Upper Columbia Alternative Flood Control and Fish Operations

Columbia River Basin

Draft Environmental Impact Statement
Appendices A through N

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Pacific Northwest Region
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APPENDIX A

Flood Control in the Columbia River Basin

Appendix A FLOOD CONTROL IN THE COLUMBIA RIVER BASIN

A.1 System Flood Control

On September 16, 1964, the United States and Canada ratified the Columbia River Treaty (CRT), which forms the basis for major hydropower and flood control related development on the Columbia River system. Under terms of the CRT, four major water storage projects were built: Mica, Arrow, and Duncan dams in Canada and Libby Dam in the U.S. The combined active storage of these treaty projects is about 25 MAF (13 MAF for primary flood control), more than double the storage capability of the system. In addition to the CRT projects, a number of other non-treaty storage projects in the basin, including Hungry Horse Dam on the South Fork Flathead River in Montana, also provide flood control storage that is managed for system and local flood control.

To manage system flood control operations, the U.S. and Canada developed of the Columbia River Treaty Flood Control Plan in 1972. "Standard" flood control (also named BASE CRT-63), completed June, 1991, updated the 1972 CRT Flood Control Plan. The basic objective of the Columbia River system flood control operations are to regulate the total reservoir system to minimize flooding at all potential flood-prone areas in Canada and the United States when possible, and, in years with very high runoff, to regulate flow at The Dalles, Oregon, to prevent storage reservoirs from filling too soon and causing the system to be in an uncontrolled situation. Flood control operations are managed to provide flood control while insuring with a high level of confidence that storage projects are refilled at the end of the spring runoff. Elements of development of annual flood control strategies include development of seasonal runoff forecasts, use of storage reservation diagrams, determination of the Initial Control Flow (which determines when system refill begins), regulation of projects to avoid jeopardizing refill, if possible, and local flood control operating criteria and project operating limits.

In the context of system flood control operations, storage reservoirs throughout the Columbia River Basin operate during January through April using guidance provided by a storage reservation diagram (SRD). A SRD shows how much water storage space is required for the current seasonal runoff forecast. In January, water supply forecasts are developed for each sub-basin and for the entire Columbia River system to The Dalles. Based on the water supply forecast, and using the SRD as guidance, the Corps will calculate the end of January through April upper storage limit at each reservoir that will provide for meeting flood control objectives at The Dalles. In February, a new water

supply forecast is used to develop updated end of February through April upper storage limits. The process repeats for each month through April.

In May through June, the refill of reservoirs is guided by upper flood control elevation limits, which vary each year. The May-June upper limits are dependent upon the natural flow at The Dalles, the amount of runoff that may remain in the system, the amount of storage available in the system, and the forecast of weather conditions.

A.2 Local Flood Control at Libby and Hungry Horse Dams

In addition to providing water storage for system flood control, water storage behind Libby and Hungry Horse Dams also provides local flood control for the river reaches closer to the projects. Each reservoir's fall and winter drawdown schedule is designed to provide space for storing both rainfall and snowmelt runoff. Storage of snowmelt runoff for system flood control provides protection for local areas as well. Operations for local flood protection occur on a real-time basis and are provided by individual project operations.

To the extent possible, Libby is operated to maintain flow in the Kootenai River below flood stage at Bonners Ferry, Idaho, of elevation 1764 feet.[1] Similarly Hungry Horse is operated to try to maintain the gage reading for the Flathead River at Columbia Falls, Montana, below 13 feet [2] (2977.67 feet msl) . In some cases when high volume inflow forecasts persist well into the spring season, it may be necessary to regulate dam releases in the interest of local flood control at high levels for extended periods of time. Although operators desire to maintain flow below flood stage at Bonners Ferry or Columbia Falls, there will be occasions when flood stage is exceeded with any flood control operation.

Additionally, there may be some occasions where the actual reservoir elevations may be higher than the maximum elevation targets defined flood control rule curve. For example, high runoff events during the winter due to rainfall or warm periods may require a dam to reduce outflows to moderate downstream river flows, resulting in an increase in reservoir elevation. After the end of the runoff event, the water that was stored during the runoff event would be released in an attempt to bring the reservoir back to the elevation defined by the flood control rule curve. In another example, the International Joint Commission (IJC) Order of 1938 requires lowering of Kootenay3

[1] Unless otherwise noted, all elevations in this document are referenced to the National Geodetic Vertical Datum of 1929 (mean sea level or msl).
[2] The flood stage at the Columbia Falls gage is 14.0 feet (2987.67 feet msl), but, when possible, Reclamation regulates to 13.0 feet (2986.67 feet msl).
[3] The American spelling is Kootenai. The Canadian spelling is Kootenay.

Lake in Canada to specific upper limit elevations during the winter months of January through March. Libby Dam releases flow into Kootenay Lake. There are times from January through March when releases from Corra Linn Dam (and the natural constriction at Grohman Narrows) at the outlet of Kootenay Lake are not enough to meet the upper limit elevation. When this occurs, the outflow from Libby Dam is reduced so that Kootenay Lake will not go above the upper limit elevation. The result is that Lake Koocanusa may be above its flood control rule curve by the end of March. The Columbia River Treaty (CRT) acknowledges the operation of the storage by the United States shall be consistent with the 1938 IJC Order on Kootenay Lake.

A.2.1 Standard and VARQ Flood Control

Prior to Endangered Species Act listings of a variety of fish species in the Columbia River Basin, Libby and Hungry Horse dams were operated primarily for flood control and hydropower using Standard Flood Control (FC). The Standard FC SRDs for Libby and Hungry Horse are shown in Figure A-1 and Figure A-2, respectively. Under Standard FC, the dams would generally draft deeply during the January-April period to provide water storage for flood control. Then, during refill, dam discharges would be held at minimum flows.

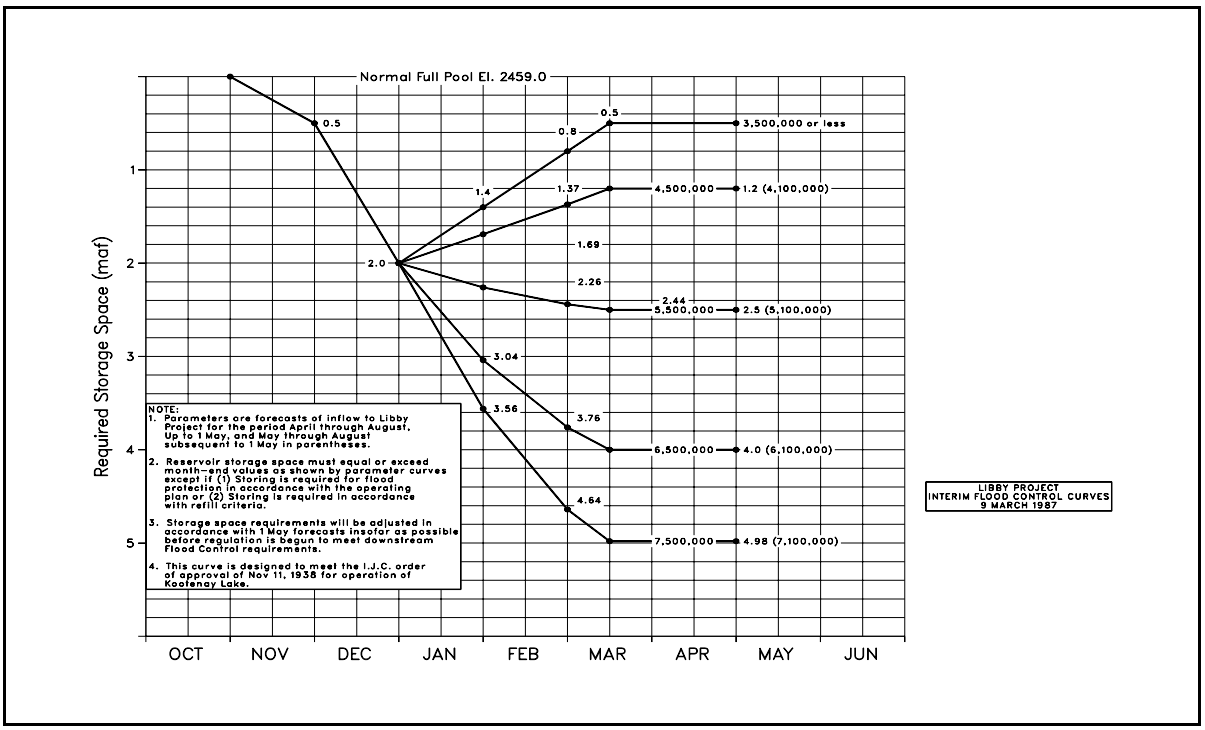

Figure A-1. Standard Flood Control Storage Reservation Diagram at Libby Dam.

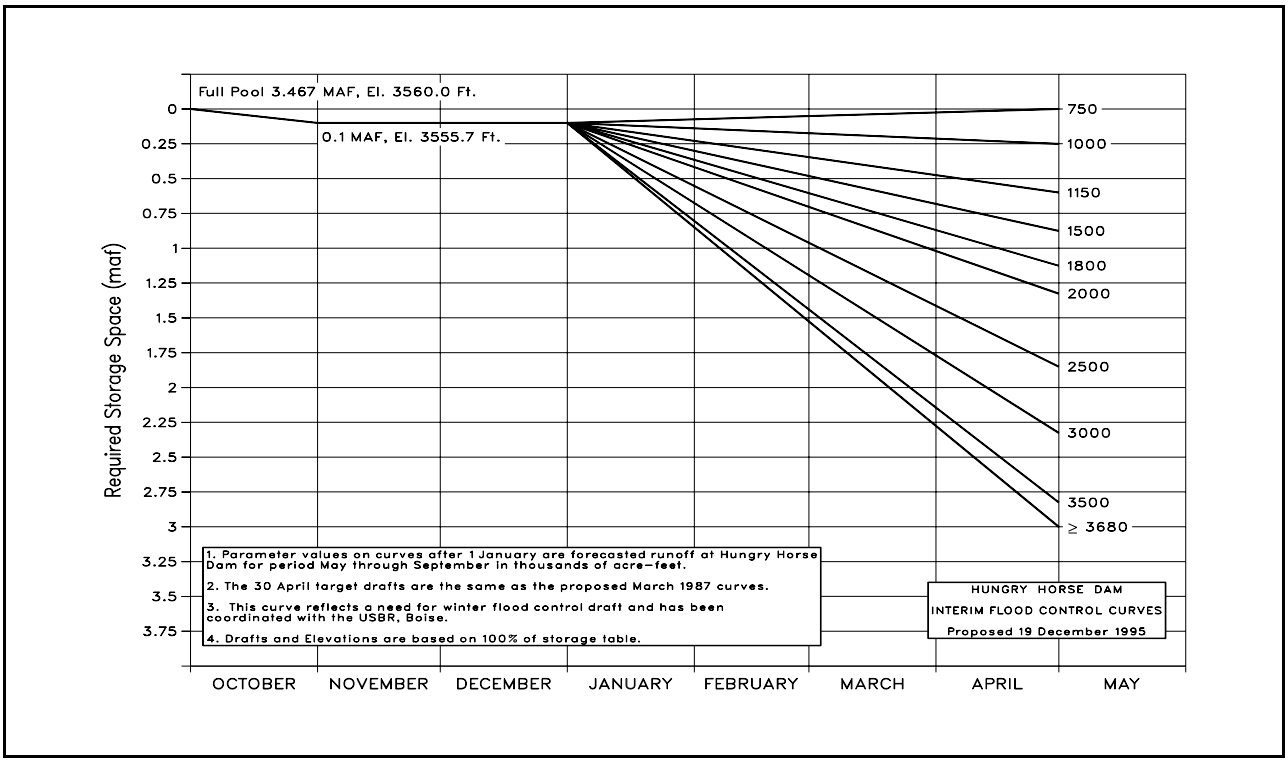

Figure A-2. Standard FC Storage Reservation Diagram, Hungry Horse Dam.

Since the early 1990s, Columbia River water management has changed due to the Endangered Species Act and the listing of various species of fish (Columbia and Snake River salmon, Kootenai River white sturgeon, and Columbia Basin bull trout) as threatened or endangered. As part of efforts to conserve and recover the listed fish species, the Corps and Reclamation release water from Columbia Basin dams for flow augmentation. At Hungry Horse Dam, these releases occur during the summer months primarily in the form of flow augmentation for salmon and during the fall and winter primarily in the form of maintenance of minimum flows for bull trout and. Libby Dam provides flows augmentation for white sturgeon in addition to summer bull trout minimum flows and salmon flow augmentation. These fish flow releases exceed those envisioned in the Standard FC plan and have adversely affected the likelihood and frequency of refill at each project.

With the objective of better assuring reservoir refill while providing fish flows, the Corps developed variable discharge (or VARQ, with Q representing engineering shorthand for discharge) FC. VARQ was first introduced as a possible alternative in the *Columbia River System Operation Review, November 1995 (SOR)*. The SOR was basically an EIS on operational actions recommended by the FCRPS Biological Opinions issued by the National Marine Fisheries Service (NMFS, now known as NOAA Fisheries) and the U.S. Fish and Wildlife Service (USFWS) in the mid-1990s. A more detailed analysis of VARQ FC was conducted for the *Columbia River Basin System Flood Control Review,*

February 1997. Results of both these evaluations indicated that more work was needed to identify the impacts to providing local flood protection for the Kootenai River. This work was completed in *Kootenai River Flood Control Study, Analysis of Local Impacts of the Proposed VARQ Flood Control Plan, January 1998*. Additional analysis of VARQ FC is contained in the body of the EIS at hand.

In their 2000 FCRPS Biological Opinions, NOAA Fisheries USFWS recommended implementation of VARQ FC at Hungry Horse and Libby dams. Recently, the NOAA Fisheries 2000 FCRPS has been superseded, but implementation of VARQ FC was carried forward in the Action Agencies Updated Proposed Action (UPA) for the NOAA Fisheries 2004 FCRPS Biological Opinion.

VARQ procedures require less system flood control space be made available prior to spring runoff and allows outflows during refill to vary based on the water supply forecast. The SRDs for VARQ FC at Libby and Hungry Horse dams are shown in Figure A-3 and Figure A-4, respectively. Comparing the SRDs for VARQ FC and Standard FC for each project, note that reservoir draft targets for a given water supply forecast tend to be less under VARQ FC than Standard FC for all but very high runoff years. At Libby, reservoir levels during July through April would likely be higher with VARQ FC for years with water supply forecasts between about 80% and 120% of average.4 At Hungry Horse, reservoir elevations would be higher with VARQ FC for years with water supply forecasts between about 80% and 120%.

The basic premise of VARQ FC is that the outflows during the refill period can vary and be higher than minimum flows as based on the seasonal water supply forecast (hence the name VARQ). Accordingly, if the amount of water that is normally stored during the refill period is instead passed through the project, then the amount of storage space needed in the project for flood control is reduced without compromising system flood control. In years where the water supply forecasts at Libby and Hungry Horse are expected to be about 80% to 120% of average, the VARQ FC refill outflow may be greater than minimum flows during the refill period of May through July. Higher releases during refill are a result of higher elevations at the start of the refill period than would have been under the Standard FC SRD. In years where the seasonal runoff

[4] The SRDs for VARQ FC require less flood control storage for water supply forecasts between about 60% and 130%. However, due to physical constraints on dam operation, the volume of reservoir inflow, and limitations on Libby Dam outflows due to constraints of the International Joint Order of 1938 concerning Kootenay Lake levels, the actual flood control operations for years with water supply forecasts greater than about 120% of average or between 60% and 80% of average would be the essentially the same for both VARQ FC and Standard FC. For example, although the SRDs for VARQ FC and Standard FC are slightly different in years with water supply forecasts between 60% and 80% of average, maintaining minimum required outflows from the dam would likely result in the same end-of-month reservoir elevations under VARQ FC or Standard FC. In years with water supply forecasts higher than 120%, limitations on Libby Dam discharges necessary to comply with the IJC Order of 1938 would likely control reservoir elevations to levels above either VARQ or Standard FC rule curve targets (resulting in trapped storage).

forecast is high (above 120% of the average volume at both Libby and Hungry Horse), VARQ FC storage space for flood control and outflows during refill are the same as Standard FC.

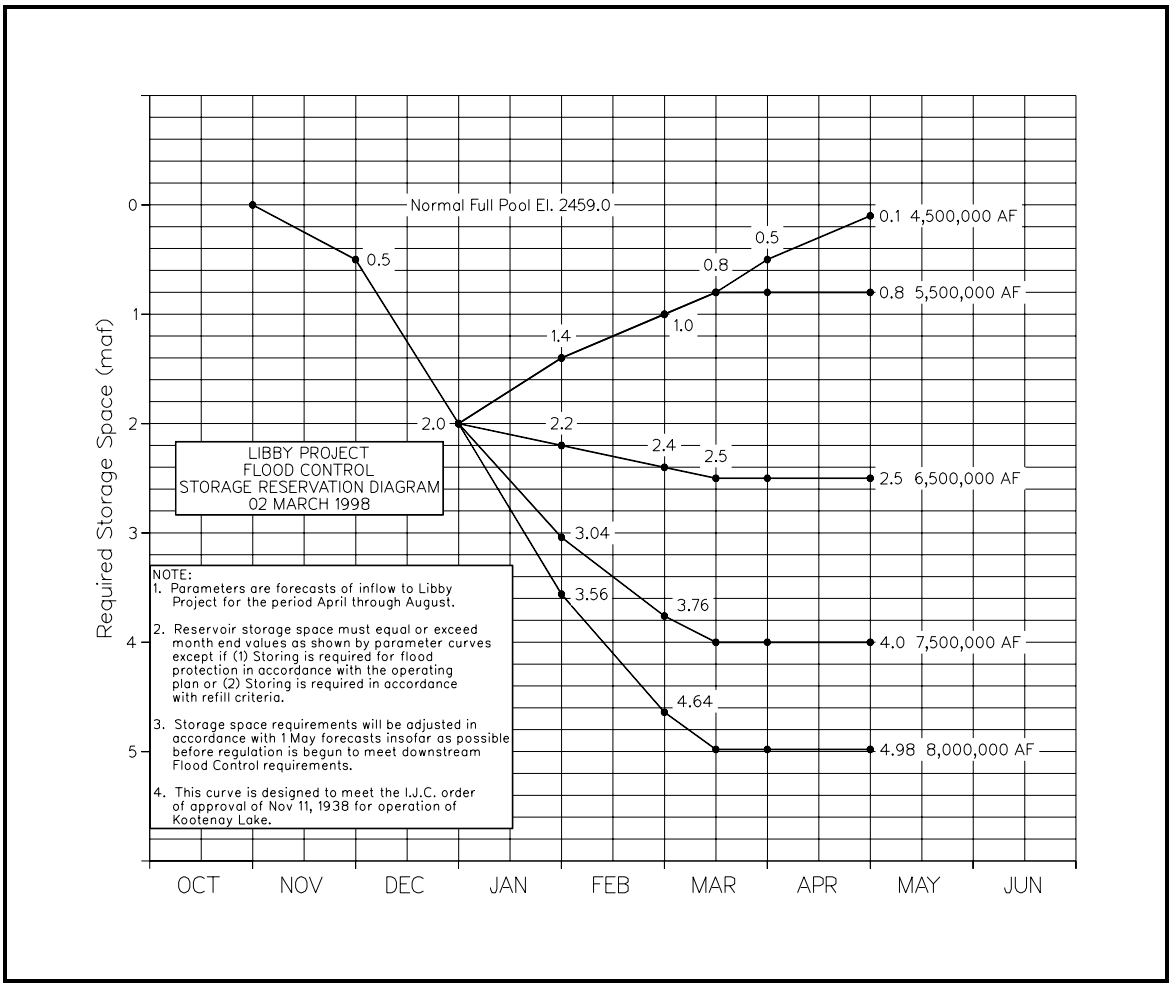

Figure A-3. VARQ FC Storage Reservation Diagram at Libby Dam.

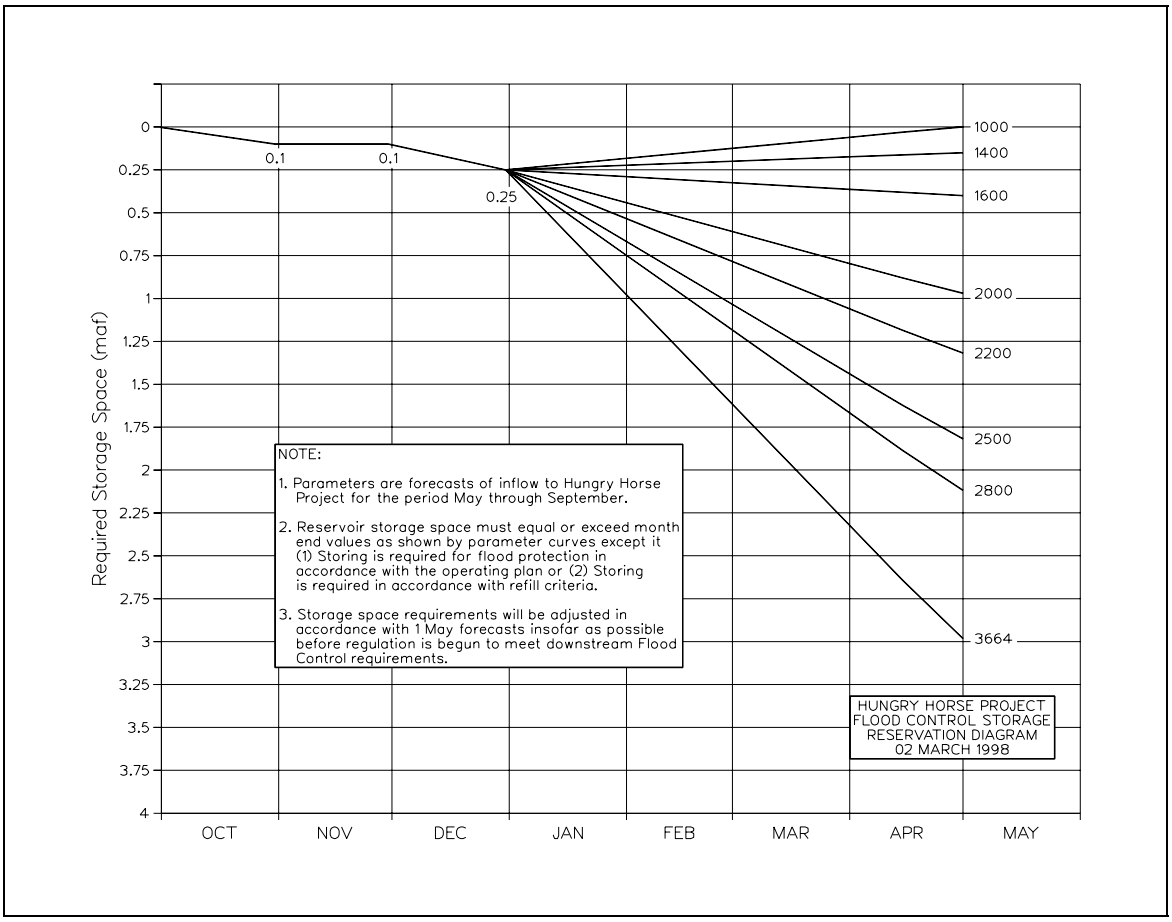

Figure A-4. VARQ FC Storage Reservation Diagram, Hungry Horse Dam

At Libby and Hungry Horse, a VARQ FC operation does not have any fish flow operations embedded in the operating strategy; however, VARQ FC does enable the operating agencies to more reliably supply spring flow for fish in the Kootenai River immediately downstream of the project. The assumption is that VARQ FC can provide higher dam discharges required for conservation and recovery of threatened and endangered species while maintaining flood protection and improving the chance of reservoir refill.

The Grand Coulee flood control draft requirement is a function of the expected April-August unregulated runoff at The Dalles and the available storage space upstream of The Dalles on May 1. Upstream space is available in Mica, Arrow, Libby, Duncan, Hungry Horse, Kerr, Noxon, Albeni Falls, Dworshak, Brownlee and John Day. The unregulated April-August runoff at The Dalles is adjusted downward for the total amount of upstream storage available on May 1 at these projects. The adjusted runoff is then used with the Grand Coulee SRD to determine the flood control draft requirement.

Under VARQ FC, Libby and Hungry Horse may be more full at the end of April, which reduces the amount of available upstream storage space on May 1. In order to maintain

flood protection at The Dalles, this requires an increased flood control draft at Grand Coulee in years with water supply forecasts between 86% and 100% of average. The difference in flood control draft at Grand Coulee does not equal the net change in draft at Libby and Hungry Horse caused by VARQ. The primary reason that Reclamation and the Corps are co-leads on this EIS is because impacts due to the change in flood control operations at both Libby (a Corps project) and Hungry Horse (Reclamation project) affect operations at Grand Coulee (Reclamation project).

APPENDIX B

Libby Dam Hydro-Regulation Modeling Report

Hydrologic Analysis of Upper Columbia Alternative Operations: Local Effects of Alternative Flood Control and Fish Operations at Libby Dam

July 2004

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Errata Sheet—

Upper Columbia Alternative Flood Control (VARQ) and Fish Operations EIS –

Hydrologic Analysis of Upper Columbia Alternative Operations: Local Effects of Alternative Flood Control and Fish Operations at Libby Dam

Nomenclature Corrections

The following information should be used when reading the subject report.

