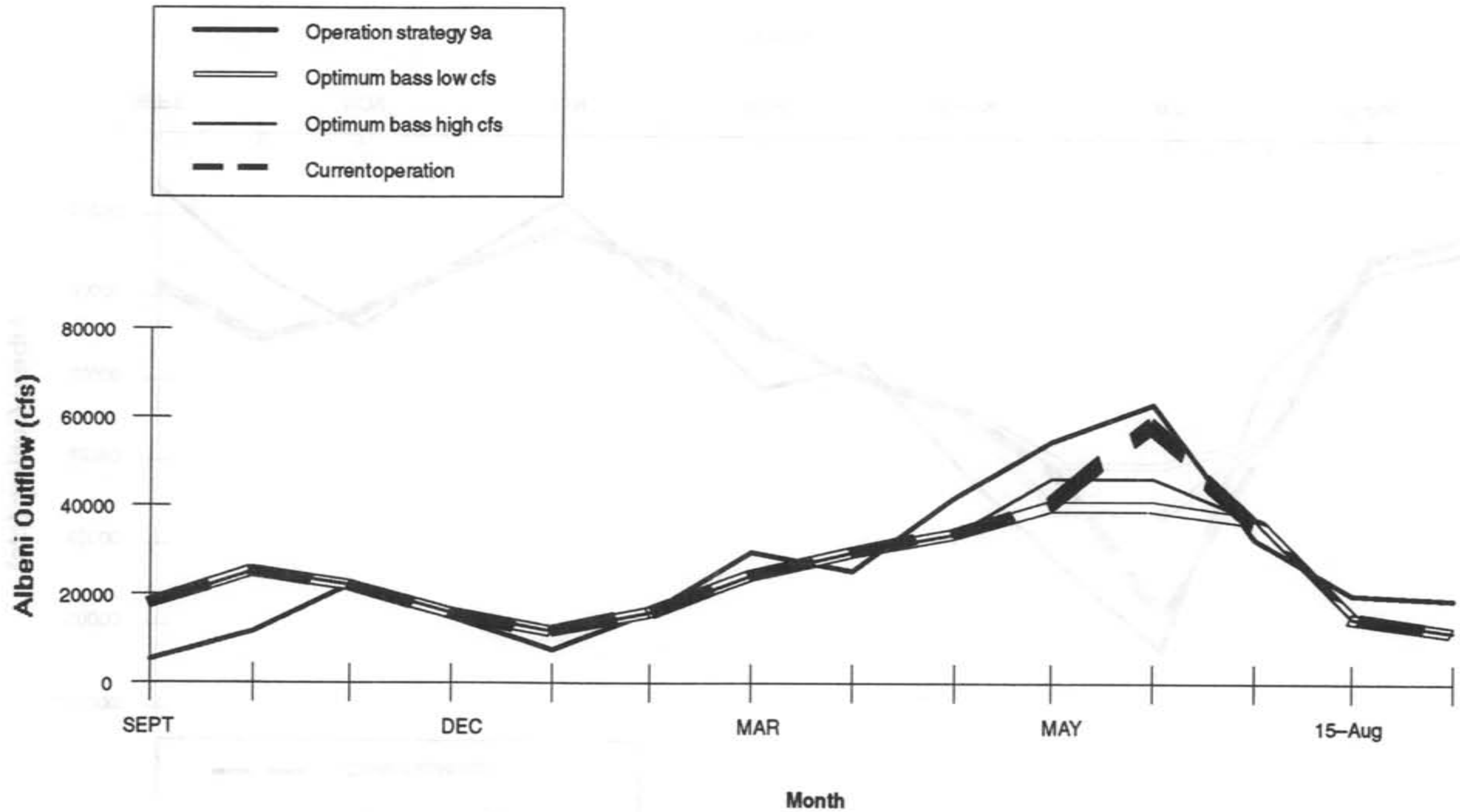


Figure 4–28. Operation at Albeni Falls Dam and Bass Spawning Requirements Under Strategy 9a

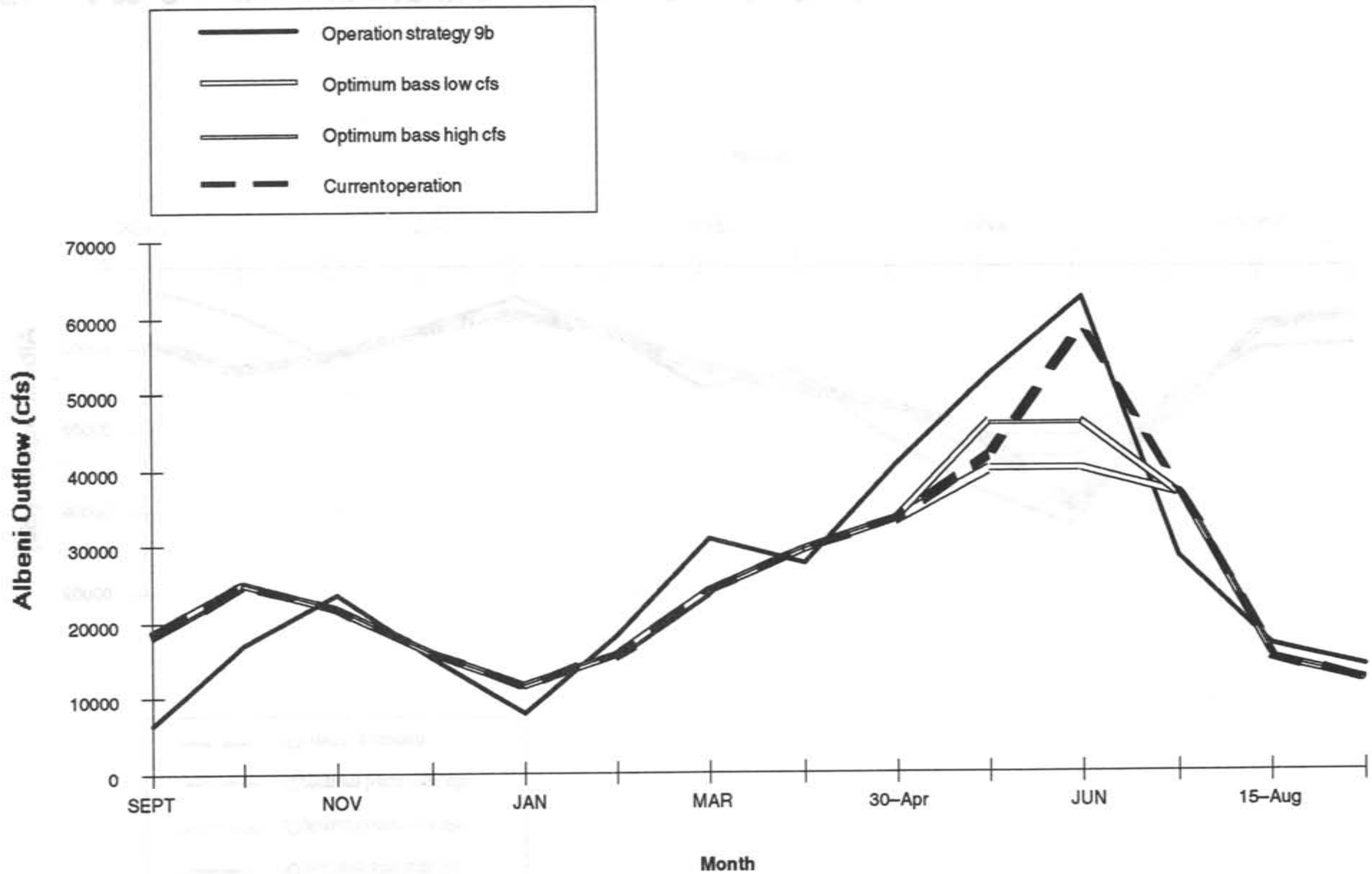


Figure 4–29. Operation at Albeni Falls Dam and Bass Spawning Requirements Under Strategy 9b

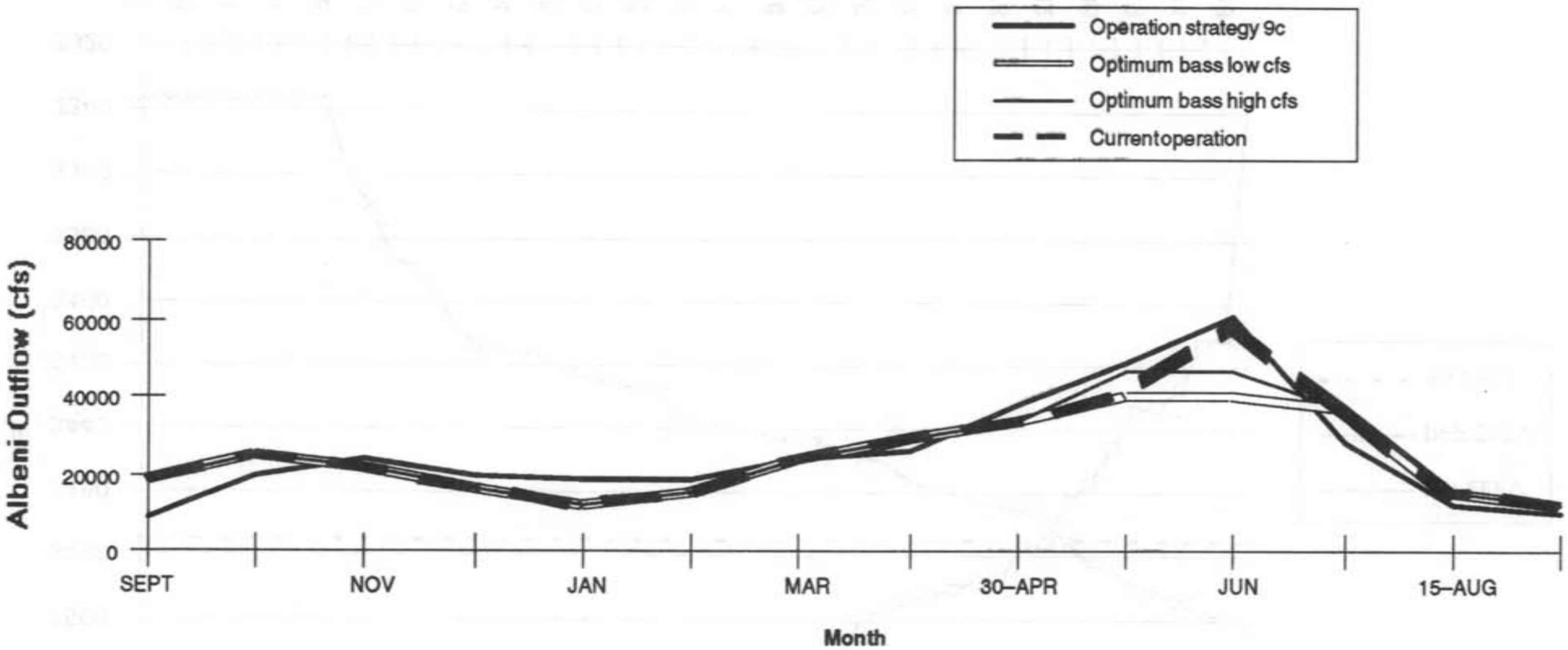


Figure 4–30. Operation at Albeni Falls Dam and Bass Spawning Requirements Under Strategy 9c

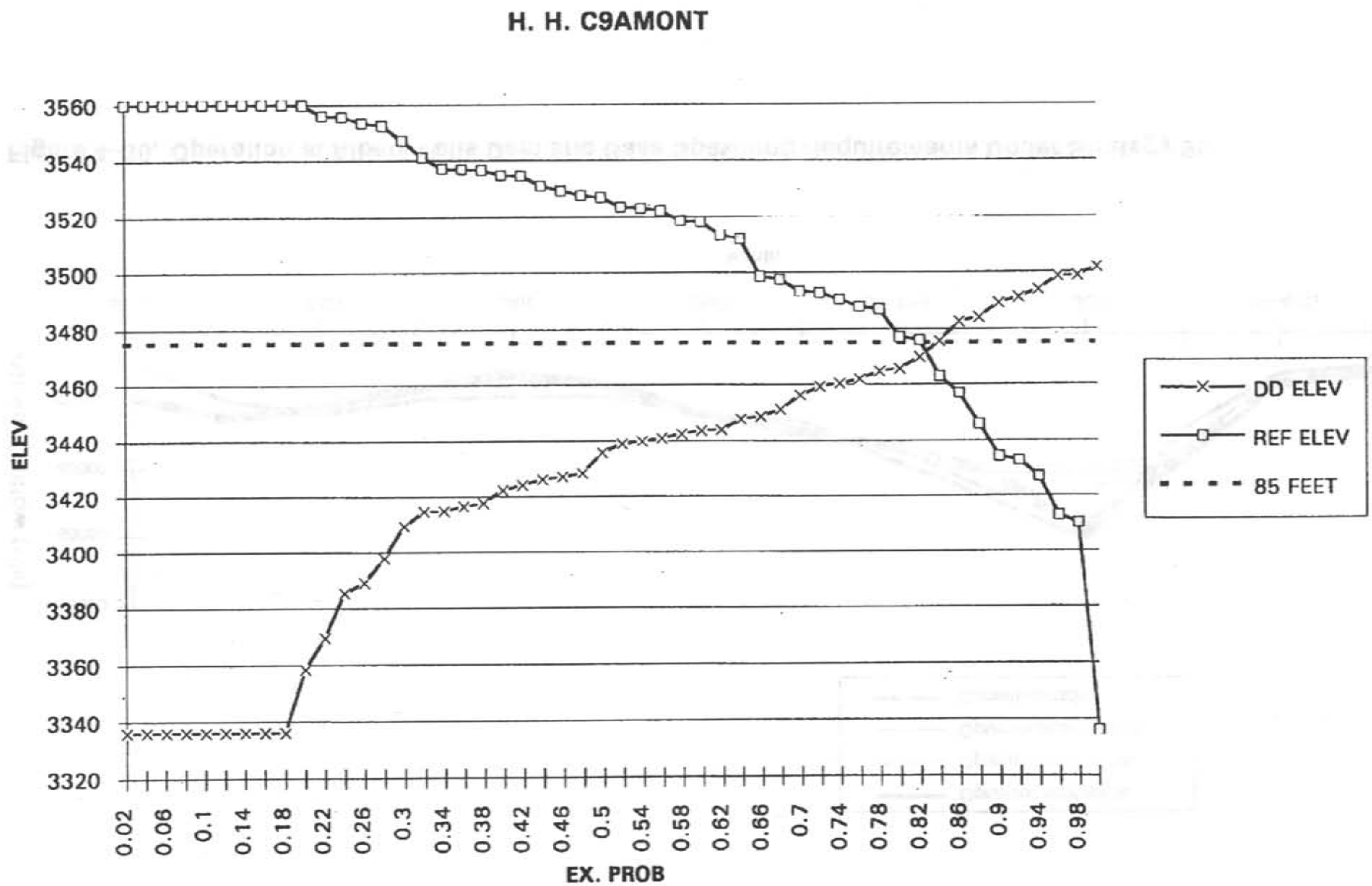


Figure 4–31. Results of a 50–year study showing the maximum elevation during the period June through August (squares), and the minimum elevation ("X") during the period March through May. Existing drawdown limits are shown in horizontal dashed line (at center). Points on the chart represent the probability of refilling or exceeding a given drawdown level.

Description of SOS9b specific to Hungry Horse Reservoir

Biological production is decreased by refill failures 46 percent of the time with refill failures to within 20 feet, 16 percent of the time. Drawdown levels exceed the 85–foot limit 20 percent of the time and are somewhat deeper than SOS4C, which exceeds the 85–foot limit 18 percent of the time (Figure 4–32).

Short– and long–term impacts

See discussion under SOS2d and SOS4c.

Description of SOS9c specific to Hungry Horse Reservoir

SOS9c is equivalent to SOS4c for Hungry Horse Reservoir (Figure 4–33).

Short– and long–term impacts

See discussion under SOS2d and SOS4c.

4.7.1.4 Lake Koocanusa

Description of SOS9a specific to Lake Koocanusa

Biological production is devastated under this plan. Refill to within 10 feet occurs only 6 percent of the time, and refill to within 20 feet occurs only 20 percent of the time. Sixty–eight percent of drawdowns exceed the 110–foot draft level and twenty–eight percent of drawdowns are at or near the bottom of active storage (2,287'). Sixteen percent of refills elevations are below the 90–foot drawdown level. This plan is worse for biological production than historical operations (Figure 4–34).

Short– and long–term impacts

See discussion under SOS2d.

Sturgeon flow needs are met for May, June and July in wet, medium and dry years.

Description of SOS9b specific to Lake Koocanusa

Biological production is harmed 66 percent of the time by reservoir refill failures of more than 10 feet, and 40 percent of the time by refill failures of more than 20 feet. Deep drawdowns at, or approaching, the bottom of active storage (2,287') 16 percent of the time, and below the 110–foot limit 56 percent of the time further harms biological production. This alternative is worse for biological production than historic operations (Figure 4–35).

Short– and long–term impacts

See discussion under 2d.

May and June flow needs are for sturgeon are met in wet, medium and dry years.

Description of SOS9C specific to Lake Koocanusa

This plan is essentially the same for Lake Koocanusa as SOS4c. Biological production is enhanced by refill failure to within 10 feet only 14 percent of the time, and drawdown levels below 110 feet only 14 percent of the time (Figure 4–36).

Short– and long–term impacts

See discussion under SOS2d and SOS4c.

Sturgeon flow goals are met best in wet years and not as well in dry years.

4.7.2 Settlement Discussion Alternatives (SOS 9a, SOS 9b, and SOS 9c) for Lake Roosevelt and mid–Columbia River

4.7.2.1 Lake Roosevelt

Description of alternative specific to Lake Roosevelt

SOS9a is modeled to not violate requirements for flood control, the Vernita Bar Agreement, and local requirements. Grand Coulee will be operated April through August to meet flow targets at the Dalles Dam according to targets selected using the previous August end–of–month storage content for Grand Coulee and Arrow combined. SOS 9b requires Coulee to be drafted to meet flow targets at McNary Dam of upper bound DFOP targets 300 kcfs

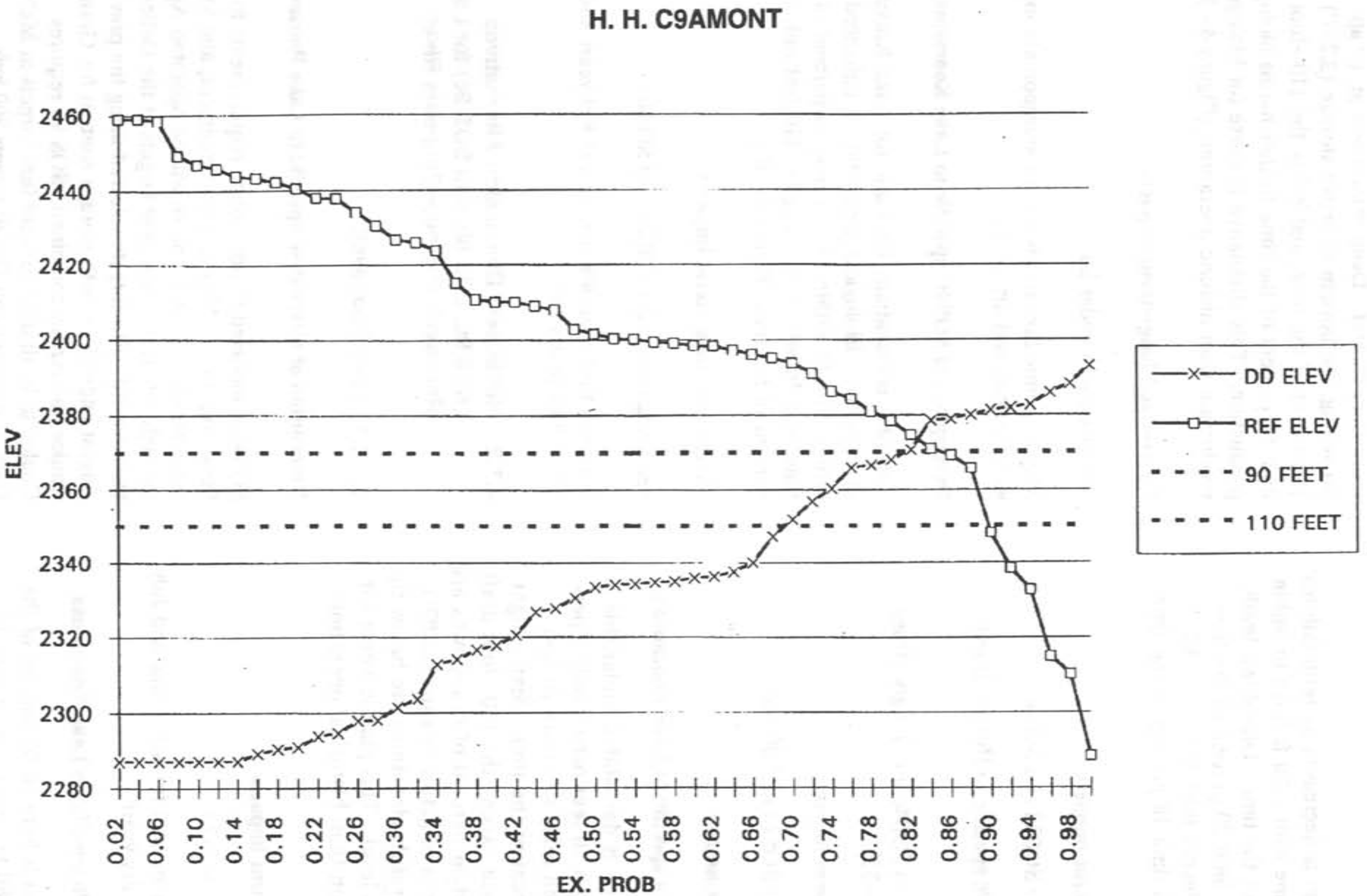


Figure 4–32. Results of a 50–year study showing the maximum elevation during the period June through August (squares), and the minimum elevation ("X") during the period March through May. Existing drawdown limits are shown in horizontal dashed line (at center). Points on the chart represent the probability of refilling or exceeding a given drawdown level.

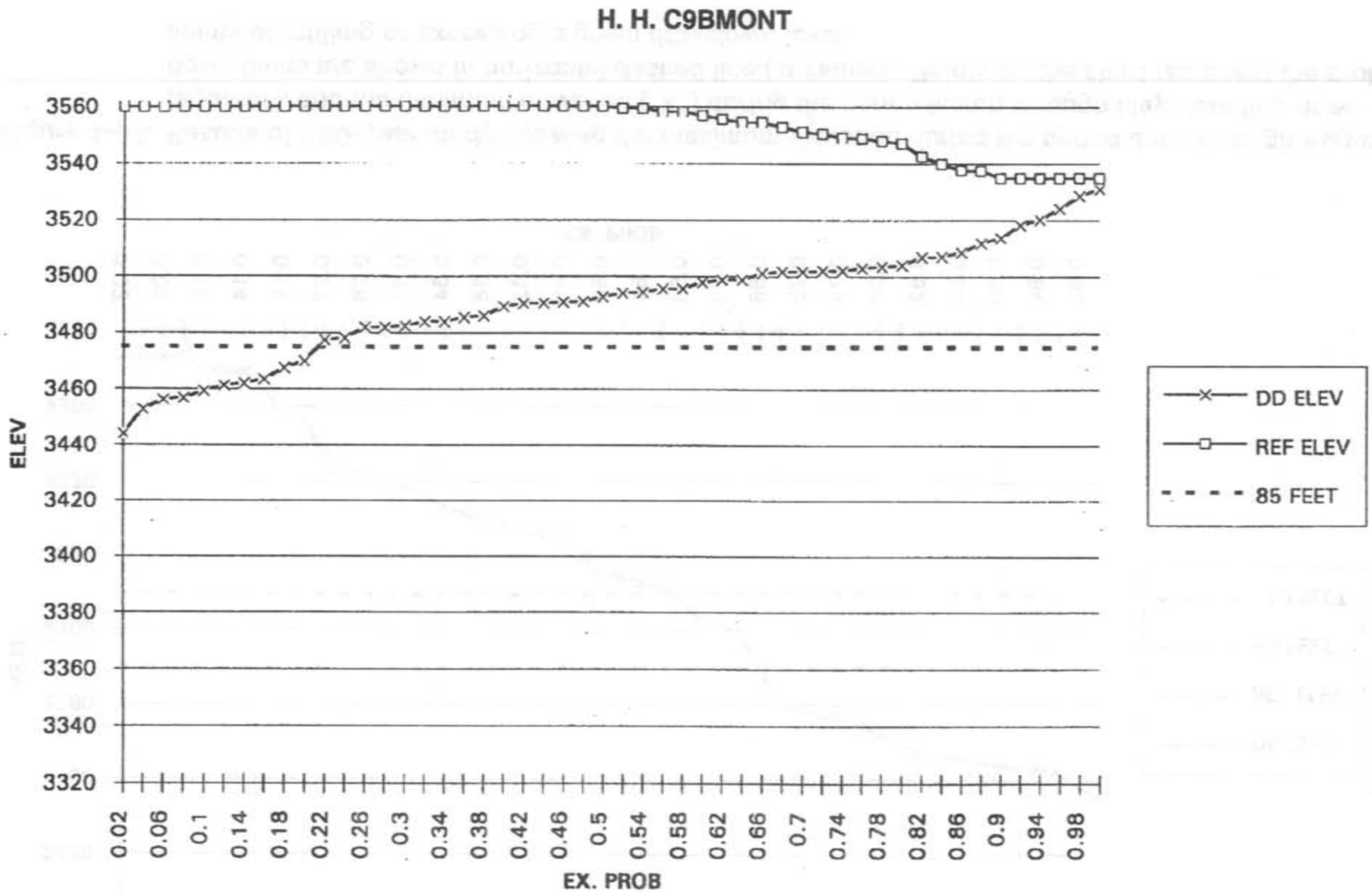


Figure 4–33. Results of a 50–year study showing the maximum elevation during the period June through August (squares), and the minimum elevation ("X") during the period March through May. Existing drawdown limits are shown in horizontal dashed line (at center). Points on the chart represent the probability of refilling or exceeding a given drawdown level.

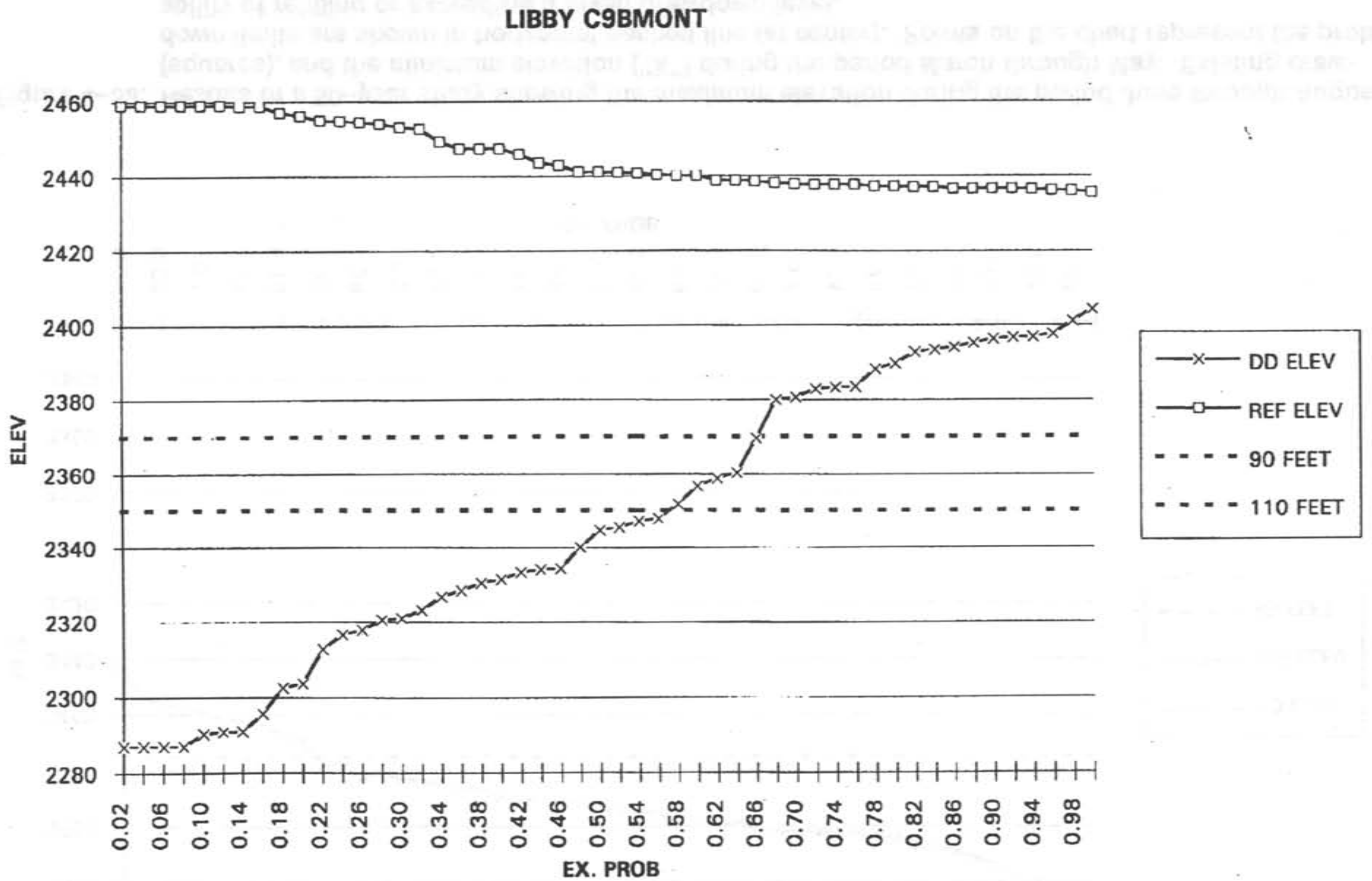


Figure 4–34. Results of a 50–year study showing the maximum elevation during the period June through August (squares), and the minimum elevation ("X") during the period March through May. Existing draw-down limits are shown in horizontal dashed line (at center). Points on the chart represent the probability of refilling or exceeding a given drawdown level.