Standard FC with fish flows at powerhouse capacity (Standard w/ FF @ powerhouse): corresponds to **Alternative LS1** in EIS

VARQ FC with fish flows at powerhouse capacity (VARQ w/ FF @ powerhouse): corresponds to **Alternative LV1** in EIS

Standard FC with fish flows at powerhouse plus 10 kcfs capacity (Standard w/ FF @ powerhouse +10 kcfs): corresponds to **Alternative LS2** in EIS

VARQ FC with fish flows at powerhouse plus 10 kcfs capacity (Standard w/ FF @ powerhouse+10 kcfs): corresponds to **Alternative LV2** in EIS

Standard FC benchmark: corresponds to **Benchmark Operation LS** in EIS

VARQ FC benchmark: corresponds to **Benchmark Operation LV** in EIS

Table of Contents

Page B-

Nomenclature Corrections ii
1.0 Introduction 1
1.1 Need for Study 1
1.2 Status of Study 3
1.3 Description of Modeled Simulations 4
1.3.1 Description of Flood Control 5
1.3.1.1 Standard FC Draft 5
1.3.1.2 VARQ FC Draft 6
1.3.1.3 Standard FC and VARQ FC Refill 7
1.3.2 Description of Fish Flows 7
1.3.3 Use of Sensitivity Runs 8
1.3.4 Statistical Analysis 8
1.3.5 Transmission Limitations 8
2.0 Hydrologic Analysis of Flood Control Methods 9
2.1 Hydro-Regulations 9
2.1.1 Period of Record for Flood Control Modeling 9
2.1.2 Water Supply Forecasts 9
2.1.3 Upper Rule Curves 10
2.1.4 Powerhouse Capacity 10
2.1.5 The 1938 IJC Order on Kootenay Lake 10
2.1.6 Initialization 11
2.1.7 Local Flood Control and Refill 11
2.2 Model Results 12
2.2.1 Analysis of Results 13
2.2.2 Lake Koocanusa 13
2.2.3 Libby Dam Outflow 19
2.2.4 Water Quality 21
2.2.5 Storage Above the URC 21
2.2.6 Bonners Ferry 24
2.2.7 Kootenay Lake 27

2.2.8 Duncan Dam 32
3.0 Hydrologic Analysis of Flood Control Methods Combined with Fish Flows 32
3.1 Hydro-Regulations 32
3.1.1 Background on Fish Flow Simulations 32
3.1.2 Initialization 33
3.1.3 Description of "Fish Flow" Template 33
3.1.3.1 Sturgeon Operation 33
3.1.3.2 Bull Trout Operation 35
3.1.3.3 Salmon Operation 36
3.1.3.4 Fish Flow Template vs. Actual Operations 36
3.2 Model Results 37
3.2.1 Analysis of Results 37
3.2.2 Lake Koocanusa 37
3.2.3 Libby Dam Outflow 41
3.2.4 Water Quality 44
3.2.5 Bonners Ferry 45
3.2.6 Kootenay Lake 48
3.2.7 Duncan Dam 53
4.0 Sensitivity Analysis 53
4.1 Hydro-Regulations 53
4.1.1 Background on Sensitivity Simulations 53
4.1.2 Description Sensitivity Scenarios 53
4.2 Model Results 55
4.2.1 Analysis of Results 55
4.2.2 Bonners Ferry Peak 1-day Stage 55
4.2.3 Bonners Ferry Maximum 15-day Average Stage 57
5.0 Conclusions 59
6.0 References 59

List of Tables

Page B-

Table 1. Simulation Runs....4
Table 2: Simulated Reservoir Elevation on 31 July (Flood Control only)....14
Table 3. Modeled TDG Exceedance, Flood Control Simulations....21
Table 4. Minimum bull trout flows to be provided from Libby Dam....36
Table 5. Monthly Average Outflow from Libby Dam – all scenarios....42
Table 6. Modeled TDG Exceedance, Flood Control with Fish Flows at Powerhouse Capacity Simulations....45
Table 7. Uncertain Parameters Modeled in Sensitivity Analysis. 54

List of Figures

Page B-

Figure 1. Kootenai River Basin Showing Canadian and U.S. Dams....2
Figure 2. Columbia River Treaty Flood Control Operating Plan Storage Reservation Diagram (SRD) at Libby Dam....6
Figure 3. VARQ Storage Reservation Diagram (SRD) at Libby Dam....7
Figure 4. VARQ Outflows at Libby Dam....11
Figure 5. Elevation-Duration Analysis: Lake Koocanusa Daily Elevation (January-April), Flood Control Simulations - Standard FC and VARQ FC Benchmarks....15
Figure 6. Elevation-Duration Analysis: Lake Koocanusa Daily Elevation (May), Flood Control Simulations - Standard FC and VARQ FC Benchmarks....16
Figure 7. Elevation-Duration Analysis: Lake Koocanusa Daily Elevation (June), Flood Control Simulations - Standard FC and VARQ FC Benchmarks....17
Figure 8. Elevation-Duration Analysis: Lake Koocanusa Daily Elevation (July), Flood Control Simulations - Standard FC and VARQ FC Benchmarks....18
Figure 9. Flow-Frequency Analysis: Libby Dam Maximum Daily Outflow (May-July), Flood Control Simulations - Standard FC and VARQ FC Benchmarks 20
Figure 10. Storage above the URC at Libby Dam as a result of Standard FC and VARQ FC Benchmarks....23
Figure 11. Stage-Frequency Analysis: Bonners Ferry Maximum Daily Elevation (May-July), Flood Control Simulations - Standard FC and VARQ FC Benchmarks 25
Figure 12. Stage-Duration Analysis: Bonners Ferry Daily Elevation (May-July), Flood Control Simulations - Standard FC and VARQ FC Benchmarks....26
Figure 13. Elevation-Frequency Analysis: Kootenay Lake Maximum Daily Elevation (May-July), Flood Control Simulations - Standard FC and VARQ FC Benchmarks28

Figure 14. Elevation-Duration Analysis: Kootenay Lake Daily Elevation (May), Flood Control Simulations - Standard FC and VARQ FC Benchmarks.....29

Figure 15. Elevation-Duration Analysis: Kootenay Lake Daily Elevation (June) , Flood Control Simulations - Standard FC and VARQ FC Benchmarks.....30

Figure 16. Elevation-Duration Analysis: Kootenay Lake Daily Elevation (July) , Flood Control Simulations - Standard FC and VARQ FC Benchmarks.....31

Figure 17. Sturgeon water volumes to be provided from Libby Dam.....34

Figure 18. Elevation-Duration Analysis: Libby Dam Daily Elevation (May), Fish Flow Simulations 38

Figure 19. Elevation-Duration Analysis: Libby Dam Daily Elevation (June), Fish Flow Simulations 39

Figure 20. Elevation-Duration Analysis: Libby Dam Daily Elevation (July), Fish Flow Simulations 40

Figure 21. Flow-Frequency Analysis: Libby Dam Maximum Daily Outflow (May-July), Fish Flow Simulations 43

Figure 22. Stage-Frequency Analysis: Bonners Ferry Maximum Daily Elevation (May-July), Fish Flow Simulations 46

Figure 23. Stage-Duration Analysis: Bonners Ferry Daily Elevation (May-July) , Fish Flow Simulations 47

Figure 24. Elevation-Frequency Analysis: Kootenay Lake Maximum Daily Elevation (May-July), Fish Flow Simulations 49

Figure 25. Elevation-Duration Analysis: Kootenay Lake Daily Elevation (May) , Fish Flow Simulations 50

Figure 26. Elevation-Duration Analysis: Kootenay Lake Daily Elevation (June) , Fish Flow Simulations 51

Figure 27. Elevation-Duration Analysis: Kootenay Lake Daily Elevation (July) , Fish Flow Simulations 52

Figure 28. Stage-Frequency Analysis: Bonners Ferry Maximum Daily Elevation (May-July), Sensitivity Simulations 56

Figure 29. Stage-Frequency Analysis: Bonners Ferry Maximum 15-Day Average Elevation (May-July), Sensitivity Simulations.....58

1.0 Introduction

1.1 Need for Study

Libby Dam is a multi-purpose storage project located on the Kootenai River in northwestern Montana (Figure 1). Construction of Libby Dam began in 1967, the structure was complete by 1973, and the project became fully operational in March, 1975. Libby Dam is operated to provide storage for system flood control on the lower Columbia River, storage for local flood control in the Kootenai basin, and hydroelectric power generation. Incidental purposes of the project are navigation and recreation.

Since the construction of Libby Dam, several populations of fish in the Kootenai and Columbia Rivers have been listed for protection under the Endangered Species Act (ESA). In December 2000, the U.S. Fish and Wildlife Service (USFWS) and the NOAA Fisheries (NMFS) each issued a Biological Opinion outlining measures to protect the listed species. Among those measures is implementation of VARQ ("variable flow," with Q representing engineering shorthand for flow) alternative flood control at Libby and Hungry Horse dams in Montana. The intent of VARQ flood control (VARQ FC) is to better assure reservoir refill in years when flood control flexibility allows it. That in turn is intended to allow more assured provision of flows to benefit endangered Kootenai River white sturgeon, threatened bull trout in the Kootenai and Flathead rivers, and various listed stocks of salmon and steelhead in the Columbia. To allow a decision whether to implement VARQ on a long-term basis, and to address certain fish-flow related provisions in the Biological Opinions, an environmental impact statement (EIS) is being prepared. The official title of the EIS is the "Upper Columbia Alternative Flood Control and Fish Operations EIS" (UCEIS). The UCEIS updates previous modeling studies (Corps 1998; Corps 1999; Corps 2002).

It is important to note that the UCEIS addresses impacts of operational changes for Libby, Hungry Horse (on the South Fork Flathead River in Montana) and Grand Coulee (on the Columbia River in Washington) dams. However, because of the differences in how these three projects fit into the Federal Columbia River Power System, this report addresses VARQ FC only at Libby Dam. The US Bureau of Reclamation is providing separate analyses of the operation of Hungry Horse Dam. This analysis and that for Hungry Horse dam are informing a system hydropower modeling study, and that feeds into analysis for Grand Coulee Dam.

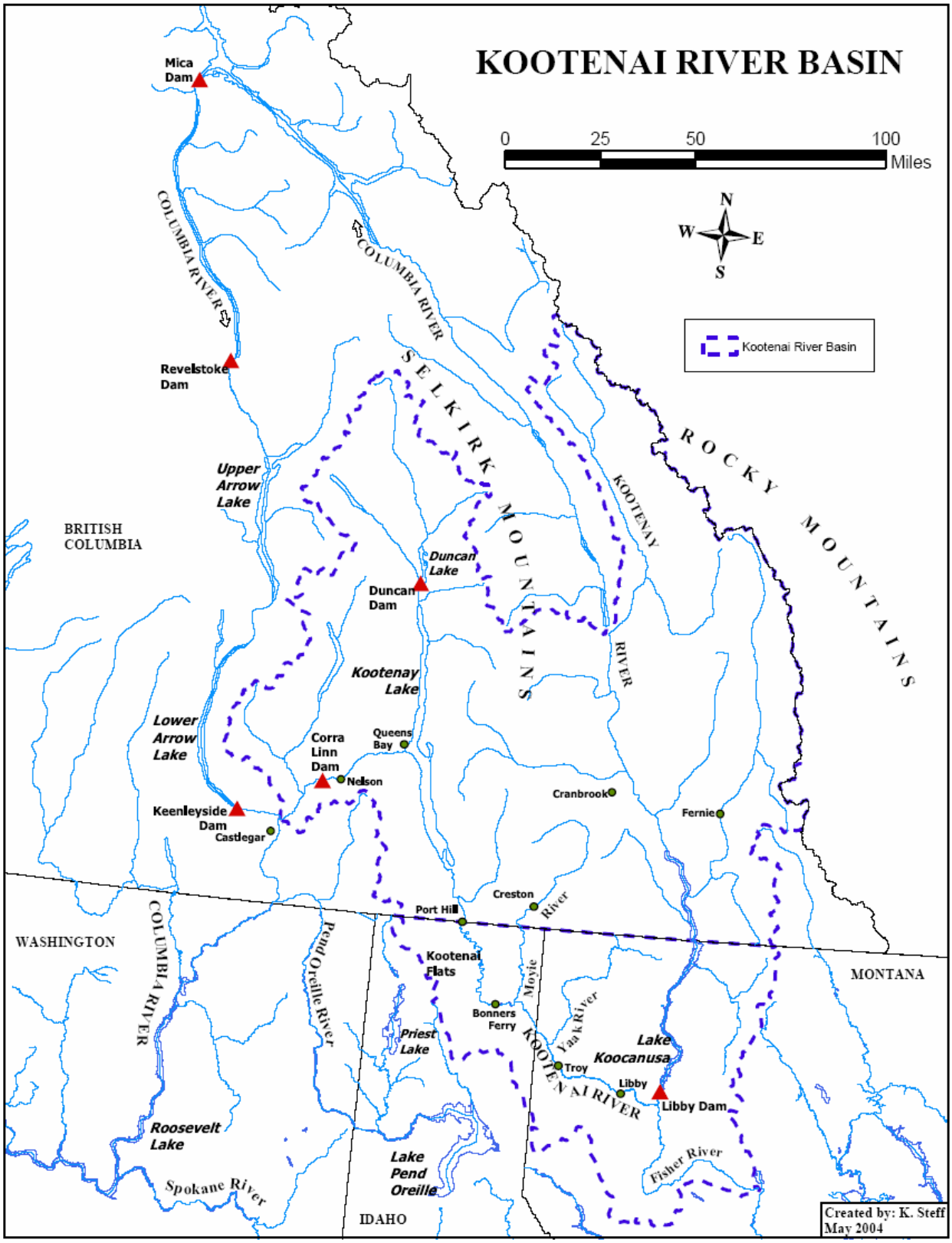

Figure 1. Kootenai River Basin Showing Canadian and U.S. Dams

The procedure currently authorized for long-term use is referred to as Standard FC, also called "BASE-CRT63". Before considering a permanent switch in flood control procedures, the Corps must perform hydrologic modeling to evaluate potential impacts from long-term implementation of VARQ FC. VARQ FC and Standard FC have the same reservoir draft *requirement* whenever the water supply forecast is greater than about 125% of normal[1]. In practice, the flood control draft *achieved* with VARQ FC would differ from the draft achieved with Standard FC only when the forecast falls between about 80%[2] and 120%[3] of normal. In other words, although the VARQ FC draft requirement differs from the Standard FC draft requirement whenever the forecast is less than 125% of normal, in practice there is a difference only when the forecast falls between about 80% and 120% of normal. A comparison of these two flood control methods is provided in Section 2.2 of this report. The VARQ FC procedure examined in this report is the same as that recommended in the USFWS and NMFS 2000 Biological Opinions.

The Biological Opinions also recommend flow augmentation (or "fish flows") for the benefit of listed species. Fish flows include: 1) sturgeon augmentation volumes which are provided in most years and vary based on the water supply forecast; 2) bull trout minimum flows which begin when sturgeon augmentation is over[4], and are also dependent on the water supply forecast; and 3) the salmon augmentation draft which begins sometime in either July or August and drafts Libby to an elevation of 2439 feet by the end of August (20 feet from full). The modeling of fish flows is described in Section 3.1.3 of this report.

1.2 Status of Study

In 2001, the Corps and the Bureau of Reclamation published a notice of intent to prepare an EIS and held public scoping meetings to begin collecting information on potential impacts from VARQ FC. The UCEIS is scheduled to be completed in 2005 in order to allow a record of decision in time to implement the selected alternative during the flood control season of 2006.

The Environmental Assessment (EA) for interim implementation of VARQ FC with fish flows (including sturgeon flows up to powerhouse capacity plus 1 kcfs spill) received a Finding of No Significant Impact in December 2003. Since then, the Corps of Engineers has been operating Libby Dam according to VARQ FC procedures and has continued to provide fish flows.

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[1] Forecast volumes expressed as "percent of normal" are based on the average observed runoff volume for the April-August period (POR: 1971 - 2000). This is the period of record used by the Northwest River Forecast Center to calculate average basin runoff volumes.

[2] For forecasts less than 80% of normal, the reservoir involuntarily drafts more water than is required by either VARQ FC or Standard FC. This is due to Libby's minimum outflow requirement of 4 kcfs.

[3] For forecasts greater than 120% of normal, Libby typically does not achieve the draft required by either VARQ FC or Standard FC. This occurs because Libby outflow must be reduced to comply with the 1938 IJC Order on Kootenay Lake.

[4] In years when sturgeon flow augmentation is not provided, a minimum bull trout flow is still required.

This report, entitled *Hydrologic Analysis of Upper Columbia Alternative Operations: Local Effects of Alternative Flood Control and Fish Operations at Libby Dam*, provides the technical analysis for the hydro-regulation model results for VARQ FC and Fish Flows at Libby Dam and is presented as an appendix to the UCEIS. Some information contained in this report is also used in further analyses such as those for economic, resident fish, and seepage impacts. Note that this report addresses results of the Kootenai basin flood control modeling alone. For a comprehensive evaluation of all possible impacts and benefits from the different dam operations investigated (including analysis of effects on agricultural seepage in the Kootenai Flats, hydropower, socioeconomics, resident fish, cultural resources, sediments, and other resources), please refer to the UCEIS main report.

1.3 Description of Modeled Simulations

All of the modeled simulations discussed in this report were developed using a numerical computer model. Simulations are also called "runs" and "hydro-regulations." A total of six different simulations were completed for this modeling report, as well as two sets of sensitivity runs (Table 1). It should be noted that all future operations will include some fish flows. Therefore, simulations 1 and 2, which do not include fish flows, are not considered "alternatives" under the UCEIS. Rather, they are "benchmark scenarios" used to assess differences between Standard FC and VARQ FC without the added impacts associated with fish flows, and to provide a basis to evaluate the effects of the fish flows.

Table 1. Simulation Runs.

Simulation 1	Standard FC Benchmark *[or LS in the EIS]*
Simulation 2	VARQ FC Benchmark *[or LV in the EIS]*
Simulation 3	Standard FC with fish flows at powerhouse capacity *[or LS1 in the EIS]*
Simulation 4	VARQ FC with fish flows at powerhouse capacity *[or LV1 in the EIS]*
Simulation 5	Standard FC with fish flows at powerhouse plus 10 kcfs capacity *[or LS2 in the EIS]*
Simulation 6	VARQ FC with fish flows at powerhouse plus 10 kcfs capacity *[or LV2 in the EIS]*
Sensitivity 1	Standard FC and VARQ FC with fish flows at powerhouse plus 10 kcfs capacity with conservative assumptions
Sensitivity 2	Standard FC and VARQ FC with fish flows at powerhouse plus 10 kcfs capacity with non-conservative assumptions

The Corps' Streamflow Synthesis and Reservoir Regulation computer model (SSARR) and the Autoreg pre/post-processing program were used to perform the model simulations for this study. Using historic unregulated streamflow records, reservoir storage-elevation relationships, rating curves for hydraulic capacity, and streamflow routing procedures, the operation of the Kootenai system was simulated according to user-defined rules. Typical rules include drafting a reservoir according to a specified rule curve, imposing maximum and/or minimum flow requirements, or providing an outflow

over a specified period of time. The simulations were conducted using a daily time step, providing daily output values for reservoir elevation, project releases, and river flows and stages.

The results form these simulations are provided in three separate sections within this report: Hydrologic Analysis of Flood Control Alternatives (Section 2.0); Hydrologic Analysis of Flood Control Alternatives with Fish Flows (Section 3.0); and Hydrologic Analysis of Sensitivity Runs (Section 4.0).

1.3.1 Description of Flood Control

The two methods of flood control compared in this hydrologic analysis are Standard FC and VARQ FC.

1.3.1.1 Standard FC Draft

Standard FC was the method used at Libby Dam prior to and through calendar year 2002. Under Standard FC, Libby Dam is regulated according to the *Columbia River Treaty Flood Control Operating Plan* (Corps 1972) as amended by the *Review of Flood Control Columbia River Basin, Columbia River and Tributaries Study, CRT-63* (Corps 1991). To determine the required flood control operation, a storage reservation diagram (SRD) specific to Libby Dam is used in combination with Libby's seasonal water supply forecasts to determine how much space in Libby needs to be made available by 15 March for flood control (Figure 2). As the season progresses and the forecasts change, so do the storage requirements. Additional storage space associated with possible power drafts[5] was not taken into consideration for Standard FC hydro-regulations.

[5] In the flood control simulations, all prescribed drafts at storage projects are made for flood control purposes, not for power generation. In the fish flow simulations, prescribed drafts also occur for the purpose of benefiting downstream fish (i.e., the 20 ft salmon draft in July-August), but again, drafting for the purpose of power generation is not included. A power modeling report is attached as a separate appendix to the UCEIS. This report discusses modeling and modeling results that have been completed to analyze the impacts from flood control, fish flows, and power operations.

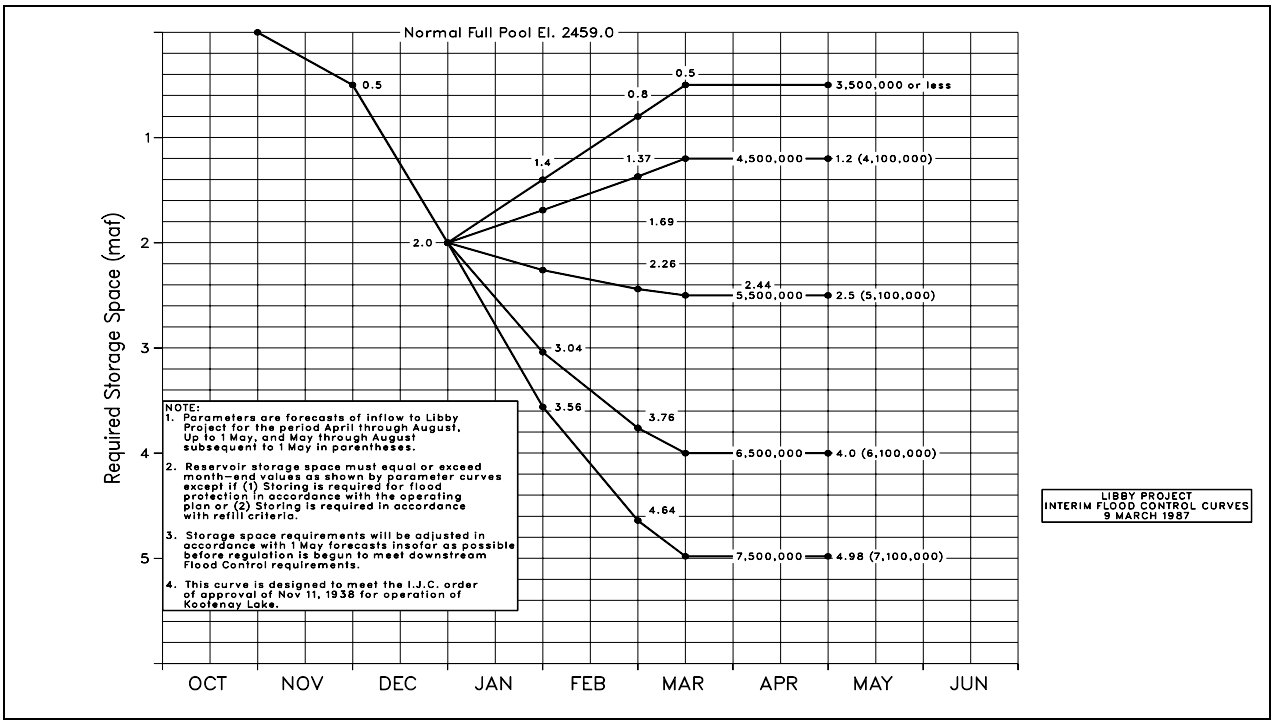


Figure 2. Columbia River Treaty Flood Control Operating Plan Storage Reservation Diagram (SRD) at Libby Dam

1.3.1.2 VARQ FC Draft

VARQ FC is the flood control method being used on an interim basis at Libby Dam, and recommended for long-term implementation in both of the Biological Opinions. Previous descriptions of VARQ FC have appeared in *Status Report -- Work to Date on the Development of the VARQ Flood Control Operation at Libby Dam and Hungry Horse Dam* (Corps 1999), as well as *Columbia River Basin System Flood Control Review – Preliminary Analysis Report* (Corps 1997). Most recently, VARQ FC was described in the *Upper Columbia Alternative Flood Control and Fish Operations Interim Implementation Environmental Assessment* (Corps 2002), previously mentioned in Section 1.2 of this report. Like Standard FC, VARQ FC requires a storage reservation diagram in conjunction with the water supply forecast to determine the flood control space needed. As the season progresses and the forecasts change, so do the storage requirements. However, as compared with the Standard FC SRD, the VARQ SRD generally requires less flood control space (Figure 3). Consistent with the Standard FC simulations, additional storage space associated with possible power drafts was not taken into consideration for VARQ FC hydro-regulations.

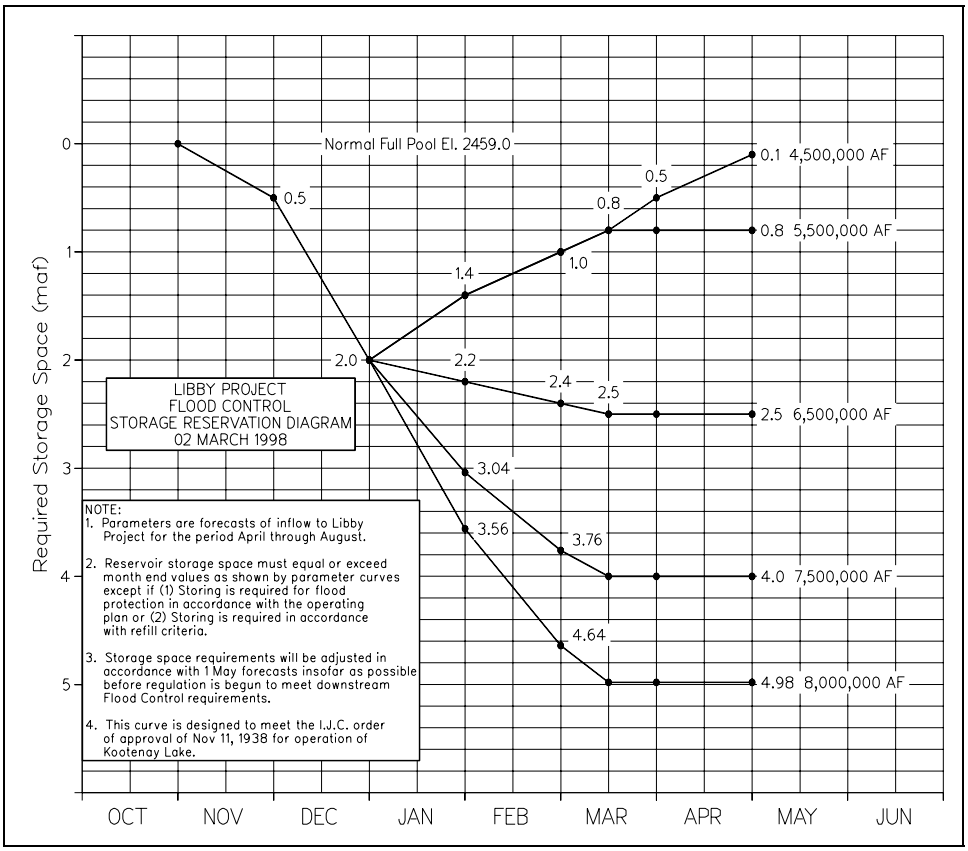


Figure 3. VARQ Storage Reservation Diagram (SRD) at Libby Dam

1.3.1.3 Standard FC and VARQ FC Refill

The Standard FC SRD for Libby Dam is part of the 1972 Columbia River Treaty Flood Control Operating Plan (FCOP), as amended, and is based on the concept that outflow from Libby Dam during the refill period will be held constant at the minimum outflow requirement of 4 kcfs. Unlike Standard FC, the VARQ SRD was developed with the assumption that outflow from Libby Dam during the refill period would vary based on the reservoir level and water supply forecast. VARQ FC is intended to improve refill reliability, thereby facilitating flow augmentations for fish. VARQ FC is intended to provide the same level of system and local flood protection as Standard FC as prescribed in the Libby Project authorizing document.

1.3.2 Description of Fish Flows

The USFWS and NMFS 2000 Biological Opinions recommended several fish flow operations to help protect Kootenai River sturgeon, Columbia basin bull trout, and various stocks of Columbia basin salmon and steelhead. The first requirement is to provide a tiered volume of water during the spring freshet for sturgeon spawning and recruitment[6], followed by a tiered minimum bull trout flow during July and August.