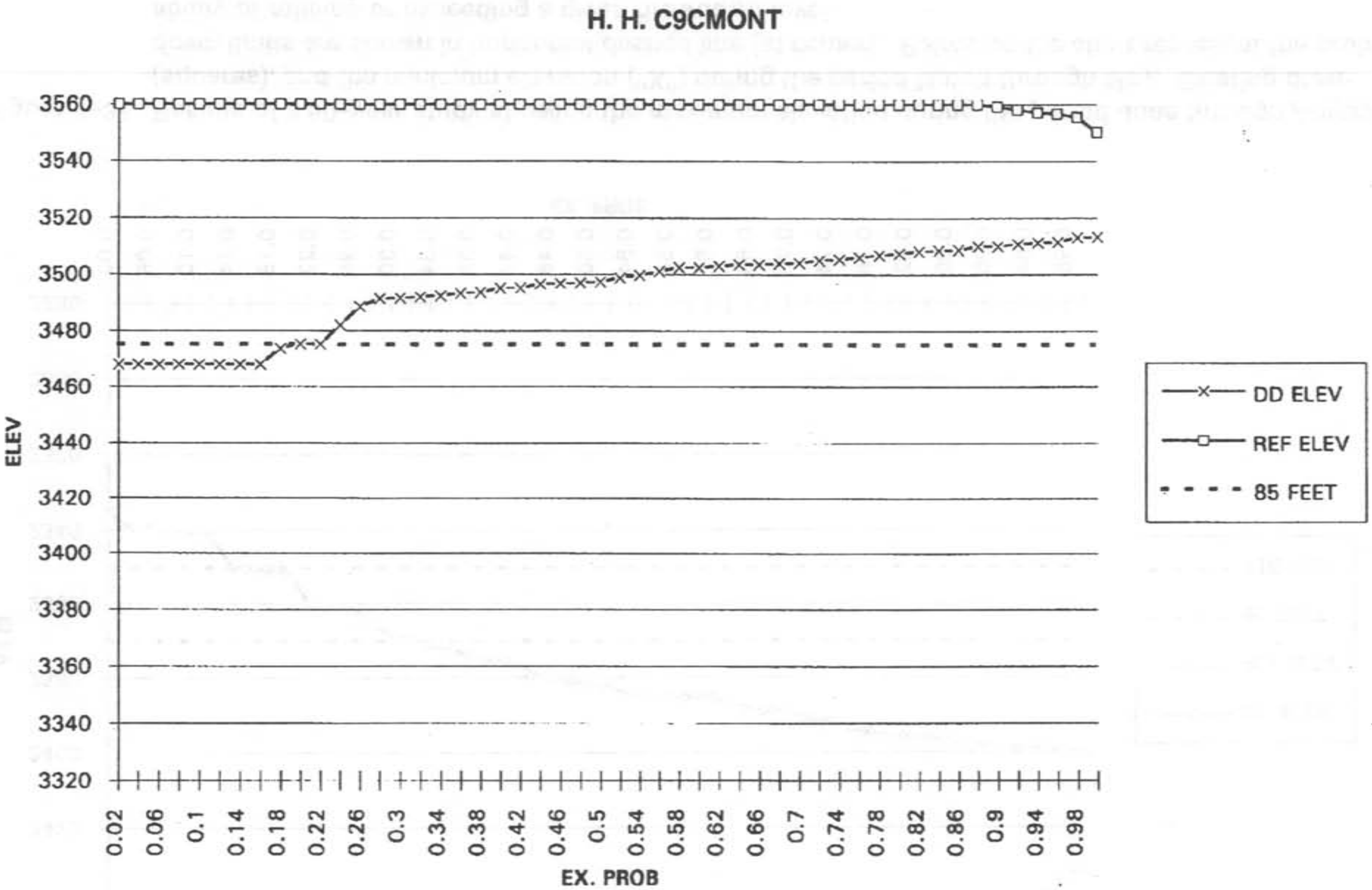


Figure 4–35. Results of a 50–year study showing the maximum elevation during the period June through August (squares), and the minimum elevation ("X") during the period March through May. Existing drawdown limits are shown in horizontal dashed line (at center). Points on the chart represent the probability of refilling or exceeding a given drawdown level.

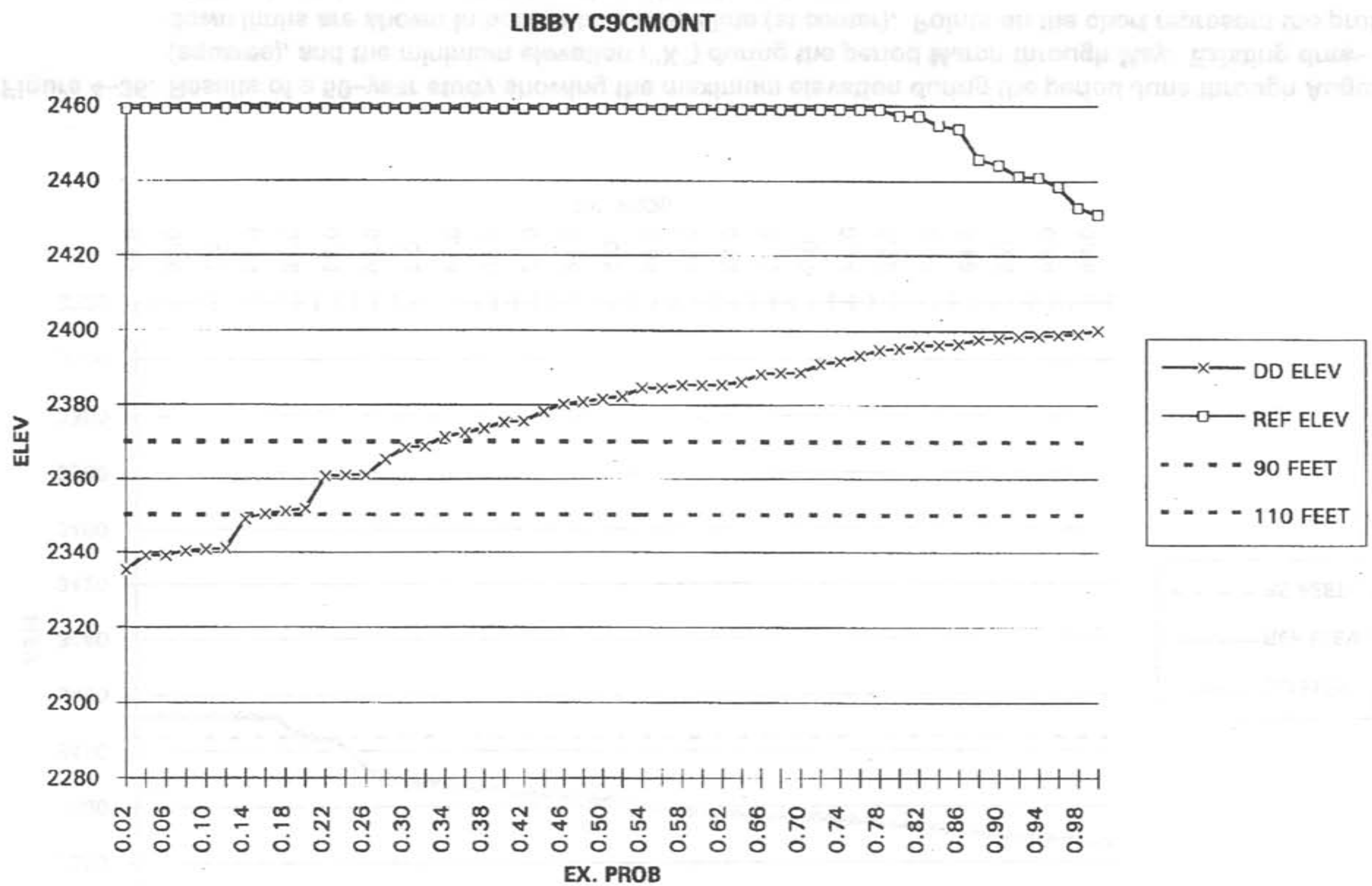


Figure 4–36. Results of a 50–year study showing the maximum elevation during the period June through August (squares), and the minimum elevation ("X") during the period March through May. Existing drawdown limits are shown in horizontal dashed line (at center). Points on the chart represent the probability of refilling or exceeding a given drawdown level.

(4/20–6/30) and 200 kcfs (7/1–7/31), and lower bound is 1994–98 Biological Opinion targets of 200 kcfs (4/20–6/30) and 160 kcfs (7/1–7/31). SOS 9c requires Coulee to meet 200 kcfs and 160 kcfs flow targets at McNary from April 16 to June 30 and in July, respectively. SOS 9 shifts flood control requirements to Grand Coulee from Brownlee and Dworshak, and uses Grand Coulee to meet specified targets at McNary.

Short–term impacts

SOS 9a offers deep drawdowns of the reservoir with full pool being reached in most years by January. During high–water years, the reservoir is kept at MOP for the entire summer. SOS 9b and 9c begin drawdowns in March and February, respectively, with full pool being reached in most years by July for most years. The majority of the outflows are above 100 kcfs, which reduces water retention times to below 30 days for the majority of the year. This would prevent zooplankton standing crops from increasing, and it would flush nutrients, zooplankton, and fish through the reservoir.

Long–term impacts

Long–term impacts from continued operations under SOS 9a, 9b, and 9c will produce adverse effects on the fisheries due to low water retention times that do not allow for nutrients to become available to fish. Additionally, high flows would flush food resources and juvenile fish through the reservoir.

Cumulative impacts

Low water retention times lead to decreased food production which results in poor fish growth. Monthly fluctuations in water levels decrease spawning success of many spring spawning resident fish in Lake Roosevelt (Beckman 1985). Due to the limited capability of the impacts could not be quantified, but would most certainly be important to the survivability of eggs and fry, and ultimately to the success of the population.

Unavoidable impacts

Unavoidable impacts due to operations under SOS 9 include loss of nutrients, loss of zooplankton, loss of benthic invertebrates, decreases in fish spawning and feeding habitat, and entrainment losses. The extent of these losses depends of season, flow and drawdown.

Mitigation

Potential mitigation measures for SOS 9 include stream and riparian zone improvements, benthic structure placement, and sonic avoidance mechanisms for fish. These measures would increase usable fish habitat, increase food sources, and decrease entrainment levels. Monitoring systems to detect unforeseen impacts would be set up to aid in determining on–site and off–site mitigation locations and actions.

4.7.3 Settlement Discussion Alternatives (SOS 9a, SOS 9b, and SOS 9c) for Middle Snake and Clearwater Rivers

4.7.3.1 Dworshak Reservoir

Description of alternative specific to Dworshak Reservoir

There are no specific operating requirements for SOS 9a at Dworshak Reservoir. A review of the end–of–month elevations shows that this option would result in the average annual elevations ranging from 1505 to 1565 feet. In any given year the maximum end–of–month elevation could be as high as 1596 feet, or as low as 1445 feet. Average monthly discharge for SOS 9a ranges from 2000 to 9000 cfs, with peak discharge as high as 25000 cfs and minimum flows as low as 1000 cfs.

SOS 9b removes Dworshak Reservoir from proportional draft for power and operates the reservoir to flood control rule curves. System flood control would be shifted to Grand Coulee. Flow would be maintained at minimum (1200 cfs) in all months except when additional releases are needed to provide flow augmentation in the lower Snake River. Dworshak Reservoir can be drafted to meet flow targets down to a minimum end of July elevation of

1490 feet. A review of the elevations for SOS 9b suggests that average end–of–month elevations range between 1490 and 1560 feet. Full pool elevations are not reached every year, and minimum elevations range between 1445 and 1535 feet. Outflow under this option is slightly higher than under SOS 9a or SOS 9c, with average monthly flows ranging from 4000 to 9000 cfs, with peak discharge frequently at 25000. Minimum discharge is similar to the other options – near 1000 cfs.

SOS 9c is similar to SOS 9b except the project can be drafted to meet flow targets down to a minimum end of July elevation of 1520 feet. Average end–of–month elevations under this option range from 1520 to 1570 feet. Maximum elevation ranges from 1570 to 1597 feet, and full pool is more often achieved under this option. In some years, minimum elevations only go as low as 1530 feet, but can drop down to 1445 feet.

Short and long–term, cumulative, and unavoidable impacts

SOS 9 is one of the worst alternatives reviewed for kokanee (Table 4–8). SOS 9a is better than SOS 9c which is better than SOS 9b, but all are bad. This alternative appears similar to SOS 2. Under SOS 9a the food production indices range from 0.35 to 0.85, and the spawning tributary access index is generally greater than 0.8. Under SOS 9b, the food production index ranges from 0.3 to 0.8, but the average tends to be lower by approximately 0.2 units. The spawning tributary access index is essentially the same as for SOS 9a. Under SOS 9c, the food production index averages around 0.7. The entrainment index for SOS 9a ranges from 0.1 (bad) to 1.0 (good), and averages around 0.5. In SOS 9b, the range is from 0.8 to 0.1, but the average is around 0.4. SOS 9c is in between these two, with the average index around 0.5.

All the options for SOS 9 are bad for smallmouth bass; the indices rarely exceed 0.2 (Table 4–8). For bull trout and cutthroat trout, SOS 9c is best, with SOS 9a second, and SOS 9b third (similar to kokanee). In fact, SOS 9b is one of the worst alternatives reviewed for bull trout and cutthroat trout. The index values for SOS 9c range from 0.5 to 0.9 and average around 0.7. For SOS 9a, the index ranges from 0.35 to 0.85, with an average around 0.65. For SOS 9b, the range is from 0.3 to 0.8 with an average around 0.5.

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.7.3.2 Brownlee Reservoir

Description of alternative specific to Brownlee Reservoir

SOS 9a calls for up to 110 KAF to be drafted from Brownlee in May, 137 KAF in July, 140 KAF in August, and 100 KAF in September. System flood control would be shifted to Grand Coulee. A review of the elevations for SOS 9a show that the average end–of–month elevations range from 2050 to 2070 feet, with minimum elevations as low as 1980 feet and maximum elevations as high as 2080 feet.

Under SOS 9b and SOS 9c, 190 KAF would be drafted April through May, 137 KAF in July, and 100 KAF in September. An additional 110 KAF and 100 KAF would be provided in May and September if the reservoir is above 2068 and 2043.3 feet, respectively. System flood control would be shifted to Grand Coulee. A review of the elevations for SOS 9b and SOS 9c show that average end–of–month elevations range from 2040 to 2060 feet. Maximum elevations reach 2080 feet in nearly all years under both options, while minimum elevations fluctuate between 1980 and 2040 feet.

Annual average monthly discharge for all options ranges from approximately 12000 to 30000 cfs. Peak discharge in some years is as high as 70000 cfs, while minimum discharge is as low as 5000 cfs.

Short and long–term, cumulative, and unavoidable impacts

SOS 9 is the worst alternative reviewed for all species of resident fish evaluated in Brownlee Reservoir (Table 4–9). For example, the indices for warmwater species range from 0.1 to 0.8, with SOS 9a slightly worse than SOS 9b and SOS 9c. The indices for smallmouth bass range between 0.3 and 0.8. The indices for rainbow trout and channel catfish are also quite low under this alternative (Table 4–9). They range from 0.4 to 0.6 for channel catfish, and 0.6 to 0.8 for rainbow trout. This is substantially worse than under previous alternatives. It appears that the reservoir elevations are fluctuated during the resident fish spawning periods under this alternative.

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.7.4 Settlement Discussion Alternatives (SOS 9a, SOS 9b, and SOS 9c) for Lower Snake River

4.7.4.1 Lower Granite Reservoir

Description of alternative specific to Lower Granite Reservoir

SOS 9a calls for flow targets at Lower Granite (assuming full pool and spillway crest elevations) as follows: 140 kcfs at full pool and 74 kcfs at spillway April 16 – June 30; 85 kcfs at full pool and 45 kcfs at spillway July 1 – July 31; and 60 kcfs at full pool and 32 kcfs at spillway August 1 – August 31. Lower Granite would be drawn down from a full pool level of 738 feet to a drawdown elevation of 705 feet from April 1 through August 31. Maximum spill at Lower Granite would be 60 kcfs. A review of the elevations for SOS 9a shows that the reservoir fluctuates between 705 and 738 feet each year. Outflow is essentially modeled the same as in other alternatives.

SOS 9b calls for Lower Granite Reservoir to be operated at the minimum operating pool (734 feet) with one foot flexibility between April 1 and August 31. Maximum spill is set at 30 kcfs. A review of the elevations shows that the reservoir is held within one foot of MOP in each of the 50 years modeled. Outflow is similar to previous alternatives.

SOS 9c draws Lower Granite down from full pool level of 738 feet to a drawdown level of 695 feet from April 1 through June 15. Refill is completed by June 30. The maximum spill allowed under this option is 30 kcfs. The annual average elevations under this option tend to be around 724 feet, with drawdowns to 695 feet and refill to 736 feet. Outflow is similar to previous alternatives.

Short and long–term, cumulative, and unavoidable impacts

Growth index values at 2, 4, and 10 year occurrence intervals for smallmouth bass, white sturgeon, and northern squawfish for all SOSs can be found in Tables 4–10 – 4–12 (additional detail can be found in the Results Exhibit). Without hydroregulated input at a time scale finer than 1 month, it is impossible to make highly accurate predictions of the impacts to resident fish in Lower Granite Reservoir. The model predictions based on the end–of–month pool elevations and our qualitative assessment of the impacts should fluctuations in the pool levels occur at a time scale finer than 1 month are presented in the following tables. Table 4–10 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of no variability in within–month pool levels; i.e., the growth index values predicted by the model based on end–of–month elevations. Table 4–11 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of minimal within–month pool fluctuations (2.5 – 4.9 feet); i.e., a qualitative estimate of the impacts should the pool be fluctuated between 2.5 and 4.9 feet within any given month. Table 4–12 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of high within–

month pool fluctuations (7.5 – 9.9 feet); i.e., a qualitative estimate of the impacts should the pool level be fluctuated between 7.5 and 9.9 feet within any given month.

SOS 9a and SOS 9c are both bad for northern squawfish, and result in some of the lowest index values of the alternatives reviewed. In fact, the impacts are similar to the impacts observed under SOS 5b (4–month drawdown). However, SOS 9b is much better, with the index values around 0.7. The improvement in index values is due to the pool being held stable year round.

The options of SOS 9 range from 0.7 to 0.8 for white sturgeon. This may be misleading because the sturgeon model is based on deep water habitat. Fluctuations in reservoir elevations will undoubtedly have impacts, although it is not likely impacts to white sturgeon will be as severe as other species of resident fish.

Nitrogen supersaturation increases with increased spill. Resident fish may be more susceptible to high dissolved gas levels than anadromous fish because they are present in the reservoir longer. The effects of gas supersaturation on resident fish was not taken into consideration in developing the model for Lower Granite.

Mitigation

Mitigation measures may include, but not be limited to offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.7.5 Settlement Discussion Alternatives (SOS 9a, SOS 9b, and SOS 9c) for Lower Columbia River

4.7.5.1 John Day Reservoir

Description of alternative specific to John Day Reservoir

SOS 9a calls for John Day to be lowered to elevation 257 feet with one foot flexibility from April 15 through August 31. Spill is not to exceed 70 kcfs. Modeled elevations fluctuate approximately 10 feet from 257 to 267 feet each year. Outflow is similar to previous alternatives.

SOS 9b calls for John Day to be lowered to elevation 262.5 with one foot flexibility from April 16 through August 31. Spill is not to exceed 30 kcfs. Modeled elevations show this option results in pool levels that are not fluctuated as much as in SOS 9a or SOS 9c. Elevations average 263 feet, and do not drop below 262.5 feet, or exceed 267 feet. Outflow is very similar to other alternatives.

SOS 9c calls for John Day to be lowered to elevation 262.5 feet with one foot flexibility from April 16 through August. Spill is not to exceed 30 kcfs. A review of the elevations shows that this alternative results in elevations that drop lower than 262.5 feet. Pool elevations are fluctuated between MOP and 267 feet. Flows are similar to other alternatives.

Short and long–term, cumulative, and unavoidable impacts

Although the index values from the model are high from this alternative, this alternative results in one of the worst set of conditions for resident fish in John Day Reservoir (Tables 4–13 – 4–15). Drawdown of John Day to minimum operating pool (MOP) will reduce the amount of shallow water habitat by approximately 6000 acres (Mark Smith, U.S. Army Corps of Engineers, Portland District, personal communication). Some new habitat will be created, but based on available information the total amount of habitat will be reduced. It is possible that the first year of drawdown may allow dormant seeds (which are at lower elevations) to germinate and give some productivity to the new habitat.

Drawdown has the potential to desiccate eggs and larvae of early spawning fish such as yellow perch. Perch in John Day begin spawning in early April and therefore, may spawn in the drawdown zone. The initial drawdown will undoubtedly reduce or eliminate populations of these early spawning fish. Smallmouth bass and crappie may be able to avoid this problem because they spawn later. Spawning areas at lower elevations have not been analyzed for habitat quality (i.e., cover, substrate, and flow). If the conditions are different from existing conditions, then it is likely that production will be less at the lower elevations.

In summary, a drawdown of John Day Pool to MOP will have a negative effect on resident fish populations. It is unknown at this time the fullest extent of the effects, but the loss of shallow water habitat, resident fish, and primary and secondary productivity will be substantial.

Mitigation

A year–round drawdown to MOP would allow habitat to develop at this elevation. It is estimated it would take 3–5 years for aquatic vegetation and a food base to develop in new shallow water areas. This would allow for some re–establishment of resident fish over several years.

It is unknown at this time to what extent habitat would develop or if acreage of shallow water habitat would be comparable to present conditions. From limited available data on pool topography it appears that the amount of shallow water areas (potential habitat development) at elevation 257 feet will be substantially less than current conditions due to configuration of the river channel (M. Smith, U.S. Army Corps of Engineers, Portland District, pers. communication). Current bathymetric information is necessary before this option is considered to determine the type, quality, and size of habitats that may be established.

Further studies are required to more clearly assess the impacts of an annual drawdown of John Day Pool to elevation 257 feet. This would include at least an assessment of habitat in backwaters (including vegetation mapping), substrate mapping, population estimates, spawning use, and bathymetric mapping.

4.8 DESCRIPTION OF IMPACTS OF SYSTEM OPERATING STRATEGIES

4.8.1 Preferred Alternative (SOS PA) for Upper Columbia River and tributaries

4.8.1.1 Lake Pend Oreille

Description of alternative specific to Lake Pend Oreille

Under the preferred alternative, Albeni Falls Dam is operated to achieve flood control elevations by April 15th in 90% of the years. Water stored in Lake Pend Oreille is used to meet flow targets downstream for anadromous fish, but is not drafted below full pool before the end of August. The lake level reaches its lowest point during December according to the alternative description. However, the modeling of the lake's elevations show the lake to be down to minimum level by the end of November. It is critical the lake be dropped to its lowest point by November 15 of each year so as not to desiccate kokanee eggs. This was assumed to be the case for our analysis. If the minimum is reached by November 15, then this alternative is very similar to status quo operations.

Short and long–term, cumulative, and unavoidable impacts

This alternative is similar to current operations (Table 4–3). The egg incubation success is very low because of the deep fall drawdowns. Egg incubation success index varies between 0.2 and 0.25. As a comparison, the egg incubation success index under SOS 4 averages around 0.7 to 0.8. Again, minimum elevations are assumed to be reached by November 15 although this was not part of the SOS description.

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.9 DESCRIPTION OF IMPACTS OF SYSTEM OPERATING STRATEGIES

4.9.1 Preferred Alternative (SOS PA) for Box Canyon Reservoir

4.9.1.1 Box Canyon Reservoir

Description of alternative specific to Box Canyon Reservoir

Under SOS PA, Albeni Falls would operate to achieve flood control elevations by April 15th 90% of the years. The project is used to meet flow target but is not drafted below full pool through August. Reservoir elevation reaches the lowest point during December and refills during the remainder of the operating year.

Short and long–term and cumulative impacts

This SOS would allow releases from Albeni Falls to gradually increase from March to a peak discharge of 61,000 cfs in June. Figure 4–37 indicates water levels from May 1 through June 30 remain constant for bass spawning requirements. Minimum outflow from Albeni Falls for bass productions would be at 40,000 cfs. Maximum outflow for bass production would be at 45,000 cfs. Fluctuating water levels in reservoirs can adversely affect spawning success of largemouth bass that rely on shallow water or nearshore areas for nest construction. Rapidly receding water levels may also result in desertion of nest, poor egg survival, and disrupted spawning (Ploskey 1986). This Preferred Alternative would fluctuate the water levels during May and June, but not as severe as other alternatives.

Unavoidable impacts

Conditions should improve under this SOS.

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations. Mitigation may also include supplementation in a largemouth bass hatchery.

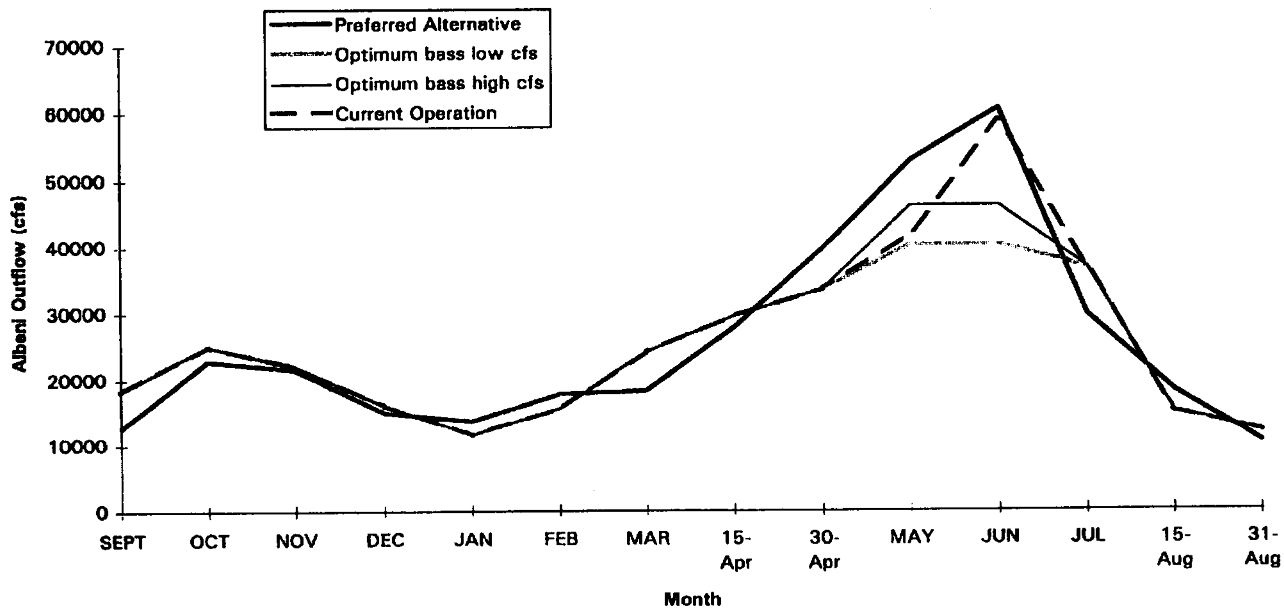


Figure 4–37. Operation at Albeni Falls Dam and Bass Spawning Requirements Under the Preferred Strategy

4.9.1.2 Hungry Horse Reservoir

Description of SOSPA specific to Hungry Horse Reservoir

The Preferred Alternative (PA) reflects the NMFS 1995–98 Biological Opinion. This PA, in its current form, produces model results similar to SOS4c and 9c. A modeling function that estimates benthic production, and thus contributes to trout growth calculations, must be examined to understand why SOS4c and 9c are superior to the PA for resident fish. Benthic insect production can be temporarily enhanced if the reservoir fails to refill. This is because warm surface layers come in contact with deeper zones containing high larval densities, causing enhanced emergence rates. This effect is short–lived (annual) and would require even greater refill failure in subsequent years to achieve the same benefit (increased trout food). Repeated refill failure ultimately impacts food availability. This PA differs from the IRC which improves refill probability, fills the reservoir around July 1 on most years, then keeps the reservoir at or near full through September 15. The PA calls for summer drafts at Hungry Horse to 20 feet from full pool by August 31. Refill probability is reduced from historic operational practices (Figure 4–38, Table 4–4).

The beginning of the water year (October 1 through mid April), however, is beneficial to biological production in Hungry Horse Reservoir. During this period, the PA is essentially equivalent to the IRCs when the provision to store water above the IRCs for later release is invoked. This provision, although costly in terms of power production, further enhances anadromous fish by maintaining reservoir elevations above the IRCs prior to runoff so that this "earmarked" volume can be released to aid downstream smolt migrations. The volume that can be earmarked each year is variable, dependent on the runoff forecast. More water can be earmarked during dry years when the threat of flooding is minimal. If done correctly, a nearly natural spring freshet can be released (within local flood constraints) without sacrificing reservoir refill. Deep drawdowns and refill failures are extremely harmful to biological production in the reservoirs, and may place viable stocks of resident fish in Montana at risk. Summer drafting reduces aquatic production during the months of peak biological production.