[6] The volume of water for sturgeon can either be released at powerhouse capacity, or at powerhouse capacity plus some additional flow capacity up to 10 kcfs. The additional flow capacity of 10 kcfs is

Finally, through July and August Libby drafts to elevation 2439 feet, 20 feet from full, for salmon flow augmentation. The ramping rates specified in the Biological Opinions were used for these simulations. Actual fish flow operations will look different than those for this model study. In real-time they are managed to address differing conditions each year, including calls from the USFWS and NMFS for specific fish flows. In contrast, evaluations based on model studies must use a consistent set of provisions in order to make valid comparisons. The rules and assumptions used for modeling fish flows are explained in further detail later in this report, under Section 3.1.3.

1.3.3 Use of Sensitivity Runs

Risk-Based Analysis for Flood Damage Reduction Studies, EM 1110-2-1619 (Corps 1996), stipulates that risk and uncertainty should be characterized, when possible, to describe the uncertainty in choice of the hydrologic, hydraulic, and economic functions, to describe parameter uncertainty, and to describe explicitly the uncertainty in results.

The team members for this study, in conjunction with community members participating in the Kootenai Valley Resources Initiative (KVRI), identified uncertain model parameter combinations to define an upper-bound scenario and a lower-bound scenario for river stage at Bonners Ferry. The rules used for sensitivity runs are explained in further detail later in this report, under Section 4.0.

1.3.4 Statistical Analysis

Potential impacts throughout the Kootenai basin as a result of VARQ FC and/or fish flows can be characterized with flow/stage-frequency curves and flow/stage-duration curves at various locations. Procedures for graphing regulated hydrologic data are outlined in a Corps Engineer Manual entitled *Hydrologic Frequency Analysis*, EM 1110-2-1415 (Corps 1993). As stipulated in the manual, frequency curves for regulated systems (like the Kootenai) are better calculated by graphical methods ("hand-fit") than by pure statistical methods. In some cases, known information outside of the modeling was used to help define specific regions of frequency curves, as will be discussed in subsequent sections (Sections 2.2.3, 2.2.6, and 2.2.7).

1.3.5 Transmission Limitations

In recent years, there has been a transmission restriction in Western Montana which has limited combined generation at Libby and Hungry Horse dams to 900 MW. Current generation capacity is 600 MW for Libby and 428 MW for Hungry Horse for a total of 1028 MW. The limit will be raised from 900 MW to at least 944 MW by the summer of 2005. Even with this increase in transmission capacity, there will still be limitations that will prevent Libby and Hungry Horse from generating at full capacity at the same time. The modeling for this report assumes that Libby is able to use its full powerhouse capacity whenever needed, and that any necessary reductions in generation are assumed by Hungry Horse Dam. This is discussed in further detail in the *Hydrologic Analysis of the VARQ Flood Control Plan at Hungry Horse Dam, Montana*, a report prepared by the

stipulated in the 2000 USFWS Biological Opinion. The means of providing the additional flow capacity is not identified in this report, or in the UCEIS itself.

Bureau of Reclamation and included as a separate appendix to the UCEIS (Reclamation 2004).

2.0 Hydrologic Analysis of Flood Control Methods

2.1 Hydro-Regulations

To evaluate flood control methods for this study, simulated hydro-regulations were used in order to compare the differences between Standard FC and VARQ FC. As stated in section 1.3, these simulations were performed to provide a comparison between the two flood control procedures without the influence of fish flows. The flood-control-only runs also serve as a basis to evaluate how the fish flows affect the basin hydrology.

The outcome of the hydro-regulations can be affected by many factors, including (but not limited to): the period of record used for modeling, the assumed water supply forecasts, and the rules used to trigger operational changes. To minimize bias, a consistent set of rules regarding flood control drafts, residual volume tracking, and foresight were applied in all model simulations. Factors affecting the hydro-regulations are discussed in greater detail later in this report.

Modeling of the Kootenai River basin was conducted using the Corps SSARR and Autoreg computer programs. The modeling was conducted using a daily time step, providing daily output of parameters such as reservoir elevation, project releases, and river flows.

2.1.1 Period of Record for Flood Control Modeling

A 52-year record (1948-1999) was used in this study. This period of time encompasses a wide variety of water years, and therefore provides a good data set for testing the two different methods of flood control. However, the data set is still limited, as it is not large enough to produce a frequency curve that depicts the probability of extremely rare events having less than a 1% chance exceedance.[7] This study makes use of a Libby Dam regulated 0.5%-chance-exceedance[8] hypothetical flood, based on the flood event of 1894, in order to extrapolate frequency curves into this range.

2.1.2 Water Supply Forecasts

In the Columbia River basin, the quantity of runoff from snowmelt is highly variable from one year to the next. Due to this variability, flood control operations at large storage projects like Libby Dam are guided by SRDs (Figure 2, Figure 3). An SRD is used in combination with a seasonal water supply forecast to determine how much space is needed for flood control. The use of forecast data in the hydro-regulations, as opposed to observed volumetric runoff, adds the element of uncertainty that is experienced in real-time water management and is a more rigorous test of a flood control operation. The water supply forecasts used for this study are a combination of derived and actual water

[7] A 1%-chance-exceedance flood has a 1 in 100 chance of being equaled or exceeded in any given year. It is sometimes called a “100-year flood.”

[8] A 0.5%-chance-exceedance flood has a 1 in 200 chance of being equaled or exceeded in any given year. It is sometimes called a “200-year flood.”

supply volume forecasts for the 1948-1999 period. The forecasts used are the Wortman-Morrow Forecasts, which have been used to predict the inflow volume to Libby Dam for real-time operation since 1986. Historic snowpack, precipitation and temperature data were used to derive the Wortman-Morrow Forecasts from 1948-1985.

2.1.3 Upper Rule Curves

As a prerequisite to performing flood control simulations for the Kootenai basin, Upper Rule Curves (URCs) that guide seasonal reservoir flood control operations during the evacuation period were developed for storage projects in the basin. URCs are developed by using a project's SRD in conjunction with seasonal water supply forecasts for the project, on a month-by-month basis, to calculate the winter and early spring reservoir levels required to provide adequate flood control that year.

In a truly single-purpose flood control simulation, Libby would operate to its URC and would deviate from it only due to a minimum flow requirement, a flood emergency requiring temporary impoundment of water above the URC, or to prevent an IJC violation at Kootenay Lake (see Section 2.1.5). However, this flood control modeling was conducted with the additional assumption that Libby may also be above its URC if it would otherwise have to spill to reach its flood control draft targets. This modeling used a fixed end-of-December target elevation of 2411 feet.[9] In the simulations, Libby tends to be slightly above elevation 2411 ft at the end of December, due to the no-spill assumption, avoidance of an IJC violation, or a combination of the two. This is a conservative assumption from a flood control standpoint, because it puts an additional strain on achieving adequate flood control space in subsequent months.

2.1.4 Powerhouse Capacity

This modeling assumed a powerhouse capacity ranging from 19 kcfs to 27.6 kcfs, depending on reservoir pool elevation (head). The powerhouse capacity-head relationship used for modeling is based on historic data from the project. This was deemed to be the most realistic choice for estimating powerhouse capacity, rather than assuming a full wicket gate opening where the maximum powerhouse capacity was as high as 29 kcfs.

The hydro-regulation modeling for this EIS assumed that all five generating units at Libby Dam were available, and that Libby would not exceed its powerhouse capacity (i.e., Libby would not spill) in order to reach its flood control targets.

2.1.5 The 1938 IJC Order on Kootenay Lake

In the flood control simulations, Kootenay Lake, located in British Columbia at the lower end of the Kootenai basin, is regulated according rules defined by the International Joint Commission (IJC) Order of 1938. When a conflict existed in meeting the 1938 Order at Kootenay Lake, Duncan Reservoir release was reduced to passing no more than inflow and Libby Dam was allowed to continue to draft, if possible. At no time were Libby or Duncan Dams required to pass less than inflow by this order. Throughout the simulations, Corra Linn Dam at the outlet of Kootenay Lake operated according to its

[9] For a discussion of the variable end-of-December draft at Libby, which was implemented after the modeling for the EIS was completed, refer to Section 1.6.1 of the DEIS or, for more details, Appendix M.

upper rule curve, unless the outflow required by the rule curve exceeded the hydraulic capacity at Grohman Narrows. Grohman Narrows is a natural constriction in the channel located upstream of Corra Linn Dam. At this location, the channel has a relatively small cross-sectional area, creating a "pinch point" that physically limits outflow to the hydraulic capacity of the opening. Once the spring rise of Kootenay Lake has commenced, the rule curve is no longer fixed and is instead determined by a "lowering" formula. During this "lowering" period, the modeled results for Kootenay Lake are based on the hydraulic capacity of Grohman Narrows.

2.1.6 Initialization

For the simulations comparing Standard FC benchmark and VARQ FC benchmark, all reservoirs in the basin were re-initialized at full pool at the beginning of each water year. (A water year begins on 1 October and ends on 30 September.) Flood control simulations are re-initialized each year, rather than run in a continuous mode, so that one year's flood control operation is independent of conditions in the previous year. From a flood control standpoint, initializing reservoirs at full pool is a conservative assumption that will provide the most rigorous test of whether adequate flood control space can be achieved at a project.

2.1.7 Local Flood Control and Refill

The assumed Bonners Ferry flood stage used in this modeling is elevation 1764 ft, which was established by the National Weather Service in 1997. Flood stage is defined as the level or stage at which a stream overflows its banks or the stage at which the overflow of a stream begins to cause damage. In all simulations, Libby was regulated to keep the stage at Bonners Ferry below elevation 1764 insofar as possible.

Operation of Libby Dam includes an evacuation phase and a refill phase. With Standard FC, the assumed release from Libby Dam during refill is the project's minimum outflow of 4 kcfs. With VARQ FC, the release during refill varies according to the graph shown in Figure 4, and is further refined depending on reservoir elevation. Hence, the name "VARQ", meaning "variable flow" ("Q" is shorthand for flow).

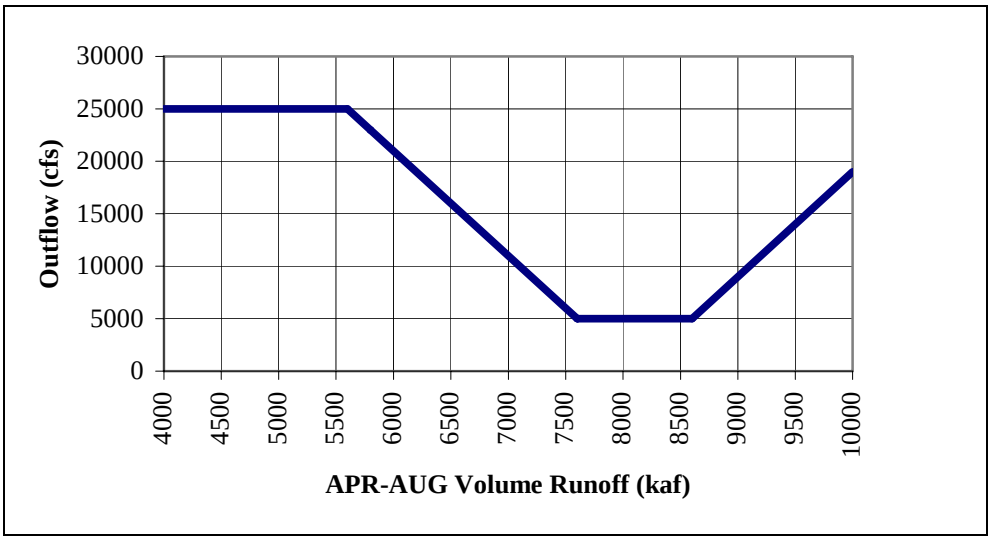


Figure 4. VARQ Outflows at Libby Dam

Refill for the standard flood control simulations began 10 days before the forecasted exceedance of the Initial Controlled Flow (ICF) at The Dales. The outflow during refill was set to the minimum flow of 4 kcfs unless the Libby reservoir elevation was significantly above the URC on the date that refill began. If this occurred, outflow from Libby was increased relative to the volume of water stored above the flood control rule curve.

Refill for the VARQ flood control simulations also began 10 days before the forecasted exceedance of the Initial Controlled Flow (ICF) at The Dalles. The VARQ outflow during refill was determined according to Appendix A: VARQ Operating Procedures, from the status report entitled *Work to Date on the Development of the VARQ Flood Control Operation at Libby Dam and Hungry Horse Dam* (Corps 1999). An abbreviated version of the rules governing VARQ FC and outflow during refill is provided at the end of this report.

The hydro-regulation model runs were performed with consistent modeling rules. Although the actual hydrograph for each historic water year is known to modelers, the modeling was conducted with limited foresight, assuming regulators would make decisions based on a 10-day streamflow forecast, and no greater. Libby outflows during refill were increased (no higher than powerhouse capacity) ten days prior to when the reservoir would otherwise fill and spill. If it appeared that Libby was not going to refill, outflows were decreased (no lower than minimum outflow) ten days before inflows dropped below powerhouse capacity. In some years, it was necessary to spill water from Libby during the late stages of refill in order to preserve flood control space. The first spill increment (2 kcfs) was used no more than five days prior to the date when the reservoir would otherwise fill and spill. If necessary, the spill was adjusted upward in a step-wise fashion using no more than three days of foresight.

In addition to the streamflow forecast foresight discussed above, adjustments were made based on volume forecasts as well. Residual volume of forecasted runoff provided an objective tool to guide the timing and magnitude of reservoir outflow adjustments. Seasonal water supply forecasts, observed runoff to date, and planned reservoir releases were used to determine whether the amount of space remaining in the reservoir was adequate to store the forecasted remaining water volume. When the residual volume ratio reached a value of two (meaning that there is twice as much water that needs to be stored as there is storage space), outflow from Libby Dam was increased in order to preserve space. This concept of residual volume tracking is also used during actual refill operations to make real-time decisions for outflow adjustments. Overall, the refill-season operations simulated for this study do a very good job of representing the actual level of skill with which reservoir refill is conducted.

2.2 Model Results

Output data from the flood control simulations were analyzed in order to quantitatively characterize the differences between the Standard FC benchmark and VARQ FC benchmark at Libby Dam. Impacts to Lake Koocanusa and Libby Dam, Bonners Ferry, Kootenay Lake, and Duncan Dam are presented in the following sections.

2.2.1 Analysis of Results

Potential impacts from VARQ FC can be characterized with flow/stage-frequency curves and flow/stage-duration curves at various locations. To illustrate the incremental difference between the two types of flood control, each figure has two curves plotted: one for the Standard FC benchmark and one with the VARQ FC benchmark. Procedures for graphing regulated hydrologic data are outlined in a Corps Engineer Manual entitled *Hydrologic Frequency Analysis*, EM 1110-2-1415 (Corps 1993).

2.2.2 Lake Koocanusa

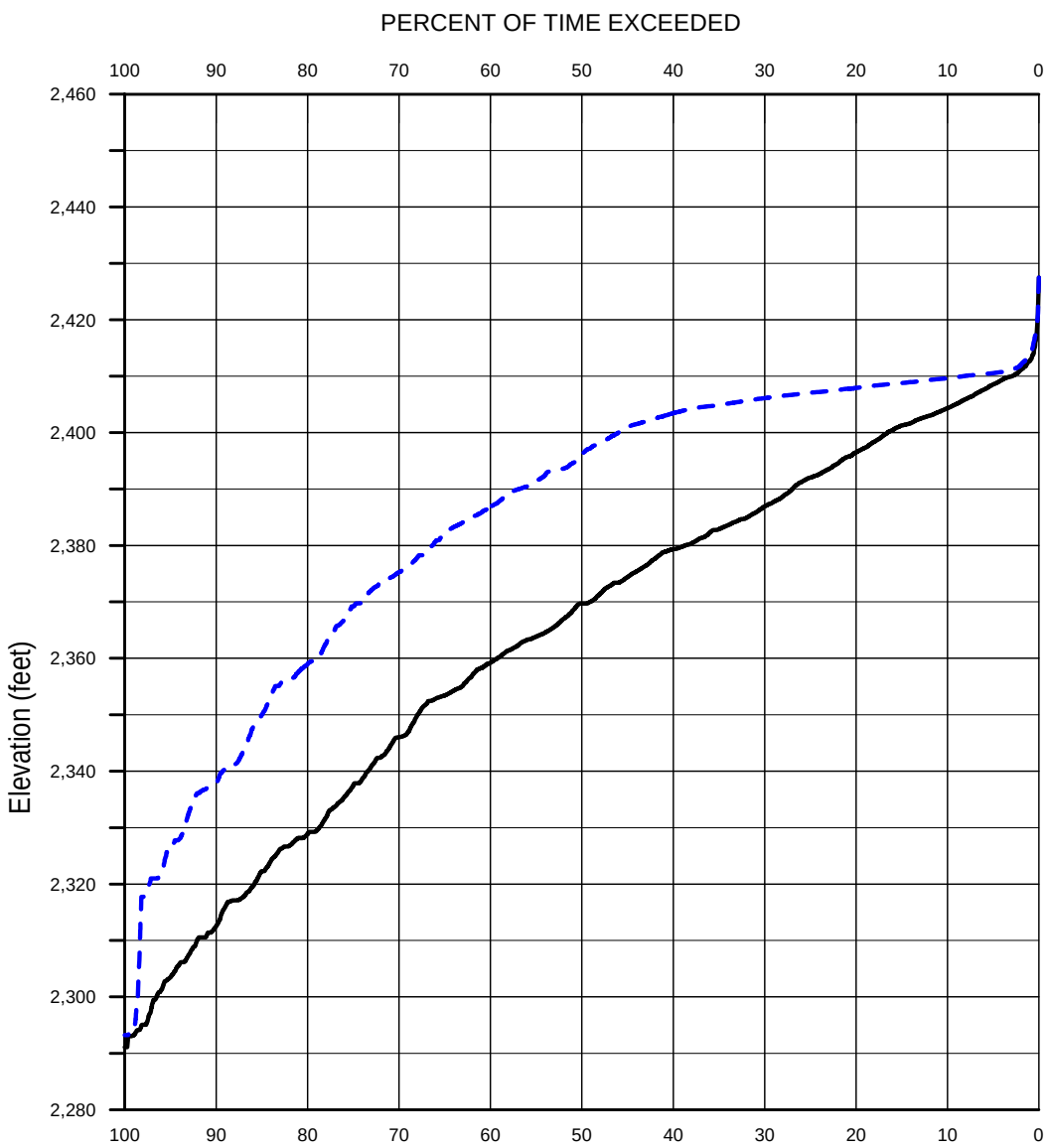
Historically, the Corps of Engineers has attempted to refill Lake Koocanusa (the reservoir behind Libby Dam) with a high degree of certainty. Model simulations for this study show that in the absence of power drafts or fish flows, it was possible to refill the reservoir within 1 foot of full before the end of July in 92% of the years, regardless of which flood control procedure is used, and within 5 feet of full before the end of July in 98% of the years, regardless of which flood control procedure is used. The simulated 31 July reservoir elevations are shown in Table 2.

When VARQ FC is being used, the reservoir is generally not drafted as deeply in the months of January through April as when Standard FC is used. In fact, with the VARQ FC benchmark, the reservoir is above elevation 2400 feet 46% of the time, as compared with the Standard FC benchmark, when it is above that elevation only 17% of the time (Figure 5). Again, in May (Figure 6) and June (Figure 7), the VARQ FC benchmark leads to higher reservoir elevations than does the Standard FC benchmark. By July, reservoir elevations are essentially equivalent (Figure 8).

Table 2: Simulated Reservoir Elevation on 31 July (Flood Control only)

Water Year	Standard FC benchmark-->LS	VARQ FC benchmark-->LV	Water Year	Standard FC benchmark-->LS	VARQ FC benchmark-->LV
1948	2459.0	2459.0	1974	2459.0	2459.0
1949	2459.0	2459.0	1975	2458.3	2459.0
1950	2459.0	2459.0	1976	2459.0	2459.0
1951	2459.0	2459.0	1977	2451.8	2453.3
1952	2458.9	2459.0	1978	2459.0	2459.0
1953	2459.0	2459.0	1979	2456.5	2456.5
1954	2459.0	2459.0	1980	2459.0	2459.0
1955	2459.0	2459.0	1981	2459.0	2459.0
1956	2459.0	2459.0	1982	2459.0	2459.0
1957	2459.0	2459.0	1983	2459.0	2459.0
1958	2459.0	2459.0	1984	2459.0	2459.0
1959	2459.0	2459.0	1985	2456.5	2459.0
1960	2459.0	2459.0	1986	2459.0	2459.0
1961	2459.0	2459.0	1987	2459.0	2459.0
1962	2459.0	2459.0	1988	2459.0	2459.0
1963	2459.0	2459.0	1989	2459.0	2459.0
1964	2459.0	2459.0	1990	2459.0	2459.0
1965	2458.9	2459.0	1991	2459.0	2459.0
1966	2459.0	2459.0	1992	2455.4	2458.5
1967	2459.0	2459.0	1993	2459.0	2459.0
1968	2459.0	2459.0	1994	2459.0	2459.0
1969	2459.0	2459.0	1995	2459.0	2459.0
1970	2459.0	2459.0	1996	2459.0	2459.0
1971	2459.0	2459.0	1997	2459.0	2459.0
1972	2459.0	2459.0	1998	2459.0	2459.0
1973	2459.0	2459.0	1999	2459.0	2459.0

Figure 5. Elevation-Duration Analysis: Lake Koocanusa Daily Elevation (January-April), Flood Control Simulations - Standard FC and VARQ FC Benchmarks



LEGEND

Standard FC

VARQ FC

2004 UPPER COLUMBIA EIS MODELING RESULTS

LIBBY DAM
MODELED STANDARD AND VARQ FLOOD CONTROL
STAGE DURATION ANALYSIS

LIBBY DAM DAILY ELEVATION
(JAN-APR)

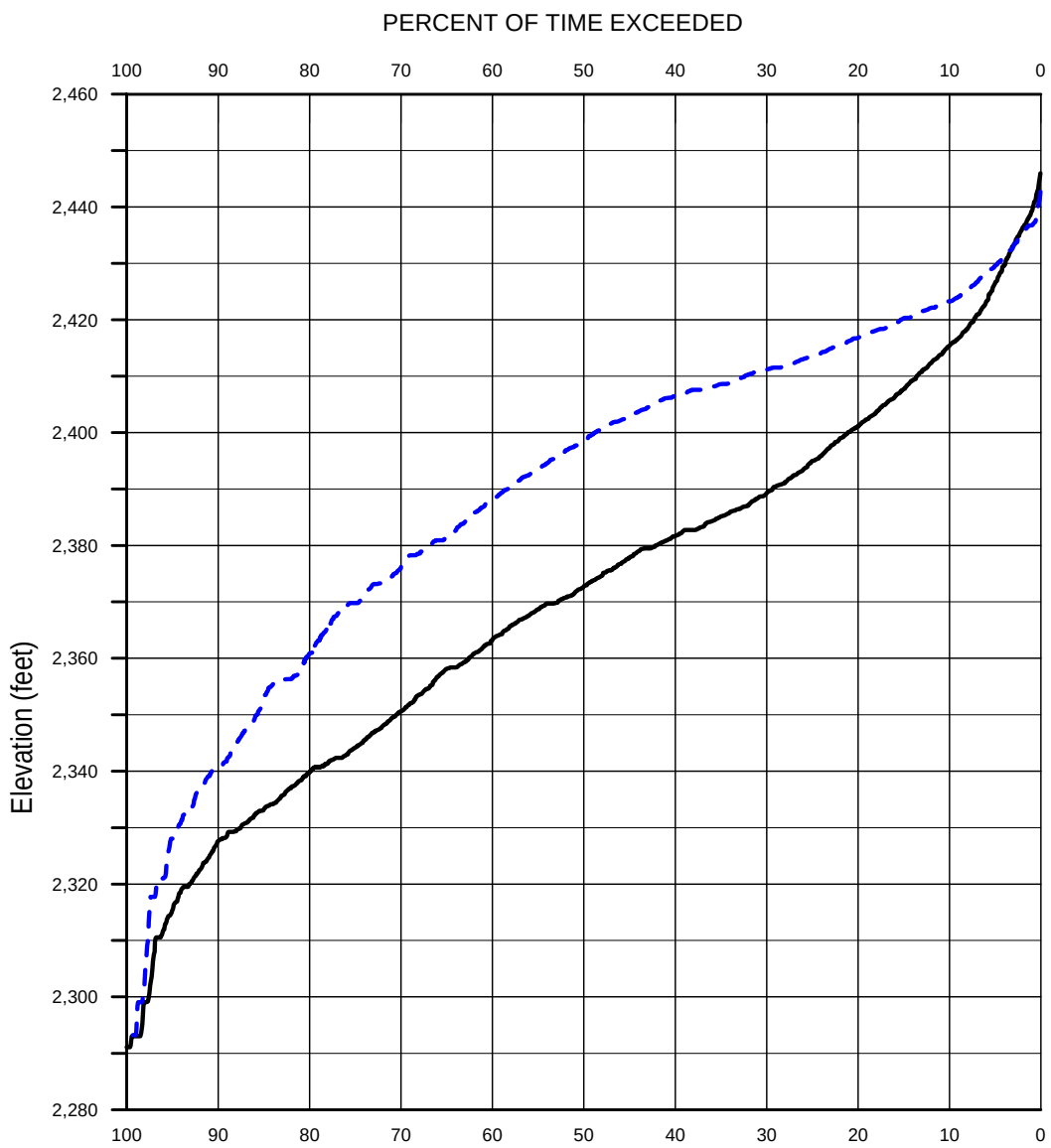
PERIOD OF RECORD: WY 1948 - 1999

DATE: 12 APR 2004

CONSTRUCTED BY: CJF

APPROVED BY:

Figure 6. Elevation-Duration Analysis: Lake Koocanusa Daily Elevation (May), Flood Control Simulations - Standard FC and VARQ FC Benchmarks



LEGEND

Standard FC

VARQ FC

2004 UPPER COLUMBIA EIS MODELING RESULTS

LIBBY DAM
MODELED STANDARD AND VARQ FLOOD CONTROL STAGE DURATION ANALYSIS

LIBBY DAM DAILY ELEVATION (MAY)