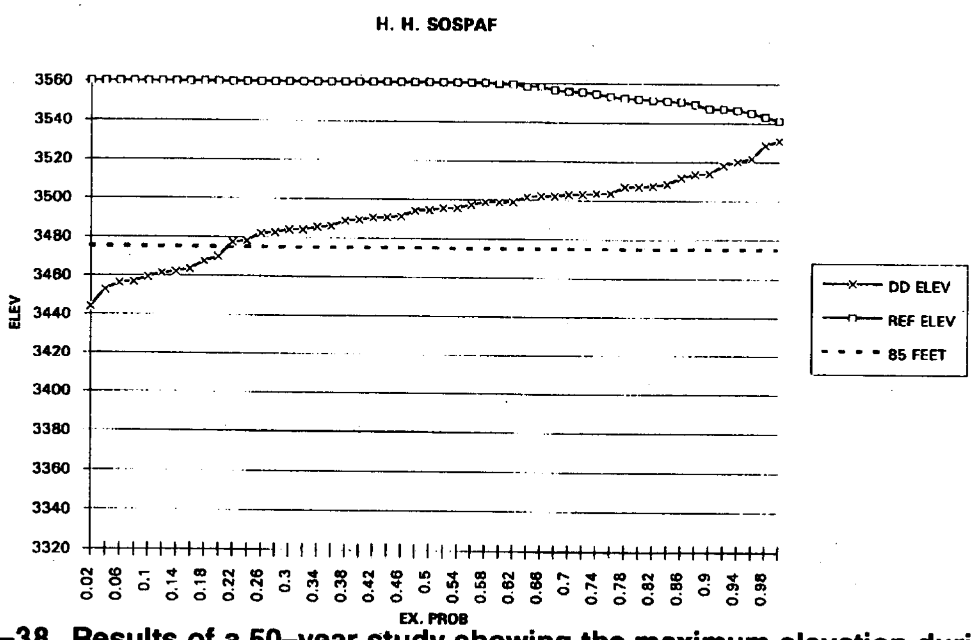


Figure 4–38. Results of a 50–year study showing the maximum elevation during the period June through August (squares), and the minimum elevation ("X") during the period March through May. Existing drawdown limits are shown in horizontal dashed line (at center). Points on the chart represent the probability of refilling or exceeding a given drawdown level.

Short– and long–term impacts

See discussion under SOS2d.

The salmon recovery program should not compromise the long–term viability of native resident fish, including bull trout and westslope cutthroat trout. The Integrated Rule Curves (IRCs) were incorporated in SOS4c and 9c. Although the IRCs do not consistently meet flow targets designated by NMFS, modeling results have shown that flows at the Dalles are improved for salmon by the IRCs without compromising reservoir refill probability. Benefits for anadromous fish species can be further enhanced by implementing the "provision" to earmark water above the IRCs for later release. Modeling runs have not, as yet, investigated the possibility of reregulating (delaying) the water released from Hungry Horse during runoff (late June) so that it arrives in the Lower Columbia during July or August. Nor have analysts adequately assessed the tradeoffs between anadromous benefits and resident fish impacts resulting from this PA.

What is the true loss associated with meeting a slightly lower target flow when it is hydrologically impossible to meet both flow targets and IRCs? Do anadromous benefits offset resident fish losses when IRCs are violated to meet flow targets? These questions should be answered based on empirical evidence.

4.9.1.3 Lake Koocanusa

Description of SOSPA specific to Lake Koocanusa

The Preferred Alternative (PA) reflects the 1995–98 Biological Opinion. This PA, in its current form, is harmful to resident fish in Montana. The PA calls for summer drafts of 20 feet from full pool by August 31. Impacts are especially great at Libby, causing drawdowns to ≈170 feet (the bottom of active storage) in 12 percent of all years and refill failure in 82 percent of all years. This is greatly reduced from historic operational practices. Also, the PA violates the existing maximum drawdown limit (90–110 feet from full pool) 56 percent of all years (Figure 4–39).

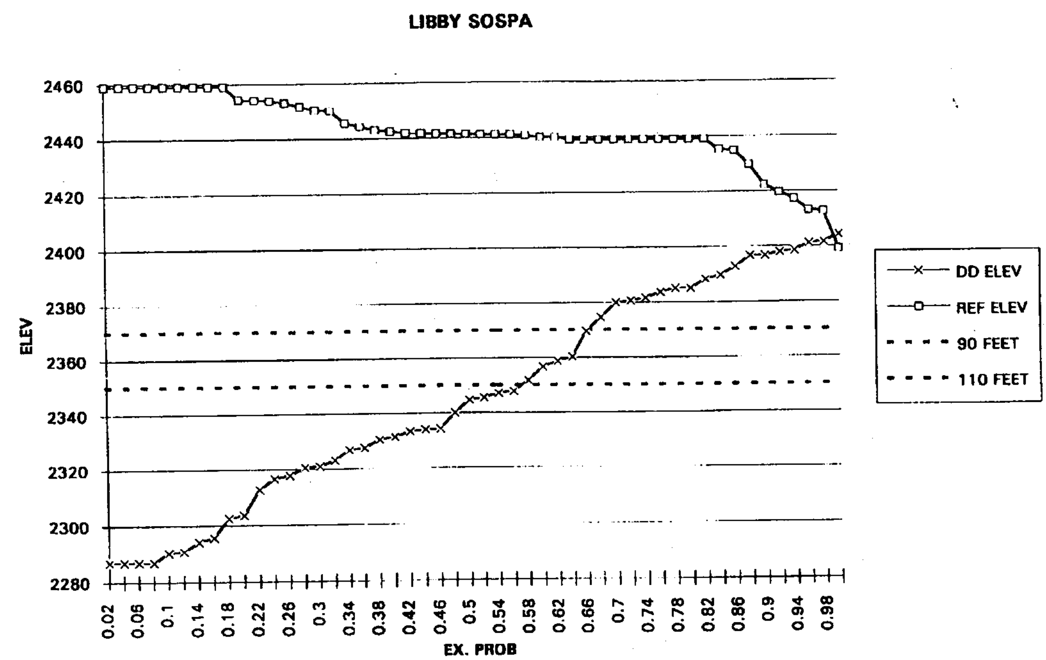


Figure 4–39. Results of a 50–year study showing the maximum elevation during the period June through August (squares), and the minimum elevation ("X") during the period March through May. Existing drawdown limits are shown in horizontal dashed line (at center). Points on the chart represent the probability of refilling or exceeding a given drawdown level.

Short– and long–term impacts

See discussion under SOS2D.

The salmon recovery program should not compromise the long–term viability of native resident fish, including white sturgeon, bull trout, inland redband and westslope cutthroat trout. The Integrated Rule Curves (IRCs) were incorporated in SOS4C and 9C. Although the IRCs do not consistently meet flow targets designated by NMFS, modeling results have shown that flows at the Dalles are improved for salmon by the IRCs without compromising reservoir refill probability. Benefits for anadromous fish species can be further enhanced by implementing the "provision" to earmark water above the IRCs for later release. This earmarked water can then be packaged for white sturgeon and anadromous species simultaneously. Modeling runs have not, as yet, investigate the possibility of reregulating (delaying) the water released from Lake Koocanusa during runoff (late June) so that it arrives in the Lower Columbia during July or August. Nor have analysts adequately assessed the tradeoffs between anadromous benefits and resident fish impacts resulting from this PA. What is the true loss associated with meeting a slightly lower target flow when it is hydrologically impossible to meet both flow targets and IRCs? Do anadromous benefits offset resident fish losses when IRCs are violated to meet flow targets? These questions should be answered based on empirical evidence.

Native inland redband populations in Montana are almost exclusively located in tributary rivers and streams. A population in Libby Reservoir is being supplemented through hatchery plants. Primary impacts are genetic introgression with westslope cutthroat and introduced stocks of rainbow. Hydropower operations are believed to have only minimal impact on remaining, genetically pure populations in the Kootenai River below Libby Dam. One exception may be effects on migrating relictual stocks from Callahan Creek near Troy, Montana. The established population in Lake Koocanusa is subject to the effects of reservoir fluctuation.

Burbot sampling in Montana revealed a sparse population, greatly reduced from historic numbers. Limited captures provide only general information about habitat requirements and life cycle biology. We, therefore, assumed that natural flows and temperatures would be beneficial to the species and that regulated hydrology, among other changes such as contaminants and introduced species, contributed to the decline of the burbot population. Continued research is needed to calibrate the IFIM model which is presently under construction for the Kootenai River. Until environmental requirements have been documented, we have assumed that natural streamflows are more beneficial than highly regulated conditions. Because white sturgeon are believed to require nearly natural conditions for recovery, evaluation criteria for sturgeon may be used as a surrogate for burbot.

Bull trout, cutthroat, mountain whitefish and rainbow also benefit from nearly natural flow conditions. The selective withdrawal structure in Libby Dam provides complete thermal control regardless of turbine discharge. Use of the spillway presents potential problems associated with gas supersaturation. Under normal operating regimes using turbine penstocks only, gas bubble disease is not an issue. Rapid flow fluctuations caused by load following and peaking negatively effect riverine fish species and their prey items and may strand insects, fish and fish eggs. Since these fish species typically spawn and rear in tributary streams, dam operations effect individuals in the river after emigration from their natal tributary. Rainbow trout, however, do spawn in the main stem Kootenai River and are sensitive to flow manipulation during the April through July period. To protect rainbow spawners and redds, Montana has recommended that experimental releases for white sturgeon spawning begin no earlier than June 1. This forces spawners to construct redds low in the stream channel so that redds will remain wetted until fry emerge.

4.9.2 Preferred Alternative (SOS PA) for Lake Roosevelt and mid–Columbia River

4.9.2.1 Lake Roosevelt

Description of alternative specific specific to Lake Roosevelt

The SOS PA operates Grand Coulee to achieve flood control elevations by April 15th 85% of the years. The project is drafted to meet flow targets down to a minimum end of August elevation of 1280 feet.

Short–term impacts

SOS PA operations will produce poor conditions for spring spawning fish. Grand Coulee will be responsible for increased outflows in the spring, which will cause entrainment, decrease spawning success, and habitat loss. The drastic changes in elevations could cause fish to pool up at the dam leading to entrainment, increase sediment harming eggs, and cause temperature problems which effect eggs and plankton production.

Long–term impacts

Long–term impacts from continued operation under SOS PA will produce an adverse effect on the fisheries. Loss of spawning habitat due to elevation changes, loss of nutrients and fish through entrainment will significantly impact the kokanee and rainbow trout fisheries.

Cumulative impacts

Low water retention times lead to decreased food production which results in poor fish growth. Monthly fluctuations in water levels decrease spawning success of many spring spawning resident fish in Lake Roosevelt (Beckman 1985). Due to the limited capability of the impacts could not be quantified, but would most certainly be important to the survivability of eggs and fry, and ultimately to the success of the population.

Unavoidable impacts

Unavoidable impacts due to operations under SOS 9 include loss of nutrients, loss of zooplankton, loss of benthic invertebrates, decreases in fish spawning and feeding habitat, and entrainment losses. The extent of these losses depends of season, flow and drawdown.

Mitigation

Potential mitigation measures for SOS PA include stream and riparian zone improvements, benthic structure placement, and sonic avoidance mechanisms for fish. These measures would increase usable fish habitat, increase food sources, and decrease entrainment levels. Monitoring systems to detect unforeseen impacts would be set up to aid in determining on–site and off–site mitigation locations and actions.

4.9.3 Preferred Alternative (SOS PA) for Middle Snake and Clearwater Rivers

4.9.3.1 Dworshak Reservoir

Description of alternative specific to Dworshak Reservoir

Dworshak Reservoir is operated on minimum flow up to flood control rule curves year round except during the flow augmentation period. During the flow augmentation period, the project is drafted to meet flow targets down to a minimum end of August elevation of 1520 feet. A review of the hydroregulated elevations shows that the minimum elevation hits 1445 feet in 13/50 years, and during other years fluctuates between 1480 and 1520 feet. The annual average end–of–month elevations fluctuate between 1525 and 1555 feet. Maximum end–of–month elevations fluctuate between 1540 and 1596 feet. Peak outflows hit 25 kcfs under this alternative in 35/50 years. The average outflows are near 7 to 8 kcfs.

Short and long–term impacts

This alternative results in severe impacts to all species of resident fish in Dworshak Reservoir (Table 4–8). Refill and flow requirements of lower

Snake River projects reduce Dworshak Reservoir pool elevation, increase outflows, and increase entrainment of kokanee. This alternative represents the worst alternative assessed in the SOR for Dworshak Reservoir kokanee. The kokanee entrainment indices stay below 0.4 and are the lowest observed in any of the alternatives analyzed. Presumably the high level of entrainment is due to the fact this alternative is primarily designed as a flow augmentation alternative for anadromous fish. The spawner index values are also very low for this alternative.

This alternative results in poor conditions for smallmouth bass, cutthroat trout, and bull trout. The indices for smallmouth bass under this alternative rarely exceed 0.2. This is because of increasing pool levels in June which is during the smallmouth bass spawning period. Late or repeat spawning activity and developing eggs and fry could be adversely affected by declining pool elevations in July. Continued drawdown during early August would primarily affect later developing juvenile smallmouth bass still near the nests.

Indices for bull and cutthroat trout range between 0.5 and 0.75, and average about 0.6. Under the preferred alternative, there is a long–term loss of food production which is expected to significantly impact cutthroat and bull trout.

Cumulative and unavoidable impacts

Routine annual drawdowns to meet downstream flow requirements and/or power production restrict the long–term reservoir productivity. This is mainly because macrophytes in the littoral zone cannot become established, the shoreline benthos are dewatered, and there is an increase in the distance from the edge of the upland vegetation to the reservoir water surface. Drawdown operations also render the littoral environment unsuitable for the spawning of redside shiners, a native forage fish species. This constitutes a long–term loss of food available to westslope cutthroat trout, bull trout, and smallmouth bass. Repeated reproductive failure of smallmouth bass would result in a loss to the fishery.

Mitigation

Certain measures could be taken to lessen the effect of this alternative, including:

- Revegetation of the drawdown zone along the more gently sloping banks. Aerial photography and a digitized reservoir contour map could aid in the identification of suitable candidate areas. Shoreline revegetation could partly offset the food and habitat deficits caused by pool level fluctuations. Follow–up on the effectiveness of this would be necessary..
- Small sub–impoundments near full pool elevation could provide a permanently wetted, relatively stable environment to promote the production of aquatic and semi–aquatic vegetation. This would provide food and substrate for aquatic insect production and could also provide a nursery area for forage fish. The sub–impoundments would also partly offset the food and habitat deficits caused by pool level fluctuations. Follow–up on the effectiveness of this program would be required.
- More water from the Snake River above Hell's Canyon Dam and/or lower pool levels in the lower Snake River would reduce the draw down requirements for Dworshak Reservoir, while providing for the migration needs of anadromous salmonids.
- Eliminating prescribed releases for flood control and power production would reduce the draw down requirements for Dworshak Reservoir and fulfill the need for flow augmentation for anadromous fish (made necessary because of other projects that continue to derive benefits for flood control, power production and irrigation).

4.9.3.2 Brownlee Reservoir

Description of alternative specific to Brownlee Reservoir

The preferred alternative drafts Brownlee to elevation 2069 feet during May, provides no refill and passes inflow. During July the project is drafted to 2067 feet with no refill and inflow passed, and in September the project is drafted to elevation 2059 feet. A review of the elevations shows that maximum elevations reach 2079 feet each year. Minimum pool levels go as low as 1980 feet in some years, and average end-of-month elevations usually fluctuate between 2040 and 2070 feet. Outflow under the preferred alternative averages between 10 and 30 kcfs. Peak discharge can reach as high as 70 kcfs, but usually is near 40 to 45 kcfs. Minimum flows range between 6 and 10 kcfs.

Short and long-term, cumulative, and unavoidable impacts

SOS PA is slightly worse for rainbow trout and channel catfish than the status quo, with index values ranging from 0.75 to 0.85, and 0.65 to 0.80, respectively (Table 4-9). However, this alternative results in poor conditions for smallmouth bass and other warmwater species, with large fluctuations in the index values (Table 4-9). This is most likely because fluctuations in reservoir elevation occur primarily in the spring when smallmouth bass are spawning.

Food production indices under this alternative range from 0.8 to 0.9, while other alternatives these indices usually range from 0.9 to 1.

Mitigation

Mitigation measures may include, but not be limited to, habitat enhancement in tributary streams, fish passage improvements at migration barriers, offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.9.4 Preferred Alternative (SOS PA) for Lower Snake River

4.9.4.1 Lower Granite Reservoir

Description of alternative specific to Lower Granite Reservoir

The preferred alternative uses a sliding scale flow target based on April to July runoff forecast for the Snake River at Lower Granite. For the spring (April 10 to June 20), the upper bound is 100 kcfs, while the lower bound is 85 kcfs assuming a runoff forecast between 20 and 16 MAF. For the summer (June 21 to August 31), the upper bound is 55 kcfs and the lower bound is 85 kcfs assuming the runoff forecast is between 28 and 16 MAF. Lower Granite would be operated at MOP (734 feet) with one foot flexibility between April 1 and August 31. Refill would begin by November 15th each year. When average flow at Lower Granite is less than 85 kcfs, then no spill occurs. When spill does occur, it will occur for 12 hours; maximum spill is set at 13.5 kcfs. A review of the elevations shows that the reservoir is held within one foot of MOP (734 feet) in each of the 50 years modeled. Outflow is similar to previous alternatives.

Short and long-term, cumulative, and unavoidable impacts

Growth index values at 2, 4, and 10 year occurrence intervals for smallmouth bass, white sturgeon, and northern squawfish for all SOSs can be found in Tables 4-10 – 4-12 (additional detail can be found in the Results Exhibit). Without hydroregulated input at a time scale finer than 1 month, it is impossible to make highly accurate predictions of the impacts to resident fish in Lower Granite Reservoir. The model predictions based on the end-of-month pool elevations and our qualitative assessment of the impacts should fluctuations in the pool levels occur at a time scale finer than 1 month are presented in the following tables. Table 4-10 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of no variability in within-month pool levels; i.e., the growth index values predicted by the model based on end-of-month elevations. Table 4-11 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of minimal within-month pool fluctuations (2.5 – 4.9 feet); i.e., a qualitative estimate of the impacts should the pool be fluctuated between 2.5 and 4.9 feet within any given month. Table 4-12 provides the growth index values at 2, 4, and 10 year occurrence intervals for each species under conditions of high within-month pool fluctuations (7.5 – 9.9 feet); i.e., a qualitative estimate of the impacts should the pool level be fluctuated between 7.5 and 9.9 feet within any given month.

The impacts to resident fish from the preferred alternative are very similar to SOS 9 (Figures 4–10, 4–12, and 4–14). The index value for smallmouth bass is 0.34 under no variability (< 2.5 feet), 0.30 under low variability (2.5 – 4.9 feet) and 0.08 under high variability (7.5 – 9.9 feet). The index value for white sturgeon is approximately 0.78. This may be misleading because the sturgeon model is based on deep water habitat. Fluctuations in reservoir elevations will undoubtedly have impacts, although it is not likely impacts to white sturgeon will be as severe as other species of resident fish. The index value for northern squawfish is 1 under no variability (<2.5 feet), 0.60 under low variability (2.5 – 4.9 feet) and 0.10 under high variability (7.5 – 9.9 feet).

Nitrogen supersaturation increases with increased spill. Resident fish may be more susceptible to high dissolved gas levels than anadromous fish because they are present in the reservoir longer. The effects of gas supersaturation on resident fish was not taken into consideration in developing the model for Lower Granite.

Mitigation

Mitigation measures may include, but not be limited to offsite fisheries improvements, project site selection and monitoring, and operation strategies which maintain full and stable reservoir elevations.

4.9.5 Preferred Alternative (SOS PA) for Lower Columbia River

4.9.5.1 John Day Reservoir

Description of alternative specific to John Day Reservoir

The preferred alternative calls for John Day to be operated at minimum operating pool (257 feet) year round with 3 feet flexibility. Spring and summer spill are to be 33% and 86% of the total flow, respectively. Maximum spill shall not exceed 9 kcfs. Modeled elevations do not fluctuate from elevation 257 feet. Outflow is similar to previous alternatives. Average annual outflow is between 120 to 260 kcfs. Minimum outflow varies between 7 and 10 kcfs, while maximum outflow ranges from 180 to 500 kcfs.

Short and long–term, cumulative, and unavoidable impacts

Although the index values from the model for smallmouth bass and northern squawfish are relatively high from this alternative, this alternative results in poor conditions for resident fish in John Day Reservoir (Table 4–13 – 4–15). Drawdown of John Day Pool to minimum operating pool (MOP) will reduce the amount of shallow water habitat by approximately 6000 acres (M. Smith, US Army Corps of Engineers, Portland District, personal communication). Depending on species, fish may spawn, rear, feed, or live the entire life cycle in shallow backwaters. In general, warmwater fish such as bluegill, yellow perch and bullheads tend to spend the majority of their time in backwater areas, and cool water species such as smallmouth bass and northern squawfish may use backwater areas only periodically depending on life stage. Some smallmouth bass may enter backwater areas in April for spawning, with juveniles remaining to rear during the summer months. Fish that use backwater areas are generally introduced species while native resident fish species occupy open water areas that more closely resemble pre–dam conditions such as tailrace areas of dams. Thus, the reduction in shallow backwater areas will likely impact introduced species more than native species.

Some new habitat will be created, but based on available information the amount of habitat will be reduced. It is possible that the first year of drawdown may allow dormant seeds (which are at lower elevations) to germinate and give some productivity to the new habitat.

Drawdown has the potential to desiccate eggs and larvae of early spawning fish such as yellow perch. Perch in John Day begin spawning in early April and therefore, may spawn in the drawdown zone. The initial drawdown will undoubtedly reduce or eliminate populations of these early spawning fish.

Smallmouth bass and crappie may be able to avoid this problem because they spawn later. Spawning areas at lower elevations have not been analyzed for habitat quality (i.e., cover, substrate, and flow). If the conditions are different from existing conditions, then it is likely that production will be less at the lower elevations.

In summary, a drawdown of John Day Pool to MOP will have a negative effect on resident fish populations. It is unknown at this time the fullest extent of the effects, but the loss of shallow water habitat, resident fish, and primary and secondary productivity will be substantial.

Mitigation

A year–round drawdown to MOP would allow habitat to develop at this elevation. It is estimated it would take 3–5 years for aquatic vegetation and a food base to develop in new shallow water areas. This would allow for some re–establishment of resident fish over several years.

It is unknown at this time to what extent habitat would develop or if acreage of shallow water habitat would be comparable to present conditions. From limited available data on pool topography it appears that the amount of shallow water areas (potential habitat development) at elevation 257 feet will be substantially less than current conditions due to configuration of the river channel (M. Smith, pers. communication). Current bathymetric information is necessary before this option is considered to determine the type, quality, and size of habitats that may be established.

Further studies are required to more clearly assess the impacts of an annual drawdown of John Day Pool to elevation 257 feet. This would include at least an assessment of habitat in backwaters (including vegetation mapping), substrate mapping, population estimates, spawning use, and bathymetric mapping.

4.10 NON–MODELED PROJECT ANALYSIS

RFWG modelling capability was limited to projects and species discussed in the foregoing part of this chapter. Fish in other areas are also potentially affected by the SOSs being evaluated, but the capability to predict these impacts was very limited. These other areas of concern include the following additional reservoirs: Kinbasket Lake, Arrow Lakes, and Kootenay Lake in Canada, B.C.; Flathead Lake, Montana; the Clark Fork River below Cabinet Gorge Dam and the Snake River below Hells Canyon Dam, both in Idaho; the Pend Oreille River below Box Canyon Dam, Lake Rufus Woods and the mainstem Columbia River downstream of Chief Joseph Dam, the mid–Columbia projects (Wells, Rocky Reach, Rock Island, Wanapum, and Priest Rapids reservoirs), and the Hanford Reach of the Columbia River, all mostly in Washington; and the Columbia River downstream of Bonneville Dam, Washington and Oregon.

Our intent was to provide a qualitative analysis of potential impacts from each of the operating strategies. We originally hypothesized that some projects would be similar enough in both their hydrology and biology so that perhaps one or more of the existing models could be used in the analysis. After investigating each of the above projects, we discovered that even a qualitative analysis is impossible at nearly all projects because (1) there are no hydroregulated output for some of the locations, including the Clark Fork River, and the Hells Canyon Reach of the Snake River, (2) where hydroregulated flows and elevations were available there was very little difference between each alternative (e.g., elevations at Kerr Dam, Mica Dam, and Chief Joseph Dam are identical year after year and alternative after alternative), (3) the temporal scale of the hydroregulated output was not sufficient and hourly hydrology was necessary to assess impacts; this was especially true in the Hanford Reach of the Columbia River, and (4) very little data exist for resident fish at many of these projects, especially those in Canada (Kinbasket, Arrow, and Kootenay lakes), the mid–Columbia projects (Wells, Rocky Reach, Rock Island, Wanapum, and Priest Rapids dams), and below Bonneville Dam. Our knowledge of these projects as they would be affected by the proposed operational strategies is limited. Therefore, we have not attempted to discuss the potential impacts to each project for each alternative, but instead provide a general overview of our conclusions to date (Table 4–16).

4.10.1 Canadian Projects (Kinbasket, Arrow, and Kootenay Lakes)

The primary constraint of assessing the potential impacts of the SOR alternatives on the Canadian projects is the lack of quantitative data on abundance and distribution of resident fish species and correlation of physical impact to fish populations and the fisheries productive potential of reservoir and river habitat. The following preliminary list represents known and suspected impacts to Kinbasket Reservoir, Upper and Lower Arrow Lakes, Kootenay Lake and Duncan Reservoir as a result of present reservoir operations:

Upstream:

- entrainment of fish and turbine mortalities because of high flows
- loss of littoral habitat because of yearly drawdown
- loss of planktonic production during high discharge periods
- decreased angling effort when reservoir is drawn down and fewer useable boat access points
- flooding of spring spawning areas in tributaries because of filling each year
- debris associated with reservoir causes boating hazards at full pool
- debris associated with reservoir can block access to spawning streams as the reservoir drops
- reservoir levels seasonally block access to spawning areas

Downstream:

- high total gas pressure (TGP) supersaturation levels below dam during spillway and "speed–no–load" operations
- dam maintenance/operation can result in extensive flow fluctuations impacting spawning and rearing habitat
- fluctuating river levels/flows which disrupt biological cues, e.g., movement, maturity, spawning periods, etc.

To alleviate the above impacts, reservoir–specific critical reservoir levels and seasonal discharge regimes related to reservoir fish populations, littoral habitat, zooplankton and benthic invertebrate production, water retention times, and downstream riverine fish populations and habitat should be determined.

Review of the thirteen System Operating Strategies indicates that the alternatives are similar to existing operations based upon present AOP/DOP. But existing operation of hydroelectric and storage facilities in the Columbia Basin in Canada have not considered fisheries impacts, either upstream or downstream and thus although most of the alternatives may not appear to affect fisheries resources beyond present conditions, they certainly will not alleviate fisheries impacts either.

Specific comments related to the SOS alternatives include:

Kootenay Lake (Corra Linn Dam)

Existing operations (based upon B.C. Hydro data from 1974 to 1988): Generally, flows in spring (May, June and July period) are similar to "natural" high freshet flows, with decreasing flows over August/September and increasing with high flows in December and January; flows decrease over February through April period. With regard to reservoir elevation levels, minimum level is usually reached in March or April and maximum levels is reached in June (but this is somewhat variable with maximum levels sometimes reached as late as September). The reservoir elevation range is small, usually less than three meters each year.

The results of the modelling of the SOS alternatives for Kootenay Lake (Corra Linn Dam) indicate some variation from existing operations:

SOS 1a = 1b; similar to SOS 5b = SOS 6b/d:

Flows are similar to existing operations, except that minimum flows occur more variable within the year. Reservoir elevation range greater than with existing operations.

SOS 2c = 2d:

Greater variation in when minimum flows occur. Reservoir level maintained within smaller range than SOS 1/5/6.

SOS 4c:

Minimum flows typically occur in September. Reservoir levels maintained similarly to SOS 1/5/6.

SOS 9a/9b/9c/PA:

Similar to SOS 4c.

Kinbasket Lake (Mica Dam)

Existing operations (based upon B.C. Hydro data from 1976 to 1992): Generally, outflows are low over May/June period, increase until August/September, decrease over October/November and then increase to February and then fluctuate until May/June. Range of outflows from Mica Dam is large. With regard to reservoir elevation levels, minimum level is usually reached in March or April and maximum level is reached in July/August/September. The drawdown range in large, with a range of 51 to 109 feet and monthly drawdowns over winter (January/February) can be as high as 26 feet per month. Normal operating ranges for the reservoir are from 2320 to 2475 feet, although data from 1976 to present indicates that the reservoir has not yet been drafted to 2320 feet.