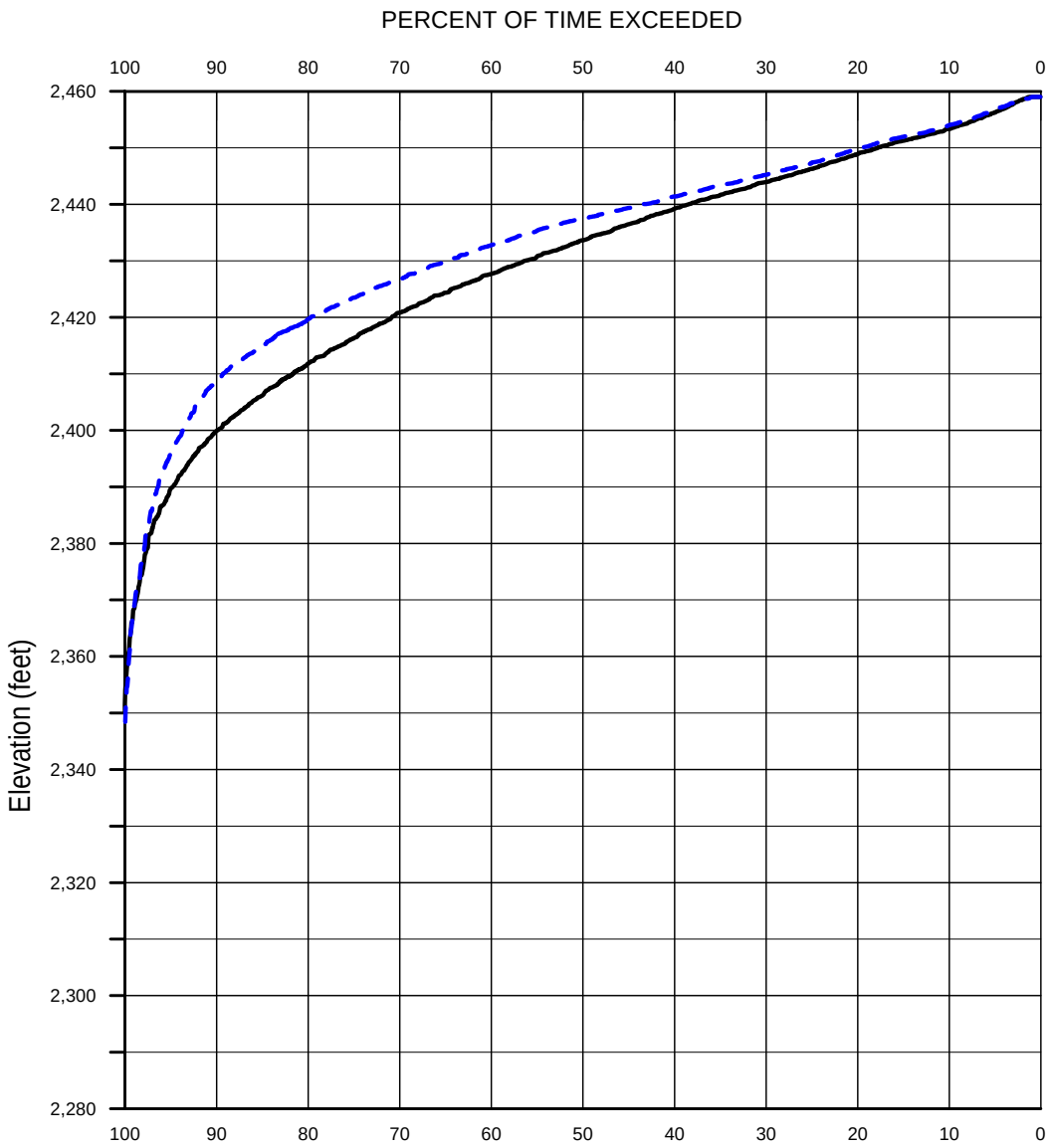
PERIOD OF RECORD: WY 1948 - 1999

DATE: 12 APR 2004

CONSTRUCTED BY: CJF

APPROVED BY:

Figure 7. Elevation-Duration Analysis: Lake Koocanusa Daily Elevation (June), Flood Control Simulations - Standard FC and VARQ FC Benchmarks



LEGEND

Standard FC

VARQ FC

2004 UPPER COLUMBIA EIS MODELING RESULTS

LIBBY DAM
MODELED STANDARD AND VARQ FLOOD CONTROL
STAGE DURATION ANALYSIS

LIBBY DAM DAILY ELEVATION
(JUNE)

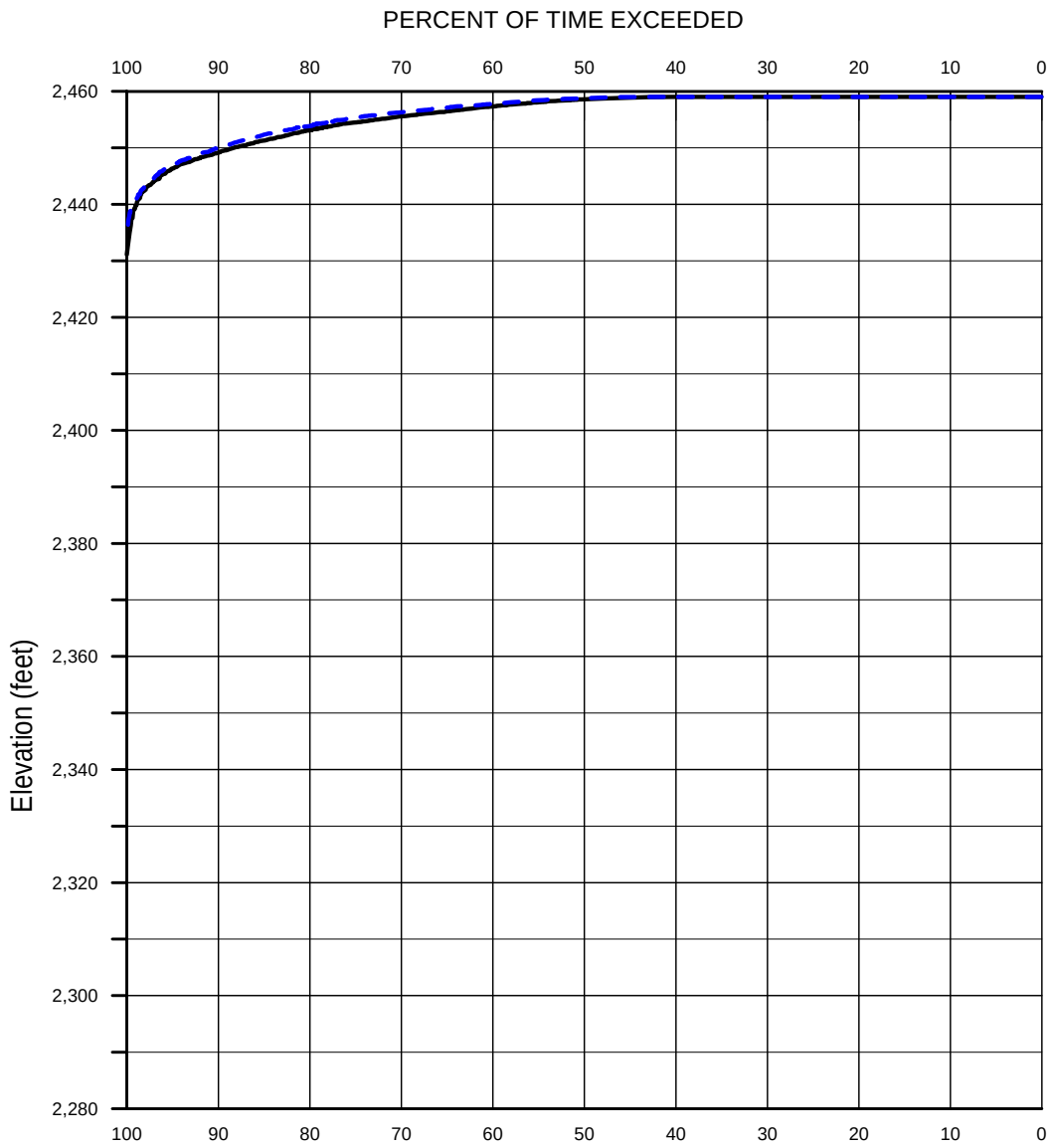
PERIOD OF RECORD: WY 1948 - 1999

DATE: 12 APR 2004

CONSTRUCTED BY: CJF

APPROVED BY:

Figure 8. Elevation-Duration Analysis: Lake Koocanusa Daily Elevation (July), Flood Control Simulations - Standard FC and VARQ FC Benchmarks



LEGEND

Standard FC

VARQ FC

2004 UPPER COLUMBIA EIS MODELING RESULTS

LIBBY DAM
MODELED STANDARD AND VARQ FLOOD CONTROL
STAGE DURATION ANALYSIS

LIBBY DAM DAILY ELEVATION
(JULY)

PERIOD OF RECORD: WY 1948 - 1999

DATE: 12 APR 2004

CONSTRUCTED BY: CJF

APPROVED BY:

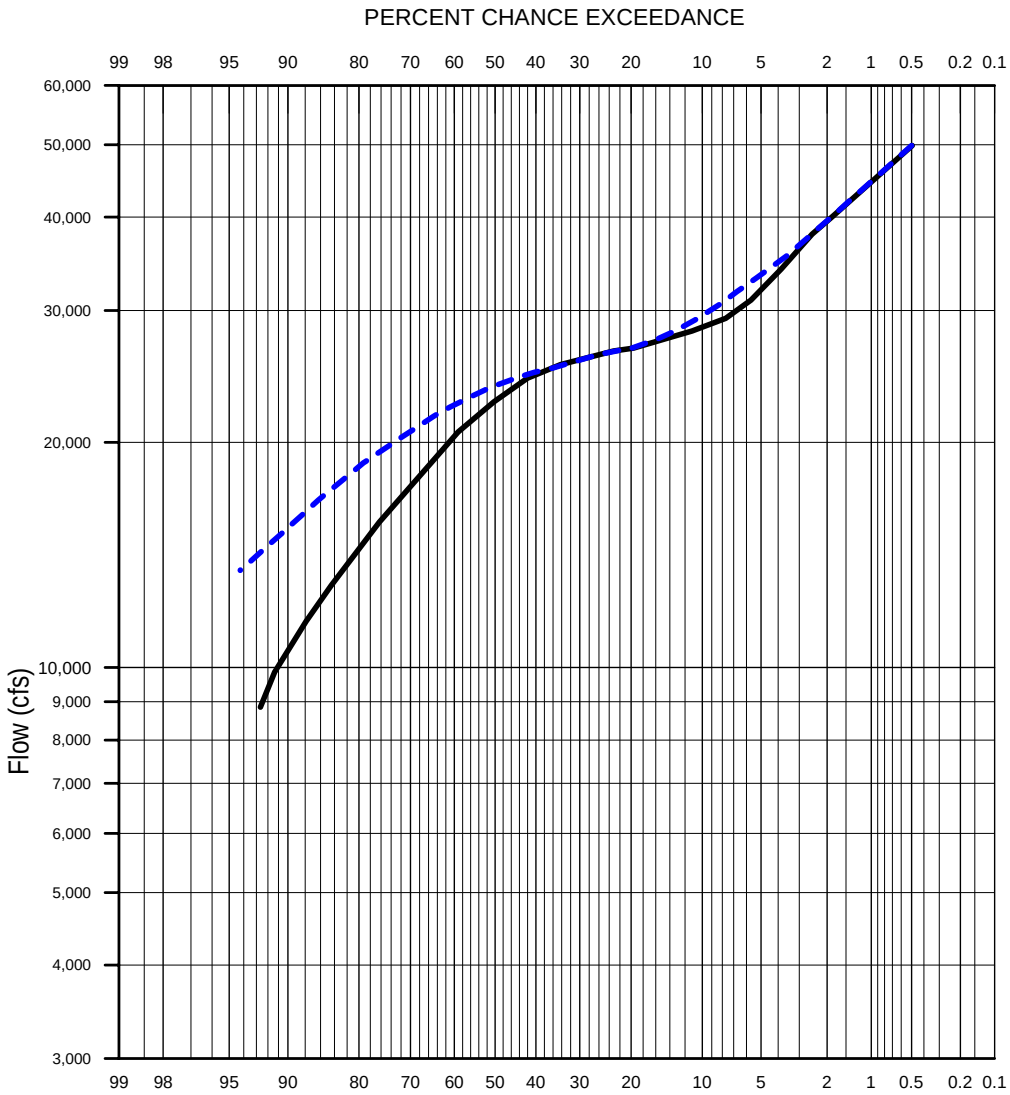
2.2.3 Libby Dam Outflow

Besides reservoir elevation, the two methods of flood control also have an impact on one-day peak outflow from Libby Dam. From a flood control perspective, the outflows during May, June, and July are of primary interest to downstream residents. A flow-frequency curve specific to those months is provided in

Figure 9[10]. At the onset of refill (usually sometime in April or May), the reservoir is generally higher with the VARQ FC benchmark than it is with the Standard FC benchmark. As a result, the Libby Dam outflows during refill are generally greater with the VARQ FC benchmark than they are with the Standard FC benchmark. For the high percent-chance-exceedance (low runoff) events (on the left side of the figure), the VARQ benchmark outflows are consistently higher than Standard FC benchmark outflows. As outflows approach the powerhouse capacity (about 25 kcfs), the two curves converge. This convergence occurs because of the modeling assumption that Libby would not exceed powerhouse capacity during refill until it was evident that spill was required to preserve flood control space. The decision to spill was made no more than five days prior to the date when the reservoir would otherwise fill and spill. For outflows just above the powerhouse capacity, the VARQ FC benchmark curve is again higher than the Standard FC benchmark curve, meaning that spilling to preserve flood control space is slightly more likely with the VARQ FC benchmark than with Standard FC benchmark. However, for the very low percent-chance-exceedance events (on the far right side of the figure), the two curves once again converge. This is because very high runoff years (April-August Libby volume inflow of 8 million acre-feet [MAF] or higher) have the exact same draft requirement for the Standard FC and VARQ FC benchmarks. In all simulations, the maximum outflow from Libby Dam remained below 40 kcfs.

[10] A regulated outflow of 50 kcfs from the hypothetical 0.5%-chance-exceedance event was used to help define the upper end of this frequency curve.

Figure 9. Flow-Frequency Analysis: Libby Dam Maximum Daily Outflow (May-July), Flood Control Simulations - Standard FC and VARQ FC Benchmarks



LEGEND

Standard FC

VARQ FC

NOTE: A regulated outflow of 50,000 cfs from the hypothetical 0.5%-chance-exceedance event was used to help define the upper end of this frequency curve.

2004 UPPER COLUMBIA EIS MODELING RESULTS

LIBBY DAM, MONTANA
MODELED STANDARD AND VARQ FLOOD CONTROL FLOW FREQUENCY ANALYSIS

LIBBY DAM MAXIMUM DAILY OUTFLOW (MAY-JULY)

PERIOD OF RECORD: WY 1948 - 1999

DATE: 27 JULY 2004

CONSTRUCTED BY: CJF

APPROVED BY:

2.2.4 Water Quality

When the existing spillway at Libby Dam must be used for flood control, there is an increase in total dissolved gas (TDG) saturation downstream. In 2002, TDG data and spill amounts from Libby Dam that occurred in June and July were used to develop a relationship between spill and TDG saturation just downstream of the dam (ERDC 2003). Using this relationship, expected TDG levels greater than 100% were tabulated for the simulated Libby outflows (Table 3). The water quality standard for TDG established by the state of Montana is 110%, maximum. This110% standard was exceeded for one or more days in 11 out of 52 years modeled using the Standard FC benchmark, and 13 out of 52 years modeled using the VARQ FC benchmark. Based on all 52 years modeled, the Standard FC benchmark had 102 days in excess of the 110% standard, and the VARQ FC benchmark had 137 days in excess of the 110% standard.

Table 3. Modeled TDG Exceedance, Flood Control Simulations

Threshold TDG saturation immed. below Libby Dam	Number of years with TDG greater than threshold (Standard FC benchmark)	Number of years with TDG greater than threshold (VARQ FC benchmark)	Number of days with TDG greater than threshold (Standard FC benchmark)	Number of days with TDG greater than threshold (VARQ FC benchmark)
100%	11	13	108	142
105%	11	13	107	141
110%	11	13	102	137
115%	8	8	61	92
120%	6	7	43	79
125%	6	7	41	78
130%	3	5	27	54

2.2.5 Storage Above the URC

There are some cases when Libby, Duncan, or both, cannot be drafted in accordance with their Storage Reservation Diagram, because doing so would violate the 1938 IJC Order on Kootenay Lake. (The 1938 IJC Order is discussed in further detail in Section 2.1.5.) When this condition occurs, the reservoir (Libby, Duncan, or both) is said to have "trapped storage." The amount of trapped storage is the volume of water stored above the URC at the time that refill begins. Storage above the URC can also happen for other reasons, such as when one or more of the generating units at Libby Dam is out of service, and/or there is a decision to maintain water quality by storing water rather than spilling it. The hydro-regulation modeling for this EA assumed that all generating units at Libby Dam were available, and that Libby would not exceed its powerhouse capacity (i.e., Libby would not spill) in order to reach its flood control targets.

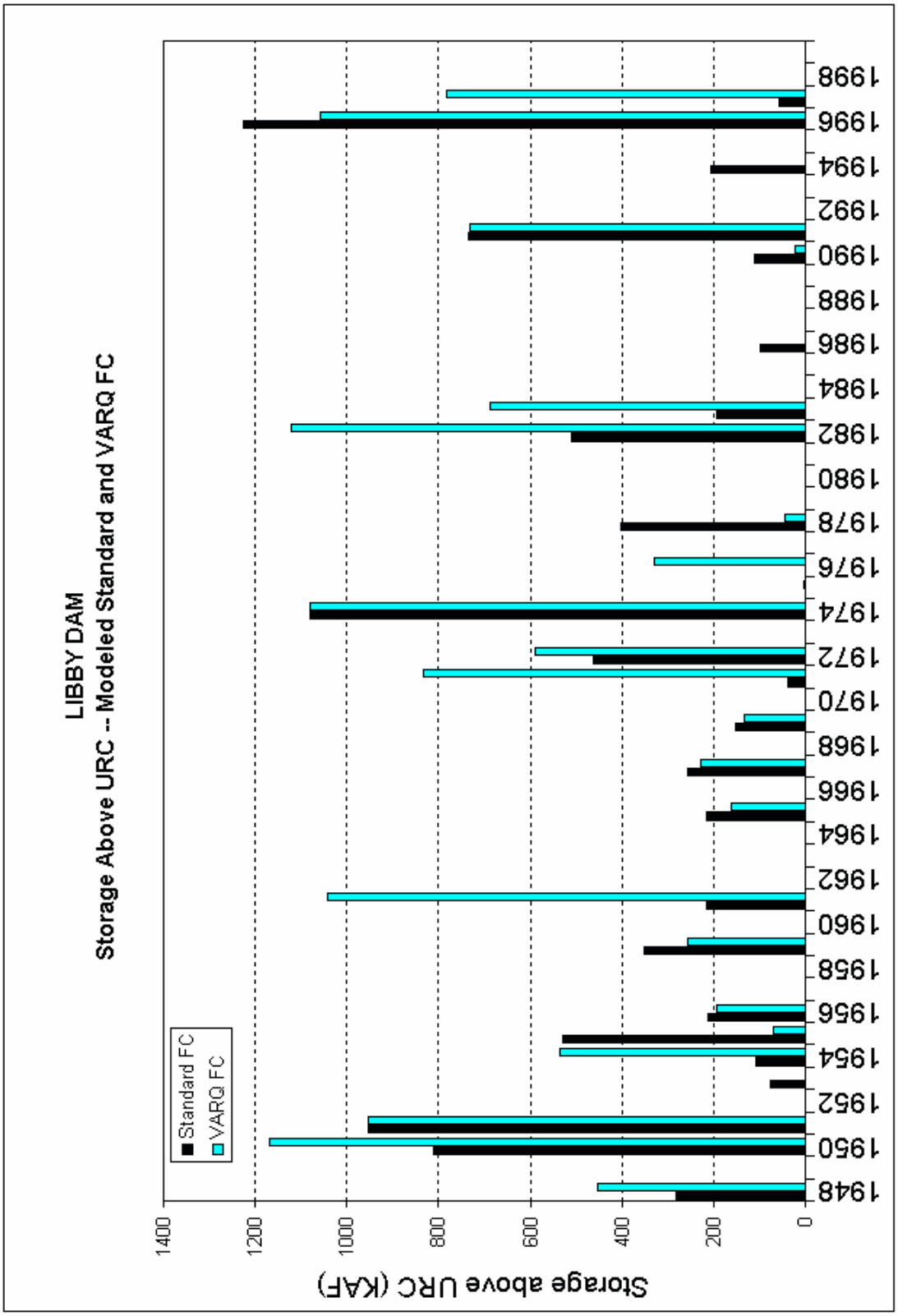
Technically, any water stored above the URC for reasons other than the IJC order on Kootenay Lake should not be called "trapped storage." It is more appropriate to call it "undesired storage", since the strict definition of trapped storage includes only the IJC Order on Kootenay Lake and mentions nothing of storage induced by other reasons (e.g., unit outages, water quality). In practice, any water stored above the URC is a concern, regardless of the reason why it is there. For this analysis, "trapped storage" and "undesired storage" are collectively referred to as "storage above the URC." Figure 10 compares the amount of storage above the URC relative to each of the two flood control operations modeled. In about half of the years modeled, some amount of storage above the URC was associated with the Standard FC benchmark, VARQ FC benchmark, or both. These years fall into three general categories: 1) years when the Standard FC and VARQ FC benchmarks both have equal storage above the URC; 2) years where the VARQ FC benchmark has more storage above the URC than the Standard FC benchmark; and 3) years where the VARQ FC benchmark has less storage above the URC than the Standard FC benchmark.

The first category, where both flood control procedures have the same storage above the URC, occurs when the seasonal volume forecasts are consistently high (greater than 8 MAF) throughout the flood control draft period. The years 1951, 1974, and 1991 fall into this category. Examination of historic operations at Libby Dam confirms the tendency to be above the URC in years with very large forecasts. This is primarily due to the draft restrictions associated with the IJC Order on Kootenay Lake.

The second category describes years where the VARQ FC benchmark has more storage above the URC than the Standard FC benchmark. This occurs when the seasonal volume forecasts later in the season (in April or May) are higher than the forecasts issued earlier in the season (Jan, Feb, or March). Due to the changing nature of the forecast, the VARQ FC benchmark ends up with more storage above the URC because the draft requirement early in the season turned out to be too small. Years such as 1954, 1961, 1971, and 1982 fall into this category.

The third category describes years where the VARQ FC benchmark has less storage above the URC than the Standard FC benchmark. This is due to the simple fact that the Standard FC benchmark requires a significantly greater draft than the VARQ FC benchmark in these years, presenting a greater opportunity for having storage above the URC. Years such as 1955, 1959, 1978, and 1994 fall into this category.

Figure 10. Storage above the URC at Libby Dam as a result of Standard FC and VARQ FC Benchmarks



2.2.6 Bonners Ferry

As well as providing system flood control for the Lower Columbia River, Libby Dam also provides local flood control for the Kootenai basin. The control point used for local flood control is the USGS gage #12310100 in Bonners Ferry, Idaho. When Libby Dam was completed in 1973, flood stage was estimated to occur at about 1770 feet at Bonners Ferry. Since then, the estimate for flood stage at Bonners Ferry has been reduced twice, and is presently estimated at 1764 feet. Flood stage is defined as the level or stage at which a stream overflows its banks or the stage at which overflow from a stream begins to cause damage.

The Corps of Engineers operates Libby Dam to minimize downstream flood impacts without compromising the local flood control objective of providing flood protection from the 0.5%-chance-exceedance flood[11] to the Bonners Ferry area from river stages greater than 1770 feet (Corps 1992) (National Geodetic Vertical Datum 1929, or NGVD 29). Since the National Weather Service presently estimates flood stage at 1764 feet for Bonners Ferry, the hydro-regulation modeling performed for this study attempted to limit river stages to 1764 feet at Bonners Ferry insofar as possible.

The highest river stages at Bonners Ferry generally occur during the months of May, June, and July. A stage-frequency curve specific to those months is provided in Figure 11[12]. In general, the VARQ FC benchmark results in higher river stages in non-flood years at Bonners Ferry than the Standard FC benchmark. However, this effect diminishes for the lower percent-chance-exceedance events (right side of graph), and both curves temporarily plateau near elevation 1764 feet. This plateau occurs because of the modeling objective to try to limit Bonners Ferry stage to that level. Beyond the elevation 1764 feet plateau, the two curves diverge a very small amount before converging again, at which point both Standard FC and VARQ FC benchmarks provide the same level of protection. This occurs around elevation 1765 feet, which is approximately a 2%-chance-exceedance event.[13]

A stage-duration curve specific to the months of May through July was also developed for Bonners Ferry, and is shown in Figure 12. As one would expect, the stage at Bonners Ferry is higher a greater percentage of time under the VARQ FC benchmark than it is with the Standard FC benchmark. This effect diminishes as the stage increases, and there is little perceptible difference between the two flood control methods as the stage approaches elevation 1764 feet. Thus, the modeling results indicate that the VARQ FC benchmark provides comparable flood protection to the Standard FC benchmark at Bonners Ferry.

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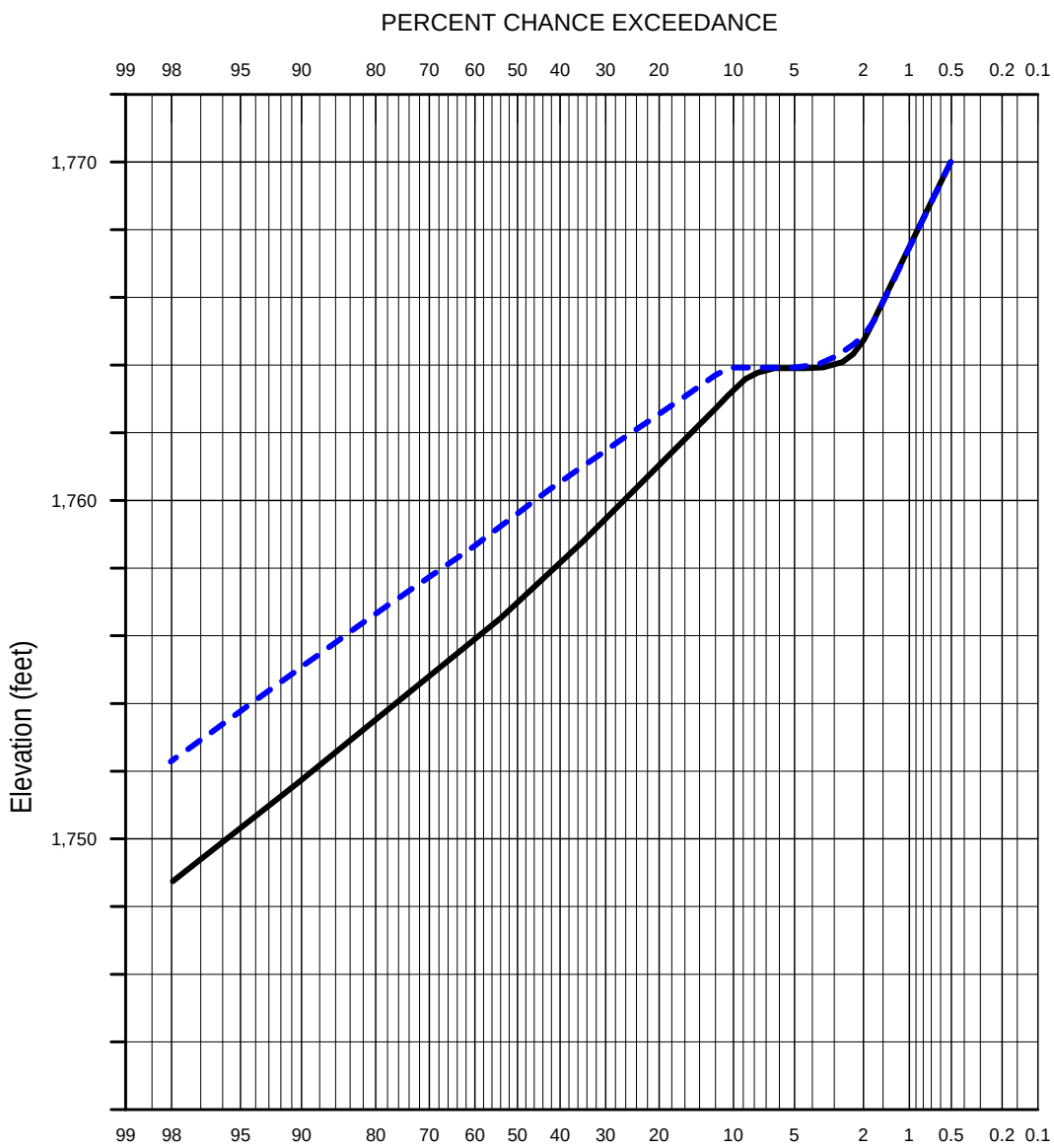
[11] A 0.5%-chance-exceedance flood has a 1 in 200 chance of being equaled or exceeded in any given year. It is sometimes called a “200-year flood.”

[12] A regulated stage of 1770 feet for the 0.5%-chance-exceedance event was used to help define the upper end of this frequency curve.

[13] A 2%-chance-exceedance flood has a 1 in 50 chance of being equaled or exceeded in any given year. It is sometimes called a “50-year flood.”

Figure 11. Stage-Frequency Analysis: Bonners Ferry Maximum Daily Elevation (May-July), Flood Control Simulations - Standard FC and VARQ FC Benchmarks



LEGEND

Standard FC

VARQ FC

NOTE: A regulated stage of 1770 feet for the 0.5%-chance-exceedance event was used to help define the upper end of this frequency curve.

2004 UPPER COLUMBIA EIS MODELING RESULTS

BONNERS FERRY, IDAHO
MODELED STANDARD AND VARQ FLOOD CONTROL STAGE FREQUENCY ANALYSIS

BONNERS FERRY MAXIMUM DAILY ELEVATION (MAY-JULY)

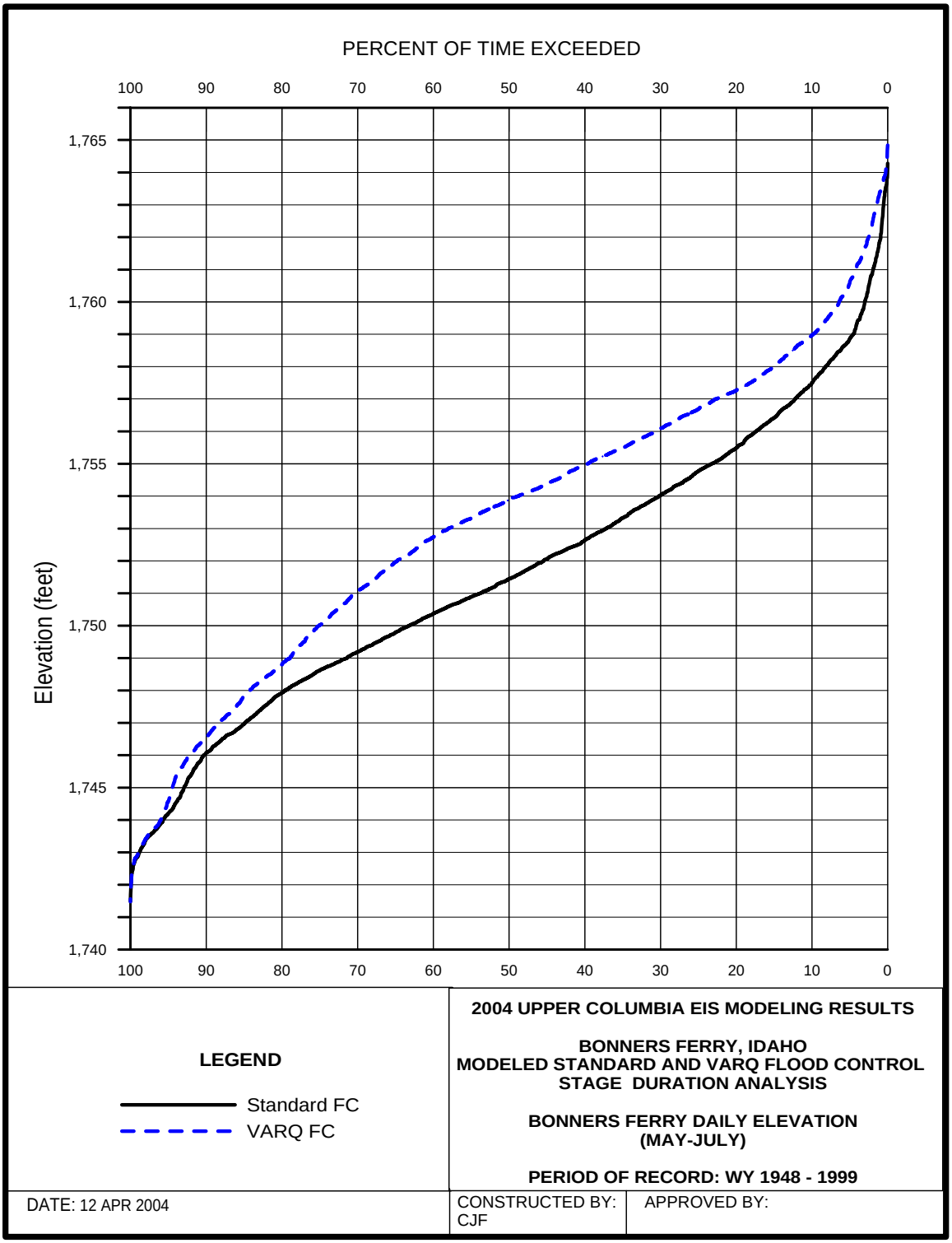
PERIOD OF RECORD: WY 1948 - 1999

DATE: 27 JULY 2004

CONSTRUCTED BY: CJF

APPROVED BY:

Figure 12. Stage-Duration Analysis: Bonners Ferry Daily Elevation (May-July), Flood Control Simulations - Standard FC and VARQ FC Benchmarks



2.2.7 Kootenay Lake

Corra Linn Dam controls the level of Kootenay Lake during the majority of the year when low runoff and base flow conditions exist. There can be periods of high flow when the lake level is controlled by the natural constriction through Grohman Narrows located upstream of Corra Linn Dam in the west arm of Kootenay Lake. The International Joint Commission (IJC) Order of 1938 on Kootenay Lake established rules governing the lake's maximum allowable level. These rules are still used today.

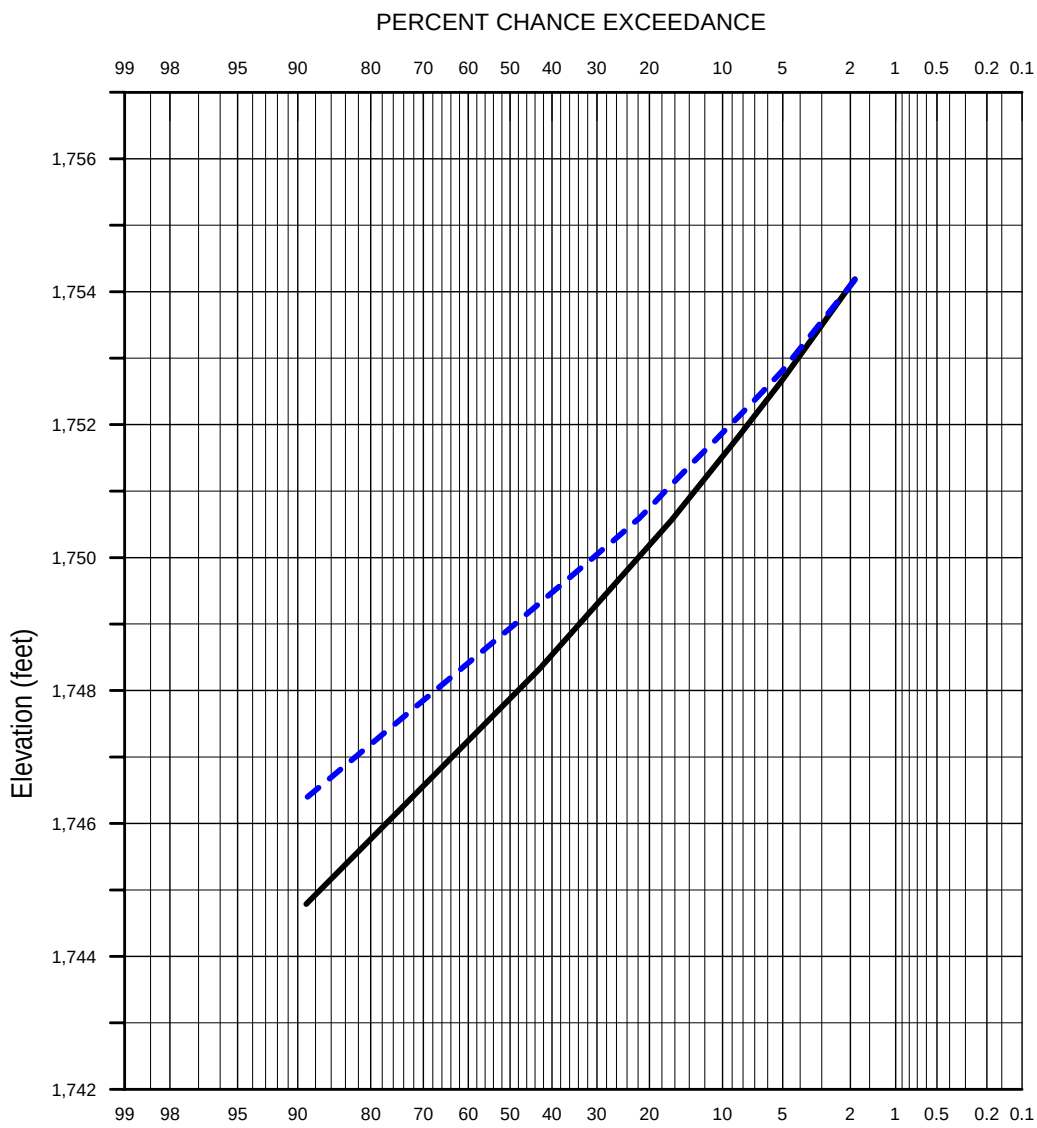
There are two hydropower facilities at the outlet of Kootenay Lake: Corra Linn Dam and the Kootenay Canal Plant with several other hydroelectric dams immediately downstream. In the modeling done for this study, they were collectively modeled as one dam. All hydro-regulations for this study met the requirements of the 1938 IJC Order. When a conflict existed in meeting the 1938 IJC Order, outflow from Duncan Dam was reduced to passing no more than inflow and Libby Dam was allowed to continue drafting if allowable.

From a flood control perspective, the impacts of VARQ FC on the level of Kootenay Lake are of greatest importance in May, June, and July. An elevation-frequency curve specific to those months is provided in Figure 13[14]. The frequency curve shows that for the high percent-chance-exceedance (low runoff) events (on the left side of the graph), the Kootenay Lake levels associated with the VARQ FC benchmark are consistently higher than those under the Standard FC benchmark. This effect diminishes as one moves toward the low percent-chance-exceedance events (on the right side of the graph), and the two curves eventually converge near elevation 1754 feet. In all simulations, the maximum stage at Kootenay Lake remained below elevation 1755 feet, regardless of which flood control procedure was used. The 1972 Columbia River Treaty Flood Control Operating Plan (FCOP) states that "damage commences at Nelson when Kootenay Lake reaches elevation 1755 feet and major damage stage is elevation 1759 feet" (Corps 1972). Since 1972, substantial encroachment around Kootenay Lake has occurred, and it is probable that damage now commences below elevation 1755 feet. The Canadian entity is endeavoring to create an updated stage-damage relationship at Kootenay Lake.

Elevation-duration curves for Kootenay Lake were developed for the months of May, June, and July. These are shown in Figure 14, Figure 15, and Figure 16, respectively. During May and June, the VARQ FC benchmark leads to higher Kootenay Lake elevations than does the Standard FC benchmark. This is also true for the month of July, but to a lesser degree.

[14] The observed elevation of 1754.23 feet at Kootenay Lake in 1974 was used to help weight the placement of the Standard FC frequency curve for the low percent-chance-exceedance events (on the right side of the graph).

Figure 13. Elevation-Frequency Analysis: Kootenay Lake Maximum Daily Elevation (May-July), Flood Control Simulations - Standard FC and VARQ FC Benchmarks



LEGEND

Standard FC

VARQ FC

NOTE: The observed elevation of 1754.23 feet at Kootenay Lake in 1974 was used to help weight the placement of the Standard FC frequency curve for the low percent-chance-exceedance events (on the right side of the figure).

2004 UPPER COLUMBIA EIS MODELING RESULTS

KOOTENAY LAKE, CANADA
MODELED STANDARD AND VARQ FLOOD CONTROL ELEVATION FREQUENCY ANALYSIS

KOOTENAY LAKE MAXIMUM DAILY ELEVATION (MAY-JULY)

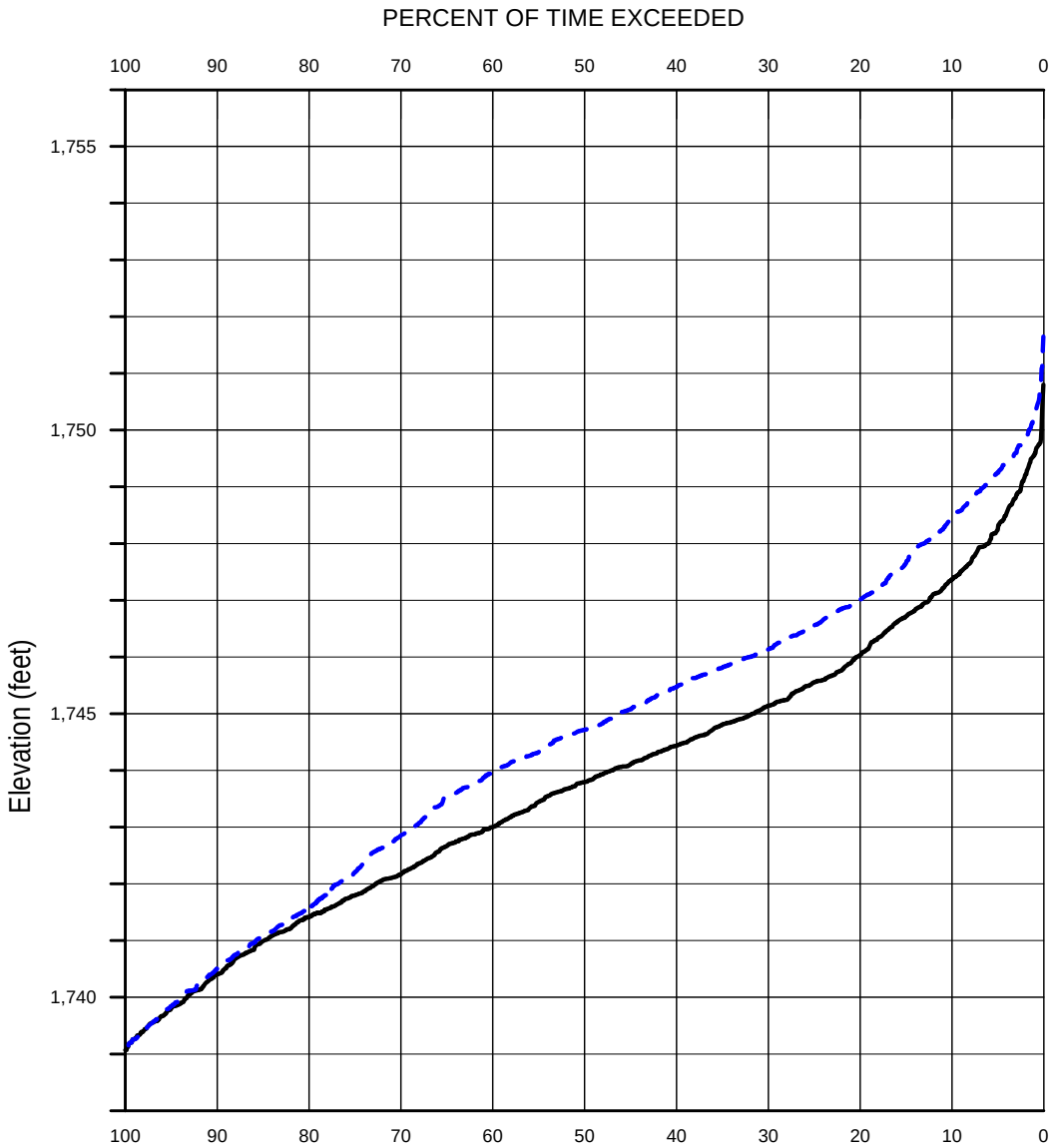
PERIOD OF RECORD: WY 1948 - 1999

DATE: 27 JULY 2004

CONSTRUCTED BY: CJF

APPROVED BY:

Figure 14. Elevation-Duration Analysis: Kootenay Lake Daily Elevation (May), Flood Control Simulations - Standard FC and VARQ FC Benchmarks



LEGEND

Standard FC

VARQ FC

2004 UPPER COLUMBIA EIS MODELING RESULTS

KOOTENAY LAKE, CANADA
MODELED STANDARD AND VARQ FLOOD CONTROL STAGE DURATION ANALYSIS

KOOTENAY LAKE DAILY ELEVATION (MAY)

PERIOD OF RECORD: WY 1948 - 1999

DATE: 12 APR 2004

CONSTRUCTED BY: CJF

APPROVED BY:

Figure 15. Elevation-Duration Analysis: Kootenay Lake Daily Elevation (June) , Flood Control Simulations - Standard FC and VARQ FC Benchmarks

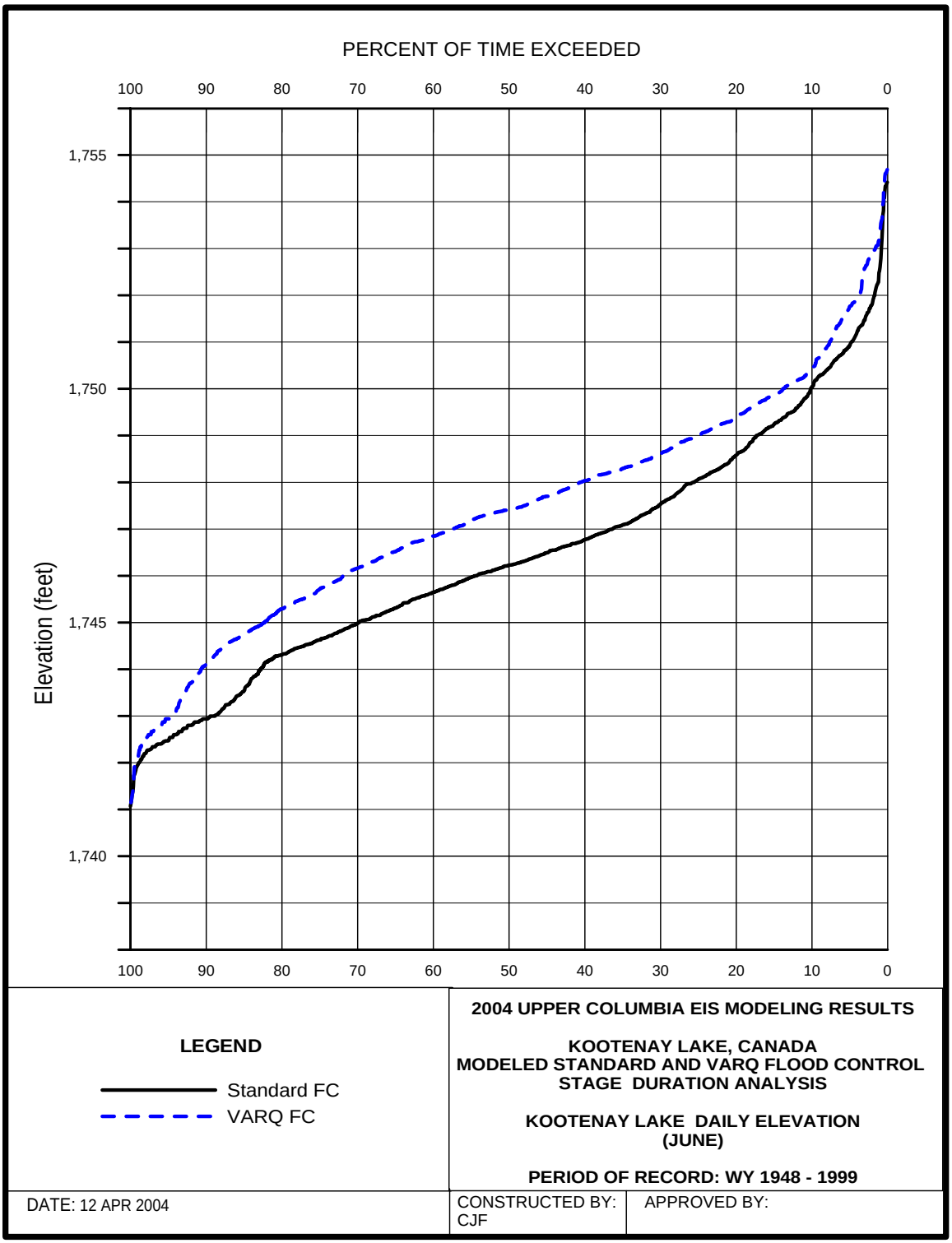
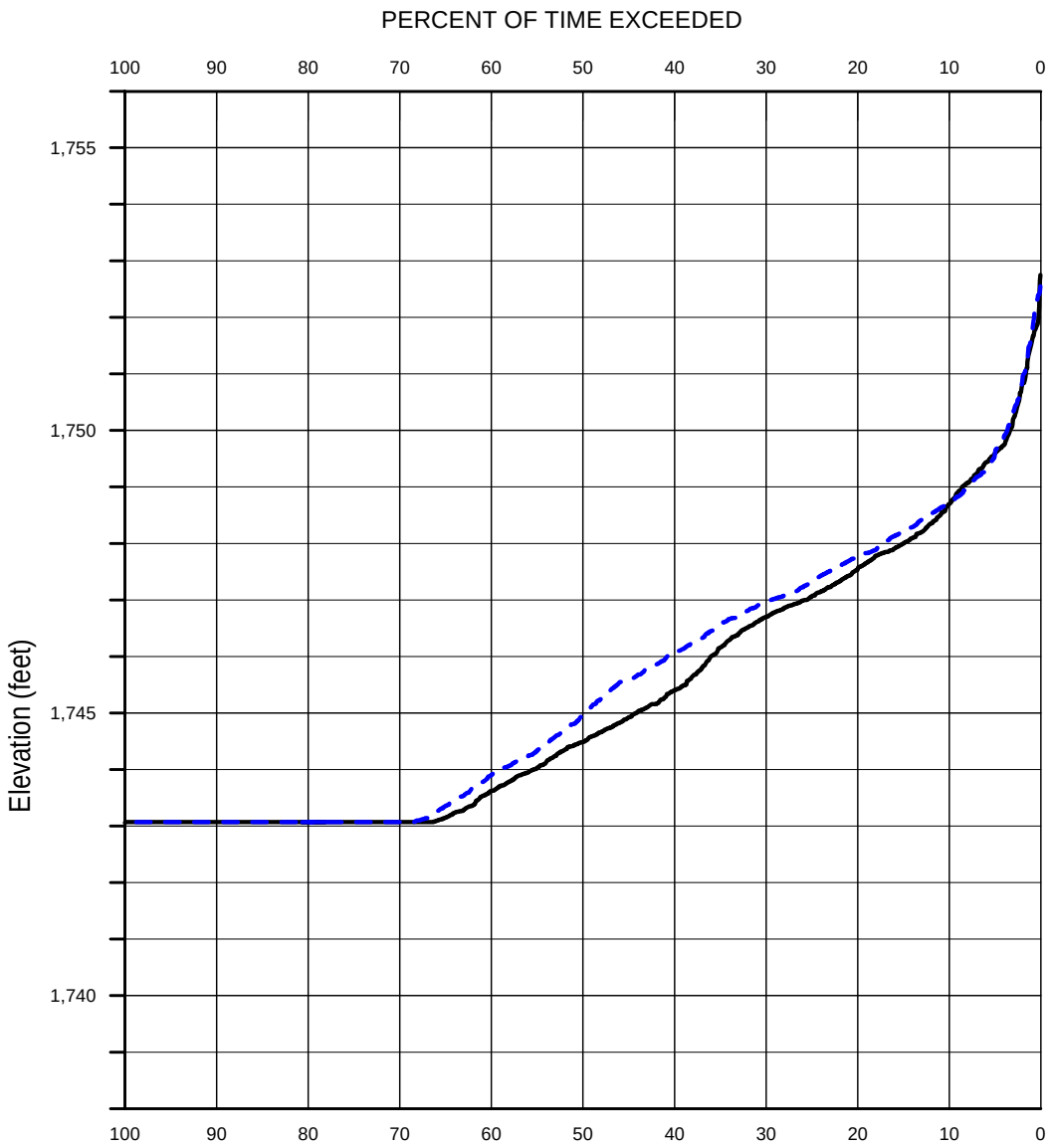


Figure 16. Elevation-Duration Analysis: Kootenay Lake Daily Elevation (July) , Flood Control Simulations - Standard FC and VARQ FC Benchmarks



LEGEND

Standard FC

VARQ FC

2004 UPPER COLUMBIA EIS MODELING RESULTS

KOOTENAY LAKE, CANADA
MODELED STANDARD AND VARQ FLOOD CONTROL STAGE DURATION ANALYSIS

KOOTENAY LAKE DAILY ELEVATION (JULY)

PERIOD OF RECORD: WY 1948 - 1999

DATE: 12 APR 2004

CONSTRUCTED BY: CJF

APPROVED BY:

2.2.8 Duncan Dam

Duncan Dam is located upstream of Kootenay Lake on the Duncan River in southern British Columbia (Figure 1). The Duncan River flows into the north arm of Kootenay Lake, and the Kootenay River flows into the south arm of Kootenay Lake. Depending on the forecasted volume runoff, Duncan can provide up to 1.27 MAF of flood control storage space (versus up to 5 MAF for Lake Koocanusa). When conflicts developed in complying with the 1938 IJC Order on Kootenay Lake in the model simulations, Libby was given priority to draft before Duncan.

The flood control simulations show that outflows and reservoir elevations at Duncan Dam are essentially equivalent with the Standard FC or VARQ FC benchmarks.