The results of the modelling of the SOS alternatives for Kinbasket Lake (Mica Dam) indicate some variation from existing operations:

SOS 1a = 1b:

Flows are similar to existing operations except that high outflows occur generally in July/August; minimum flow for each year is maintained at 10 kcfs most years. Maximum reservoir elevation is reached almost every year, usually in August/September; range of drawdown from 61.6 to 74.5 feet per year. Monthly reduction in reservoir elevations consistent without serious drawdowns as seen with existing operations.

SOS 2c = 5d/6:

Similar flow and reservoir trends as SOS 1. Greater variation in range of drawdown, from 61.6 to 87.2 feet.

SOS 4 = 2d/5c/9/PA:

Very similar to SOS 1, except minor differences.

Upper and Lower Arrow Lakes (Keenleyside Dam)

Existing operations (based upon B.C. Hydro data from 1968 to 1992): Generally, outflows are low at various times of the year (usually in February, and March–June period), and are high in December/January, June/July (sometimes) and August/September. Range of outflows from Keenleyside Dam is large. With regard to reservoir elevation levels, minimum level is usually reached in February/March/April period and maximum levels reached in June/July/August period. The reservoir elevation range is large, with a range of 11 to 67 feet but it is typical for the reservoir to fluctuate from month to month both up and down. Normal operating ranges for the reservoir are from 1378 to 1444 feet.

The results of the modelling of the SOS alternatives for Upper and Lower Arrow Lakes (Keenleyside Dam) indicate some variation from existing operations:

SOS 1A = 1b:

Overall, the outflow trend is similar to existing operations. Reservoir elevations reach minimum levels of 1377.9 feet 27 of the 50 years of modelling and reach full level (1444 feet) almost every year; levels are usually stable over July/August/September period. Greatest monthly drop in elevation (25 feet) usually occurs in December/January. Drawdown from 39 to 66 feet per year.

SOS 2c = 6b/6d/5b:

Similar flow and reservoir trends as SOS 1 but greater variation in flow trend. Greater variation in range of drawdown from 34 to 66 feet. Monthly drop in elevation increased to 31 feet.

SOS 2d = 9c/PA:

Similar to SOS 2b with minor differences.

SOS 9a:

SOS 4c similar to 5c; difference in flows.

Operational considerations for Keenleyside Dam are to provide steady or increasing flows over the period from early or mid–March to the end of June to prevent impacting rainbow trout spawning/incubation in the Columbia River at the Norns Fans. It would be beneficial to "shape" the release of this water such that steady or increasing flows during rainbow trout spawning can be achieved at about the time that water from Arrow Lakes is required downstream for anadromous salmon in the U.S.

Duncan Reservoir/Dam

Existing operations (based upon B.C. Hydro data from 1968 to 1992): Maximum outflows usually occur in December/January/February period, decrease in March through to June; outflows fluctuate from June to December. Duncan has wide range of outflows from 100 to 10000 cfs. Reservoir reaches maximum level usually in June/July/August and minimum level in February/March/April; annual drawdown range is from 61 to 98 feet and monthly elevations drops from 25 to 35 feet are common in the November through February period. Normal operating range of 1794 to 1892 feet.

The results of the modelling of the SOS alternatives for Duncan Lake/Dam indicate some variation from existing operations:

SOS 1A = 1B:

Similar flow trends as existing operations but with slight shift; outflow range greater. Monthly average minimum flow of 100 cfs occurs almost every year of 50 year modelling results and can precede or follow a month of high flow. Reservoir level trend consistent over modelling period: maximum level (1892 feet) reached in July/August/September with stable levels over two to three month period. Range of annual drawdown from 51 to 98 feet; monthly drops similar to existing operations.

SOS 2c = 2d:

Similar to 1A; some differences.

SOS 4c:

Similar flow trends as other SOS's. Range of drawdown from 77 to 98 feet and monthly drops in elevation from 20 to 35 feet.

SOS 5/6:

Similar to 2c. Drawdown range from 29 to 98 feet and monthly drops in elevation from 20 to 35 feet.

SOS 9/PA:

Drawdown range from 26 to 98 feet.

Duncan Dam is drafted heavily now and in the modelling results; details on specific fisheries issues beyond those previously indicated are not available to provide operational recommendations. The potential variation in outflows from Duncan (because of possible minimum and maximum flows) causes concerns with regard to habitat downstream and may be an issue which arises when the SOS's are revisited.

General

With regard to the modelling results, it seems improbable that any of these reservoirs, except perhaps Kootenay Lake (because of the narrow range of reservoir elevation), will be operated such that the minimum and maximum operating levels will be reached as often as the modelling indicates. As well, because the input to the model are end–of–month elevations, significant operational variation may be occurring during the month which would not be represented by end–of–month elevations (same point made of page 59 for short term impacts).

In terms of providing qualitative comments on the 21 system operating strategies presented under the SOR process, considerable fisheries and fish habitat data should be used to determine the best overall strategy for the entire Canadian Columbia River system, as well as the Peace River system. To clarify, 45% of B.C. Hydro's energy is produced in the Columbia and 38% is produced in the Peace; production and outflows in the Peace system are adjusted to balance power production changes to the Columbia system as a result of B.C. Hydro/BPA negotiations. In addition, because of the flexibility that B.C. Hydro has within the system to store or discharge water and still provide the U.S. water requirements under the Columbia River Treaty, these modelling results may not necessarily represent the operations which will occur. Without understanding the significance of present operational regimes on the reservoirs and downstream areas, it is difficult to provide recommendations or to point out specific operations of the SOS's which are beneficial or detrimental, other than maintaining stable reservoirs and providing natural outflows.

4.10.2 Flathead Lake

The fundamental problem with the regulation of lake levels in Flathead Lake is that Hungry Horse and Kerr dams are operated independently when, in fact, they are interrelated economically and ecologically (Stanford and Hauer 1992). It is not apparent how the proposed operational strategies at Hungry Horse Dam affect Flathead Lake (see the Results Exhibit for flows and elevations at Hungry Horse Dam). It appears that over the 50 year period of the hydroregulated simulation, average flows at Kerr Dam are nearly the same for all SOSs and end–of–month elevations at Kerr Dam are identical for all SOSs. Based on flows at Columbia Falls (approximately 25 miles upstream of Flathead Lake) and flows and elevations at Kerr Dam, similar impacts to resident fish are anticipated to result from each of the strategies, although this is speculative. It is not obvious these impacts will be different than under current operations of this system. However, with the exception of stable reservoir elevations at Hungry Horse Dam and a return to a more natural outflow, probably no other operations will alleviate the impacts to kokanee salmon that currently result from lake level fluctuations under the existing operations. Shoreline spawners in Flathead Lake are negatively impacted by lake level fluctuations caused by Kerr Dam, and upper Flathead River spawners are negatively impacted by peaking operations at Hungry Horse Dam.

4.10.3 Clark Fork River (below Cabinet Gorge Dam)

No determination of impacts is possible because there is no information on hydroregulated flows or elevations available for this location. In addition, estimates of abundance and distribution of resident fish populations in this location are poorly documented. There is only a limited amount of information available on the timing of spawning or food habits of the resident fish species. Peaking power operations at Cabinet Gorge that result in extreme daily fluctuations in flow (flow range: 425 cubic meters/sec. to 85 cubic meters/sec.) are currently the primary limiting factor for resident fish species within the Clark Fork River (Maiolie 1991). In general, peaking flows can have numerous deleterious effects on resident fish including unpredictable watering/dewatering of spawning, feeding, and rearing habitat, temperature fluctuations, entrainment, and gas supersaturation.

Table 4–16. A summary of the alternative comparisons for the non–modeled projects.

Project Name (DAM)	Key Resident Fish Species	Hydroregulated Data	Hydroreg Comparison	Other Hydrology	Which Model
Kinbasket Reservoir (Mica Dam)	Mountain whitefish, bull trout, rainbow trout, burbot, kokanee	Flows and elevations (elevs) at Mica Dam	See Section 4.9.1	Not readily available	None
Arrow Lakes (Arrow Dam, also called Keenleyside Dam)	Rainbow trout,bull trout, kokanee, mountain whitefish	Flows and elevations at Arrow Dam	See Section 4.9.1	Not readily available	None
Kootenay Lake (Corra Linn Dam)	Rainbow trout, bull trout, kokanee, mountain whitefish, burbot	Flows and elevations at Corra Linn Dam	See Section 4.9.1	Not readily available	None
Flathead Lake (Kerr Dam)	Kokanee, yellow perch, mountain whitefish, lake trout, largemouth bass, bull trout, cutthroat	Flows at Columbia Falls on the Flathead River (20–25 mi upstream of lake	SOS 1, 2, 5, and 6 similar to SOS 4, 9, and PA slightly different	Yes, in Flathead River system	None
		Flows and elevations at Kerr Dam	Elevs: SOS 1, 2c, 5b, 6 same Flows: SOS 1, 2, 5, 6 approx. same; SOS 4, 9, PA same with slight differences		
Clark Fork River (Below Cabinet Gorge Dam)	Bull trout, brown trout, cutthroat trout, rainbow trout, kokanee	None	Not applicable	Yes	None

Table 4–16. A summary of the alternative comparisons for the non–modeled projects. – CONT

Project Name (DAM)	Key Resident Fish Species	Hydroregulated Data	Hydroreg Comparison	Other Hydrology	Which Model
Pend Oreille River (Below Albeni Falls Dam)	Yellow perch, largemouth bass, tench, brown trout,n. squawfish	None	Not applicable	Yes	None
Lake Rufus Woods/ (Columbia River below Chief Joseph Dam)	N. squawfish, peamouth, suckers, kokanee (from Grand Coulee)	Flows and elevations at Chief Joseph Dam	Elevs: All same Flows: SOS 1, 2, 5, 6, 9 approx. same; SOS4	Yes	None
Mid–Columbia River (Wells Dam Rocky Reach Rock Island Dam Wanapum Dam Priest Rapids Dam)	Walleye, white sturgeon, mountain whitefish, suckers, stickle backs, n. squawfish, channel catfish	 Flows Flows Flows Flows Flows	Flows: all SOSs very similar for all projects, only slight differences in SOS 4 and 9	Yes	None
Hanford Reach (Below Priest Rapids Dam)	White sturgeon, smallmouth bass, mountain whitefish, sandrollers (state sensitive), suckers, sculpins	Flows at Priest Rapids Dam	Flows: all SOSs very similar, only slight differences in SOS 4, 9, and PA	No other gaging besides at Priest Rapids Dam	None
Columbia River below (Below Bonneville Dam)	White sturgeon walleye, smallmouth bass, largemouth bass	Flows at Bonneville Dam	Flows: all SOSs very similar, only slight differences in SOS 4, 9, and PA	Yes	None
Hells Canyon Reach of the Snake River (Below Hells Canyon Dam)	White sturgeon, smallmouth bass, rainbow trout channel catfish, mountain whitefish	None	Not applicable	Yes	None

4.10.4 Pend Oreille River (below Albeni falls Dam)

Information on hydroregulated elevations is not available for this location. Without hydroregulated flows and elevations, a determination of impacts is very speculative. Under existing operations at Box Canyon Dam, resident fish populations in the Pend Oreille River are adversely affected by fluctuating surface elevations and water temperatures that control growth and the timing of spawning. Impacts to cutthroat and bull trout spawning, and largemouth bass recruitment are of particular concern. Non–game species likely to be negatively impacted are northern squawfish, tench, and largescale sucker.

4.10.5 Lake Rufus Woods and Columbia River below Chief Joseph Dam

Hydroregulated elevations at Chief Joseph Dam are identical for all SOSs (953 ft) suggesting that the impacts resulting from each SOS are likely to be similar. Lake Rufus Woods acts as a run–of–river reservoir. SOSs resulting in increased flows will cause loss of nutrients and increased entrainment of kokanee, walleye and other fish, as well as plankton.

4.10.6 Mid–Columbia River

The resident fish species within the five reservoirs formed by the mid–Columbia run–of–river facilities (Wells, Rocky Reach, Rock Island, Wanapum, and Priest Rapids reservoirs) have not been well studied. Based on counts at the fishways, the resident fish community appears to be dominated by sticklebacks, minnows, and suckers (Mullan et al. 1986). The principal sport fish species throughout the mid–Columbia River are walleye, northern squawfish, and smallmouth bass (Bennett 1991). These reservoirs currently function primarily as coldwater tailwaters to the Grand Coulee Dam storage reservoir (Lake Roosevelt). Hydroregulated flows are nearly the same for all SOSs at all the mid–Columbia projects. No hydroregulated elevations are available for any of these run–of–river projects. Water temperature and high water velocities (low water retention time) are most likely the primary factors limiting the success of resident fish species throughout the mid–Columbia reservoirs. Reduced spring and summer water temperatures limit the spawning opportunities for non–native warmwater species such as sunfish, bass, and catfish that can spawn only in atypical warm backwaters. High water velocities probably lead to entrainment of resident fish species resulting in decreased fish populations. Bennett (1991) states the primary factor that limits squawfish abundance is probably shallow water rearing habitat for young–of–year (<50 mm).

4.10.7 Hanford Reach

The Hanford Reach remains the last unimpounded reach of the Columbia River in the United States. The resident fish species which exist in this area are typical of resident fish species found in a riverine type environment. Although the Hanford Reach is unimpounded, the flows and fluctuating water levels are highly influenced by operation of Priest Rapids Dam. Fluctuations in water level may be over 10 feet in a single day cycle, depending on inflow to Priest Rapids Reservoir and power demand at Priest Rapids Dam. These extreme daily fluctuations significantly impact the spawning and incubation, rearing, and overwinter survival of nearly all resident fish which inhabit the Reach. Smallmouth bass migrate from as far away as the Yakima River and spawn in the backwater sloughs of the Hanford Reach in mid–March. Extreme water surface fluctuations potentially either displace adults from the spawning nests, and/or impact newly emergent fry which are very dependent upon stable and warm water in which to feed. Species such as sturgeon and mountain whitefish are dependent upon adequate velocities in order to successfully spawn. Species of special concern, including the sandroller, mountain sucker, paiute sculpin, and reticulate sculpin are all dependent on stable river flows. Any operations that resemble natural flows will tend to benefit resident fish. We are not able to document specific impacts from the operating strategies proposed because most of the impacts occur in hourly increments. Water surface elevations within the Hanford Reach are not available, and hydroregulated flows are only available at monthly time steps. This makes the assessment of impacts speculative.

4.10.8 Columbia River below Bonneville Dam

The primary constraint in assessing impacts below Bonneville Dam is the lack of published studies documenting the abundance and distribution of resident fish and the lack of hydroregulated surface water elevations downstream of Bonneville Dam. Ninety percent of the sport fishing effort in the lower Columbia River is directed toward anadromous species. Resident fish species have not received much attention in this stretch of the river. The principal species of concern is the white sturgeon. The impacts to white sturgeon are being evaluated by the Anadromous Fish Work Group.

4.10.9 Snake River below Hells Canyon Dam

In the Snake River below Hells Canyon Dam, as in the Columbia River below Bonneville Dam, the white sturgeon is the principal resident fish species of concern. Information on hydroregulated flows and elevations is not available at Hells Canyon Dam. Mortality of resident fish species resulting from lethal levels of gas supersaturation has been reported below Hells Canyon Dam following periods of long spills (Lukens 1986). Flow fluctuations have the potential to impact resident fish downstream. However, lacking hydroregulated flows at Hells Canyon Dam limits our ability to assess specific impacts to resident fish from these operation strategies.

CHAPTER 5

COMPARISON OF ALTERNATIVES

A preliminary comparison of the system operation strategies (SOSs) for each of the modeled resident fish species is provided for Lake Pend Oreille (Figure 5–1), Hungry Horse Reservoir (Figure 5–2), Lake Koocanusa (Figure 5–3), Grand Coulee Reservoir (Figure 5–4), Dworshak Reservoir (Figure 5–5), Brownlee Reservoir (Figure 5–6), Lower Granite Reservoir (Figure 5–7), and John Day Reservoir (Figure 5–8)

These figures depict the 'goodness' of each alternative for each species and are useful only for making relative comparisons between the alternatives modeled. A ranking of 'best' does not imply that this is the best way to operate a particular project for resident fish, but rather, that this is the best alternative reviewed by the RFWG for the particular project and the particular species of fish. There may be other alternatives which were not available to be evaluated that are better than the alternatives presented.

At many projects, the RFWG was not able to identify which alternative represented current operations. Therefore, it was difficult or impossible to determine how each alternative compared with existing operations.

The RFWG purposely used different symbols in the comparison figures to emphasize that comparisons between reservoirs are not possible because the different biology and hydrology within each project necessitated that each project be modeled differently.

Comparisons across models would be erroneous, and the fact that an alternative ranked best at two projects does not imply that the alternative is a preferred alternative for both projects.

In summary:

- Based on this analysis, SOS 4 appears to be the best strategy analyzed for resident fish.
- SOS 5 and 6 (drawdown alternatives) provide some of the worst conditions analyzed for resident fish (species analyzed) at most projects, with the exception of Dworshak Reservoir.
- SOS 9 appears to be a fairly poor strategy for most species at most projects.
- SOS 2 simulates "baseline" operations and is relatively poor for resident fish.
- For specific project results, see the chapter 5 figures.

Lake Pend Oreille

System Operating Strategy	Kokanee	Bull Trout/ Rainbow Trout	Cutthroat Trout	Warm Water Species
SOS 1A	Worse	Worse	Worse	Worse
SOS 1B	Worse	Worse	Worse	Worse
SOS 2C	Worse	Worse	Worse	Worse
SOS 2D	Worse	Worse	Worse	Worse
SOS 4C	Best	Best	Best	Best
SOS 5B	Worse	Worse	Worse	Worse
SOS 5C	Worst	Worst	Worst	Worst
SOS 6B	Worse	Worse	Worse	Worse
SOS 6D	Worse	Worse	Worse	Worse
SOS 9A	Worse	Worse	Worse	Worse
SOS 9B	Worse	Worse	Worse	Worse
SOS 9C	Worse	Worse	Worse	Worse
SOS PA	Worse	Worse	Worse	Worse

▲ - Best - Better - Middle - Worse △ - Worst

- The modeling of the effects of the SOS's is very simplified, and many important factors in the survival, reproduction, and growth of resident fish species in each project have not been accounted for or are unknown. Nevertheless, the models are intended to compare the effects of the SOS's, and should be useful in this regard.
- This evaluation examines the relative biological influences of each of the system operation strategies. SOSs coded "best" do not represent optimum biological conditions for the project, but rather, this is the best alternative reviewed by the RFWG for the particular project and particular species of fish. There may be other alternatives which were not available to be evaluated that are better than the alternatives reported here.
- All options under SOS 4 result in substantial improvements for all species in Lake Pend Oreille. Changes could increase the harvest of sport fish 2 to 3 times above existing conditions.
- All other SOSs continue to markedly impact all fish species in Lake Pend Oreille. Populations of these species will remain at a low level, kokanee harvest will remain at 10 to 20% of historic levels, and a warm water fishery will remain non-existent.

Figure 5-1. Relative comparisons between system operating strategies at Lake Pend Oreille.

Hungry Horse Reservoir

System Operating Strategy	Reservoir Ecological Production
SOS 1A	○
SOS 1B	○
SOS 2C	○
SOS 2D	○
SOS 4C	●
SOS 5B	○
SOS 5C	○
SOS 6B	○
SOS 6D	○
SOS 9A	●
SOS 9B	○
SOS 9C	○
SOS PA	

● - Best ◉ - Better ◐ - Middle ⊙ - Worse ○ - Worst

- The modeling of the effects of the SOS's is very simplified, and many important factors in the survival, reproduction, and growth of resident fish species in each project have not been accounted for or are unknown. Nevertheless, the models are intended to compare the effects of the SOS's, and should be useful in this regard.
- This evaluation examines the relative biological influences of each of the system operation strategies. SOSs coded "best" do not represent optimum biological conditions for the project, but rather, this is the best alternative reviewed by the RFWG for the particular project and particular species of fish. There may be other alternatives which were not available to be evaluated that are better than the alternatives reported here.
- Reservoir scores incorporate food availability and temperature conditions for all important fish species (including the target species westslope cutthroat trout).
- Integrated rule curves (SOS 4) were designed to balance biological conditions in the river and reservoir.
- SOSs coded "worst" were nearly identical. If one of these SOSs is selected, resident fish problems associated with present conditions would be expected to continue.

Figure 5–2. Relative comparisons between system operating strategies (SOS) at Hungry Horse Reservoir.

Lake Koocanusa

System Operating Strategy	Reservoir Ecological Production	White Sturgeon
SOS 1A	Worst	Worst
SOS 1B	Worst	Worst
SOS 2C	Worse	Worst
SOS 2D	Worse	Worst
SOS 4C	Better	Best
SOS 5B	Worst	Worst
SOS 5C	Worst	Worst
SOS 6B	Worst	Worst
SOS 6D	Worst	Worst
SOS 9A	Best	Best
SOS 9B	Worst	Worst
SOS 9C	Worst	Worst
SOS PA		

- Best - Better - Middle - Worse - Worst

- The modeling of the effects of the SOS's is very simplified, and many important factors in the survival, reproduction, and growth of resident fish species in each project have not been accounted for or are unknown. Nevertheless, the models are intended to compare the effects of the SOS's, and should be useful in this regard.
- This evaluation examines the relative biological influences of each of the system operation strategies. SOSs coded "best" do not represent optimum biological conditions for the project, but rather, this is the best alternative reviewed by the RFWG for the particular project and particular species of fish. There may be other alternatives which were not available to be evaluated that are better than the alternatives reported here.
- Reservoir scores incorporate food availability and temperature conditions for all important fish species (including the target species kokanee salmon).
- Integrated rule curves (SOS 4) incorporate flow augmentation to enhance white sturgeon spawning.
- Flows to enhance white sturgeon were included in SOS 2b but were not reflected in the model results, hence the poor rating.
- SOSs coded "worst" were nearly identical. If one of these SOSs is selected, the fishery would decline from present conditions.

Figure 5–3. Relative comparisons between system operating strategies (SOS) at Lake Koocanusa.

Lake Roosevelt

System Operating Strategy	Percent of Kokanee Left	Kokanee Growth
SOS 1A	Worse	Middle
SOS 1B	Worse	Better
SOS 2C	Middle	Better
SOS 2D	Better	Middle
SOS 4C	Better	Middle
SOS 5B	Middle	Best
SOS 5C	Middle	Best
SOS 6B	Middle	Best
SOS 6D	Middle	Best
SOS 9A	Worst	Worst
SOS 9B	Worse	Worse
SOS 9C	Worse	Worse
SOS PA	Best	Worse

◆ - Best ◆ - Better ◆ - Middle ◈ - Worse ◇ - Worst

- The Model of the effects of the SOS's is very simplified, and many important factors in the survival, reproduction, and growth of resident fish species in each project have not been accounted for or are unknown. Nevertheless, the models are intended to compare the effects of the SOS's, and should be useful in this regard.
- This evaluation examines the relative biological influences of each of the system operation strategies. SOSs coded "best" do not represent optimum biological conditions for the project, but rather, this is the best alternative reviewed by the RFWG for the particular project and particular species of fish. There may be other alternatives which were not available to be evaluated that are better than the alternatives reported here.
- Under SOS 1, extreme changes in elevation and outflow lead to high entrainment of kokanee salmon.
- Under SOS 2, there were many months when the water retention time was less than 30 days which increased entrainment and decreased food production.
- Under SOS 5 and 6, there are many months where water retention times are less than 30 days which impacts food production and increases entrainment.

Figure 5–4. Relative comparisons between system operating strategies at Lake Roosevelt.

Dworshak Reservoir

System Operating Strategy	Kokanee	Smallmouth Bass	Cutthroat Trout	Bull Trout
SOS 1A	Better	Worse	Better	Middle
SOS 1B	Best	Worse	Better	Middle
SOS 2C	Worse	Worse	Middle	Middle
SOS 2D	Worse	Worse	Worse	Worse
SOS 4C	Better	Best	Best	Best
SOS 5B	Middle	Middle	Better	Middle
SOS 5C	Better	Middle	Middle	Better
SOS 6B	Middle	Middle	Middle	Better
SOS 6D	Middle	Middle	Middle	Better
SOS 9A	Worse	Worse	Worse	Worse
SOS 9B	Worse	Worst	Worst	Worst
SOS 9C	Worse	Worse	Middle	Middle
SOS PA	Worst	Worse	Worse	Worse

● - Best ◉ - Better ◒ - Middle ⊙ - Worse ○ - Worst

- The modeling of the effects of the SOS's is very simplified, and many important factors in the survival, reproduction, and growth of resident fish species in each project have not been accounted for or are unknown. Nevertheless, the models are intended to compare the effects of the SOS's, and should be useful in this regard.
- This evaluation examines the relative biological influences of each of the system operation strategies. SOSs coded "best" do not represent optimum biological conditions for the project, but rather, this is the best alternative reviewed by the RFWG for the particular project and particular species of fish. There may be other alternatives which were not available to be evaluated that are better than the alternatives reported here.
- The Clearwater River was not included in the evaluation due to limitations of simulated hydroregulation.
- Among those strategies evaluated, SOS 4c is the best overall for the fish species evaluated.
- Strategies emphasizing flow augmentation (SOS's 2 and 9) are the worst for resident fish in Dworshak Reservoir.

Figure 5–5. Relative comparisons between system operating strategies at Dworshak Reservoir.

Brownlee Reservoir

System Operating Strategy	Rainbow Trout	Channel Catfish	Smallmouth Bass	Warm Water Species
SOS 1A	Middle	Middle	Better	Middle
SOS 1B	Middle	Middle	Better	Middle
SOS 2C	Middle	Middle	Middle	Better
SOS 2D	Middle	Middle	Middle	Better
SOS 4C	Best	Best	Best	Best
SOS 5B	Middle	Middle	Middle	Middle
SOS 5C	Middle	Middle	Middle	Middle
SOS 6B	Middle	Better	Middle	Better
SOS 6D	Middle	Better	Better	Better
SOS 9A	Worse	Worse	Worse	Worst
SOS 9B	Worst	Worst	Worst	Worst
SOS 9C	Worst	Worst	Worst	Worst
SOS PA	Worse	Middle	Middle	Worse

■ - Best ▣ - Better ⬓ - Middle ◘ - Worse □ - Worst

- The modeling of the effects of the SOS's is very simplified, and many important factors in the survival, reproduction, and growth of resident fish species in each project have not been accounted for or are unknown. Nevertheless, the models are intended to compare the effects of the SOS's, and should be useful in this regard.
- This evaluation examines the relative biological influences of each of the system operation strategies. SOSs coded "best" do not represent optimum biological conditions for the project, but rather, this is the best alternative reviewed by the RFWG for the particular project and particular species of fish. There may be other alternatives which were not available to be evaluated that are better than the alternatives reported here.

Figure 5–6. Relative comparisons between system operating strategies at Brownlee Reservoir.

Lower Granite Reservoir

System Operating Strategy	Smallmouth Bass	White Sturgeon[1]	Northern Squawfish
SOS 1A	Worse	Middle	Worse
SOS 1B	Worse	Middle	Best
SOS 2C	Middle	Middle	Middle
SOS 2D	Middle	Middle	Middle
SOS 4C	Middle	Middle	Middle
SOS 5B	Worst	Worse	Worst
SOS 5C	Best	Worst	Best
SOS 6B	Worse	Middle	Worst
SOS 6D	Worse	Middle	Worst
SOS 9A	Worse	Middle	Worst
SOS 9B	Middle	Middle	Middle
SOS 9C	Worst	Middle	Worst
SOS PA	Better	Middle	Best

▼ - Best ▼ - Better ▼ - Middle ▽ - Worse ▽ - Worst

[1] Sturgeon model results are based on a preference for deepwater habitat only

- The modeling of the effects of the SOS's is very simplified, and many important factors in the survival, reproduction, and growth of resident fish species in each project have not been accounted for or are unknown. Nevertheless, the models are intended to compare the effects of the SOS's, and should be useful in this regard.
- This evaluation examines the relative biological influences of each of the system operation strategies. SOSs coded "best" do not represent optimum biological conditions for the project, but rather, this is the best alternative reviewed by the RFWG for the particular project and particular species of fish. There may be other alternatives which were not available to be evaluated that are better than the alternatives reported here.
- Monthly hydroregulator output is insufficient to fully assess impacts to resident fish in Lower Granite Reservoir since fluctuations in reservoir elevation occurr at a shorter time scale than one month. Short–term fluctuations would exacerbate impacts reported here.
- Hydroregulator output for SOS 1a is incorrect and inconsistent with the alternative description. However, it was modelled as provided by the hydroregulators. Therefore, the analysis of impacts to resident fish reflects this mistake. In reality, SOS 1a and SOS 1b would be expected to be similar.
- Because of the dramatic change in reservoir elevations, the drawdown alternatives (SOS 5 and 6) appear to be bad for resident fish. Since all the indicator species reported here are adapted to flowing water, the impacts may not be as severe if the pool is held constant in a drawdown condition, i.e., SOS 5c. Resident fish will do better under year–round drawdown operations than under seasonal drawdowns. Further, the decreased cross–sectional area of the reservoir may provide for better feeding opportunities for smallmouth bass and northern squawfish and increase the available spawning habitat for white sturgeon. For these reasons, smallmouth bass, northern squawfish, and white sturgeon may do better under drawdown conditions than predicted by the models. Resident fish will do better under year–round drawdown operations than under seasonal drawdowns.
- It is possible that large–scale lowering and raising of Lower Granite Reservoir (as in the drawdown alternatives) may entrain fish through the dam into Little Goose Reservoir. Potential entrainment of this sort is not accounted for in the models.

Figure 5–7. Relative comparisons between system operating strategies at Lower Granite Reservoir.

John Day Reservoir

System Operating Strategy	Smallmouth Bass	Walleye	Northern Squawfish
SOS 1A	Middle	Better	Middle
SOS 1B	Middle	Middle	Middle
SOS 2C	Best	Middle	Middle
SOS 2D	Best	Middle	Middle
SOS 4C	Best	Middle	Middle
SOS 5B	Worst	Worst	Worst
SOS 5C	Worst	Worst	Worst
SOS 6B	Worst	Worst	Worst
SOS 6D	Worst	Worst	Worst
SOS 9A	Worst	Worst	Worst
SOS 9B	Middle	Middle	Middle
SOS 9C	Worst	Worst	Worst
SOS PA	Better	Best	Best

- Best - Better - Middle - Worse - Worst

- The modeling of the effects of the SOS's is very simplified, and many important factors in the survival, reproduction, and growth of resident fish species in each project have not been accounted for or are unknown. Nevertheless, the models are intended to compare the effects of the SOS's, and should be useful in this regard.
- This evaluation examines the relative biological influences of each of the system operation strategies. SOSs coded "best" do not represent optimum biological conditions for the project, but rather, this is the best alternative reviewed by the RFWG for the particular project and particular species of fish. There may be other alternatives which were not available to be evaluated that are better than the alternatives reported here.
- Monthly hydroregulator output is insufficient to fully assess impacts to resident fish in John Day Reservoir since fluctuations in reservoir elevation occurr at a shorter time scale than one month. Short–term fluctuations would exacerbate impacts reported here.

Figure 5–8. Relative comparisons between system operating strategies at John Day Reservoir.

CHAPTER 6

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CHAPTER 7

RESIDENT FISH GLOSSARY AND ACRONYMS

Acre–foot: The volume of water that will cover one acre to a depth of one foot.

Adfluvial: Fish that ascend from freshwater lakes to reproduce in streams and rivers.

Anadromous fish: Fish, such as salmon or steelhead trout, that hatch from egg in freshwater, migrate to and mature in the ocean, and return to fresh water as adults to spawn.

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 historical conditions prior to the Endangered Species Act (especially in late summer) by releasing water from storage reservoirs.

Benthic production: Pertaining to the production of aquatic organisms, such as insects and crustaceans, from the bottom of a lake or river, or the littoral zone of a lake.

Benthos: Organisms living on the bottom of a lake, river, or ocean.

Biological rule curve: A reservoir operating rule curve that provides benefit to resident fish by recognizing relationships between water elevation and food production requirements, and other life history needs of a particular species.

Biomass: The amount of living matter in a given habitat, expressed either as the weight of organisms per unit area or as the volume of organisms per unit volume of habitat; in an aquatic environment, the total weight of fish, or of organisms that serve as fish food.

BoR: Bureau of Reclamation

BPA: Bonneville Power Administration

Calibration (model): Adjustment of model processes to reflect known data.

Capacity (power generation): The maximum sustainable amount of power that can be produced by a generator or carried by a transmission facility at any instant.

CAR: Coordination Act Report

CBFWA: Columbia Basin Fish and Wildlife Authority; represents regional fish agencies (state and federal) and tribes.

Centrarchidae: Family of fish consisting of bass, crappie and sunfish (not native to the Columbia Basin).

cfs: cubic feet per second; a measure of water flow rate (discharge) in rivers.

Corps: U.S. Army Corps of Engineers

CRITFC: Columbia River Intertribal Fish Commission

Critical period (power generation): 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. Used to plan for firm power generation.

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 as to guide reservoir operation for power.

Cyprinidae: Family of fish consisting of carp, goldfish, shiners and squawfish.

Discharge: Volume of water flowing in a given stream at a given time, usually expressed in cubic feet per second.

Draft: Net release of water from a reservoir; drawing down the pool elevation.

Drawdown: The distance that water surface of a reservoir is lowered from a given elevation as water is released from the reservoir. In the current EIS application, drawdown generally refers to elevational changes below MOP.

EIS: Environmental Impact Statement

Endemism: The quality of being limited in distribution to a certain region (endemic).

Energy content curves: A set of curves which establish limits on the amount of reservoir draft permitted for non–firm energy production.

Entrainment: The carrying along of fish out of a reservoir due to dam operations. Entrainment is presumed to lead to mortality for the fish that would otherwise complete a part or all of their life–cycle in the habitat reservoir.

Epilimnion: A fresh water zone of relatively warm water in the top layer of a reservoir, in which mixing occurs as a result of wind action and convection currents.

ESA: Endangered Species Act

Escapement: Number of adult fish that spawn.

Fish hatchery: A facility in which fish eggs are incubated and hatched and juvenile fish are reared for release.

Fish ladders: A series of ascending pools constructed to enable fish to by–pass dams.

Fish passage facilities: Features of a dam that facilitate fish movement around, through, or over the dam. Generally an upstream fish ladder or a downstream by–pass channel.

Fishery (sport and commercial): Of or pertaining to the catching and processing of fish; sport fishery refers to the practice of catching and processing fish for sport; commercial fishery refers to the catching and processing of fish for commercial sale.

Flip lips (also known as spill deflectors): Structural modifications made to 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 create storage space to impound high runoff in order 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.

Fluvial: Inhabiting a river or stream.

fmsl: feet above mean sea level

Forebay: The portion of a reservoir immediately upstream of the dam.

fps: feet per second; a measure of water velocity

Freshet: A rapid temporary rise in streamflow caused by heavy rains or rapid snowmelt.

Fry: An early life stage of fish, at which they have begun to feed after absorption of the yolk sac.

Full pool: The maximum level of a reservoir under its established normal operating range.

Gas supersaturation: Concentrations of dissolved gas in water that are above the saturation (100 per cent capacity) level of the water, due to forcing air into solution (by heavy spill from a dam, for example). Excess dissolved gas can harm aquatic organisms.

gpm: gallons per minute. 448.8 gallons per minute = 1 cfs.

Habitat alterations: Changes in the environmental conditions which determine the number and types of fish in a body of water; can be natural or human–caused.

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.

Hypolimnion: A lower level stratum of water in a stratified lake, characterized by a relatively uniform temperature that is cooler than that of other strata in the lake.

I.D.F.G.: Idaho Department of Fish and Game

Introduced (fish): Fish not native to a particular habitat; stocked for any number of purposes including to create a new fishery or to balance the growth of competing species.

Juvenile: An early life–stage (e.g., of a fish).

KAF: thousand acre–feet

kcfs: 1,000 cfs

Levee: An embankment constructed to prevent a river from overflowing.

Littoral: On or along the shoreline.

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.

Low pool: At or near the minimum level of a reservoir under its established normal operating range.

Macrophytes (aquatic): A rooted aquatic plant large enough to be visible to the unaided eye.

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.

MDFWP: Montana Department of Fish, Wildlife, and Parks

Mid–Columbia: The section of the Columbia River from Chief Joseph Dam to its confluence with the Snake River.

MOP (Minimum Operating Pool): The minimum elevation of the established normal operating range of a reservoir. Generally refers to operation of a run–of–river project.

MRCs: mandatory flood control rule curves (refer to flood control rule curves)

msl: mean sea level

Native species: Species that originated naturally in the geographic area under consideration.

NEPA: National Environmental Policy Act

Net–pen operations: A fish rearing facility that employs net–enclosures in lakes or reservoirs, as opposed to onshore enclosures.

NFH: National Fish Hatchery

NMFS: National Marine Fisheries Service

Nonpower operating requirements: Operating requirements at hydroelectric projects that pertain to navigation, flood control, recreation, irrigation, and other uses of the river.

NPPC (or NWPPC): Northwest Power Planning Council

NTU: Nephelometric turbidity units; a measure of the amount of light attenuation in the water.

NWR: National Wildlife Refuge

OA/EIS: 1992 Options Analysis/Environmental Impact Statement

Oligotrophic (of a lake): Characterized by a low accumulation of dissolved nutrient salts, supporting but a sparse growth of algae and other organisms and having a high oxygen content owing to the low organic content.

Operating limits: Limits or requirements that must be factored into the planning process for operating reservoirs and generating projects. (Also see operating requirement, 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, describing reservoir elevations; operating rule curves guide the operation of a particular reservoir under specific conditions and for specific purposes.

Peak loads: The maximum electrical demand in a stated period of time; may be the maximum instantaneous load or the maximum average load within a designated period of time.

Pelagic: Of or pertaining to the open water of a lake away from shore.

Percidae: Fish family consisting of perch and walleye (not native to the Columbia Basin).

Phytoplankton: plant plankton (see *PLANKTON*)

Plankton: Single–celled (or otherwise very small) plants and animals suspended in a body of water which swim weakly and thereby drift with the currents.

PNCA: Pacific Northwest Coordination Agreement. An agreement among BPA, the Corps, BoR, and the major generating utilities in the Pacific Northwest that stems 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.

Pool: Reservoir; a body of water impounded by a dam.

ppm: parts per million

Predation: The relationship among animals in which one captures and feeds on another.

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.

PUD: Public Utility District

Pulsing: Use of augmented flow releases from Dworshak to move smolts through the river system. Pulsing is coordinated with the Water Budget and nighttime peaking activities through the Fish Passage Center and NMFS coordination.

Recruitment: The production of fish from one lifestage to another, e.g., recruitment from egg to fry. Also, the transition of young fish to a size at which they are available to be captured by fishing gear.

Redds: Salmon and trout spawning areas, usually nests in the gravel bottoms of rivers/streams.

Refill: The point at which the storage reservoirs of the hydro system are considered "full" from the seasonal snowmelt runoff.

Reliability (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 release of water from storage behind a dam reduces the elevation of the reservoir.

Reservoir elevation: The surface level of the water stored behind a dam; stated in reference to mean sea level.

Reservoir storage: The volume of water in a reservoir at a given time.

Resident fish: Fish that complete their life–cycles in fresh water.

Residualism: A condition in which migrating juvenile salmonid lose their urge to migrate, physiologically revert to their freshwater life form, and remain in fresh water rather than migrate to the sea.

RM: river mile

Rule curves: Water levels, represented graphically as curves, that guide reservoir operations.

Run–of–river dams: Hydroelectric generating plants that are operated 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.

Salmonidae: Fish family consisting of salmon, trout, steelhead, whitefish and char. (Most species found in the Columbia Basin are native.)

Sedimentation: The deposition or accumulation at the bottom of a body of water of mineral or organic matter.

SEIS: Supplemental Environmental Impact Statement

Sensitivity: The degree to which a given outcome is subject to change, based on changes in assumptions or input parameters. A sensitivity test is intended to compare the consequences of the same action under differing sets of assumptions.

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.

SOR: (Columbia River) System Operation Review

Spawning: The release of eggs by the female of a fish species, and the fertilization of those eggs by the male.

Species composition: The make–up of different types of fish species in a defined habitat; the diversity of species.

Spill: Water passed over or through a spillway or through regulating outlets without going through turbines to produce electricity. Spill can be forced when there is no storage capacity and flows exceed turbine capacity, or planned; for example, when water is spilled to enhance juvenile fish survival.

Spillway: Overflow structure of a dam.

Stocking (fish): To release to a body of water a species or variety of fish that may or may not be native to that body of water.

Storage reservoirs: Reservoirs that provide space for retaining water from springtime snowmelts. Retained water is used as necessary for multiple uses: power production, flood control, water supply, fish benefits, irrigation, and navigation.

Streamflow: The rate at which water passes a given point in a stream, usually expressed in cubic feet per second (cfs).

Tailrace: The canal or channel that carries water away from a dam.

TDG: Total dissolved gas

Thermal stratification: The development of different layers of water, each at a different temperature, due to low mixing and differing water densities.

Thermocline: The layer of water in a body of water in which the temperature decreases relatively rapidly with increase in depth: usually accompanied by more stable temperature layers above and below (epilimnion and hypolimnion, respectively).

Turbine: Machinery that converts kinetic energy of a moving fluid, such as falling water, to mechanical or electrical power.

USFWS: U.S. Fish and Wildlife Service

Usable storage: Water occupying active storage capacity of a reservoir.

Usable (active) 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.

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.

VARQ: A screening alternative in SOR, formulated for flood control revision by the Flood Control Work Group.

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 retention time: The amount of time that water in a reservoir is retained there, before being flushed through the system by drawdown (similar to water particle travel time); relating to the amount of time nutrients have to develop in the stable water.

Water Rights: Priority claims to water. In the western states, water rights are based on the principle "first in time, first in right," meaning older claims take precedence over more recent ones.

Zooplankton: Animal plankton (see *PLANKTON*).

EXHIBIT A

TECHNICAL EXHIBITS

LAWS, REGULATIONS AND MANAGEMENT PLANS AFFECTING RESIDENT FISH

(broader than simply those pertaining to operation of federal dams)

Federal Laws and Regulations

Clean Water Act

Endangered Species Act

Fish and Wildlife Coordination Act

National Environmental Policy Act

Executive Order 11990, Protection of Wetlands

Pacific Northwest Electric Power Planning and Conservation Act

Estuary Protection Act

Rivers and Harbors Act

Watershed Protection and Flood Protection Act

Wild and Scenic Rivers Act

National Wildlife Refuge System Administration Act

Columbia River Gorge National Scenic Area Act

Water Resources Development Act of 1990

US Code, Title 16, Ch. 13 (governs interstate transport of fish)

Idaho Laws and Regulations

Idaho Code

Title 36 (basis for establishment of fish and game laws)

Title 42, Chapter 38 (defines laws governing alteration of stream channels)

Spokane Tribe Laws and Regulations

1 Kappler, Indian Affairs, Laws and Treaties, 925 (1904) (establishes boundaries of Spokane Reservation and subsistence fishing rights)

Winters Doctrine (Winters vs US), 207 US 564, 28S.CT.207 (1908) (establishes Spokane Tribe's water rights, including those necessary to maintain a fishery) This document provides reference to the Spokane Tribe's water rights. The basis of this legal doctrine can be explained as sufficient water was reserved at time of reservation establishment to achieve the purpose of the reservation. Thus the Tribe has a priority date for water use and can expand its water use over time in response to changing reservation needs. These water rights include those waters which are needed to maintain a fishery. Citation: Winters vs U.S., 207U.S.564,28S.CT.207(1908).

Executive Order Establishing Spokane Indian Reservation January 18, 1881. This document establishes the boundaries of the Spokane Indian Reservation as being the far sides of the Chamokane, Spokane and Columbia Rivers. The order also established the Spokane's as a fishing people with rights to the fishing resources for subsistence.

Citation: 1 Kappler, Indian affairs, laws and Treaties, 925 (1904)

Washington Laws and Regulations

State Environmental Policy Act

Hydraulic Project Approval (Ch. 75.20 RCW)

Fish Screen Requirement (Ch. 75.20 RCW)

Reservoir Permit (Ch. 90.03 RCW)

Temporary Modification of Water Quality Criteria (Ch. 90.48 RCW)

Shoreline Permit (Ch. 90.58 RCW)

Nez Perce Tribe Laws and Regulations

The following treaties with the Nez Perce Tribes reserve the exclusive right to take fish in all streams running through or bordering the Nez Perce Tribe Reservation and further reserve the right to take fish at all the usual accustomed places in common with non–treaty interests. They constitute the statutory authority for the Nez Perce Tribe to manage resident fish:

Treaty with the Nez Perces, 1855, II Kappler 702, 12 Stats., 957.

Treaty with the Nez Perces, 1863, II Kappler 843, 14 Stats., 647.

Treaty with the Nez Perces, 1868, II Kappler 1024, 15 Stats., 693.

ENDANGERED SPECIES ACTIONS

Petition to List Kootenai River White Sturgeon: June 11, 1992

Petition to List Bull Trout: October 30, 1992

MITIGATION PLANS

Hungry Horse Mitigation Plan (March 1991)

Hungry Horse Mitigation Implementation Plan (1993)

Hungry Horse Management Plan (1989–94)

Libby mitigation planning effort (underway 1993)

NORTHWEST POWER PLANNING COUNCIL (NPPC) ACTIONS

NPPC Fish and Wildlife Program (1987 Amendments)

NPPC Phase 4 Resident Fish Amendments (26 November, 1993)

RFWG SCREENING ALTERNATIVES

Alternative: RES_IRRFLO

Objective:

Assumes current extent (acreage) of irrigated lands in the Middle–Upper Snake River, Salmon River, and Columbia River Basins but with an extensive and intensive water conservation program. The water "saved" or conserved would be made available for downstream beneficial users for fish and wildlife. Uncontracted (available) storage space would be dedicated for instream flow management. This alternative strives to reduce consumptive water use and to use uncontracted storage space to offset impacts of consumptive water use. The primary objective of a successful water conservation program is to benefit nonconsumptive uses for resident fish, anadromous fish and wildlife. Brownlee and Grand Coulee Reservoirs would pass new inflow regimen resulting from the water conservation program. All other reservoirs would pass natural inflows.

Specific Reservoir Operating Requirements:

Libby – maintain at elevation 2459 year–round

Hungry Horse – maintain at elevation 3560 year–round

Dworshak – maintain at elevation 1600 year–round

Albeni Falls – maintain at 2062 year–round

Grand Coulee – maintain at elevation 1290 year–round

Brownlee – maintain at elevation 2077 year–round

All run–of–river projects – full pool year–round

System Operation Requirements:

In most cases for storage reservoirs, inflow is unregulated, and would meet natural flow objectives. Brownlee and Grand Coulee inflows are currently influenced by consumptive water use for irrigation. A comprehensive water conservation program within irrigation projects would be the most demanding system operation requirement of this alternative.

Discussion:

One approach to address problems caused by competing uses for water is to increase the availability of water through water conservation. This approach has been presented by USBR as an attainable means of making more water available downstream from the Columbia Basin Project in Washington. Components of the Columbia Basin Plan include;

a. reserving a portion of "project water: for fish flows,

b. permits and other institutional requirements for implementation,

c. development and implementation of a water conservation program directed at conveyance systems and on–farm efficiencies and

d. coordination with fish and wildlife interests to assure compatibility of the conservation program with wetland values.

Implementation of this alternative would increase water availability and lessen the necessity to juggle reservoir levels to achieve desired instream flows, thereby benefiting resident fish. Anadromous fish would also benefit, as well as water quality (thermo-pollution, siltation, fertilizers, pesticides, etc.), wildlife and recreation. Power production may also receive a "passive: benefit from increased instream flows, especially during the hot, dry months. Alternative analysis could assume that basin–wide water conservation measures would result in water savings per irrigated acre on the same order as that projected for the Columbia Basin Project program.

Alternative: RES_FLD

Objective:

Keep pool elevations as high as possible for as long as possible while providing local flood control

Specific Reservoir Operating Requirements:

No Peaking Power Operations in any Reservoir

Lake Pend Oreille

1. Maintain a stable pool elevation from June for as long as local flood control can be maintained.

2. During 90% of the historic record, flood control will be contained by filling the reservoir from stable pool elevation to full pool. During the remaining 10% (wet years), a 4ft. drawdown before runoff is acceptable.

3. Evacuate flood storage as rapidly as local flood control will permit.

4. Return to stable pool by July and maintain until June.

5. When storage by the above method is not adequate to maintain local flood control (10% of the time) or return to stable pool by June, than drafting will begin with compilation of spring runoff projections. The reservoir will be drawn to store flood waters in excess of the storage capacity available by filling (stable pool to full pool).

6. Flood Control Group to solve for highest elevation.

7. Limit draft to elevation 2060 in the low through med–high screening years, otherwise follow base case.

8. draft from 2060 to 2056 (draft limit) in March of highest screening year, otherwise follow base case.

Grand Coulee

1. Minimum elevation: 1255 by April 1 with maximum outflow not to exceed 108K during drawdown.

2. Full pool by July 1 with outflows not to exceed 145K.

3. Maintain highest stable pool between July 1 and April 1. Flood Control Group to solve for highest elevation.

4. Drawdown to accommodate flood control should be at a rate 50% of existing flood control rule curves.

5. During refill period, filling should be continuous.

6. Reduce flood control space requirements by 50%

7. Operate to reduced URCs, but limit draft to elevation 1255.

Brownlee

1. Fall draft per Base Case with 20ft. limit

2. Maintain draft elevation. Refill only to accommodate local flood control.

3. Operate to base case with 20' draft limit.

Dworshak

1. During 75% of the historic record, flood control will be contained by filling the reservoir from stable pool elevation to full pool. A stable pool is maintained until April 1.

2. Evacuate flood storage as rapidly as local flood control will permit.

3. Return to stable pool by July and–maintain until June.

4. When storage by the above method is not adequate to maintain local flood control (25% of the time) drafting will begin with compilation of spring runoff projections. The reservoir will be drawn prior to April 1 to store flood waters in excess of the storage capacity available by filling (stable pool to full pool).

5. Flood Control Group to solve for highest elevation that will accommodate local flood control.

6. Stable pool elevation is 1570'

7. Reduce flood control space requirement by 50%.

8. Operate at 1570 until interception of reduced URC, draft and refill on reduced URC.

9. Return to 1570 by July 31 with 25 kcfs max outflow.

Libby

1. Minimum outflow is set at 5kcfs to maximize wetted perimeter and habitat in the river channel.

2. SEE ATTACHED TABLE FOR MONTHLY POOL ELEVATIONS AND DISCHARGES

Hungry Horse

1. Infow is–unregulated and only local flood control constraints are considered

2. Minimum outflow is set at 1200 cfs to maximize wetted perimeter and habitat in the river.

3. SEE ATTACHED TABLE FOR MONTHLY POOL ELEVATIONS AND DISCHARGES

Discussion:

RES_FLD attemptsto optimize resident fish populations by maintaining stable pools during summer and fall spawning,and encouraging shoreline vegetation which will provide fish shelter and increase terrestrial (allochthonous) food sources. The filling and drafting regimes described above (75/25) can be changed to maximize pool elevation within local flood control constraints. In Libby and Hungry Horse Reservoirs the requested elevations attempt to limit drawdown for maximum volume and food production. Full pool and peak biological production occur concurrently and discharges are shaped to mimic natural hydrology.

Table A–1. Monthly Pool Elevations and Discharges

Periods	Libby		Hungry Horse	
	Elevation Ft.	Discharge Kcfs	Elevation Ft.	Discharge Kcfs
OCT	2459	5.391	3560	1.281
NOV	2458.13	5.002	3560	1.138
DEC	2455.88	5.001	3560	1.264
JAN	2452.63	5.001	3559.86	1.220
FEB	2449	5.781	3559.70	1.233
MAR	2435.84	12.650	3551.61	4.603
APR 1	2424.54	19.596	3543.08	9.152
APR 2	2418.67	22.588	3537.46	9.352
MAY	2423.73	25.386	3545.86	9.342
JUN	2445.86	22.801	3560	9.012
JUL	2456.53	12.592	3560	4.432
AUG 1	2458.51	7.111	3560	1.396
AUG 2	2459	7.000	3560	1.438
SEP	2459	6.128	3560	1.518

Alternative: RES_PECT

Objective:

This alternative attempts to maximize the biological balance betwen the needs of fish in the storage reservoirs and the needs in the rivers just below. We attempt to construct the most natural discharge possible, sacrificing system flood control, while retaining enough flexibility to allow local flood control. The alternative incorporates the best available information to maximize the biological balance above and below Hungry Horse and Libby Dams. Flood control within the Flathead System was incorporated into the recommended operation schedule as a hard constraint. Flood control was modeled for the Kootenai System downstream to Con–a Linn Dam at the outlet of Kootenay Lake. However, in either system, no attempt was made to control flooding in offsite areas, caused by oftsite waters. Losses to power production and associated revenues were also minimized within the range of operations needed to protect or enhance resident fish.

From the standpoint of Lake Roosevelt, this alternative will not necessarily minimize resident fish loss due to low water retention times. However, it is thought to strike a reasonable compromise wherein resident fish are protected from the most severe impacts while allowing for resonably high water flows downstream for anadromous fish passage. At Brownlec, Dworshak, and Lake Pend Oreille we have attempted to increase stability in pool elevations, particularly during critical spawning and rearing periods.

Specific Operating Requirements:

Hungry Horse and Libby:

The following schedule assumes the average shape and volume of inflow. The schedule was originally designed using a daily time–step, then averaged within the standard 14 time–step format. Dam discharges were constrained by the maximum turbine capacity/hydraulic head relationships foil Hungry Horse and Libby Dams. yalues represent the end of month elevations and average discharge for each period.

Table A–2. Hungry Horse and Libby Monthly Pool Elevations and Discharges

Period	Libby		Hungry Horse	
	Elevation	Q Kcfs	Elevation	Q Kcfs
October	2459	5.391	3560	1.281
November	2458.13	5.002	3560	1.138
December	2455.88	5.001	3560	1.264
January	2452.63	5.001	3,559.86	1.220
February	2449	5.781.	3559.70	1.233
March	2435.84	12.650	3551.61	4.603
April 1	2424.54	19.596	3543.08	9.152
April 2	2418.67	22.588	3537.46	9.352
May	2423.73	25.386	3545.86	9.342
June	2445.86	22.801	3560	9.012
July	2456.53	12.592	3560	4.432
August 1	2458.51	7.111	3560	1.395
August 2	2459	7.000	3560	1.438
September	2459	6.128	3560	1.518

Grand Coulee:

Operate Coulee to achieve minimum elevation of 1255 ft. by April 1. During the drawdown period outflow should not exceed 108 Kcfs. Refill should be continuous and completed by July with outflows not exceeding 145 Kcfs. Maintain stable pool between July 1 and November 1. Thereafter, drawdown can begin as determined by flows.

Dworshak:

Operate Dworshak Reservoir to achieve minimum elevation of 1536 ft. no later than April 1. Refill with steadily increasing water levels after April 1 and, achieving full pool by June 1. Maintain stable pool through November 1.

Pend Orielle:

Pend Orielle would be held at full pool during the summer months (June, July, August, and September). Drawdown could commence on October 1, but under all circumstances must be completed by November 1, with a minimum pool of 2056 ft. The highest lake elevation between November 1 and December 30 becomes the winter minimum pool.

Brownlee:

Brownlee operations would allow drafting for water budget flows, but refilling as soon as possible in May. Brownice pool will then remain full and stable through the remainder of May and during June, July and August. No more than a 20 foot drawdown could commence in September.

Discussion:

The alternative attempts to limit drawdown for maximum volume and food production in the reservoirs. Full pools occur concurrently with peak biological production and/or during periods most likely to benefit resident fish. Dam discharges should mimic a natural hydrograph, yet allow drawdowns for local flood control, only.

Alternative: RES.COMP

Objective:

This alternative attempts to maximize the biological balance in Hungry Horse Reservoir and Flat–head River yet operate the dam within the hydrologic constraints of the dam structure–and drain–age basin. Using a quantitative biological model called LRMOD, the alternative also incorporates the best available information tp maximize the biological balance above and below Libby Dam. Flood control within the Flathead System was incorporated into the recommended operation schedule as a hard constraint Flood control was modeled for the Kootenay System downstream to Corra Linn Dam at the outlet of Kootenay Lake. However, in either system, no–attempt was made to control flooding in offsite areas, caused by offsite waters. Losses to power production and associated revenues were also minimized within the range of operations needed to protect or enhance resident fish.

From the standpoint of Lake Roosevelt, this alternative will minimize resident fish loss due to low water retention times at inappropriate times of the year. It also allows for high water flows downstream for anadromous fish passage. The alternative also strives to optimize fish growth within the reservoir by preventing the loss of zooplankton through the reservoir. At Brownlee, Dworshak, and Lake Pend Oreille we have attempted to increase stability in pool elevations, particularly during critical spawning and rearing periods.

Specific Operating Requirements:

Hungry Horse:

The Biological Rule Curve (IRC) proposed here incorporates two sliding scales. First, the maximum depth of withdrawal is dependent on the predicted inflow volume. Drawdown from full pool should begin no earlier than September 15. Reservoir drafting should be conservative prior to the first inflow forecast in January (no deeper than –34 feet or 3526 msl on December 31). The rate of reservoir drafting is then updated upon receipt of each successive inflow forecast; much like a Variable Rule Curve. We developed a series of Variable Integrated Rule Curves (VIRC's) for each volume of inflow

(Figure A–1). During an average water year (100 percent of normal), the trajectory of the draft could increase toward elevation 3496.5 msl (–63.5 feet) on January 31, allowing for increased generation during the cold month. The draft rate would then decrease toward 3485 (–75 feet) on April 15. After April 15, the reservoir would store spring runoff and fill on July 1.

During higher water years (greater than 100 percent normal inflow), following a variable IRC may allow greater reservoir drawdown depending on the inflow forecast. These IRCs have been modeled using BPA's power and hydro–regulation models.

During low water years (less than 75 percent normal inflow) the reservoir could fail to refill. During refill failure, drafting should be restricted to keep reservoir elevations above 3524 msl (–36 ft), declining no lower than elevation 3512 (–46 ft) by September 30. This will allow some drafting to maintain a minimum flow of 3500 cfs in the Flathead River at Columbia Falls and a variable amount of electrical generation. Upon refill failure, follow the critical period IRCs 24 (Table A–3) until the inflow forecast exceeds 75 percent of normal, when first year variable IRCs are resumed. We consider IRC 1–4 to be worse case scenarios or lower limits. Reservoir elevations above the IRCs are acceptable.

Table A–3. Maximum drawdown elevation recommended to reduce impacts on resident fish in Hungry Horse Reservoir during a four–year critical period.