3.0 Hydrologic Analysis of Flood Control Methods Combined with Fish Flows

3.1 Hydro-Regulations

For this part of the study, fish flows from Libby Dam were added to the flood control hydro-regulations. The results from the simulations are used to compare the differences between Standard FC and VARQ FC when fish flows from Libby Dam are introduced.

3.1.1 Background on Fish Flow Simulations

The 2000 Biological Opinions call for augmented flows from Libby Dam to benefit several listed fish populations downstream from the project. While the flood control simulations described in Section 2.0 of this report are useful in assessing incremental differences between Standard FC and VARQ FC, the added complexity of providing fish flows from Libby Dam must also be assessed. To do this, the following simulations were completed for water years 1948-1999:

- Standard FC with fish flows (including sturgeon flows to outflow capacity at powerhouse) *[or LS1 in the EIS]*
- VARQ FC with fish flows (including sturgeon flows to outflow capacity at powerhouse) *[or LV1 in the EIS]*
- Standard FC with fish flows (including sturgeon flows to outflow capacity at powerhouse plus 10 kcfs)[15] *[or LS2 in the EIS]*
- VARQ FC with fish flows (including sturgeon flows to outflow capacity at powerhouse plus 10 kcfs) *[or LV2 in the EIS]*

[15] The maximum sturgeon outflow called for in the U.S. Fish and Wildlife Service (USFWS) 2000 Biological Opinion is the current powerhouse capacity + 10 kcfs.

3.1.2 Initialization

For the fish flow simulations, the reservoir elevation at Libby Dam was re-initialized at elevation 2439 feet (20 feet below the full pool elevation of 2459 feet) at the beginning of each water year to depict a realistic starting condition caused by the previous year's salmon draft. The other reservoirs in the Kootenai basin were re-initialized at full pool.

3.1.3 Description of "Fish Flow" Template

The following paragraphs describe the fish flow operations and assumptions used in this modeling effort. Actual operations will look different because they must be managed to address differing conditions each year, including calls from the USFWS and NMFS for specific fish flows. Dam discharges will be "shaped" in real time to address requirements for fish and to meet flood control constraints. In contrast, an evaluation like the one documented below must use a consistent set of provisions in order to make valid comparisons.

In general for this evaluation, between October and April, Libby Dam operates the same in the fish flow simulations as it did in the flood-control-only simulations. Special operation of Libby Dam to provide fish flows for ESA-listed fish populations downstream is not required until the late spring and summer. In May and/or June, discharge from the project is increased for the benefit of sturgeon downstream in the Bonners Ferry reach of the river. Immediately following the sturgeon flow augmentation, minimum flows ranging from 6 to 9 kcfs are required for bull trout. Then, before August 31, a portion of the water stored behind Libby Dam must be released for the benefit of salmon in the lower Columbia.

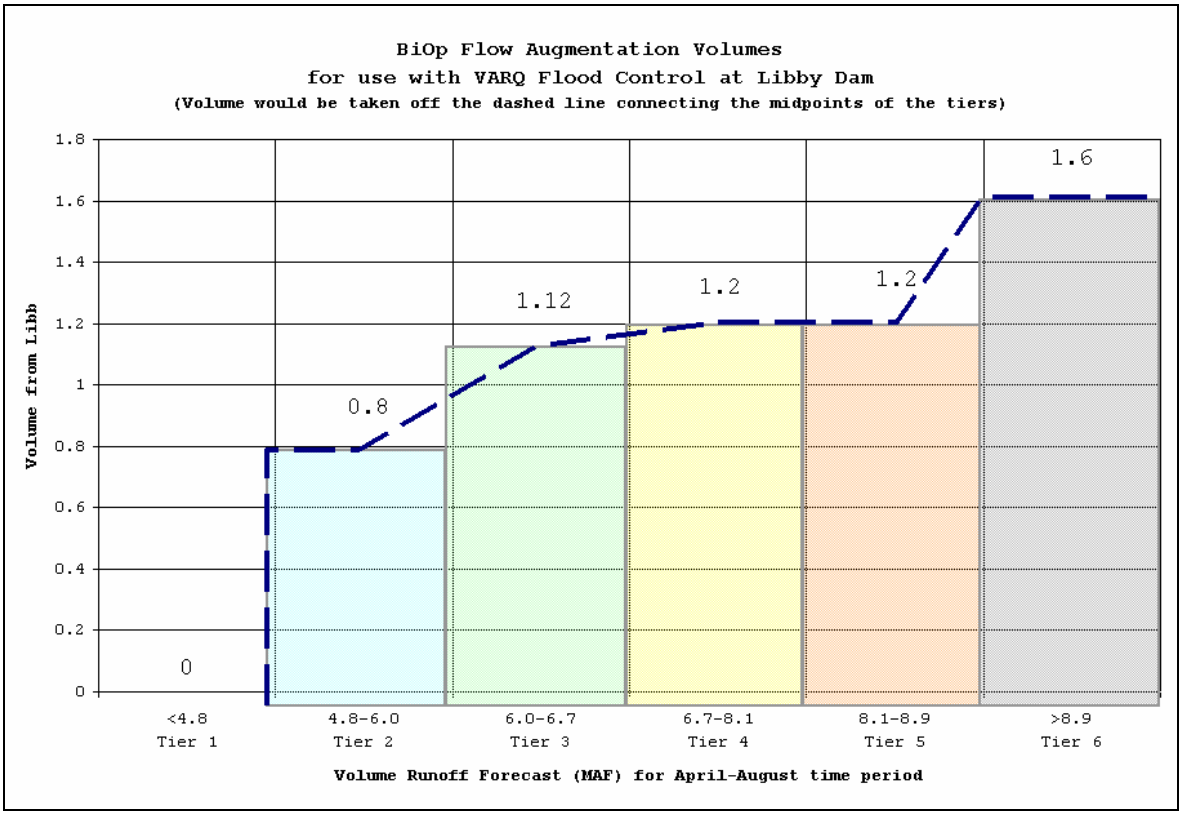
3.1.3.1 Sturgeon Operation

On March 25 and 26, 2002, representatives from the Corps of Engineers and the USFWS met to discuss measurement and delivery of augmented water volumes for sturgeon. It was decided that augmentation volumes will be measured at Libby Dam. This facilitates volume accounting and greatly simplifies the modeling process. It was further decided that the augmentation volume should be interpolated according to the runoff forecast, as shown below in Figure 17.

A fish flow template was also developed to define the timing and shaping of fish flows for modeling purposes. The sturgeon volumes as measured at Libby Dam and the fish flow template to be used for the EIS modeling were memorialized at the executive level in August 2002.

The aforementioned method for measuring and delivering sturgeon water was used to perform the fish flow simulations. If the seasonal water supply forecast was less than 4.8 MAF no sturgeon water was provided. If the forecast was greater than 8.9 MAF, the amount of water provided for sturgeon was capped at 1.6 MAF.[16] The minimum release of 4 kcfs from Libby Dam is not included in the accounting of sturgeon water.

Figure 17. Sturgeon water volumes to be provided from Libby Dam



[16] In assessing the effects of future sturgeon operations, reliant upon water stored under VarQ flood control procedures, it should be noted that sturgeon augmentation flows are not expected to occur annually in the long-term.
The Kootenai River White Sturgeon Recovery Plan indicates that the species could be downlisted to threatened status when: 1) successful natural recruitment can be documented in at least three years out of a 10 year period; 2) the population is stable or increasing; and 3) a management strategy is in place which describes the environmental conditions necessary for this natural recruitment with emphasis on its repeatability.

Successful natural recruitment is defined in the recovery plan as the documentation of at least 20 individuals reaching age one or more from a given year class. However, in spite of the remarkably high fecundity, no year class since 1974 is known to have fulfilled even this minimal success threshold. Until the required conditions to downlist the sturgeon are met, flow augmentation for the species can be expected to occur regularly.

In practice, the timing and shaping of these volumes are based on seasonal requests from the USFWS. However, for modeling purposes, the following guidelines from the fish flow template were used:

- for years when the April-August forecast (issued in May) was between 4.8 and 6.0 MAF, ramp-up for the sturgeon flows began on 16 May
- for years when the April-August forecast (issued in May) was between 6.0 and 6.7 MAF, the ramp-up for sturgeon flows began on 23 May
- for years when the April-August forecast (issued in May) was greater than 6.7 MAF, the ramp-up for sturgeon flows began on 1 June

For modeling, the outflow was ramped up to the maximum sturgeon flow of either powerhouse capacity or powerhouse capacity plus 10 kcfs according to Biological Opinion ramp rates. Then, the outflow was held constant at either powerhouse capacity or powerhouse capacity plus 10 kcfs for whatever duration was necessary so that the full sturgeon volume was delivered before the end of the ramp-down to bull trout flows. In cases where there was a conflict between providing flood control at Bonners Ferry (by holding the river below flood stage) and sturgeon augmentation water from Libby Dam, local flood control operations took precedence.

At the present time, it is not possible to discharge anything higher than full powerhouse capacity plus 1-2 kcfs via the spillway without exceeding Montana state water quality limits of 110% for total dissolved gas (TDG) in parts of the river just downstream of the dam (ERDC 2003). Nonetheless, the powerhouse capacity plus 10 kcfs sturgeon flows were modeled to address the flow recommendations listed under RPA 8.2 in the USFWS 2000 Biological Opinion. The model simulations assume that it would be possible to discharge powerhouse capacity plus 10 kcfs from Libby Dam for sturgeon flow augmentation, regardless of reservoir elevation. In other words, it was not necessary for the simulated reservoir elevation to be above the spillway crest to discharge more than the powerhouse capacity. No assumption was made concerning which outlets were used for this release. This is an important point, because the mechanism for implementation of additional flow capacity has not been determined, and may ultimately involve spill. For this analysis, no mechanism could be assumed. Further analysis and documentation will occur as necessary if and when a mechanism is developed.

3.1.3.2 Bull Trout Operation

Immediately following ramp-down from the sturgeon flow augmentation, the model required Libby Dam to release the minimum bull trout outflow ranging from 6 to 9 kcfs until at least the end of June. In years where sturgeon augmentation was not required due to a low runoff forecast, the bull trout flow began on 1 July. The bull trout flow requirement is based on the April-August forecast (issued in June), as shown in Table 4.

Table 4. Minimum bull trout flows to be provided from Libby Dam

April-August forecast (MAF) issued in June	Minimum bull trout flow to be provided (cfs)
Less than 4.8	6,000
4.8 – 6.0	7,000
6.0-6.7	8,000
Greater than 6.7	9,000

3.1.3.3 Salmon Operation

For the months of July and August, an attempt was made to provide steady outflow from Libby Dam such that the reservoir would be drafted to elevation 2439 feet by the end of August, as stipulated in RPA 19 of the NMFS 2000 Biological Opinion. A steady outflow operation over the months of July and August was modeled to avoid the "double-peak" that can occur if salmon water is released solely in the month of August. In that scenario, a drop in outflows following sturgeon operations reduces the wetted perimeter of the river channel and impacts aquatic invertebrates and juvenile fish, and is then followed by a rewatering. It is better to maintain flows sufficient to keep the river margins submerged. In cases where the steady outflow operation called for a lower discharge than the minimum bull trout flow, the minimum bull trout flow was provided. This modeling approach was discussed and approved by NMFS on August 28, 2003.

In some years, the modeled sturgeon flow augmentation ended during the last week of June. Rather than providing the minimum bull trout flow for one week (or less) and then increasing to a steady salmon flow beginning on 1 July, an immediate transition from sturgeon flows to salmon flows was made. By transitioning in this manner, a double-peak operation was avoided. In all cases, the outflow from Libby Dam following the sturgeon operation was greater than or equal to the minimum bull trout flow required.

3.1.3.4 Fish Flow Template vs. Actual Operations

In development of scenarios with fish flows, a template of outflow was developed for use in all fish flow model runs. The increase of outflow from Libby Dam began on a fixed date, depending on the magnitude of the water year. In actual operations, the fish flow operation may begin earlier or later than the dates specified in the fish flow template.

Because of the short forward-looking weather forecast and the rigid fish flow template used by modelers, the model output results will be different than real-time operations, although the trends will be preserved. Real-time adaptive management allows for flexibility in the operation of Libby Dam to better meet multi-purpose needs. In real-time adaptive management, some high flow may be somewhat reduced by use of operational flexibility that could not be injected into these scenarios.

3.2 Model Results

Output data from period-of-record flood control simulations with fish flows are presented in the following sections, which depict impacts to Lake Koocanusa and Libby Dam, Bonners Ferry, Kootenay Lake, and Duncan Dam.

3.2.1 Analysis of Results

Potential impacts from fish flows can be characterized with flow/stage-frequency curves and flow/stage-duration curves at various locations throughout the Kootenai basin. To illustrate the differences between Standard FC and VARQ FC when fish flows are introduced, each figure has four curves plotted:

- Standard FC with fish flows at powerhouse capacity *[or LS1 in the EIS]*
- VARQ FC with fish flows at powerhouse capacity *[or LV1 in the EIS]*
- Standard FC with fish flows at powerhouse capacity plus 10 kcfs *[or LS2 in the EIS]*
- VARQ FC with fish flows at powerhouse capacity plus 10 kcfs *[or LV2 in the EIS]*

Procedures for graphing regulated hydrologic data are outlined in a Corps Engineer Manual entitled *Hydrologic Frequency Analysis*, EM 1110-2-1415 (Corps 1993).

3.2.2 Lake Koocanusa

Model simulations for this study show that when fish flows are included in the operation of Libby Dam, it is no longer possible to refill the reservoir with the same degree of certainty as was possible with the flood-control-only scenarios. Elevation-duration curves for the months of May, June, and July are shown in Figure 18, Figure 19, and Figure 20, respectively. In all cases, reservoir elevations for the fish flow simulations are higher when VARQ FC is used instead of Standard FC, as expected. Also, the reservoir elevations in the fish flow scenarios are all depressed from those in the flood-control-only scenarios (refer to Section 2.2.2).

Figure 18. Elevation-Duration Analysis: Libby Dam Daily Elevation (May), Fish Flow Simulations

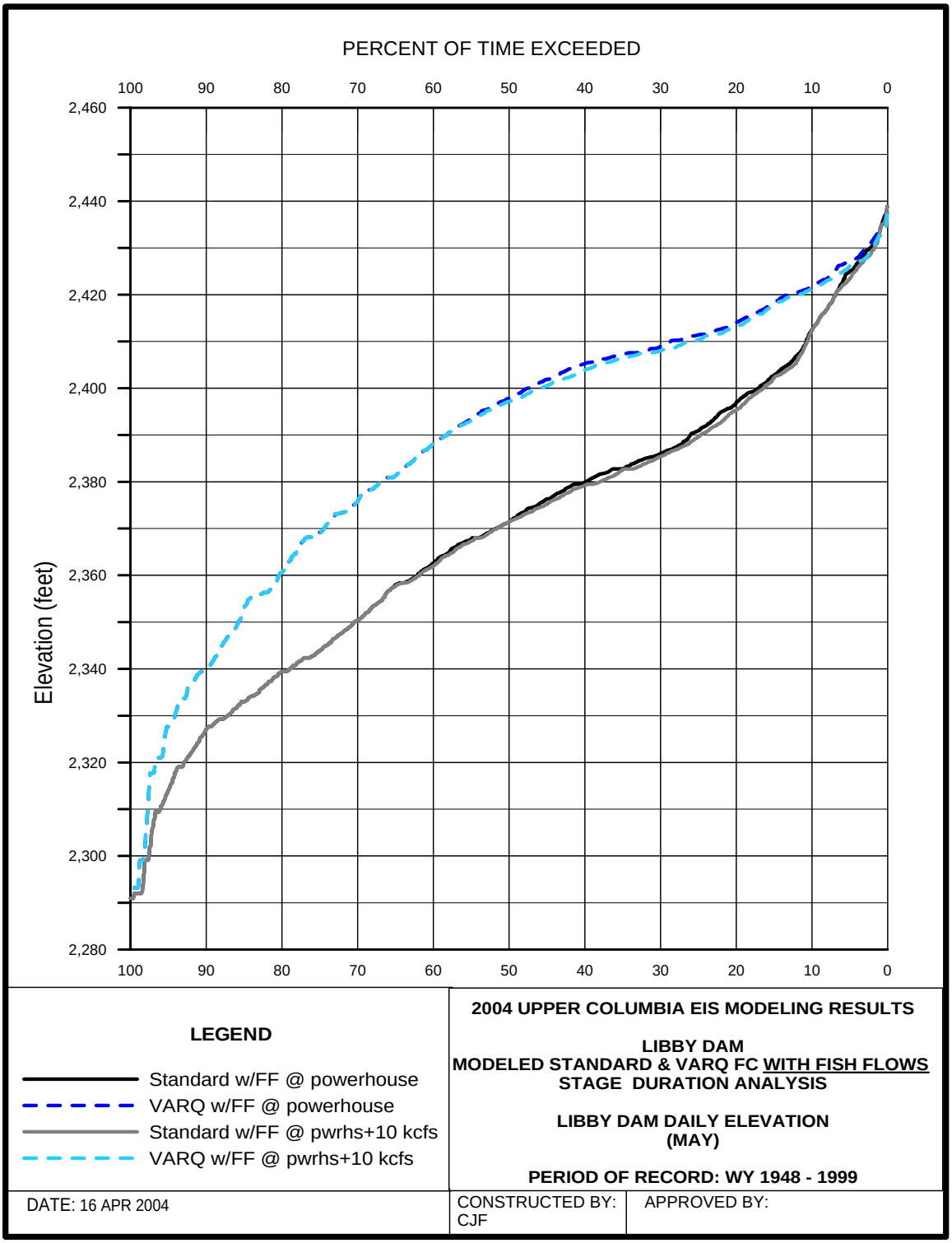
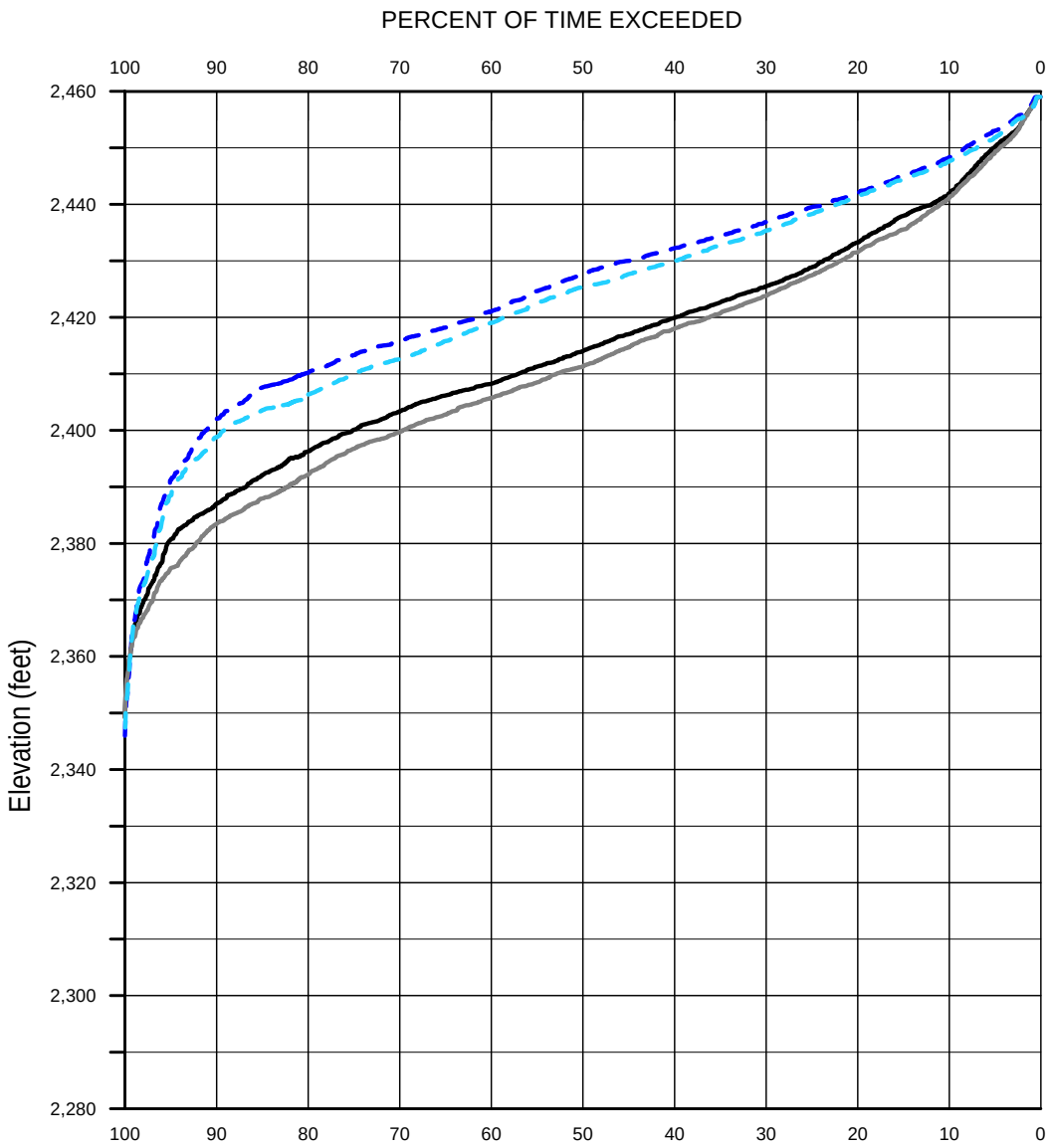


Figure 19. Elevation-Duration Analysis: Libby Dam Daily Elevation (June), Fish Flow Simulations



LEGEND

- Standard w/FF @ powerhouse
- VARQ w/FF @ powerhouse
- Standard w/FF @ pwrhs+10 kcfs
- VARQ w/FF @ pwrhs+10 kcfs

2004 UPPER COLUMBIA EIS MODELING RESULTS

LIBBY DAM
MODELED STANDARD & VARQ FC WITH FISH FLOWS
STAGE DURATION ANALYSIS

LIBBY DAM DAILY ELEVATION
(JUNE)

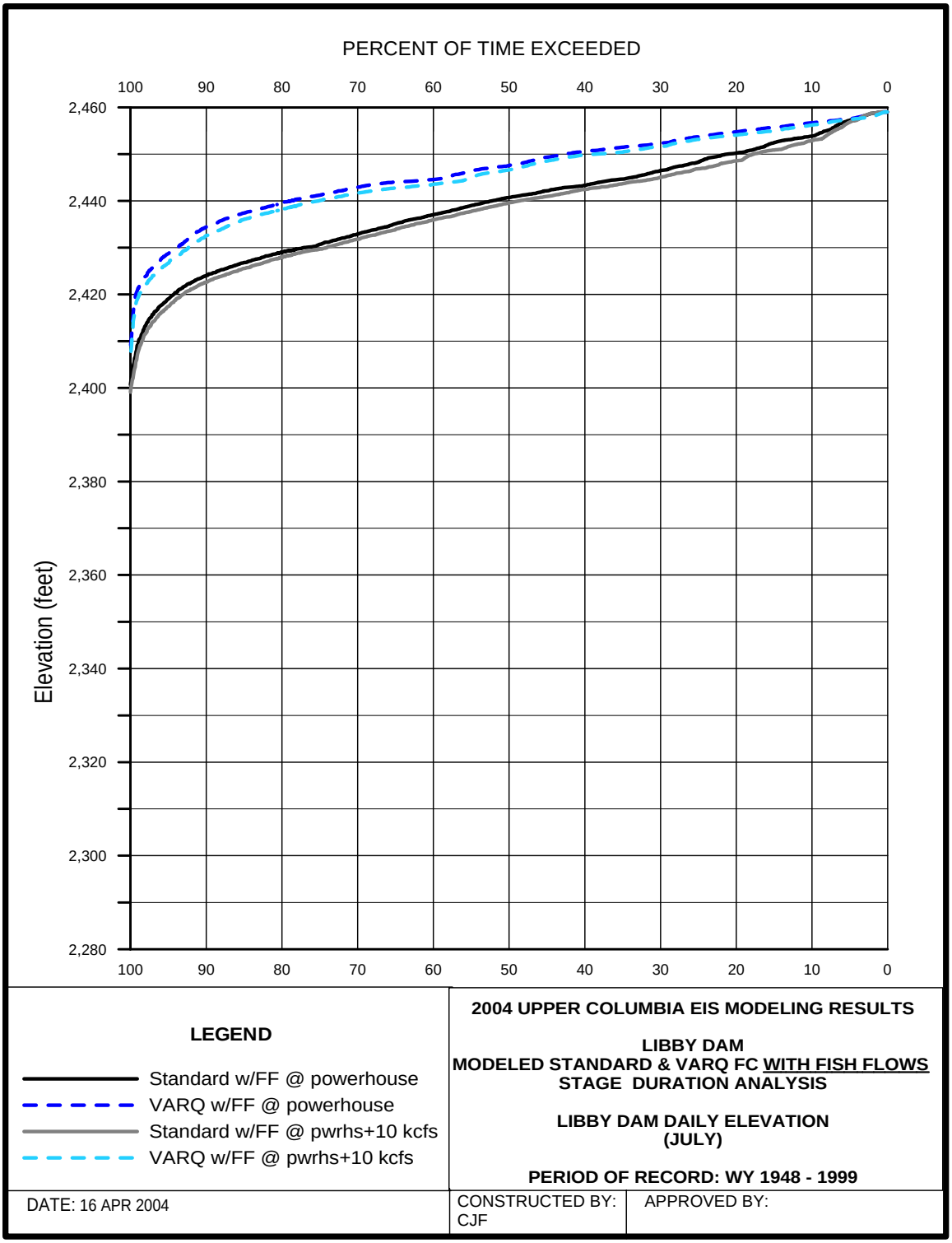
PERIOD OF RECORD: WY 1948 - 1999

DATE: 16 APR 2004

CONSTRUCTED BY: CJF

APPROVED BY:

Figure 20. Elevation-Duration Analysis: Libby Dam Daily Elevation (July), Fish Flow Simulations



3.2.3 Libby Dam Outflow

Besides reservoir elevation, the introduction of fish flows will obviously have an impact on outflow from Libby Dam. A flow-frequency curve based on the maximum outflow between May and July is provided in Figure 21. To model the sturgeon operation, the outflow was ramped up to either powerhouse capacity or powerhouse capacity plus 10 kcfs according to Biological Opinion ramping rates. The outflow was then held constant at either powerhouse capacity or powerhouse capacity plus 10 kcfs for whatever duration was necessary so that the full sturgeon volume was delivered before the end of the ramp-down to bull trout flows. Therefore, the first two curves in Figure 21 are relatively flat in the vicinity of 25-28 kcfs (powerhouse flow) and the next two curves are relatively flat in the vicinity of 35-38 kcfs (powerhouse plus 10 kcfs). The VARQ FC with fish flow curves plot slightly above the Standard FC with fish flow curves for the high percent-chance-exceedance events (at the left side of the graph). Moving to the right, the lines begin to converge, and there is no difference between Standard and VARQ FC for the low percent-chance-exceedance events when fish flows are introduced.