End of Period Dates	IRC1	Critical Period Elevations (feet msl)		
		IRC2	IRC3	IRC4
SEP30	3560.00	3511.73	3501.95	3491.54
OCT 31	3548.79	3504.68	3494.46	3483.53
NOV 30	3537.58	3497.22	3486.48	3474.94
DEC 31	3526.00	3489.01	3477.65	3465.31
JAN 31	3496.5	3480.20	3468.09	3454.75
FEB 28	3489.24	3494.01	3459.17	3444.87
MAR 31	3485.14	3467.43	3454.05	3439.38
APR 15	3485.00	3472.54	3459.78	3445.53
APR 30	3491.3	3479.36	3467.17	3453.77
MAY 31	3513.24	3502.86	3492.51	3481.47
JUN 30	3525.13	3515.40	3505.83	3495.68
JUL 31	3524.13	3514.36	3504.73	3494.51
AUG 15	3521.30	3511.38	3501.57	3491.15
AUG 31	3517.54	3507.42	3494.37	3486.64

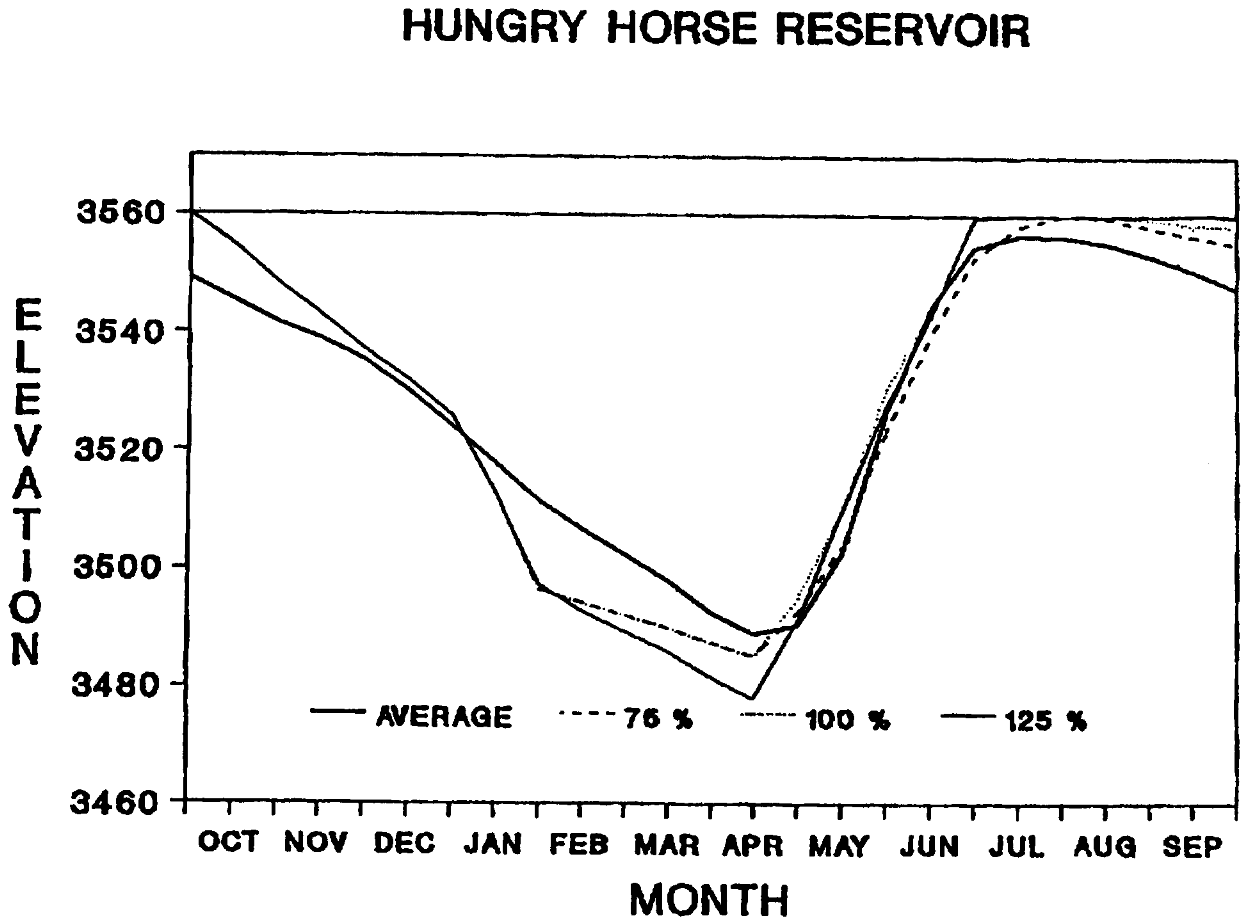


Figure A–1 Example of variable biological rule curves (UIRC) dependent on inflow forecasts. Bold solid line represents mean daily reservoir elevations for the period 1954–1989. Dashed, dotted and thin solid lines are recommended drawdown schedules for low annual inflows of 75 percent of normal, average and high inflows, 125 percent of normal. Rule curves have also been developed.

Libby:

Again, we use a IRC which incorporates two sidin scales. First, the maximum depth of withdrawal is dependent on the predicted inflow volume. Drawdown from full pool should begin no earlier than October 15. Reservoir drafting should be conservative prior to the first inflow fore–cast in January. Here we assume a 2 million acre–feet storage space on January 1 (–47.7 feet below full pool or elevation 2411.3 msl). The rate of reservoir drafting is then updated upon receipt of each successive inflow forecast. In such fashion, we have developed a series of preliminary Variable Integrated Rule Curves for each volume of inflow (Figure A–2). These curves, however, have not been tested as thoroughly as those developed for Hungry Horse.

During an average water year, the draft could continue after January 31, allowing for generation during the cold months and evacuation of flood storage as the reservoir approached 2379 msl on

April 15. After April 15, the reservoir would store spring runpoff and fill on or near July 1.

During higher water years, follow a VIRC which may allow greater reservoir drawdown depending on the inflow forecast. The IRCs for Libby have been modeled using the same techniques as applied at Hungry Horse.

During low water years the reservoir could fail to refill. During refill failure, drafting should be restricted to keep reservoir elevations from declining no lower than elevation 2416.2 msl (−42.8 ft) on September 30. This will allow some drafting to maintain a minirnum flow of 4000 cfs in the Kootenai River below Libby Dam and a variable amount of electrical generation. Upon refill failure, follow the critical period IRCs 2−4 (Table A−4) until the forecast exceeds 75 percent of normal, when first year variable IRCs are resumed. Again, we consider IRC 1−4 to be worst case scenarios. Reservoir elevations above the IRCs are acceptable.

Table A–4. Maximum drawdown elevation recommended to reduce impacts on resident fish in Libby Reservoir during a four−year critical period.

End of Period Dates		Critical Period Elevations (feet msl)		
	IRC1	IRC2	IRC3	IRC4
SEP30	2459.00	2416.16	2414.23	2413.00
OCT 31	2459.00	2414.61	2413.26	2412.00
NOV 30	2437.04	2412.86	2411.67	2410.42
DEC 31	2412.41	2410.05	2408.76	2407.41
JAN 31	2408.10	2406.01	2404.72	2403.37
FEB 28	2404.19	2402.10	2400.81	2399.41
MAR 31	2400.14	2398.00	2396.44	2394.95
APR 15	2398.37	2396.07	2394.65	2393.16
APR 30	2407.24	2405.15	2403.86	2402.51
MAY 31	2407.41	2405.32	2404.03	2402.68
JUN 30	2397.67	2395.37	2393.95	2392.47
JUL 31	2407.28	2405.19	2403.90	2402.55
AUG 15	2408.74	2406.65	2405.36	2404.01
AUG 31	2409.54	2407.45	2406.16	2404.81

* Curves were developed using the worst inflow volume on record, water year 1926, for four consecutive new. Drawdown was controlled by discharges needed to meet local flood control, maintenance of resident fish, and spring migration of salmon amolts.

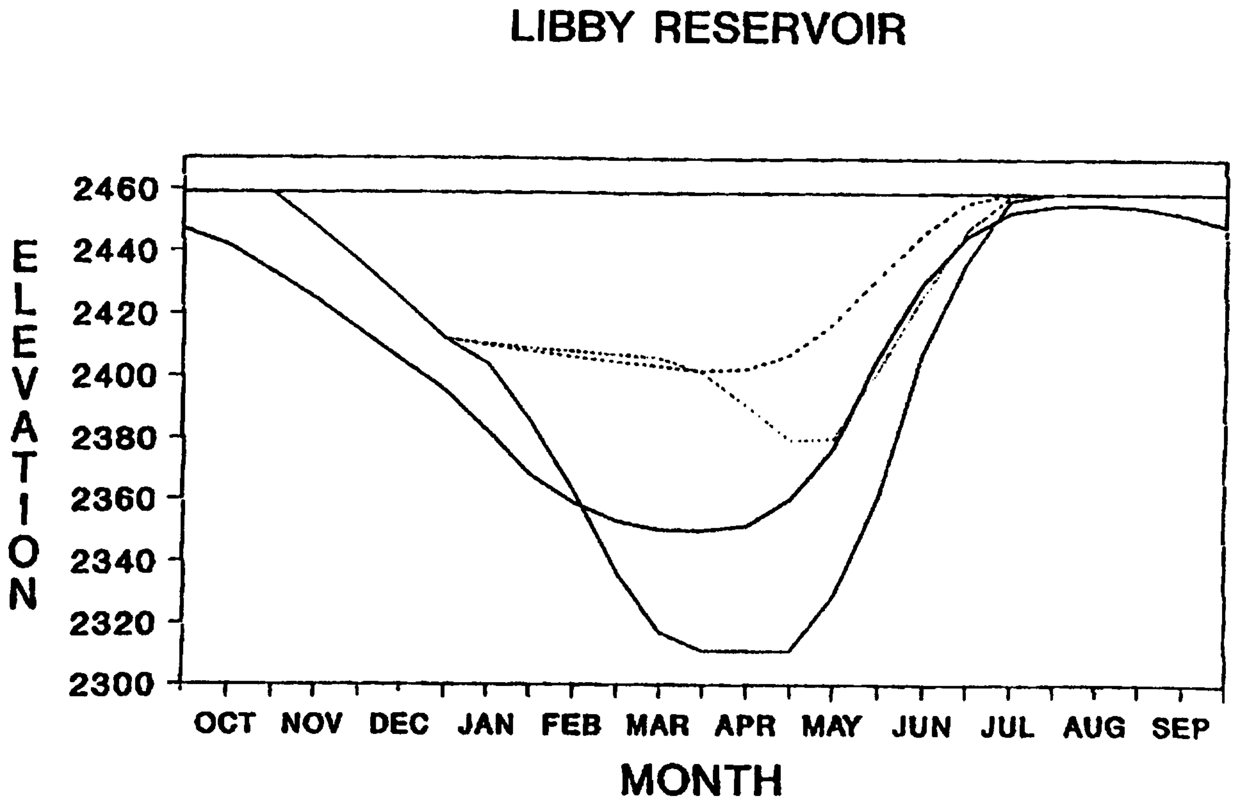


Figure A-2 **Example of variable biological rule curves (UIRC) dependent on inflow forecasts. Bold solid line represents mean daily reservoir elevations for the period 1974-1990. Dashed, dotted and thin solid lines are recommended drawdown schedules for April to August inflows of 75 percent of normal, average and high inflows, 125 percent of normal.**

Grand Coulee:

Vary reservoir elevations so outflows fall within the following ranges specified to meet water retention time (WRT) requirements:

Month	WRT(days)	Outflow Range
Oct	60	32–77
Nov	60	32–77
Dec	50	38–93
Jan	45	42–103
Feb	40	48–116
Mar	35	55–132
Apr 1	30	64–154
Apr 2	30	64–154
May	35	55–132
Jun	40	48–116
Jul	45	42–103
Aug 1	50	38–93
Aug 2	60	32–77
Sep	60	32–77

Dworshak:

Operate Dworshak Reservoir with an 80 foot winter drawdown, beginning in September and gradually drafting through January 1. Operations could then be adjusted based on inflow forecasts. Dworshak operations could allow water budget flows but there would be no drafting during the months of June, July, and August. September through December "gradual" draft is 20' per month. Lake should be full by 5/31. Reduce Jan–May outflows to minimum (2k Jan–Apr, 10k May) as necessary to–reach full on 5/31.

Pend Oreille:

Pend Oreille would be held at full pool during the summer months (June, July, August) and allow only a 4 foot drawdown in the fall. This drawdown could commence in September, but under all circumstances must be completed by November 1. The pool should remain stable through the remainder of the year. Draft 2' in September and 2' in October. Maintain stable pool from November until interception of base case spring refill levels which are followed for refill.

Brownlee:

Brownlee operations would allow drafting for water budget flows, but refilling as soon as possible in May. Brownlee pool will then remain full and stable through the remainder of May and during June, July and August. No more than a 20 foot drawdown could commence in September. Fall draft per base case with 20' limit. Maintain lake at 20' draft until interception of base case refill levels which are followed for refill.

Alternative: RES_WRT

Objective:

This alternative will minimize resident fish loss through the reservoir due to low water retention times at inappropriate times of the year. It also allows for high water flows downstream for anadromous fish passage. This will also optimize fish growth within the reservoir by preventing the loss of zooplankton through the reservoir.

Specific Reservoir Operation Requirements:

Month	WRT (days)
Oct	60
Nov	60
Dec	50
Jan	45
Feb	40
Mar	35
Apri	30
Apr2	30
May	35
Jun	40
Jul	45
Aug 1	50
Aug 2	60
Sep	60

System Operating Requirements:

This alternative would require the upper reservoirs to manage water flows to ensure that water retention time through Grand Coulee does not drop below the minimum water retention time and elevations listed.

Discussion:

This alternative does not take into account rosorvoir elevation but rather minimum water retention times that must be met in order to keep a stable population of resident fish withIn the reservoir.

Alternative: RES.SWAP

Intra–regional Energy Transfer Alternative and Associated Fisheries Benefits

Since November, 1990, the Montana Department of Fish, Wildlife and Parks has been using quantitative biological reservoir models to investigate tlie fishery benefits of seasonal, intraregional energy transfers. Our intent is to provide protection for resident fish concerns in headwater storage projects (eg. Hungry Horse and Libby reservoirs), yet respond to needs in the Lower Columbia River. Our efforts have accelerated in light of the endangered salmon recovery program, the System Operation Review process (SOR) and impending energy load/resource imbalance in the Bonneville Power Administrations service area.

Energy transfers are not new. For some time, power marketing to the southwest from Columbia River dams has been used to capitalize on excess power during spring runoff. A powerline called "intertie" has been expanded to increase power transfers. Similarly, power has been marketed out of region when flows were increased during the juvenile salmon downstream migration period. This fish flush called the water "budget" speeds downstream emigration times to improve survival and decrease predation as the smolts travel seaward.

Hydropower generated during the water budget provides clean renewable energy to the southwest during their peak load period, replacing coal–fired and combustion turbine generation that exacerbates air quality problems.

Historically, water in storage reservoirs has been drafted to produce power during fall and winter to meet peak loads in the nortliwest. Early fall drafting or "provisional drafting" has been used to provide inexpensive power for Direct Service Industry (DSI), including aluminum plants.

Problems occur for resident fish in reservoirs when reservoirs are drawn down beginning in early fall. The reduced volume and surface area limits the fall food supply and volume of optimal water temperatures during a critical trout growth period. Surface elevations continue to decline during winter, arriving at the lowest point in the annual cycle during April. Deep drafts reduce food production aid concentrate young trout with predators like northern squawfish. Of greatest concern is the dewatering and desiccation of aquatic insect larvae in the bottom sediments. These insects provide the primary spring food supply for westslope cutthroat, a species of special concern in Montana, and other important game and forage species. Deep drawdowns also increase the probably that the reservoirs will fail to refill. Refill failure negatively impacts recreation, and reduces biological production which decreases fish survival and growth in the reservoirs.

The ongoing salmon recovery program can cause important changes in storage reservoir operation. Anadromous fish (ocean run salmon and steelhead) require high water velocities in the Lower Columbia to aid in their migrations. This requires releases from storage reservoirs during the May through August period. Historically, the reservoirs refill from mid April through early July. Thus, if the reservoirs are drawn down deeply, releases for the water budget can further reduce the probability of refilling the reservoirs. Also, a lack of stored water could compromise the system's ability to maintain minimum flows required to maintain fish species in critical river reaches.

The RES.SWAP alternative being considered in the SOR process provides a solution to the apparent conflict between resident fish and anadromous salmon concerns, within the realities of flood control and power. The proposed operational strategy expands existing power sales to the southwest during spring runoff. Additional firm contracts can be let to transfer surplus power out of the Columbia hydropower system during spring and return power to the system during fall and winter. This allows a portion of the northwest's peak power needs and DSI demand to be met by imported power. Reservoir storage which is normally released during the cold months for power purposes can then be "saved" for release during spring. Possible seasonal markets include the low sulfur coal–fired projects at Basin Electric, the wind farm project on the Blackfoot Reservation, the Glenn Canyon area and the Southwest.

The RES.SWAP alternative attempts to expand power markets to benefit resident and anadromous fish. Resident fish in headwater storage projects benefit from higher reservoir elevations during winter and early spring. Stored water is released (within regional flood constraints) during spring and summer to augment salmon migration flows. The result is shallower maximum drawdowns in storage reservoirs like Hungry Horse and Libby and improved reservoir refill probability. Recall that refill failure impairs biological productivity in the reservoirs. Even infrequent deep drafts cause long lasting biological impacts. The energy swap strategy attempts to reduce–these effects.

Spring releases benefit resident fish below storage projects by returning the rivers to a nearly natural hydrography. Specific improvements include maintenance of minimum flows, flow stimulus as a cue to initiate spawning and channel maintenance flows.

White sturgeon in the Kootenai River require a high spring river discharge and favorable water temperatures to assure successful spawning. Research by–Idaho Fish and Game revealed that no young white sturgeon have been recruited to the population since Libby Dam was installed. The failure to reproduce has been linked to regulated flows below Libby Dam. The Idaho Conservation League has recently proposed listing the Kootenai River white sturgeon under the Endangered Species Act. Power marketing could make it possible to release storage during late June to provide the necessary spawning stimulus without compromising reservoir refill probability. Westslope cutthroat and rainbow trout also respond favorably to a spring discharge.

In the Flathead River, flow regulation is causing sediment accumulation, channel braiding and bank erosion. Short–term flow fluctuations from Hungry Horse Dam pulse water into the riverbanks. The water then returns to the river from the saturated banks carrying sediments and causing the banks to collapse. Most sediment deposition is occurring jn the lower 22 miles of river influenced by Flathead Lake elevations. These problems could be mitigated by high spring flows (below flood stage) when Flathead Lake is near low pool. Since spring runoff occurs naturally in the unregulated North and Middle forks of the Flathead, water stored in Hungry Horse would only be needed to augment natural discharge to assure a high flow event. A flushing flow would carry sediments out of the affected reach, resorting gravels and maintaining the channel. Resorted gravels enhance insect production and reduce river braiding that threatens adjacent lands.

Flood control must be considered by the proposed alternative. For modeling purposes, we have assumed that non–operational techniques (those measures that do not affect dam operation such as levees, offsite storage and floodplain zoning) will be implemented to the fullest extent possible. Also, Flathead Lake and Kootenay Lake in B.C. are used to protract the runoff over a longer period and re.regulate high peaks in discharge.

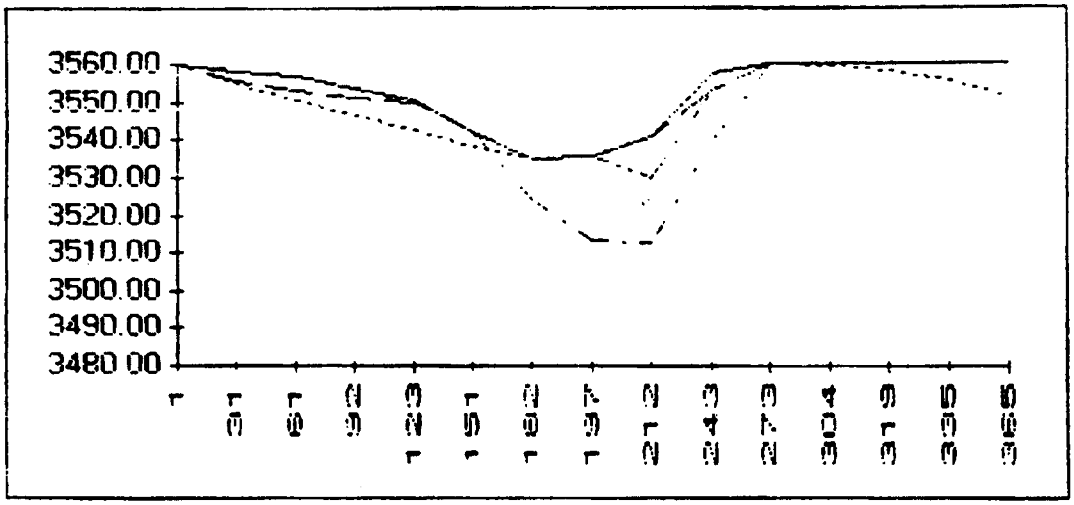
The attached alternative RES.SWAP was submitted to the SOR process through the resident fish workgroup. Since then, MDFWP has used the biological models HRMOD and LRMOD to assess the utility of the energy swap alternative. Results summarized in the enclosed figures reveal that biological benefits are hydrologically possible and would greatly enhance the fishery in Hungry Horse and Libby reservoirs.

The SOR modelers are cuuently conducting a system.wide computer simulation analysis to reassess RFS.SWAP. Initial simulations did not adequately capture the intent of the alternative, resulting in a relatively low score in the SOR screening process for both resident and anadromous fish. The new simulation will incorporate Integrated Rule Curves specifically calculated for Hungry Horse and Libby. Dworshack Reservoir will be drafted for anadromous concerns and Grand Coulee will operate for anadromous target flows. It is our intent to maximize water retention times in Grand Coulee to improve conditions for resident fish. The model will also be configured to re–regulate high spring flows to within local flood constraints. The results of the SOR system analysis will be appended to this summary when the data becomes available.

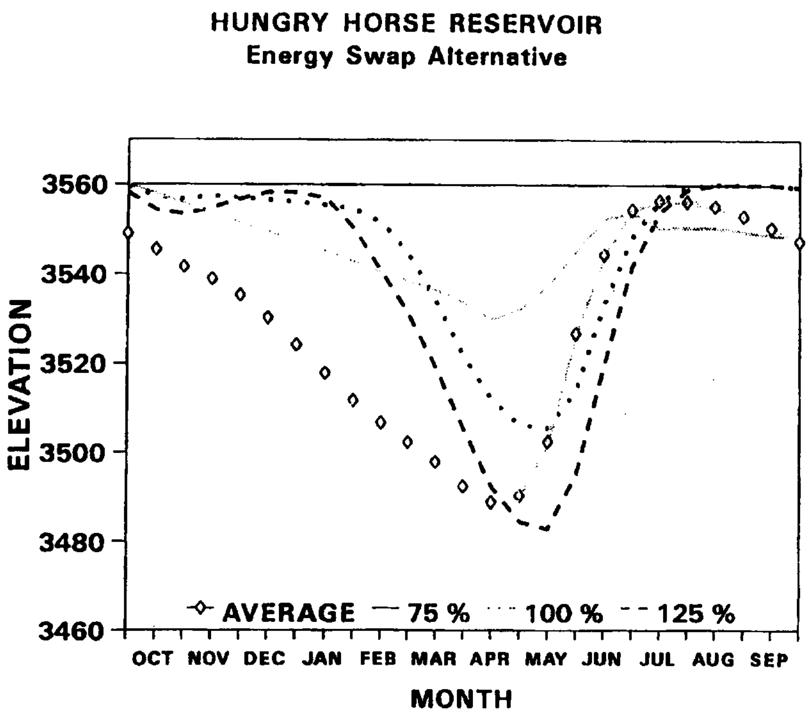
IRC VALUES (HUNGRY HORSE)

DAY	WATER YEARS 1931	1938	1940	1956	1957
1	3560.00	3560.00	3560.00	3560.00	3560.00
31	3558.18	3555.67	3555.24	3558.18	3558.13
61	3557.01	3553.17	3550.59	3557.01	3557.01
92	3554.12	3551.59	3547.05	3554.12	3554.12
123	3550.72	3550.07	3542.58	3550.72	3550.72
151	3542.00	3542.00	3538.38	3542.00	3542.00
182	3535.00	3535.00	3535.00	3524.45	3535.00
197	3536.30	3536.00	3536.00	3513.47	3535.90

212	3541.16	3541.16	3541.16	3512.32	3530.16
243	3558.00	3553.08	3558.00	3558.00	3553.00
273	3560.00	3560.00	3560.00	3560.00	3560.00
304	3560.00	3560.00	3559.57	3560.00	3560.00
319	3560.00	3560.00	3558.09	3560.00	3560.00
335	3560.00	3560.00	3555.78	3560.00	3560.00
365	3560.00	3560.00	3551.24	3560.00	3560.00



Hungry Horse Reservoir elevations resulting from energy transfer simulations. Five test years used in the SOR screening analysis range from Columbia River Low Water conditions (1931) to high annual flow volumes (1957).

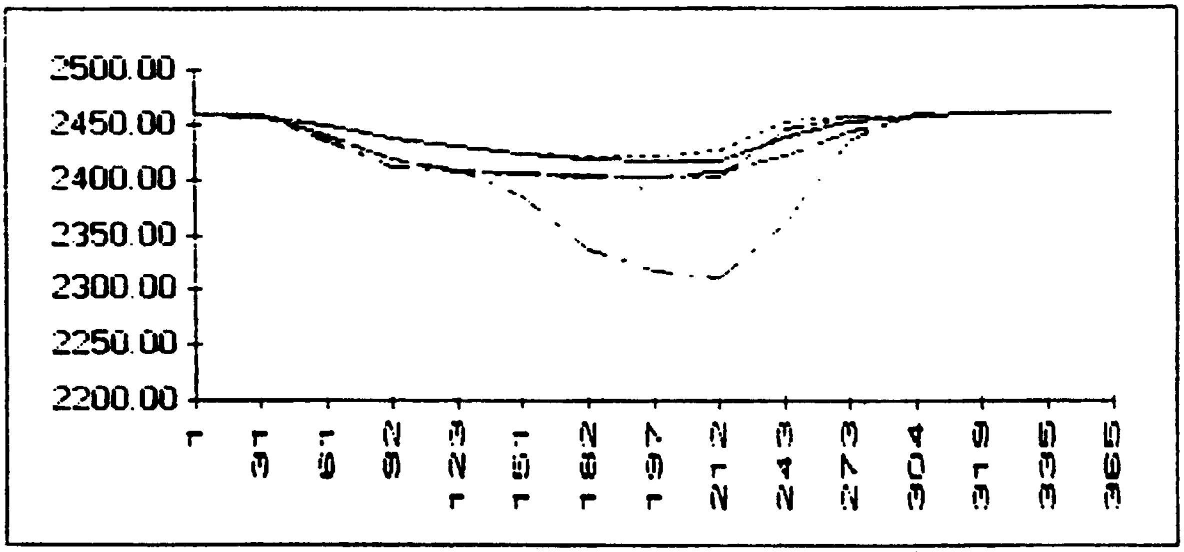


Hungry Horse Reservoir elevations resulting from energy transfer simulations, and compared to average daily drawdowns on record. Simulations assumed that energy markets and transmission facilities were fully implemented. Water years range from 75 to 125 percent of normal conditions.

IRC (STURGEON) VALUES

WATER YEARS

DAY	1931	1938	1940	1956	1957
1	2459.00	2459.00	2459.00	2459.00	2459.00
31	2458.72	2458.99	2458.99	2458.99	2458.99
61	2449.17	2440.74	2449.17	2436.56	2440.74
92	2439.46	2418.18	2439.46	2411.87	2418.18
123	2429.86	2409.04	2429.86	2409.06	2407.54
151	2423.24	2400.97	2423.24	2385.60	2404.27
182	2418.81	2403.71	2420.20	2335.93	2402.35
197	2417.43	2403.12	2421.07	2317.07	2401.60
212	2416.67	2406.29	2425.76	2311.00	2401.91
243	2439.12	2420.51	2452.98	2360.49	2445.31
273	2451.69	2443.58	2457.15	2436.56	2457.60
304	2457.88	2457.51	2457.89	2459.00	2457.92
319	2459.00	2459.00	2459.00	2459.00	2459.00
335	2459.00	2459.00	2459.00	2459.00	2459.00
365	2459.00	2459.00	2459.00	2459.00	2459.00



Libby Reservoir elevations resulting from energy transfer simulations. Five test years used in the SOR screening analysis range from Columbia River low water conditions (1931) to high annual flow volumes (1957).

Alternative: RES_FULPL

Objective:

Provide full. stable pools at storage and run–of–river reservoirs year–round (pass inflow). with no power peaking. Purpose is to more closely approximate natural lake (given that the reservoirs exist) and river conditions.

Specific Reservoir Operation Requirements:

Libby – – keep at el. 2459 year–round

Hungry Horse – – keep at el. 3560 year–round

Dworshak – – keep at el. 1600 year–round

Albeni Falls – – keep at el. 2062 year–road

Grand Coulee – – keep at el. 1290 year–round

Brownlee – – keep at el. 2077 year–round

All run–of–river projects – – full pool year–round

System Operating Requirements:

In most cases for storage reservoirs. inflow is regulated, and meets objectives. Operation of Clark Fork projects should not significantly. impact Lake Pend Oreille objectives. since the main concern is for the reservoir and river reach above Albeni falls Dam in that case. Grand Coulee is subject to regulation from several upstream projects, but pool stability at that project as well is the main concern for this alternative.

Discussion:

The concerns here are for protection of shoreline and shallow–water reservoir spawning (eg. kokanee in Lake Pend Oreille; warmwater fish in mainstem reservoirs). It is also to protect and provide a stable source of aquatic insect production, which is important for trout feeding and growth. Kokanee entrainment would be reduced at Dworshak and possibly other prolects. Furthermore, the natural inflow cycle benefits river fish and insect populations, especially if peaking is reduced or eliminated. Kootenal R. white sturgeon are a prime example, and may be listed later under the GSA. Anadromous fish should also benefit, but full pool on mainstem reservoirs will not likely be optimum for them, and another alternative with lower, but stable, pool elevations may be suggested. Problem is severe lack of data regarding resident fish populations and habitat in most mainstem reservoirs. This alternative serves as a resident fish maximization alternative, without regard to other functions.

DEVELOPMENT OF BIOLOGICAL RULE CURVES AND OF SOS4

SOS #4

Historical Perspective

Integrated Rule Curves (IRC's [formerly BRC's]) for dam operation were developed by the Montana Department of Fish, Wildlife and Parks (Department) to enhance biological production in Hungry Horse and Libby reservoirs and associated river basins. Operational strategies described by the curves were developed pursuant to measures 903(b)(1–3) of the Northwest Power Planning Council's (Council) Fish and Wildlife Program (Council 1987). The objectives were to maintain and enhance the fisheries resources and provide recommendations in the event a conflict occurs between river and reservoir operational requirements, measure 903(a)(6).

Preliminary IRC's were calculated in 1989 using quantitative biological models HRMOD and LRMOD for Hungry Horse and Libby reservoirs, respectively. Initial estimates of IRC's focused primarily on the reservoir biota (Fraley et al. 1989). In 1991 updated IRC's were developed to achieve balance between upstream and downstream concerns in both river basins. The IRC's successfully balanced the hydrology downstream to Kerr Dam at the outlet from Flathead Lake and Corra Linn Dam on the Kootenay River, B.C. System models were required to examine corresponding effects in the lower Columbia River. This enabled researchers to find compromise between resident and anadromous fish requirements.

The reservoir models were empirically calibrated using field data from an extensive sampling program 1983 through 1990. Field data from 1991 through present were later used to refine and correct uncertainties in the models. The models were critically reviewed by the Fisheries Research Institute, Seattle, in 1991 and revised to incorporate recommendations. It was decided that our modeling strategy was best suited to the specific purpose of comparing one operational strategy to another, and assessing their relative effects on the aquatic environment. The models facilitate the assessment of power and flood control operations under varying water conditions, drought to flood. The models were expanded to include downstream hydrology and temperature effects in 1991. The Hungry Horse model incorporated wild and regulated flows in the Flathead River System, Flathead Lake elevations and relationships controlling Kerr Dam discharges at the outlet from Flathead Lake. The Libby model was refined to assess water balance in the Kootenai River, Kootenay Lake, Duncan Dam and Corra Linn Dam operations. This facilitated the assessment of white sturgeon requirements and regional flood control. The full scale fortran models (HRMOD and LRMOD) were designed to be compatible with Columbia system hydroregulation models SAM, HYSSR and HYDROSIM. Although the model analyses were based on daily operations, subroutines enable the models to input and output monthly data (with April and August split into two half–month intervals) required by the system models. Thus, results from the Hungry Horse and Libby models could be readily input to the system models.

Integrated Rule Curves

The most recent family of IRC's, developed in 1992 and 1993, incorporate two incremental adjustments to allow for uncertainties in water availability. These create flexibility during first year operations and progressively deeper reservoir drafting during the four–year critical period in an extended drought. First year operations (IRC1) is a family of curves intended for use similar to flood control rule curves. In real time, the dam operator would receive an inflow forecast in early January and operate the dam to achieve the correct elevation as dictated by the curve corresponding with that inflow forecast. Upon receipt of an updated forecast, the operator would adjust the elevation to the new curve corresponding with the updated inflow volume, and so on.

The actual operation, then, is flexible and variable over time.

During a critical period (IRC2–4) the biological curves allow progressively deeper drawdown each year. These curves were developed using the lowest historic inflow to each project for four consecutive years. The critical IRC's protect the fisheries resource from excessive drawdown. Initial power analyses conducted by Bonneville Power Administration (BPA), using the System Analysis Model (SAM), showed that moss impacts on firm power generation occur in the fourth year of the critical period (IRC4). The Department requested a probability analysis to determine the frequency of reservoir drawdown, in ten foot increments, during the third and fourth critical year. If excessive drawdown is infrequent (low probability), the critical IRC could be adjusted to share the risk with power planners. Modeling and field research indicate that reservoir productivity can, with time, rebound after infrequent deep drawdowns. However, even infrequent deep drafts have long lasting biological effects. These effects are especially evident in benthic insects, an important spring food supply for trout. The requested probability analysis is, as yet, incomplete so the curves have not been adjusted.

The Integrated Rule Curves were included in the Columbia Basin System Operation Review (SOP) alternative SOS #4. Unfortunately some of the original intent of the operational strategy was lost in the process. The following description provides the rationale for the intended IRC design.

Local and System Flood Control

The IRC strategy for flood abatement is to route water through the system so that large peaks in runoff are eliminated. Reregulation of runoff creates a long duration salmon passage flow and a four month power marketing block. The need for "system" flood control at Libby and Hungry Horse (storage reservoirs in general) is reduced by the protracted water routing strategy which extends the spring runoff volume so that flows remain within flood stage limitations. The IRC alternative for system flood control assumes that non–operational control measures will be implemented to the fullest extent. Levees, dikes and berms must be fully functional to withstand extended durations of bank full flows.

Analyses using HRMOD and LRMOD have shown that the IRC's successfully protract the runoff to maximize spring discharges yet remain within local flood constraints. Notable exceptions will continue to exist where maximum storage is insufficient to control floods caused by unregulated sources (eg. North and Middle forks of the Flathead River cause flooding even though Hungry Horse discharge is reduced to the minimum outflow of 145 cfs); or Kootenay Lake floods even though Duncan, Libby and Kootenay Lake adhere to maximum flood constraints). Uncontrollable flooding can occur now, and will not be exacerbated by implementing the IRC strategy. Our IRC's, of course, allow deep drafts when needed for local flood control.

Hungry Horse Reservoir/Flathead River

In the Flathead River, flow regulation is causing sediment accumulation, channel braiding and bank erosion. Short–term flow fluctuations from Hungry Horse Dam pulse water into the riverbanks. The water then returns to the river from the saturated banks carrying sediments and causing the banks to collapse. Most sediment deposition is occurring in the lower 22 miles of river influenced by Flathead Lake elevations. These problems could be mitigated by high spring flows (below flood stage). A flushing flow would carry fine sediments out of the affected reach. Removal of fine sediments will decrease "embeddedness" of the substrate (increase interstitial spaces) to provide insect habitat and hiding cover for juvenile salmonids (eg. bull trout). At present, the fine sediments accumulating in the lower 22 miles of the Flathead River have shifted the insect biota from a stonefly/mayfly assemblage to a midge nominated community, affecting food availability.

Local flood constraints have reduced the frequency of channel maintenance flows. IRC's were constructed to disallow flooding at the immediate downstream critical flood control center at Columbia Falls, Montana. Discharges reduce to the absolute minimum (145 cfs) when the combined flows of the unregulated North and Middle forks approach flood stage (44,810 cfs). Channel maintenance flows can be enhanced through controlled releases during spring runoff. Spring discharges from Hungry Horse should be released during spring runoff (late yearly June) in a controlled volume to avoid conflicts with local flood control. Discharge should be less than the channel capacity of the South Fork below Hungry Horse Dam (20 kcfs), yet high enough to resort fine materials in the Flathead River bed (less than 5 mm diameter). Dam discharges would only augment natural discharges from the unregulated North and Middle forks. A bank full flow for approximately 48 hours every 2.5 years would flush course substrate materials, resorting gravels and maintaining the channel. Channel maintenance will reduce river braiding that threatens adjacent lands.

Modifications to Albeni Falls Operations

The System Operation Review alternative SOS #4 proposed changes to the current operations of Albeni Falls Dam to better integrate flows throughout the system for resident fish, anadromous fish and system flood control.

The proposed elevations for Lake Pend Oreille fit well with the proposed Integrated Rule Curves for Hungry Horse and Libby. As Lake Pend Oreille fills, it stores and reregulates much of the spring flows from the Clark Fork River. Then during July, the surface level of the lake is dropped about two feet. Thus, Lake Pend Oreille extends the runoff period, and reduces the peak flows into the Pend Oreille River Drainage.

The lower elevation of the lake during July provides benefits to wetlands for waterfowl. The higher winter pool elevation (2,056) will provide dramatic increases in the amount of spawning gravels for kokanee. Kokanee harvest has dropped from an average of 1,000,000 fish in the 1950s and 1960) to only 100,000–200,000 in 1985–1991. In years between 1952 and 1966 high winter pool elevations lead to higher harvest of kokanee when those year classes entered the fishery. We believe increasing the winter pool elevation will again improve the kokanee population in Lake Pend Oreille.

Lake Koocanusca/Kootenai River

Local flood control measures extend downstream to Corra Linn Dam at the outlet from Kootenay Lake. LRMOD has been modified to calculate side flows to the Kootenai River (from in flowing water sources) between Libby Dam and Bonners Ferry. We can now set Kootenai River flow targets at Bonners Ferry and Kootenay Lake elevational targets to avoid flooding. Conversely, the dynamic side flow estimates can be added to Libby discharge to calculate the resultant flow at Bonners Ferry. Inflows to Kootenay Lake, flood control storage at Duncan Reservoir and lake stage/discharge relationships for Corra Linn Dam were incorporated in the model to mimic coordinated flood control measures stated in the IJC treaty.

An understanding of flood control–criteria at Bonners Ferry and Kootenay Lake was necessary to examine spring releases that enhance the river fisheries. Based on the currently available information, white sturgeon in the Kootenai River require a high spring river discharge and favorable water temperatures to assure successful spawning. Research by Idaho Fish and Game revealed that no young white sturgeon have been recruited to the population since Libby Dam was installed. The failure to recruit juvenile sturgeon into the existing population has been linked to regulated flows below Libby Dam. Apparently, no fry have been successfully produced since Libby Dam began impounding water. The Idaho Conservation League petitioned to list the Kootenai River white sturgeon under the U.S. Endangered Species Act. The Fish and Wildlife Service listed the sturgeon as endangered. Power marketing could make it possible to store water during fall and winter explicitly for release during June to provide the necessary spawning stimulus without compromising reservoir refill probability. Westslope cutthroat and rainbow trout also respond favorably to a spring discharge if timing of releases correspond with their life cycle requirements.

Modifications to Grand Coulee Operations

Coordinated simulations involving the system models were required to address flood control problems from Grand Coulee downstream. The intent of SOS #4 is to draft Grand Coulee approximately 30 feet prior to receiving the spring releases from the upper storage projects. Releases from headwater storage projects arrive at Coulee in a protracted shape, Coulee releases anadromous fish flows while filling (this further reregulates the runoff and maximizes water retention times in Coulee). The idea is to remove runoff peaks and keep Coulee releases below flood stage (assuming non–operational flood control devices are maximized). This strategy for system flood control reduces flood storage requirements in the head after storage projects so that additional water can be stored prior to spring runoff for coordinated release for riverine fish species (eg. Kootenai white sturgeon, spring spawning cutthroat and rainbow and anadromous smolt migration).

Anadromous Species Recovery

The ongoing salmon recovery program can cause important changes in storage reservoir operation. Anadromous fish (ocean run salmon and steelhead) require high water velocities in the Lower Columbia to aid in their migrations. This requires releases from storage reservoirs during the May through July period. Historically, the reservoirs refilled from mid April through early July and discharges were reduced to specified minimum limits. Thus, if the reservoirs are drawn dawn deeply in April, releases for the water budget can further reduce the probability of refilling the reservoirs. Refill failures effect the ability of the system to supply water budget flows in subsequent years. Also, a lack of stored water could compromise the systems ability to maintain minimum flows required to maintain resident fish species in critical river reaches.

The IRC's were designed to balance the conflict between anadromous and resident fish requirements. This was accomplished by storing water during the fall through early spring period, in the headwater reservoirs, for release during late May and June. Deep drafts and refill failures could then be minimized while serving the needs of anadromous species. Spawning ques for river species such as the Kootenai white sturgeon and spring spawning trout are simultaneously provided.

The ability of IRC's to balance anadromous and resident fish requirements was tested during the SOR process. System models were used to evaluate simulations incorporating the IRC's. Although some of the original intent of the proposed strategy was lost, system models showed that IRC s provided anadromous flow targets at the Dalles as frequently as did the existing alternative provided by the anadromous fish workgroup. Model results proved that the IRC's can improve conditions for salmon migration, yet protect resident fish in the headwaters.

Power Operations

Problems occur for resident fish in reservoirs when reservoirs are drawn dawn beginning in late summer or early fall. The reduced volume and surface area limits the fall food supply and volume of optimal water temperatures during a critical trout growth period. Surface elevations continue to decline during winter, arriving at the lowest point in the annual cycle during April. Deep drafts reduce food production and concentrate young trout with predators like northern squawfish. Of greatest concern is the dewatering and desiccation of aquatic insect larvae in the bottom sediments. These insects provide the primary spring food supply for westslope cutthroat, a species of special concern in Montana, and other important game and forage species. Deep drawdowns also increase the probability that the reservoirs will fail to refill. Refill failure negatively impacts recreation, and reduces biological production which decreases fish survival aid growth in the reservoirs.

Integrated rule curves were designed to limit the duration and frequencies of deep drawdowns and reservoir refill failure. Reduced drawdown protects aquatic insect larvae, assuring that a large percentage of insects will survive to emerge as pupae and adults which provide an important springtime food supply for fish. Increased refill frequency maximizes biological production during the warm months. Refill provides an ample volume of optimal temperature water for fish growth and a large surface area for the deposition of terrestrial insects from the surrounding landscape. Refill timing also assures that passage into spawning and rearing habitat in tributaries is maintained for species of special concern, including westslope cutthroat trout and the recently petitioned bull trout.

Intraregional Power Marketing

The cost of foregone power production capability has been a persistent barrier to modifying system operation to improve the Columbia River fishery. Negative effects on the power system can be reduced by a power marketing strategy that employs interregional energy exchanges to facilitate operational changes to protect and enhance native fish species in the Columbia Basin.

Energy transfers are not new. For some time, power marketing to the southwest from Columbia River dams has been used to export excess power during spring runoff. A powerline called "intertie" was expanded to increase power transfers to and from the southwest. Power has also been marketed out of the region when flows were increased during the juvenile salmon downstream migration period. Hydropower generated during the water budget provides clean renewable energy to the southwest during their peak load period, replacing coal–fired and combustion turbine generation that exacerbate air quality problems.

Other intertie pathways exist for routing energy throughout the region. One intertie connects the asynchronous, western and eastern AC grids via a DC transformer that links east to west for bi–directional transfers. Some Montana utilities have indicated interest in expanding such links to simultaneously increase the efficiency of adjoining electrical grids. Southwestern utilities have also shown interest in linking the hydropower system in the Glen Canyon area with the Columbia System through a north/south intertie. This could result in better conditions for Colorado River species and the associated power supplies.

Another example of potential benefits involves the proposed wind farm on the Blackfoot Indian Reservation. Wind generation peaks during fall and winter on the east front of the Rocky Mountains in Montana. Winds subside during the late spring through summer period. Wind power could be imported during fall and winter to "save" water in storage reservoirs. Hydropower could export power to supplement the wind grid during the low wind period, when stored water is released for fisheries enhancement. Both grids could benefit from the transfer, IRC's would be achievable operationally, and economic hardships attributed to foregone firm energy could be partially offset by new markets.

Integrated Rule Curves provide a solution to the apparent conflict between resident fish and anadromous salmon concerns, within the physical realities of flood control and power. The proposed operational strategy expands existing power sales to the southwest during spring runoff. Additional firm contracts can be let to transfer surplus power out of the Columbia hydropower system during spring and return power to the system during fall and winter. This allows a portion of the northwest 's peak power demand to be met by imported power. Reservoir storage which is normally released during the cold months for power purposes can then be "saved" for release during spring. Resident fish in headwater storage projects benefit from higher reservoir elevations during winter and early spring. Stored water is released (within regional flood constraints) during spring and summer to augment Kootenai white sturgeon spawning and salmon migration flows. The result is shallower maximum drawdowns in storage reservoirs like Hungry Horse and Libby and improved reservoir refill probability. Recall that refill failure impairs biological productivity in the reservoirs. Even infrequent deep drafts cause long lasting biological impacts. The energy transfer strategy attempts to reduce these effects.

Although hydropower is relatively benign compared to other traditional generation techniques, environmental effects of hydropower facilities are well documented and costly in terms of lost recreation, food production and fisheries maintenance. Modified operations and wise power marketing strategies can lessen costs to the ratepayer, yet improve the quality of the aquatic environment. Admittedly, adoption of the IRC's and proposed operational strategy will carry initial costs. The U.S. Army Corps of Engineers will provide a flood control examination to the Northwest Power Planning Council during 1993. An evaluation of the effects of IRC's on power production is presently underway. Power demands continue to grow and the region has approached load resource balance. Drought and an overall–reduction in electrical generation native to the demands on the system have necessitated increases in power rates. Markets to transfer energy are young and must be fostered. Transmission facilities must be expanded to increase intertie access. Yet, it is important to include the–hidden costs of ecosystem degradation, normally considered "externalities" in economic analysis. The costs of species restoration is significant, operations should be modified to avoid future listings.

Opponents of the IRC concept cite increased reliance on coal fired plants and combustion turbine facilities that are considered less environmentally benign than hydropower. For this reason, IRC's were intentionally designed to limit impacts on the hydropower system, yet maintain the aquatic environment. We have recommended alternative marketing and water management to reduce effects on generation and revenue. Concerns surrounding combustion generation are warranted, however. Seasonal scheduling of power transfers relative to atmospheric conditions (wind dispersal and CO_2 buildup) may result in benefits to air quality.

Some consider the potential for transmission losses associated with interregional power transfers to be cost prohibitive. Again, all costs should be considered. The proposed energy transfers are seasonal and of limited capacity. Technological advances in transmission efficiency will partially offset transmission losses. Transmission distances can be reduced through marketing and coordination between interconnected facilities. Personnel with expertise specifically suited to solving the problem should be consulted.

Price disparity between energy imports and exports is considered by some to be the largest drawback to interregional energy transfers. At present, springtime exports are inexpensive whereas fall/winter imports come at great cost to the region. This problem bay be solved by federal controls and utility regulation. A balanced system operation is truly in the best interest of the nation.

Some utilities mention problems with "environmentalists" blocking attempts to build or expand intertie lines to connect regional power grids. We recommend the expansion of existing interties and the use of developed corridors (eg. rail routes, highways, man–made canals and buried cable) rather than new locations. Most controversy surrounds the development of presently unaltered areas.

Conclusion

The IRC operational strategy was designed to improve conditions for all native fish species in the Columbia River System within the realities of flood control and power production. Flexible river flow and reservoir elevational targets allow for compromise among the often competing uses in the basin. System models have shown that flow requirements for anadromous fish can be achieved, when hydrologically possible, without sacrificing native resident fish populations. Coordinated springtime releases from storage projects can achieve a protracted runoff, with peaks removed, to avoid flooding. The extended runoff aids salmon migrations in the lower Columbia and creates a four–month marketing block for interregional power exports. Imported power during fall and winter allows headwater reservoirs to store water explicitly for release during spring. Resident fish benefit from high reservoir elevations, decreased drawdowns and improved refill probability. Impacts to power generation capability are reduced by intraregional power marketing. We believe this is the best compromise for a balanced system operation in the Columbia Basin.

LETTERS

COLUMBIA RIVER SYSTEM OPERATION REVIEW

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

January 13, 1993

Dennis McDonald, Director
Kootenay Region
British Columbia Ministry of Environment, Lands, and Parks
617 Vernon
Nelson, British Columbia
Canada, V1L4E9

Dear Mr. McDonald:

As you may be aware, the Corps of Engineers, Bureau of Reclamation, and Bonneville Power Administration have undertaken the Columbia River System Operation Review (SOR) to review operation of Federal Dams in the U.S. and to renew the Pacific Northwest Coordination and the Canadian Entitlement Allocation agreements. The SOR Team is embarking on its final, full-scale phase of technical analysis leading to an Environmental Impact Statement concerning possible changes in operation of U.S. system dams. Since these operational changes have the potential to impact river reaches, projects and reservoirs in Canada, it is important that Canadian interests be involved.

This letter is to request the availability of Mr. Jay Hammond, head of the Fisheries Section, Fish and Wildlife Branch. Mr. Hammond has served on the Columbia Basin Fish and Wildlife Authority's Resident Fish Committee, and the SOR Resident Fish Work Group has need for his expertise in resident fish matters pertaining to British Columbia portions of the Columbia Basin.

The effort involved would include travel to meetings on up to a monthly basis in the U.S., and consultation on resident fish matters. During those meetings and in the intervals between, Mr. Hammond may be asked to provide advice and background materials to the SOR Resident Fish Work Group. He may also be asked to serve as a point of contact for the work group with other experts in BC.

Interagency Team, P.O. Box 2988, Portland, Oregon 97208-2988
503-230-3478 (Portland) ■ 1-800-622-4519 (Toll Free)

Your early response would be appreciated, since our analysis is getting underway now. If you have any questions, you may call me at (503) 326-5189. If you have questions regarding the Resident Fish Work Group, you may contact Mr. Jeff Laufle, the group coordinator, at (205) 764-6578, US Army Corps of Engineers, Seattle District.

Thank you for your consideration.

Sincerely,

Witt Anderson

For Interagency Team

cc:
Jeff Laufle, Resident Fish Group
Steve Foster, Seattle District
Jim Fodrea, Bureau of Reclamation
Phil Thor, BPA-PG
Official File, BPA-PG
Public Record, BPA-ALP

Province of British Columbia

MINISTRY OF ENVIRONMENT, LANDS AND PARKS

BC Environment

617 Vernon Street
Nelson
British Columbia
V1L 4E9
Telephone: (604) 354-6333
Fax: (604) 354-6332

March 30, 1993.

Mr. Witt Anderson
Interagency Team
Columbia River System Operation Review
P.O. Box 2988
Portland, Oregon 97208-2988
U.S.A.

Dear Mr. Anderson:

I apologize for my delay in responding to your January 13, 1993 letter requesting the involvement of Mr. Jay Hammond, Fisheries Section Head, Kootenay Region in the SOR Resident Fish Work Group. However, I have now received clarification that the Province of British Columbia does not propose to involve staff directly in the American SOR. The Province will be carrying out its own review of the Columbia River Treaty developments on the Canadian portion of the Columbia River Basin.

I must advise, therefore, that Mr. Hammond will not be involved in your review but could, if circumstances warrant, attend occasional meetings of the SOR Resident Fish Work Group in an observer capacity.

I have previously advised Mr. Jeff Laufle of this decision by phone.

Yours truly,

Dennis McDonald
Regional Director

DM/ss

bcqeu

cc: R. Morley
J. Hammond
D. Narver

Fisheries and Oceans
Pêches et Océans

Pacific Region
Suite 400 - 555 West Hastings St.
Vancouver, B.C.
V6B 5G3

Région du Pacifique
Pièce 400 - 555 rue Hastings ouest
Vancouver (C.-B.)
V6B 5G3

Your file Votre référence

Our file Notre référence

June 7, 1993

US Army Corps of Engineers
P.O. Box C-3755
4735 E. Marginal Way S.
Seattle, WA
98124-2255

FAX: 1 (206) 764-6676

Attention: Jeffrey Laufle
Fisheries Biologist

Dear Mr. Laufle:

Re: Resident Fish Work Group - System Operation Review

This letter is to formally indicate the Department of Fisheries and Oceans' intention to participate in future Resident Fish Work Group meetings associated with the Columbia River System Operation Review (SOR). The Department will be prepared to attend such meetings, review documents and provide feedback regarding effects to the Canadian fisheries resource which may result from the various dam operation alternatives developed during the System Operations Review.

Please note that the Department's representative at these meetings will be Cathy Gee. Please address all correspondence to her at the above address.

Should you require clarification or wish to discuss the above, please contact me at (604) 666-2057 or Cathy Gee at (604) 666-2365.

Yours sincerely,

G.L. Ennis

Gordon L. Ennis, R.P. Bio.
Chief, Eastern B.C. Unit
Habitat Management Division

cc: C. Gee

Canada

United States Department of the Interior

FISH AND WILDLIFE SERVICE

911 N.E. 11th Avenue
Portland, Oregon 97232-4181

SEP 17 1992

Memorandum

To: Regional Director, Bureau of Reclamation
Boise, Idaho

From: Acting Regional Director, U.S. Fish and Wildlife Service
Region 1, Portland, Oregon (AFWE)

Subject: Columbia Basin System Operation Review Planning Aid Letter

This planning aid letter is provided in fulfillment of the fiscal year 1992, scope of work for the Columbia River Basin System Operation Review (SOR). It has been prepared under the authority of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) and the Endangered Species Act (ESA) of 1973 (87 Stat. 884, as amended; 16 U.S. C. 1531 et seq.), and is provided to assist the Bureau of Reclamation (Reclamation), Bonneville Power Administration, and Army Corps of Engineers in the evaluation of the candidate system operation strategies.

Candidate System Operation Strategies

GENERAL COMMENTS

The U.S. Fish and Wildlife Service's (Service) primary concern at this point is that the candidate system operation strategies (SOS) not be allowed to limit the range of alternatives that will go forward to full-scale screening. The screening process was intended to provide a general idea of the effects of the proposed alternatives on fish and wildlife. The assumption was that the knowledge gained through the screening process could then be used by the work groups to generate alternatives for full-scale analysis beyond those used for screening. Instead, it appears that the alternatives derived from screening are being adopted for full-scale analysis.

At this stage, the candidate SOS's lack definition and specific detail necessary for us to complete a thorough review. Some of the technical work groups, such as the Anadromous Fish Work Group, have not even had a chance to discuss the candidate SOS's in any detail. We will continue to participate in the various technical work groups to help refine, develop, and add to the candidate strategies. The Service intends to provide additional formal comments in planning aid letters in the near future as the candidate SOS's are further developed.

The limitations of the screening process for resident fish and wildlife are obvious. The modeling only looked at a limited number of projects within the system for evaluation of impacts to resident fish and wildlife. In developing the candidate SOS's, results from population data, habitat acreage, and habitat units for a limited number of resources were combined to evaluate wildlife impacts, a questionable process at best. The resident fish modeling only looked at storage reservoirs and did not evaluate run-of-the-river projects or free-flowing stretches in any significant manner. The subsequent pooling of these data obscured differences and rendered difficult the task of balancing the impacts and benefits at different projects. Therefore, while the screening process is useful for assisting in developing final alternatives, it is inadequate from a resident fish and wildlife standpoint for producing alternatives to go forth for full-scale screening. Along the same line, we are concerned about the charts and tables describing impacts to various elements of the system which have been prepared and distributed without any accompanying discussion of their limitations. These again only give a small picture of alternative impacts, and may be used or interpreted by non-resource managers or the public in an inappropriate manner.

Another point of concern is that several strategies out of the System Configuration Study (SCS) are included as equal strategies at this time under SOR. These alternatives are being studied under the SCS and will require extensive evaluation, are implementable only on a very long timeframe, and are dependant on Congressional authorization. The potential exists under SOR to implement straightforward, beneficial changes to the system on a fairly short timeframe. Including the SCS alternatives has the potential to bog down the process as they are essentially at a reconnaissance level of study, and numerous unanswered questions surround them.

There needs to be a clear division between true operational changes which can be implemented on a short-term basis, and system changes, which are implementable only on a very long-term basis. The process should move forward in such a way that short-term solutions are evaluated and implemented in a timely manner while long-term strategies are being pursued.

SPECIFIC COMMENTS

The impact of these proposals in a general sense has been fairly well established and discussed during the screening process. Drawdown of storage facilities will be detrimental to resident fish, but will not greatly affect the already generally low values of storage reservoirs for wildlife. Severe drawdowns of run-of-the-river projects will greatly affect resident fish and wildlife, but drawdowns to minimum operating pool (MOP), not including John Day, will generally be of minor consequence. Reductions in water fluctuations at MOP would ameliorate impacts to resident fish and wildlife. Impacts of the altered flow regimes on free-flowing stretches are less well established and variable, but depend on flow fluctuations, timing of changes, water temperature, and amount of flow.

Since specific alternatives and their operating criteria have not yet been developed, specific comments cannot be provided as described in the Scope of Work. However, the Service will provide general observations and comments on these strategies.

3

(1) Post Regional Act with ESA and 1992 Options Environmental Impact Statement (EIS) Operations

The preliminary vegetation monitoring results from this alternative suggest that these alternatives will have minimal to positive results on wildlife on run-of-the-river projects on the Lower Snake River. We were encouraged that the 1992 operation of the Lower Snake River projects at MOP (although fluctuations above MOP occurred regularly) resulted in the establishment of moderately dense to heavy vegetation within the normal operating zone. Along some shorelines with a very flat gradient, this has resulted in an extension of riparian and wetland vegetation by several hundred feet. This will be beneficial for wildlife. However, the Service believes that the draft preliminary report by Battele Pacific Northwest Lab on the shoreline monitoring is overly optimistic in the benefits that are attributed to this vegetation response. These include the description of the buffer zone as a "vast habitat for wildlife", a filter for sediment from agricultural fields, and as a creator of food chains which should "aid in the salmon problem."