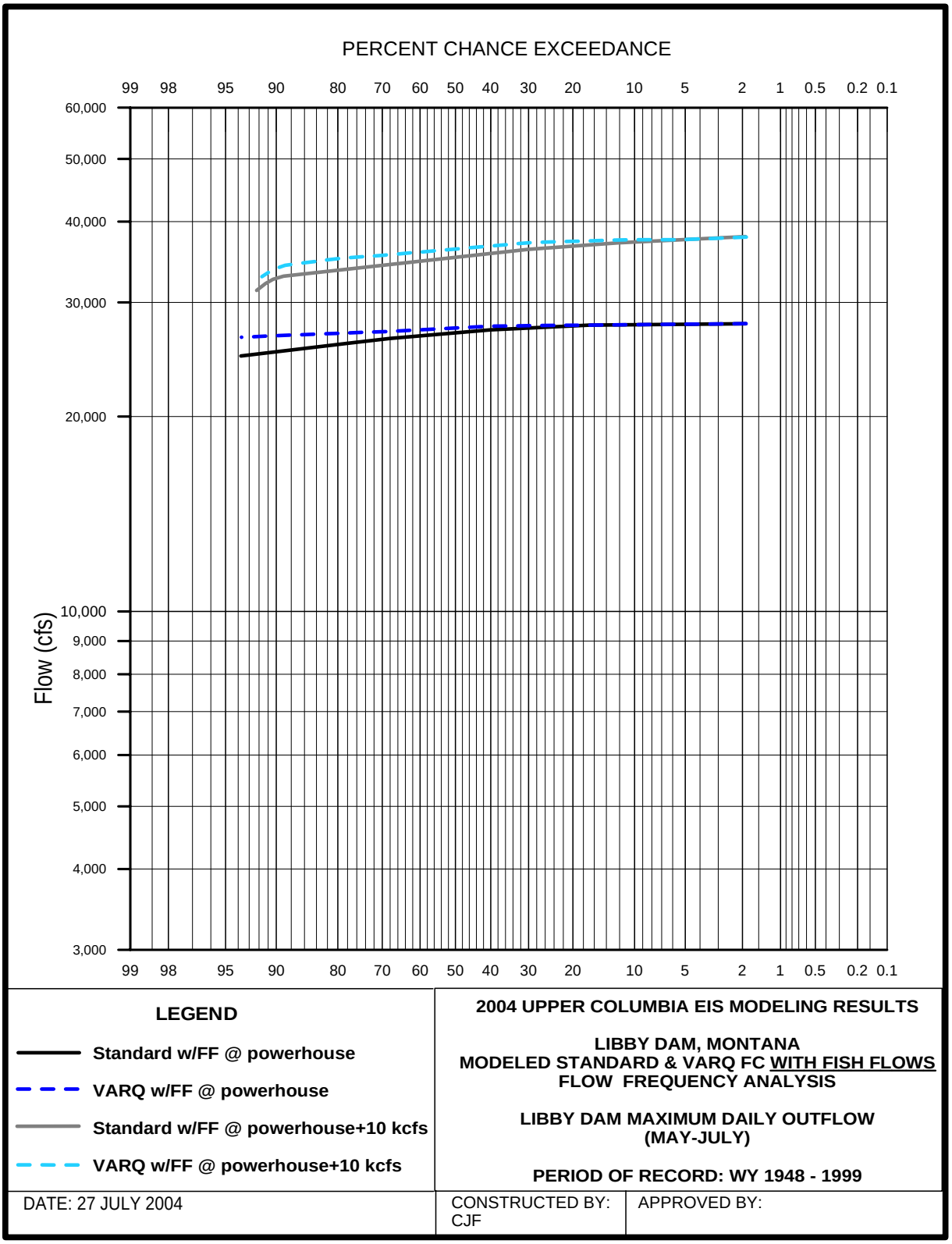
In reality, the sturgeon operations called for by USFWS have not always been at full powerhouse capacity. For instance, in 1995, 1998, and 2003, the maximum flow provided for sturgeon ranged between 20 kcfs and 22 kcfs. Thus, the model results tend to over-predict outflow from Libby Dam and river stages at Bonners Ferry when compared with the flows and stages that have actually occurred.

Due to the timing of the fish flows, the fish flow scenarios tend to increase outflow from Libby Dam between May and August. This is shown in Table 5, which also includes results from the flood control only simulations for comparison purposes. During May and June, the fish flow scenarios show high outflow because sturgeon flows are being provided. During the month of July, there is not much of a difference between the flood control only outflows and the fish flow outflows. This is because the sturgeon volume provided in the fish flow scenarios serves to preserve flood control space, reducing the required outflow in July. During the month of August, the fish flow scenarios show high outflows because the reservoir is being drafted to elevation 2439 feet by the end of the month.

Table 5. Monthly Average Outflow from Libby Dam (kcfs) – all scenarios

Month	Standard FC benchmark	VARQ FC benchmark	Standard FC w/ fish flows (powerhouse)	VARQ FC w/ fish flows (powerhouse)	Standard FC w/ fish flows (powerhouse +10 kcfs)	VARQ FC w/ fish flows (powerhouse +10 kcfs)
January	20.9	13.7	20.5	13.2	20.5	13.2
February	14.7	10.8	14.7	10.8	14.7	10.8
March	7.5	6.4	7.5	6.4	7.5	6.4
April	5.7	6.4	5.7	6.4	5.7	6.4
May	6.0	12.1	9.8	14.3	10.9	15.3
June	9.2	13.8	18.0	18.3	17.9	18.3
July	14.9	15.4	14.1	17.0	13.7	16.5
August	9.7	9.8	13.6	16.1	13.2	15.7

Figure 21. Flow-Frequency Analysis: Libby Dam Maximum Daily Outflow (May-July), Fish Flow Simulations



3.2.4 Water Quality

When fish flows are introduced to the flood control simulations, spillway use at Libby Dam for flood control becomes less frequent. The first two fish flow scenarios assume the maximum outflow from Libby Dam (for fish purposes) would be limited to the powerhouse capacity, whereas the last two fish flow scenarios assume an outflow of powerhouse plus 10 kcfs as the maximum fish flow. As stated previously, this modeling did not consider the mechanism by which the additional 10 kcfs would be released, so there is no relationship to assume regarding flow and TDG for the last two scenarios. In other words, it was assumed that the additional 10 kcfs could be released from Libby Dam even if the modeled pool elevation was below the spillway crest.[17] Therefore, a TDG analysis has been performed only for the first two fish flow scenarios, where fish flows are limited to the powerhouse capacity. Any spill associated with these first two fish flow scenarios is done for flood control purposes, not as flow augmentation for fish. A summary of the TDG exceedance for the first two fish flow scenarios is provided in Table 6. The TDG values used to develop this table come from the derived relationship between spill and TDG saturation downstream of the dam (ERDC 2003). The Montana water quality standard of 110% was exceeded in 1 out of 52 years for Standard FC with fish flows at powerhouse, and 3 out of 52 years for VARQ FC with fish flows at powerhouse. Based on all 52 years modeled, Standard FC with fish flows at powerhouse had 2 days in excess of the 110% standard, and VARQ FC with fish flows at powerhouse had 31 days in excess of the 110% standard. Comparing Table 6 with Table 3 (see Section 2.2.4), one sees that by introducing fish flows into to the simulations, the amount of spill needed to preserve flood control space is reduced. While this reduction in spill is beneficial from a water quality point of view, it comes at a price – namely, depressed elevations for Lake Koocanusa in the late spring and summer (see Section 3.2.2).

[17] Although the mechanism for providing the additional 10 kcfs was not considered, modeled reservoir elevations indicate that the spillway would not be available to provide this additional flow in several years, as the pool elevation at the time of the sturgeon flow augmentation (according to the fish flow template) would be below the spillway crest. For the Standard FC with fish flows at powerhouse + 10 kcfs scenario, the spillway would only be available for use in 12 out of the 49 years when sturgeon flows are provided (based on the timing in the fish flow template). For the VARQ FC with fish flows at powerhouse + 10 kcfs scenario, the spillway would be available for use in 26 out of the 49 years when sturgeon flows are provided (based on the timing in the fish flow template) – significantly more often than the previous scenario.

Table 6. Modeled TDG Exceedance, Flood Control with Fish Flows at Powerhouse Capacity Simulations

Threshold TDG saturation immed. below Libby Dam	Number of years with TDG greater than threshold Standard FC	Number of years with TDG greater than threshold VARQ FC	Number of days with TDG greater than threshold Standard FC	Number of days with TDG greater than threshold VARQ FC
100%	1	3	3	31
105%	1	3	3	31
110%	1	3	2	31
115%	0	2	0	25
120%	0	2	0	25
125%	0	2	0	24
130%	0	1	0	12

3.2.5 Bonners Ferry

The highest river stages at Bonners Ferry generally occur during the months of May, June, and July. A stage-frequency curve for the fish flow scenarios specific to those months is provided in Figure 22. For the high percent-chance-exceedance events (on the left side of the graph), the VARQ FC with fish flows curves plot above the Standard FC with fish flows curves, as expected. As was the case with the flood control only benchmark scenarios (refer to Section 2.2.6), this effect diminishes as one moves to the right toward the lower percent-chance-exceedance events. All four curves plateau at elevation 1764 feet. This plateau occurs because of the modeling objective to try to limit Bonners Ferry stage to that level. At the far right side of the graph, there is no perceptible difference between any of the fish flow scenarios. Note that peak stages above about 1758 feet occur much more frequently when fish flows are introduced than they do in the flood-control-only scenarios (refer to Section 2.2.6).

A stage-duration curve for the fish flow scenarios, covering the months of May through July, was also developed for Bonners Ferry, and is shown in Figure 23. As one would expect, the stage at Bonners Ferry is higher more often for the VARQ FC with fish flow scenarios than the Standard FC with fish flow scenarios. Also, stages of 1759 feet and above are more likely to occur when the fish flows are provided at powerhouse + 10 kcfs than they are when just the powerhouse is used.

Figure 22. Stage-Frequency Analysis: Bonners Ferry Maximum Daily Elevation (May-July), Fish Flow Simulations

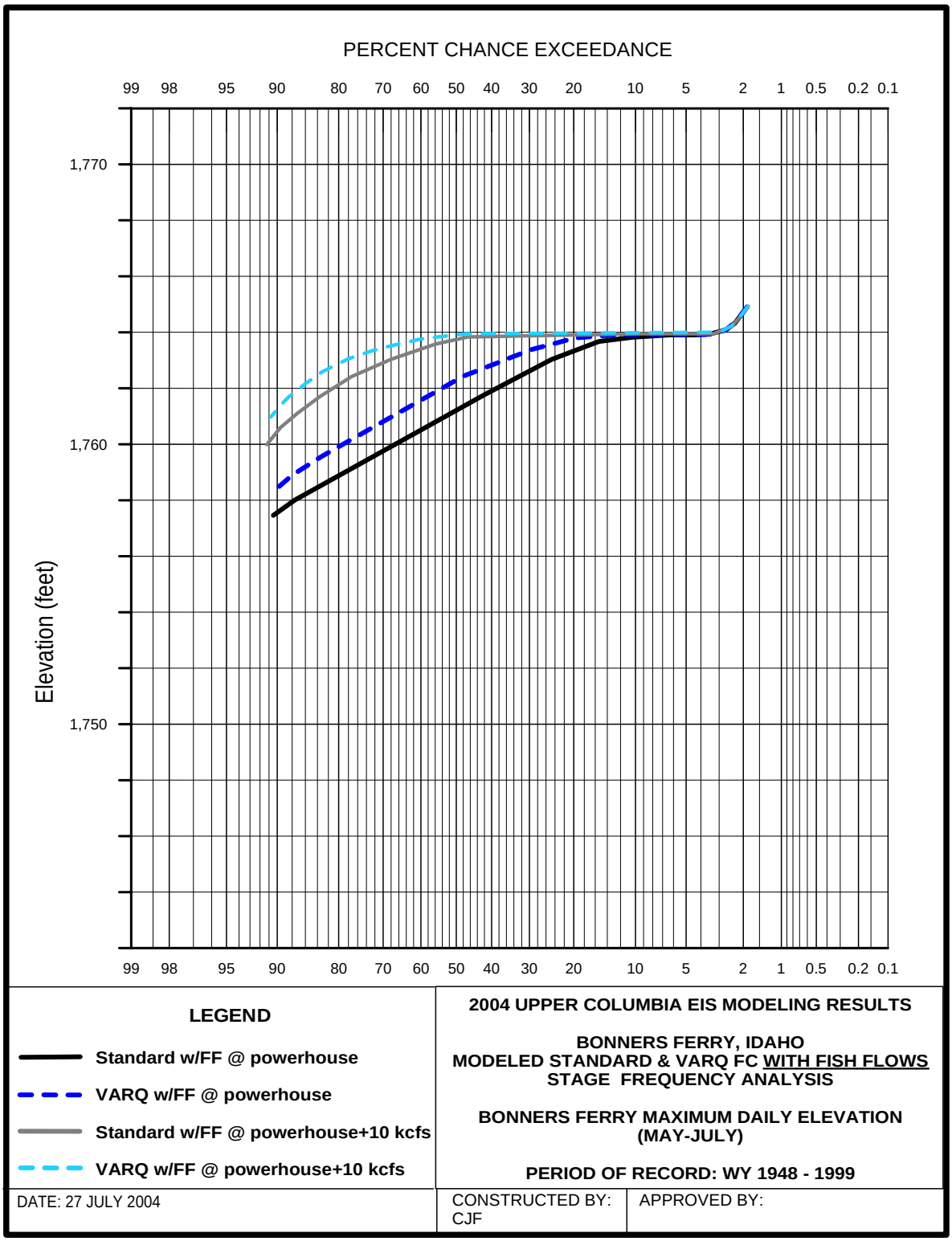
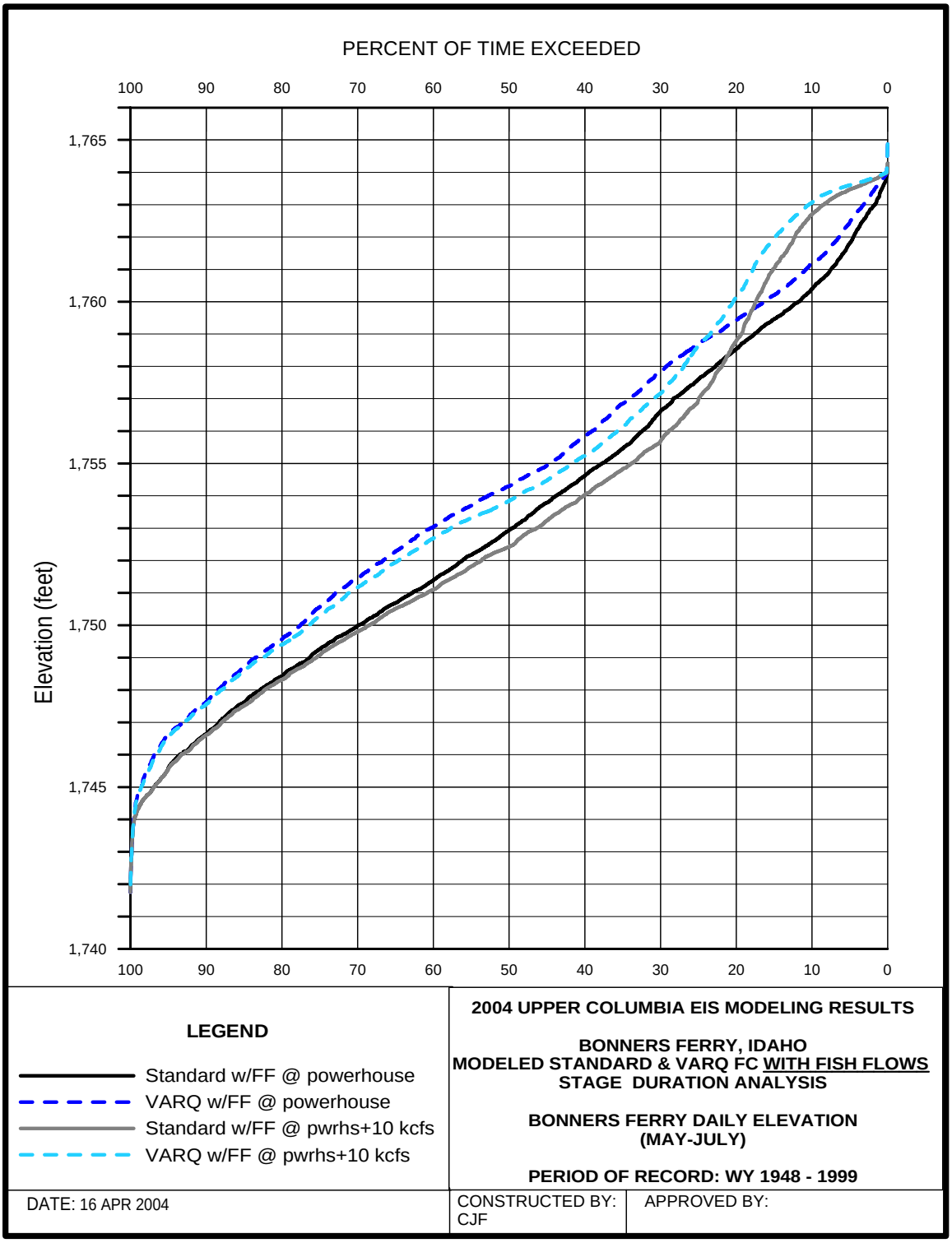


Figure 23. Stage-Duration Analysis: Bonners Ferry Daily Elevation (May-July) , Fish Flow Simulations

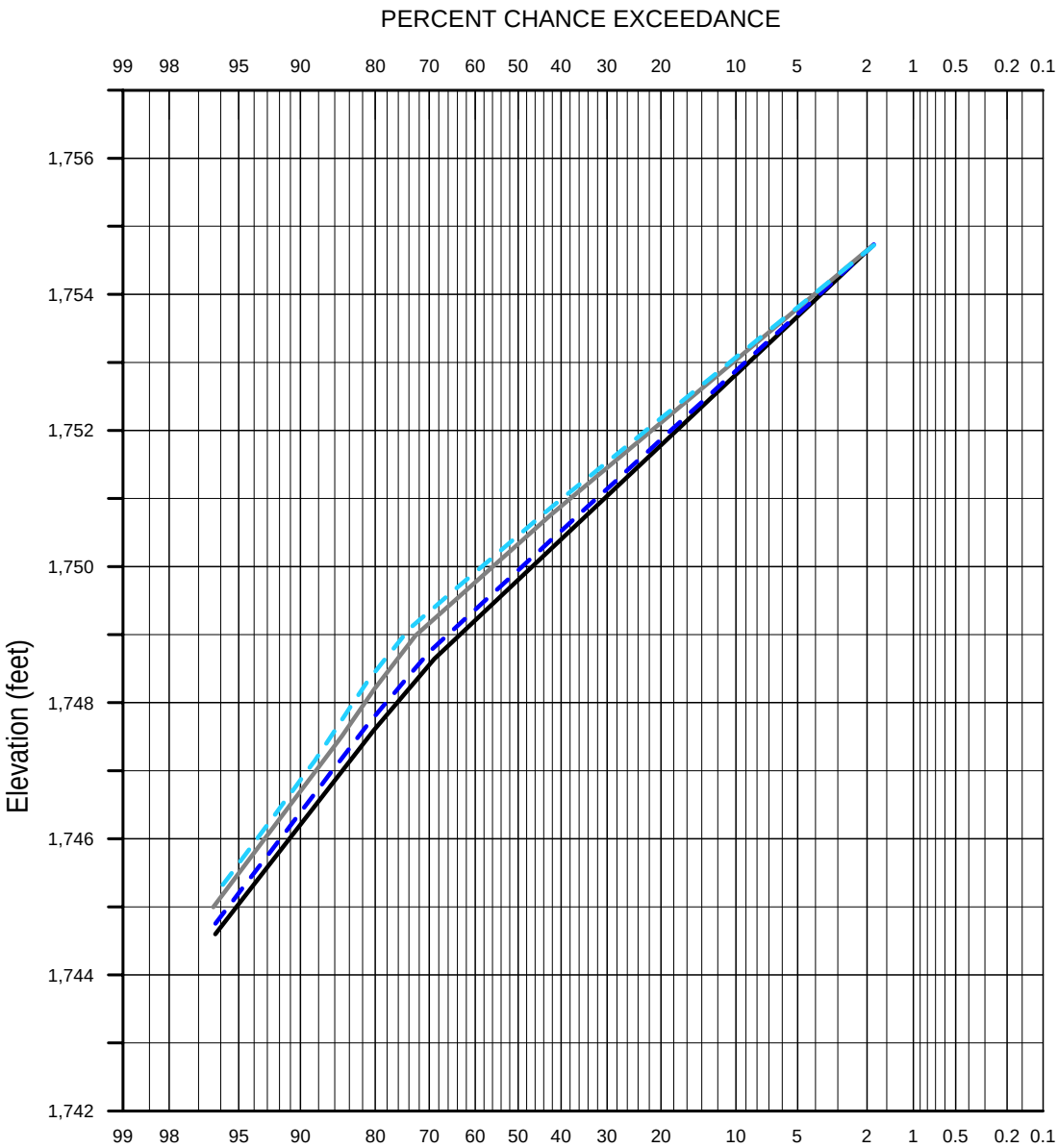


3.2.6 Kootenay Lake

From a flood control perspective, the impacts of fish flows on the level of Kootenay Lake are of greatest importance in May, June, and July. An elevation-frequency curve specific to those months is provided in Figure 24. For the high percent-chance-exceedance events (on the left side of the graph), the VARQ FC with fish flows curves plot above the corresponding Standard FC with fish flows curves, as expected. Also as expected, the scenarios where fish flows are provided at powerhouse capacity plus 10 kcfs result in a higher Kootenay Lake stage than the scenarios where fish flows are limited to powerhouse capacity. As was the case with the flood control only scenarios (refer to Section 2.2.7), the curves converge as one moves to the right toward the lower percent-chance-exceedance events. In all of the fish flow simulations, the maximum stage at Kootenay Lake remained below elevation 1755 feet.

Elevation-duration curves for Kootenay Lake for the fish flow scenarios were developed for the months of May, June, and July. These are shown in Figure 25, Figure 26, and Figure 27, respectively. During May, VARQ FC with fish flows leads to higher Kootenay Lake elevations than does Standard FC with fish flows. This is also true for the months of June and July, but to a lesser degree. Overall, the fish flow scenarios all lead to higher spring and summer time elevations at Kootenay Lake than would with a pure flood control operation (refer to Section 2.2.7).

Figure 24. Elevation-Frequency Analysis: Kootenay Lake Maximum Daily Elevation (May-July), Fish Flow Simulations



LEGEND	2004 UPPER COLUMBIA EIS MODELING RESULTS
Standard w/FF @ powerhouse	KOOTENAY LAKE, CANADA MODELED STANDARD & VARQ FC WITH FISH FLOWS ELEVATION FREQUENCY ANALYSIS
VARQ w/FF @ powerhouse	KOOTENAY LAKE MAXIMUM DAILY ELEVATION (MAY-JULY)
Standard w/FF @ powerhouse+10 kcfs	PERIOD OF RECORD: WY 1948 - 1999
VARQ w/FF @ powerhouse+10 kcfs	

DATE: 27 JULY 2004	CONSTRUCTED BY: CJF	APPROVED BY:

Figure 25. Elevation-Duration Analysis: Kootenay Lake Daily Elevation (May) , Fish Flow Simulations