Annual operation at MOP could encourage restoration of riparian vegetation, although additional monitoring will be required to evaluate long-term vegetation trends. If the regenerating willows, cottonwood, and alders become established, the wildlife values of these areas could be considerable. Minor modifications of this alternative, such as periodic short-term pool raises to re-wet regenerating vegetation, would assist this process.

One potential negative effect is that the drawdown conditions may provide improved conditions for the spread of purple loosestrife by exposing suitable substrates for germination. This is an issue that has not been addressed by the work groups.

This alternative appears to have positive and negative impacts on resident fish. Operation at MOP on the Lower Snake River appears to be beneficial for resident fish. Maintenance of stable pools at MOP in 1991 coincided with a very strong year class of most resident fish, while the failure to maintain MOP in 1992 coincided with a reduced number of young-of-the-year resident fish (Bennett, Pers. comm.). However, water retention time and flushing of adult fish from Grand Coulee would be affected by the storage required under this strategy. Besides the negative impacts which may occur, planning management strategies for Lake Roosevelt will be very difficult because of changing water retention times from year to year.

For anadromous fish, this strategy does not provide the kind of in-river migration conditions that we believe are necessary for recovery and rebuilding of upriver salmon stocks. National Marine Fisheries Service (NMFS) concluded in their biological opinion that more stringent requirements than those imposed to achieve the 1992 interim goal of improving survival and making progress toward reversing the decline may be necessary. Candidate SOS's should include migration conditions that will maintain self-sustaining salmon and steelhead populations that can support viable treaty Indian and non-Indian commercial and recreational fisheries rather than just meeting a minimum viability standard under the ESA.

4

This strategy relies on an operational approach rather than a firm planning approach to provide flow augmentation. Flow levels and operations to augment flows are flexible under an operational approach. For example, the flows through the hydropower system during the 1992 migration season and 1992 operations were actually substantially lower than NMFS assumed in their biological opinion and incidental take statement for the operation of the Federal Columbia River Power System. In the Snake River, Idaho Power Company refused to implement one program measure that called for the release of up to 200 KAF above planned outflows during the period September 1 to 30, to benefit adult fall chinook. Thus, conditions that are assumed in an analysis may not occur during actual implementation. This degree of uncertainty makes it difficult to assess the impacts of this kind of strategy. The specific operations and the projects that will be involved in an operational approach need to be clearly described and fully disclosed in order to determine fish and wildlife impacts. The Service also recommends that the amount of - uncertainty between assumed and actual operations be assessed for each candidate strategy.

(2) Natural River Option

It should first be pointed out that the title of this alternative is somewhat misleading. It is a very unnatural flow regime and will reduce the biological productivity and diversity of the system for resident fish and wildlife.

This alternative could be detrimental to wildlife for a number of reasons which are not captured in the screening models. Riparian and wetland vegetation could be substantially reduced under the 4½-month drawdown scenario and could be greatly altered under the 2-month scenario. The wide range of wildlife species dependant on this type of habitat would be impacted. Some differences in terms of impact or vegetational response might be expected, however, because of annual rainfall differences along the Lower Snake River, which range from 7 inches at Kennewick to 19 inches at Lower Granite and 14 inches at Clarkston.

The drawdown period would be initiated prior to the Canada goose nesting season (approximately February 16), so nesting would be eliminated on existing islands because of land-bridging and associated predation by furbearers. Newly created islands could be used for nesting, but would not be very attractive because of a lack of nesting cover. The 97- to 115-foot drawdown would create very poor conditions for brood rearing. The drawdown would also eliminate furbearer use of the Lower Snake River by preventing access to denning sites and greatly reducing food availability. Irrigation of Habitat Management Units would be impossible without modification of the pumping facilities, which may or may not be possible.

Populations of all exotic warm water resident fish, such as smallmouth bass, crappie, catfish, bullhead, carp, and perch would drastically decline as the shallow, backwater areas which they typically prefer for spawning and rearing would be eliminated. Water temperatures are also likely to be lowered, which will inhibit spawning. Reduced productivity, through a loss of benthic production and reduced water retention time, will result in reduced food availability.

5

One exotic resident fish that may benefit is the walleye. Walleyes presently only occur up to the tailwaters of Ice Harbor. However, they are known to move up through tainter gates in the Upper Mississippi River (Pitlo 1990) during the spawning season, and could potentially invade the Snake River provided other conditions are favorable. They spawn in tailwaters and riverine habitat and spawning may be enhanced under the altered flows.

Impacts to native fish are likely to be more mixed. Spawning white sturgeon are likely to benefit from riverine flow conditions and the restoration of flows will flush sediment from gravel and rubble preferred by sturgeon as a spawning substrate. There may also be more genetic mixing of populations which have been artificially isolated by the dams, because adults may potentially negotiate the open channel outlets and juveniles will be able to pass downstream more easily. The reduced productivity of the system, however, may offset some of these benefits. Non-game native fish, such as squawfish and suckers, will persist in reduced numbers, primarily because biological productivity and the quantity of habitat available in the system will be reduced.

On the other hand, for salmon and steelhead this alternative provides the greatest potential over the long-term to increase in-river survival and maintain the diversity of salmon and steelhead populations in the Snake River. Operational alternatives alone may not be adequate to reduce smolt mortality in the Snake River to levels that will sustain healthy anadromous fish populations. As we have stated, drawdown strategies requiring major facility modifications should be treated in the review separately from alternative operational changes. The main focus of the SOR should be on operational changes for immediate implementation while long-term strategies are pursued.

3) Fixed Drawdown Below MOP

4) Drawdown to Below MOP to Meet Target Velocities of Flow

Impacts from these strategies on resident fish and wildlife are likely to be very similar as those of the natural river option, without having the benefits related to re-establishment of river characteristics. However, the reductions in biological productivity will not be as great for these strategies as for the natural river option. The drawdown to meet target velocities is likely to be a little more detrimental to resident fish than the fixed drawdown because of water level fluctuations.

Impacts to anadromous fish are much more uncertain for these two drawdown strategies than for the natural river option. These strategies require major modifications to juvenile bypass and adult passage facilities. Under the natural river option, no new juvenile bypass facilities or fish ladders are required. For options 3 and 4, it is uncertain whether new fish bypass and passage facilities will operate successfully which will add several years for testing and facility modifications. This kind of uncertainty should be evaluated for any alternatives requiring major facility modification.

5) Spring Flow Augmentation with Guaranteed Power Operation

As the exact elevations for this proposal are not known, specific effects to resident fish and wildlife cannot be clearly identified. However, they would appear to be similar to alternative No. 1, provided that drawdowns are not significantly below MOP. Drawdown below MOP could potentially occur, but its extent is not specified.

Flow targets for this alternative are substantially lower than levels we believe are necessary to sustain healthy salmon populations throughout the upper Columbia River Basin. This strategy also shifts water from the summer migration period to the spring migration period. In July, critical and average flows through the lower Columbia River are the same (150 kcfs) while flows in June increase from 180 kcfs under critical condition to 220 kcfs under average conditions. Improved migration conditions in the spring are at the expense of fish migrating in the summer months. This candidate system operating strategy should clearly describe this tradeoff.

6) Target Flows for Anadromous Fish Year Round

The description for this alternative indicates that results from screening will be used to set the target flows. The Service questions the usefulness of the screening results in setting flow targets since the screening analyses were very coarse and did not look at the entire life-cycle of anadromous fish. Target flows for anadromous fish should be established based on the best available information.

The description also states that the strategy should strive toward Columbia Basin Fish and Wildlife Authority (CBFWA) flow targets. CBFWA flow targets were established in March, 1990. More recent information indicates that these flow targets may not be adequate for some time periods such as the summer migration period. The Service will provide more specific input on this issue through the Anadromous Fish Work Group.

As the exact elevations for this proposal are not known, specific effects to resident fish and wildlife cannot be clearly identified.

7) Stable Storage Reservoirs with Near Natural Flows

8) Storage Reservoirs Filled in Late Spring

9) Pre-Regional Act Operations

Strategies such as nos. 8 and 9, that obviously have large negative impacts to anadromous fish and would obviously violate the ESA, should be eliminated from consideration at this point. We believe any further consideration of these options is a waste of time.

In conclusion, the alternatives which the Service will support are those that maximize anadromous fish benefits, and which also maintain the biological integrity of the system or which approximate historical conditions to the greatest extent, particularly in resource areas with endangered species or with high values for native species. The natural river and drawdown options, as proposed, create some concern from this perspective. While providing physical conditions which appear to be favorable for anadromous fish, they will greatly disrupt biological conditions with largely unknown effects. Our predictive capabilities are very low across the entire range of alternatives, but particularly so for these.

Final Evaluation Methodology

Final screening strategies have not yet been selected for resident fish or wildlife, and the Service, therefore, cannot comment directly on them. However, it has become apparent that if any meaningful results are to come from final screening, the methodology should be based on quantifiable physical data, at least in key resource areas. These data should tie habitat changes to operational changes. Changes in fish and wildlife populations could then be related to habitat changes, if so desired, and data are available.

Final evaluation methods have also not been determined for anadromous fish. The Service will provide further comments on this issue as evaluation methods are developed.

Data Gaps

There are data gaps at this time which, in our opinion, prevent final screening alternatives from even being developed. Data on flow-elevation relationships on the Hanford Reach have been requested through the wildlife work group and have not yet been provided. This is a key area where system operation continues to impact major biological resources, and changes could provide significant benefits. When appropriate data are provided, final alternatives must be generated that provide improved flows on Hanford. The alternatives should reduce the impacts from extreme daily peaks and more closely approximate historical flow patterns.

There are also gaps in technical or resource data which should be filled prior to selection of a preferred alternative. These are discussed below.

There was continuing discussion in the wildlife work group on the need for bottom contour data of the reservoirs to evaluate habitat which would be lost or created under different alternatives. These data were never provided. The same type of information should be the basis for evaluating incremental effects to resident fish, particularly in shallow water areas used for spawning and rearing.

Bathymetric data where landbridging of islands may occur has been lacking. The sole exception is at John Day, where data have been obtained under the SCS. These data would enable an accurate and direct evaluation of impacts to island habitat, rather than the crude type of modeling that has been performed.

There has been considerable discussion of effects on riparian vegetation of various drawdown scenarios, and no clear consensus has emerged as to exactly what would happen. This is an area where expert opinion should be enlisted if suitable data cannot be generated.

There is a lack of knowledge about molluscs in those areas which are proposed for drawdown, which was evident during the 1991-92 test drawdown of Lower Granite, when Federal candidate threatened and endangered species, the shortface lanx, (*Fisherola nuttalli*), and the California floater, (*Anodonta californiensis*), were exposed (Frest and Johannes, 1992a). Although species diversity is not high, a malacologist needs to evaluate habitat suitability and the potential drawdown impacts.

Threatened, Endangered and Candidate Species

Federally listed endangered, threatened, and candidate species may exist in the project area. The information provided here, however, does not constitute a formal listing of these species as required under section 7 of the ESA of 1973, as amended.

Kootenai River White Sturgeon

This section addresses issues of concern related to the Kootenai River White Sturgeon, (*Acipenser transmontanus*), a category 1 candidate species, and also identifies needs and opportunities for recovery of the species through the SOR planning process. It is the policy of the Service to seek opportunities and, when appropriate, implement processes to conserve candidate species and the ecosystems that support them. These conservation actions should tangibly contribute to the reduction of existing threats to candidate species.

Conservation actions undertaken on candidates may or may not reduce the need to list these species at a later date, but are viable interim measures. By undertaking conservation actions, the Service can retain management flexibility, reduce conflict with development, minimize the costs of recovery if listing is pursued, and avoid the potential need for restrictive land use policies in the future. Conserving candidate species can also avoid the confrontational atmosphere often encountered during listing, consultation, and implementing recovery actions.

BACKGROUND

Federal Status

The Kootenai River white sturgeon, (*Acipenser transmontanus*), was included as a category 1 candidate in the November 21, 1991, Animal Notice of Review (56 FR 58804). On June 11, 1992, the Service received a petition from the Idaho Conservation League, Northern Idaho Audubon, and Boundary Backpackers for a rule to list the Kootenai River white sturgeon as threatened or endangered under the ESA. A letter acknowledging receipt of the petition was mailed to the petitioners on July 1, 1992.

On July 10, 1992, the Boise Field Office completed a draft 90-day administrative finding on the petition. In the finding, we determined that the petition presented substantial information indicating that listing as threatened or endangered may be warranted; therefore, the Service will initiate a formal review of the status of the species.

On a related matter, the Service has joined efforts with the Idaho Department of Fish and Game (Department), the Corps of Engineers, Bonneville Power Administration, and other regional agencies in forming a Technical Committee to develop a pre-listing, regional recovery plan for the Kootenai sturgeon. The goal of the Technical Committee is to evaluate various alternatives that provide for natural flows necessary to meet sturgeon spawning and rearing needs in the Kootenai River within existing water management system constraints. The petitioners have declared that they will withdraw the petition if a pre-listing agreement can be drawn up that meets the approval of the Department and Service.

Life History and Current Status

The Kootenai River white sturgeon (*Acipenser transmontanus*) is restricted to approximately 270 river kilometers in the Kootenai River, primarily upstream of Corra Linn Dam from Kootenay Lake, British Columbia through the northeast corner of the Idaho panhandle to Kootenai Falls, 50 kilometers below Libby Dam, Montana. Kootenai Falls represents an impassible barrier to the upstream migration of the sturgeon. A natural barrier at Bonnington Falls downstream of Kootenay Lake has isolated the Kootenai River white sturgeon from other white sturgeon populations in the Columbia River Basin for approximately 10,000 years (Apperson and Anders 1991).

Recent genetic analysis using electrophoresis indicates that the Kootenai River sturgeon is a unique stock and constitutes a distinct interbreeding population (Setter and Brannon 1990). The electrophoretic analysis found ample evidence to describe these fish as a genetically distinct, isolated population based on differences in allele frequencies, genetic distance calculations and the overall quantity of variation displayed.

In general, individual sturgeon are broadly distributed and may move widely throughout their range in the Kootenai River and Kootenay Lake, although they are not commonly found upstream of Bonner's Ferry into Montana (Apperson and Anders 1991). During the summer, when sturgeon are relatively inactive, they appear to inhabit water deeper than 12 meters, while individuals found in shallower water were exhibiting more extensive or seasonal movements. Kootenai River sturgeon feed on a variety of prey items, including bottom dwelling macroinvertebrates and fish.

Based on recent studies, the population of Kootenai River sturgeon has declined to less than 1,000 individuals (Apperson and Anders 1991). This translates to an average density of seven sturgeon per river kilometer from Kootenay Lake upstream to Bonners Ferry. The population is considered reproductively mature, with approximately 80 percent of the sturgeon over 20 years old. There has been an almost complete lack of recruitment of juveniles into the population since 1974, soon after Libby Dam began operation (Partridge, 1983, Apperson and Anders, 1991). The youngest fish sampled in the most recent study was from the 1977 year class.

10

The lack of natural flows in the Kootenai River below Libby Dam is considered the primary reason for the Kootenai River sturgeon's declining population (Apperson and Anders, 1991). Since 1972, when Libby Dam began operating, spring flows in the Kootenai River have been reduced an average of 50 percent and winter flows have increased by 300 percent over normal. As a consequence, natural high spring flows rarely occur during the May to July sturgeon spawning season. In addition, elimination of side channel slough habitat in the Kootenai River floodplain due to diking to protect agricultural lands from flooding is a contributing factor to the sturgeon decline. The former slack water areas were considered important rearing and foraging habitat for early age sturgeon and their prey (Partridge 1983).

Recovery Needs and Candidate System Operating Strategies

As stated previously, the lack of natural flows in the Kootenai River below Libby Dam is the primary reason for the Kootenai sturgeon's declining population. It is the Service position that providing for successful "natural" reproduction will form the basis for all Kootenai sturgeon recovery efforts. Therefore, any pre-listing recovery plan should focus efforts towards changes in the existing flow management for the Kootenai River necessary to create an ecosystem that allows sturgeon to reproduce both naturally and successfully.

With these concerns in mind, the Service has prepared comments on the 10 candidate SOS alternatives as they might affect management and future recovery actions on behalf of the Kootenai River white sturgeon. Because the summary information available at this time describing the SOS elements and screening alternatives is limited, we have narrowed our evaluation and comments to only those alternative SOS's that provide obvious benefits or adverse impacts to sturgeon recovery.

SOS Nos. 1 to 5:

The Service believes that benefits to Kootenai sturgeon from implementing any of the first 5 SOS alternatives would be minimal or non-existent. None of these alternatives describes how flow operations would be affected in the Upper Columbia River above Grand Coulee, therefore, we must assume that existing power and flood control curves would be retained for the Kootenai River and non-power needs are not considered.

SOS No. 6: Target Flows for Anadromous Fish Year Round

It appears this alternative would provide increased natural flows in anadromous waters during the spring outmigration season, especially during years of normal or above runoff. This operating strategy would benefit Kootenai sturgeon only if realistic flow targets for the species could be determined for each life stage and Libby Dam is then operated for the species' benefit.

11

SOS No. 7: Stable Storage Reservoir Elevations with Near Natural Flows

Of the 10 SOS alternatives, this operating strategy would, under certain conditions, provide the most benefits for Kootenai River sturgeon. Because storage reservoirs would pass "approximately natural inflows", spring spawning flows necessary for successful sturgeon spawning and early rearing could be achieved most years.

However, two critical assumptions of this SOS must be considered and maintained to benefit Kootenai River sturgeon: 1) biological rule curves are developed for sturgeon; and 2) Canadian reservoirs are held at stable elevations.

1) The first element of this SOS states that "storage reservoirs are kept at target elevations less than full based on biological rule curves." The Service feels that any consideration of target reservoir elevations for the Kootenai River system will need to incorporate biological rule curves for all resident fish, including the riverine Kootenai River sturgeon and burbot. The SOR screening process needs to better define what is a resident fish or what resident fish species are being evaluated because the screening alternatives and elements seem to consider project impacts to resident fish/fisheries found only in reservoirs.

2) Libby Reservoir must be held at a stable elevation for this SOS to benefit Kootenai sturgeon. Since this assumption violates the scoping of the SOR, Reclamation will need to consider various flow management options outside of SOR for the Kootenai River below Libby dam that provide natural flows necessary for successful sturgeon spawning and rearing. These options could include renegotiating power contracts with Canada and seasonal out-of-basin power exchanges that would allow Libby Reservoir to operate as a stable elevation pool.

SOS No. 8: Storage Reservoirs Filled in Late Spring.

Under this alternative, spring flows are used to fill the storage reservoirs, and natural inflows would not be available in downstream reaches. Implementation of this alternative would not provide the natural spring flows necessary for successful sturgeon spawning and early rearing in the Kootenai River below Libby Dam. Therefore, under this operating strategy the Service would determine whether it is warranted to proceed with a proposed listing rule for the species.

This flow scenario may also adversely impact other resident fish in the Kootenai River that have co-evolved with the same natural hydrograph as the Kootenai sturgeon. These species include the burbot or ling, and the Kootenay Lake stock of kokanee salmon.

SOS No. 9: Pre-Regional Act Operations

Since this SOS would be subject only to power and flood control constraints, measures to protect, maintain and recover Kootenai River sturgeon would

12

require further negotiation, possibly including a special spill agreement. Similar to SOS no. 8, the Service would determine that implementing this operating strategy would not provide the flows necessary for successful spawning and early rearing and would constitute a threat to the sturgeon's continued existence. Therefore, it would be warranted to proceed with a proposed listing rule for the species.

Snake River Aquatic Snails

This section addresses issues of concern regarding five Snake River aquatic snails, the Bliss Rapids snail (undescribed), Snake River Physa (*Physa natricina*), Idaho Springsnail (*Fontelicella idahoensis*), Utah valvata snail (*Valvata utahensis*), and the Banbury Springs lanx (*Lanx n. sp.*), proposed for listing as endangered in south central Idaho (55 FR 51931). Because operation of the Columbia River system incorporates water stored and released from the Snake River Basin above Brownlee Reservoir, the Service feels that the SOR should analyze impacts to these species from project changes in the upper Snake River Basin.

The section also identifies needs and opportunities for recovery of the species through the SOR planning process. The Boise Field Office has submitted a final rule with the Service's recommendations for listing the five species, and we anticipate a final listing determination in the Federal Register at any time.

BACKGROUND

Federal Status

Based upon status surveys for these candidate species and also acting on information received for the Utah valvata snail, the Service published a proposed rule (December 18, 1990; 55 FR 51931) for listing as endangered five aquatic snails, the Bliss Rapids snail, Snake River Physa snail, Idaho Springsnail, Utah Valvata snail and the Banbury Springs Lanx. The proposed rule included information provided by Taylor (1982 a, c, d, and 1988) and Frest (1989b) on the Bliss Rapids, Idaho Springsnail, and Snake River Physa snails, by Taylor (1982b) for the Utah valvata snail, and by Frest (1989a) and the Service for the Banbury Springs lanx.

In preparing the Final Rule, the Service considered comments received during three public comment periods and also oral testimony from two public hearings. In addition, aside from previously cited studies and reports used for the proposed rule, the Service reviewed and considered new information regarding the distribution and life history for the five taxa from eight recent mollusc surveys in the Snake River basin. After carefully assessing this information, the Boise Field Office submitted the final rule with our recommendations concerning the listing of the five Snake River snails during May,-1992.
If the Final Rule is published in the Federal Register and the snails are federally listed, section 4(f) of the ESA directs the Service to develop and implement a recovery plan. The goal of recovery is the maintenance of secure, self-sustaining wild populations of species with the minimum necessary investment of resources. The Service will coordinate recovery actions with

13

other Federal, State and local agencies, private individuals, and major land users to develop and implement an effective recovery program. In addition, the Service also plans to pursue actions prior to listing to assure recovery, such as implementation of a conservation agreement.

Life History and Current Status

Ecologically, the five species share many habitat characteristics, and in some locations two or more are sympatric. Basically, they require cold, clean, well-oxygenated flowing water of low turbidity. All the species except the Utah valvata prefer gravel to boulder size substratum. Despite these affinities, each of the five species has slightly different habitat preferences. The Idaho springsnail and Snake River Physa are found only in the free-flowing mainstem Snake River while the remaining three candidates are usually associated with spring or spring-like river habitats. For example, the Bliss Rapids snail can be found in both small, shallow spring or large, deep spring outflows, while the Banbury Springs lanx is known only in large spring outflows. The Utah valvata snail is able to tolerate slower flowing environments with silty vegetated substrate better than the rest, although it cannot tolerate true impoundment or reservoir conditions (Frest 1989b). In the mainstem river, they are found in areas of the river not subject to daily or seasonal fluctuations. None of the species tolerates whitewater areas with rapid flow.

The species also share similar life history characteristics related to longevity. With the possible exception of Snake River Physa and Utah valvata, the species are considered annual species with an average longevity of 1 year. Bliss Rapids snail and Banbury Springs lanx experience a dieoff of older adults during the late winter-early spring season following reproduction, although for the Bliss Rapids snail the dieoff is less pronounced in large-spring colonies (Frest and Johannes 1992b). Utah valvata are believed to have a maximum longevity of 2 years, although a majority only survive a single year. Although little is known of general life history for Snake River Physa, longevity likely coincides with related Physa sp. and other pulmonates, averaging 2 years.

Implications to survival of the candidate species is that annual species with localized distribution and small populations become vulnerable to extirpation from stochastic and/or catastrophic changes in environmental conditions. The remaining free-flowing river and spring/springstream outflow habitats for these species have been fragmented between several impounded reaches of the Snake River in southern Idaho. The Swan Falls, C. J. Strike, Bliss Rapids, Lower Salmon Falls, and Upper Salmon Falls Dams on the mainstem Snake River inundated free-flowing habitat and have extirpated populations of these species. Past diversion of large spring outflows for hydroelectric and agricultural purposes have destroyed habitat for Bliss Rapids and Utah valvata snails in Box Canyon (Taylor 1985) and Thousand Springs.

Another more recent threat is the discovery of the New Zealand mudsnail (*Potamopyrgus antipodarum*) in the middle Snake River. The eurytopic mudsnail is experiencing explosive growth in the river and shows a wide range of tolerance for water fluctuations, velocity, temperature, and turbidity. The species is more tolerant of warmer, pollutant-impacted waters than are the native snails. At present, it is not abundant in habitats preferred by Banbury Springs lanx, Bliss Rapids snail, or the Utah valvata. However, the species does compete directly for habitats of the Snake River Physa and Idaho springsnail in the mainstem Snake River.

In summary, with the exception of lanx (discovered in 1988), four of the taxa have declined over all but a small fraction of their historical range. The free-flowing, cool water environments required by these species have been impacted by and are vulnerable to continued adverse habitat modification and deteriorating water quality from: hydroelectric development, peak-loading effects from existing hydroelectric project operations, water withdrawal and diversions, water pollution, possible habitat competition from an exotic snail, and inadequate regulatory mechanisms. Low flow conditions due to the effects of over 5 years of drought have contributed to declining water quality conditions in the middle Snake River.

Today, these endemic species are currently restricted to a few isolated free-flowing reaches or spring alcove habitats in the middle Snake River characterized by cold, unpolluted water. Lanx is known only from three spring stream locations along a 5-mile stretch of the Snake River near Hagerman.

Recovery Needs and Candidate System Operating Strategies

In general, operating strategies that would minimize peak-loading effects and augment existing flows through the middle Snake River would benefit the five taxa. Minimizing diel peak-loading, a practice that results in dewatering snail habitats in shallow, littoral shoreline areas, would allow four of the five taxa, except Lanx, to recolonize these favorable habitats. Augmenting flows through the Middle Snake River, especially during the low flow irrigation season, would improve water quality in this stretch by increasing dissolved oxygen and lowering water temperatures.

The SOR is not evaluating operating strategies in the Snake River above Brownlee. Therefore, we have limited our comments only to SOS No. 1 because this is the only alternative that discusses changes in flow or would depend upon flow augmentation from this reach of the river to meet SOR objectives.

1) Post-regional Act with ESA and 1992 Options EIS Operations

One SOS No. 1 operating element states that "137 KAF is released from Brownlee via outflow increased during July and returned to storage by increase in inflow from Upper Snake release." While a significant portion of the 137 KAF refill will likely come from releases at Cascade and Deadwood Reservoirs, the Service is aware of efforts to secure water from the Upper Snake through Bonneville Power Administration's water rental negotiations.

In general, the Service supports flow augmentation through the Middle Snake River through the summer irrigation season to benefit habitats for the candidate snails. However, our primary concern is that the water remains in and flows through the mainstem of the Snake River and is not diverted through the irrigation canal network. Reclamation should ensure that any proposal to provide water from the Upper Snake River for flow augmentation below Brownlee Reservoir transports the water through the mainstem river.

In summary, the Service will extend protection to these taxa and their habitat through the recovery process and through the section 7 jeopardy standard. Although the remaining nine SOS alternative summaries do not discuss or describe obvious changes in flow management in the Snake River above Brownlee Reservoir, Reclamation will need to evaluate how each SOS alternative might impact these taxa.

Coordination Act Report Development

The Coordination Act Report (CAR) for the SOR may be developed from the perspective that the Columbia River should be treated as an ecosystem when considering changes to hydropower operation throughout the basin. The SOR process provides an excellent opportunity to protect and enhance an entire ecosystem - the Columbia River Basin Ecosystem.

The dominant theme of the CAR may be that the hydropower system would be best operated in a way which most approximates the natural hydrograph (i.e. pre-impoundment conditions). In this manner, impacts from hydropower development to native species of fish and wildlife from pre-impoundment conditions should be minimized for all native species throughout the basin. This is based on the logic that since all native species of fish and wildlife in the Basin co-evolved under pre-impoundment conditions, approximating those conditions should minimize impacts to all native species, minimizing the amount of mitigation necessary for impacts to each individual species. This approach should be viewed as an effort to effect ecosystem protection.

Operating the system to approximate natural river flows is also consistent with the direction of the ESA to protect listed species and the ecosystems on which they depend. With this approach, most native species, including those already listed under the ESA, will also suffer the least amount of impact beyond the baseline of pre-impoundment conditions. The Service acknowledges that strict adherence to this approach may cause some native species to decline in abundance from levels which exist today, if those population levels are artificially high compared to the baseline of pre-impoundment conditions.

The idea of ecosystem protection is based on a prioritization system which considers native species to be more important than non-native, or exotic species. This prioritization system may guide the Service throughout the CAR process. For example, operating strategies which approximate historic river flow conditions could benefit anadromous fish migration, sturgeon spawning, and Canada goose nesting on river islands. However, it may adversely impact reservoir fisheries for non-native fishes such as the artificially created Kokanee Fishery in Lake Roosevelt.

One obvious potentially serious shortfall of operating the system in the manner outlined above is that several impoundments may exist in series in a given drainage. Therefore, consideration must be given to how to operate these serial projects to provide the greatest benefit to indigenous species with the least impact to non-native fish and wildlife resources. In some

16

instances, it may be appropriate to consider managing for an entirely different composition of exotic fish or wildlife species at a given project site in an effort to mitigate for impacts of operating the system to best approximate natural flow conditions. Also, consideration must be given to "institutionalized" mitigation measures, especially those which support native fauna, such as the National Wildlife Refuge system on the mid-Columbia River.

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