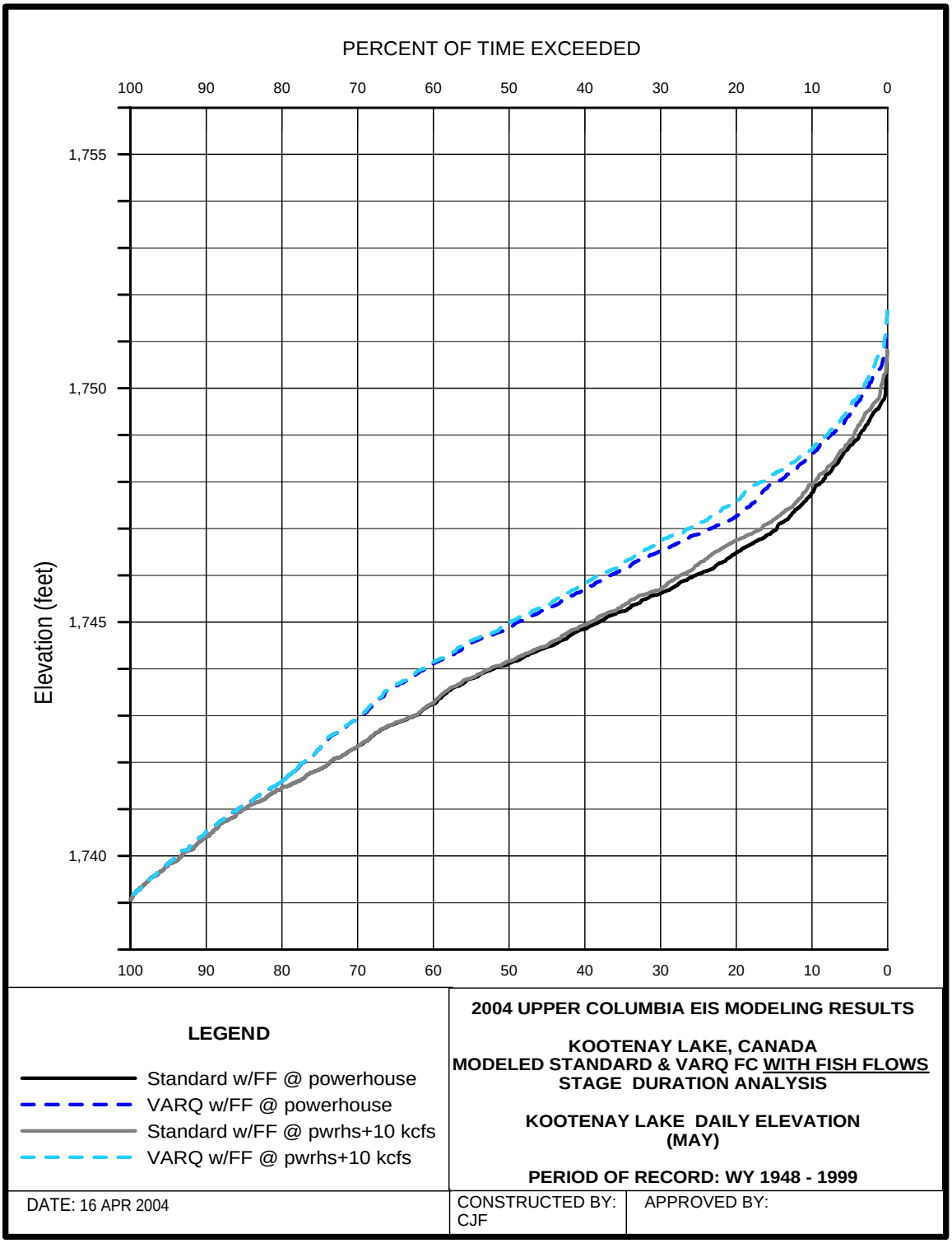
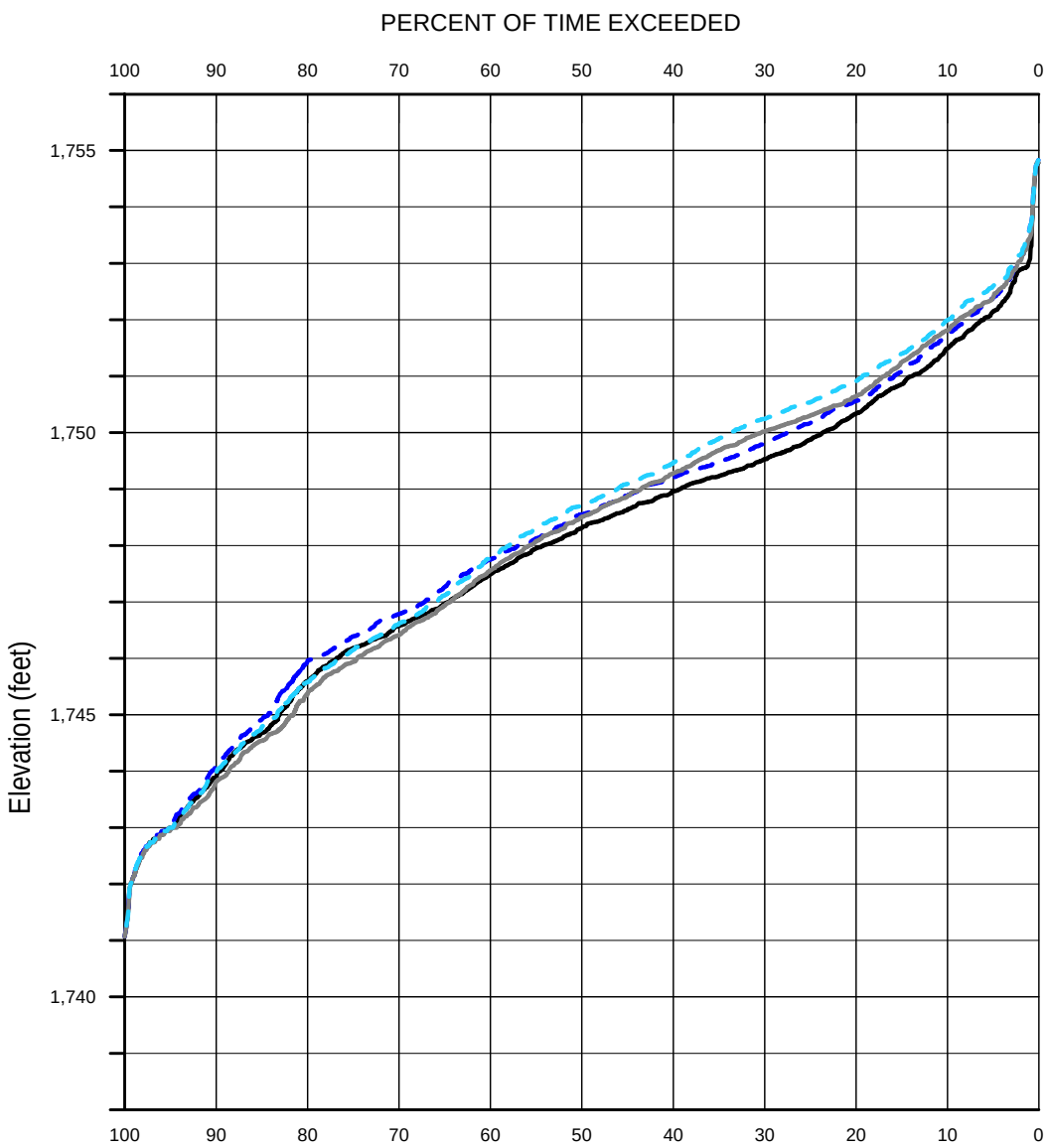


Figure 26. Elevation-Duration Analysis: Kootenay Lake Daily Elevation (June) , Fish Flow Simulations



LEGEND

- Standard w/FF @ powerhouse
- VARQ w/FF @ powerhouse
- Standard w/FF @ pwrhs+10 kcfs
- VARQ w/FF @ pwrhs+10 kcfs

2004 UPPER COLUMBIA EIS MODELING RESULTS

KOOTENAY LAKE, CANADA
MODELED STANDARD & VARQ FC WITH FISH FLOWS
STAGE DURATION ANALYSIS

KOOTENAY LAKE DAILY ELEVATION (JUNE)

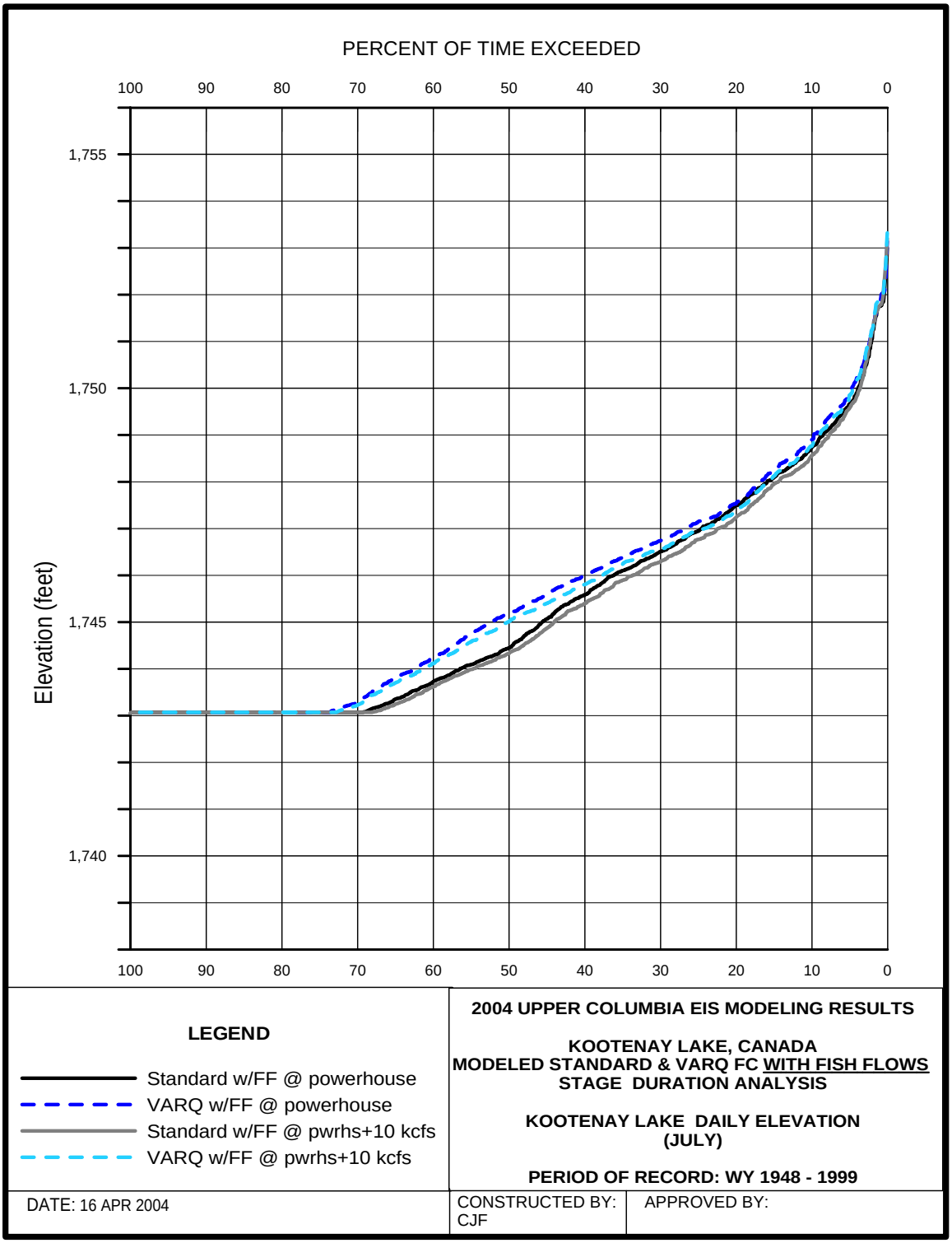
PERIOD OF RECORD: WY 1948 - 1999

DATE: 16 APR 2004

CONSTRUCTED BY: CJF

APPROVED BY:

Figure 27. Elevation-Duration Analysis: Kootenay Lake Daily Elevation (July) , Fish Flow Simulations



3.2.7 Duncan Dam

The scenarios with fish flows have the exact same operations at Duncan Dam as the flood control-only scenarios (refer to Section 2.2.8). There is no significant change in either the maximum daily outflow or the maximum daily lake elevation.

4.0 Sensitivity Analysis

4.1 Hydro-Regulations

For this part of the study, twenty years were simulated to characterize the sensitivity of model results when certain modeling assumptions are modified. These sensitivity simulations are in accordance with guidelines set forth in *Risk-Based Analysis for Flood Damage Reduction Studies*, EM 1110-2-1619 (Corps 1996).

4.1.1 Background on Sensitivity Simulations

The team members for this study, in conjunction with USFWS, NMFS, and community members participating in the Kootenai Valley Resources Initiative (KVRI) in Boundary County, Idaho, identified uncertain model parameter combinations to define an upper-bound scenario and a lower-bound scenario for certain model runs. These upper- and lower-bound combinations were each applied to the following two simulations: Standard FC with Fish Flows at powerhouse capacity plus 10 kcfs and VARQ FC with Fish Flows at powerhouse capacity plus 10 kcfs. The intent of the sensitivity analysis is to show how much the river stage at Bonners Ferry can vary depending on the modeling assumptions that are used. The assumed start date and discharge pattern of sturgeon flows are of particular importance, because in real life these are in-season management decisions, and can be quite different from the fish flow template discussed in Section 3.1.3. The sensitivity runs performed are listed below:

- Standard FC, fish flows (including sturgeon flows to outflow capacity of powerhouse + 10 kcfs), and upper-bound assumptions
- VARQ FC, fish flows (including sturgeon flows to outflow capacity of powerhouse + 10 kcfs), and upper-bound assumptions
- Standard FC, fish flows (including sturgeon flows to outflow capacity of powerhouse + 10 kcfs), and lower-bound assumptions
- VARQ FC, fish flows (including sturgeon flows to outflow capacity of powerhouse + 10 kcfs), and lower-bound assumptions

4.1.2 Description Sensitivity Scenarios

The uncertain model parameters used to define upper- and lower-bound sensitivity runs are shown in Table 7. The model parameters were selected through a collaborative process between the team members for this study, USFWS, NMFS, and KVRI to ensure that community concerns regarding the modeling were addressed. To select the twenty years, model output from the flood control with fish flows at powerhouse capacity plus 10 kcfs scenarios was used. The years were ranked according to their maximum 15-day average stage at Bonners Ferry, and the top twenty years were chosen for sensitivity

modeling. One should note that in all cases, the full volume of water allocated to sturgeon was delivered in the simulations. In practice, the augmentation volume for sturgeon may actually be less than what is shown in Table 7 (see Section 3.1.3.1). The reservoir re-initialization procedures used for the fish flow scenarios (see Section 3.1.2) were also used in the sensitivity scenarios.

Table 7. Uncertain Parameters Modeled in Sensitivity Analysis.

Parameter	Lower Bound Value (tends to decrease stage below dam)	Value Used for full period of record modeling	Upper Bound Value (tends to increase stage below dam)
Residual Volume trigger[18]	1.5 times residual volume	2.0 times residual volume	2.5 times residual volume
Streamflow forecast assumed foresight[19]	15-days	10-days	5-days
Allowable spill for flood control[20]	5 kcfs	2 kcfs	0 kcfs
Sturgeon flows start date[21]	Start sturgeon flows 9 days earlier than template	Tier 2 = 16 May Tier 3 = 23 May Tier 4-6=01 Jun	Start sturgeon flows 15 days later than template
Shape of sturgeon flows[22]	3-day pulse when IJC allows, then QPHC +10 kcfs per template	Powerhouse +10 kcfs Per template	Highest flow that can be sustained for at least 21 days per template
Managing Salmon Flow Augmentation[23]	Forecast to avoid double peak, draft to 2449' (swap with Canadian Storage)	Forecast to avoid double peak, be at 2439' by Aug 31	Pass inflow if <2439 on 1 Jul; otherwise forecast to avoid double peak, be at 2439' by Aug 31

[18]Once each month the Reservoir Control Center (RCC) gets an April – August *volume* forecast. The residual volume is the amount of water, based on the forecast that needs to be stored (forecast seasonal runoff volume – inflow volume to date – projected outflow volume). A factor of 2 means that the residual volume is twice as large as the volume of storage remaining. Operational changes are made when the parameter exceeds the values in the table.

[19] During real-time reservoir control, RCC gets long-lead *streamflow* forecasts once a week and 10-day forecasts 3 times per week. This parameter defines the lead time used to make decisions. For instance, if the model shows that the reservoir fills and starts spilling on 20 June, then an operational change will be made based on an assumed streamflow forecast either 15 days, 10 days, or 5 days before 20 June.

[20] For the full period of record modeling, the reservoir will preemptively begin spilling 2 kcfs five days prior to a forecasted fill and spill. By changing the pre-emptive spill amount to a *larger* value (5 kcfs), more storage space is preserved in the reservoir, reducing the likelihood of the reservoir filling while inflows greatly exceed powerhouse capacity (resulting in involuntary spill).

[21] For the full period of record modeling, sturgeon flow start dates ("the template") were determined in a meeting with USFWS, State of Montana, and the Corps in March, 2002. This parameter defines the start date for the main sturgeon flow augmentation.

[22] For the full period of record modeling, the sturgeon volume is delivered as quickly as possible with an outflow of powerhouse + 10 kcfs. For the lower-bound, some of the sturgeon volume will be used for a "pulse" early in the season, and the remaining volume will be delivered as quickly as possible with an outflow of powerhouse + 10kcfs. For the upper-bound, the sturgeon volume will be delivered such that there will be at least 21 days of sustained high flows, not to exceed powerhouse +10 kcfs.

[23] From p. 9-63 in the Biological Opinion: "If Libby is below elevation 2,439 feet on July 1, the Action Agencies shall provide the USFWS bull trout minimum flow or inflow during the July and August salmon flow season. If this operation results in Libby storing above elevation 2,439 feet in July or August, that storage may be used for salmon flow augmentation before August 31. Instead of "passing inflow or bull trout flows", the period of record modeling forecasts a constant outflow. This modeling approach was coordinated with NMFS via phone and email in August, 2003.

Also in the Biological Opinion: "…Libby may be operated in a manner that reduces impacts to other listed species, while releasing water to meet salmon flow objectives. Reduction in a second peak operation can be achieved by implementation of a Canadian storage/Libby exchange of water or by releasing water earlier…" So lower bound includes a Libby-Canada storage swap.

4.2 Model Results

Impacts to the river stage at Bonners Ferry are the focus of this sensitivity analysis. Output data from the twenty years of sensitivity runs are presented in the following sections.

4.2.1 Analysis of Results

The sensitivity of model results is characterized with stage-frequency curves for Bonners Ferry. Because prolonged high river stages are of concern to the downstream community, the maximum 15-day average stage at Bonners Ferry is analyzed in addition to the maximum daily stage. To compare the upper- and lower-bound sensitivity runs with the actual flood control with fish flow simulations, six curves are presented on each frequency curve:

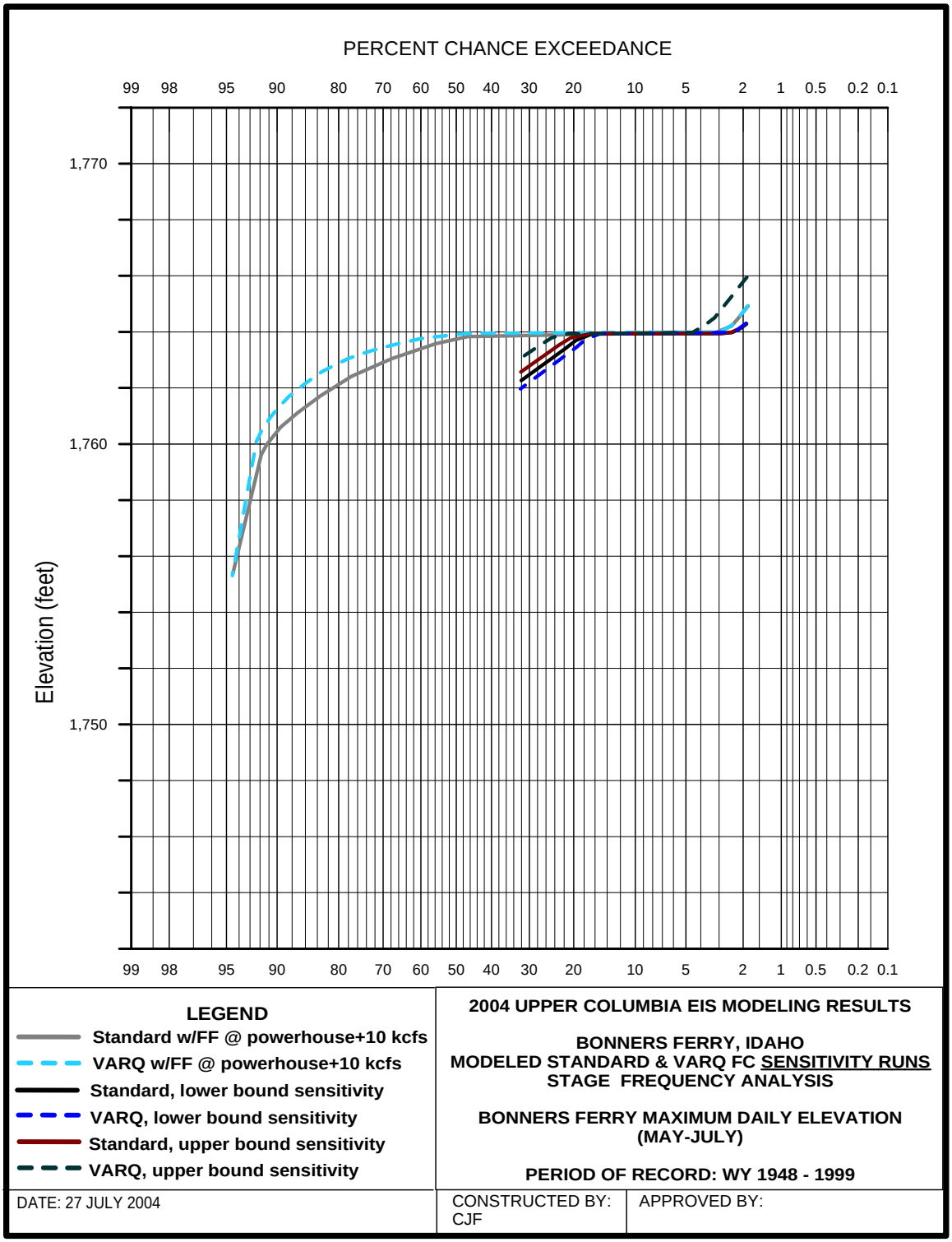
- Standard FC with fish flows with outflow capacity at powerhouse plus 10 kcfs
- VARQ FC with fish flows with outflow capacity at powerhouse plus 10 kcfs
- Standard FC, fish flows with outflow capacity of powerhouse plus 10 kcfs, and upper-bound assumptions
- VARQ FC, fish flows with outflow capacity of powerhouse plus 10 kcfs, and upper-bound assumptions
- Standard FC, fish flows with outflow capacity of powerhouse plus 10 kcfs, and lower-bound assumptions
- VARQ FC, fish flows with outflow capacity of powerhouse plus 10 kcfs, and lower-bound assumptions

Procedures for graphing regulated hydrologic data are outlined in a Corps Engineer Manual entitled *Hydrologic Frequency Analysis*, EM 1110-2-1415 (Corps 1993).

4.2.2 Bonners Ferry Peak 1-day Stage

The highest river stages at Bonners Ferry generally occur during the months of May, June, and July. A stage-frequency curve specific to those months is provided in Figure 28. The most significant feature of the frequency curve is that all six curves plateau near elevation 1764 feet. Despite the assumptions expected to create an upper- and lower-bound, the modeling assumption that Bonners Ferry will be regulated to 1764 feet to the extent possible is the most dominant feature. On the far right hand side of the graph, one sees that there is about a two foot range between the upper- and lower-bound curves for the VARQ FC scenario. Moving to the left, the upper- and lower-bound curves for both the Standard FC and VARQ FC scenarios all plot below the respective Standard FC or VARQ FC with Fish Flows curves, suggesting that the approach described in Section 3.0 of this report is already quite conservative from a flood control perspective. In other words, the modeling rules used in Section 3.0 present the highest river stages at Bonners Ferry that would result from the alternatives.

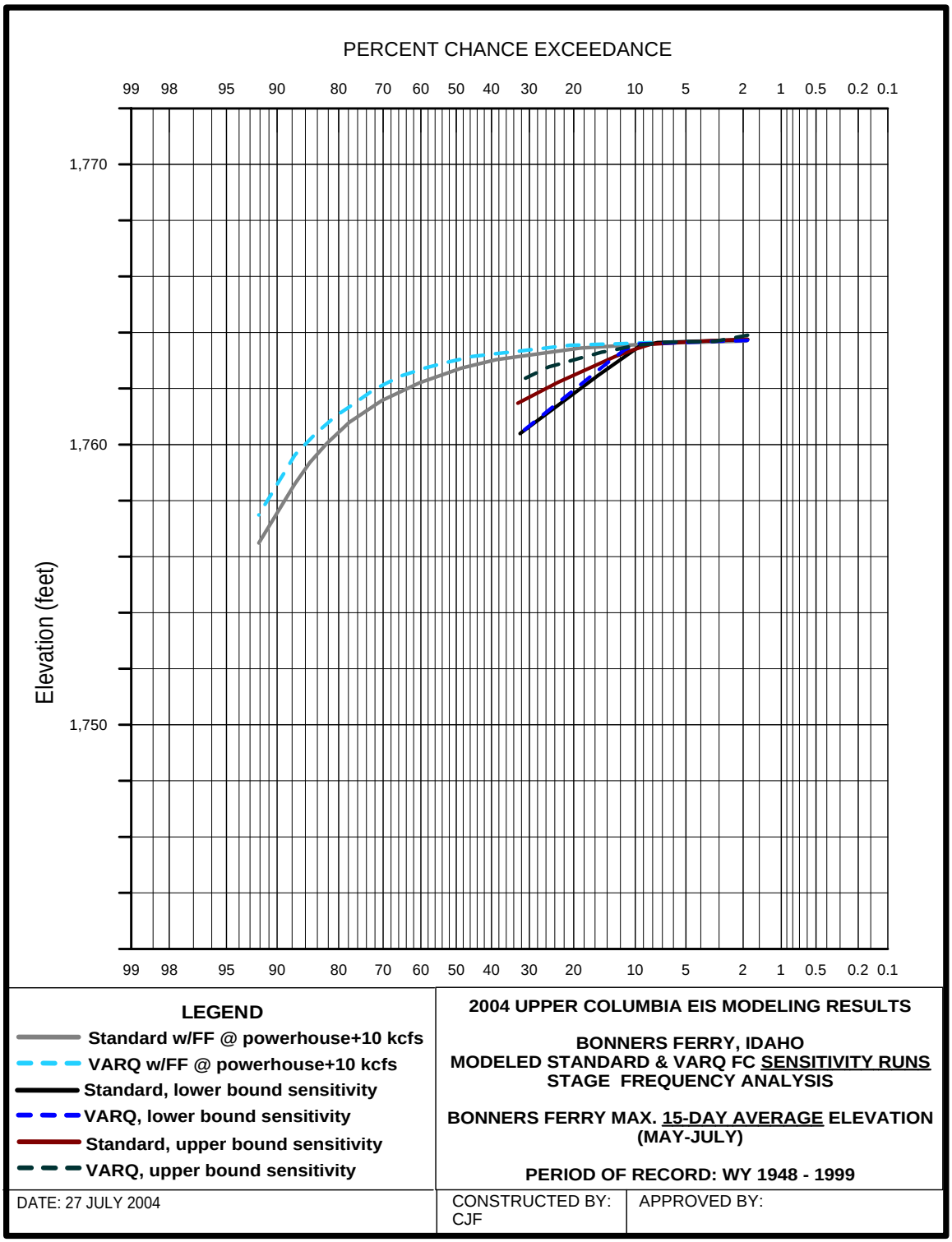
Figure 28. Stage-Frequency Analysis: Bonners Ferry Maximum Daily Elevation (May-July), Sensitivity Simulations



4.2.3 Bonners Ferry Maximum 15-day Average Stage

In addition to peak 1-day water levels at Bonners Ferry, the local community is also concerned with sustained high flows at Bonners Ferry. Therefore, a stage-frequency curve for the maximum 15-day average stage was prepared. This curve covers the period from May through July, and is provided in Figure 29. Figure 29 is very similar to Figure 28, except that all of the curves are shifted downward, as would be expected with the 15-day average. All six curves plateau just under elevation 1764 feet, again from the assumption that Bonners Ferry will be regulated to the current flood stage of 1764 feet to the extent possible. For both the Standard FC with Fish Flows and VARQ FC with Fish Flows scenarios, the assumptions for creating upper and lower bounds all led to lower stages at Bonners Ferry, again suggesting that the modeling assumptions described in Section 3.0 are very conservative from a flood control perspective. In other words, the modeling rules used in Section 3.0 present the highest river stages at Bonners Ferry that would result from the alternatives.

Figure 29. Stage-Frequency Analysis: Bonners Ferry Maximum 15-Day Average Elevation (May-July), Sensitivity Simulations



5.0 Conclusions

The hydrologic modeling described in this report was performed in order to evaluate potential impacts in the Kootenai basin from VARQ FC and fish flows. The flood-control-only simulations discussed in Section 2.0 show that both methods of flood control have a high probability of reservoir refill in the absence of power drafts and flow augmentation for listed species. The simulations also show that the outflow from Libby Dam, the river stage at Bonners Ferry, and the elevation of Kootenay Lake all tend to increase in the late spring/early summer under VARQ FC, but that this effect diminishes for lower percent-chance exceedance events. Beyond the 2%-chance-exceedance event (sometimes referred to as the "50-year flood"), the lines on the frequency curves converge, demonstrating that the two flood control procedures provide the same level of local flood protection. At Bonners Ferry, the two flood control operations are essentially equivalent for events where the river is at or above flood stage. Previous studies (Corps 2002) have demonstrated that the two flood control procedures provide the same level of system flood protection to the Portland-Vancouver area.

The simulations discussed in Section 3.0 show that Libby Dam outflow, Bonners Ferry stage, and Kootenay Lake elevation tend to increase when fish flows are modeled in addition to flood control. Additionally, Lake Koocanusa has a lower chance of refilling when fish flows are provided from Libby Dam. VARQ FC with fish flows does a better job of getting the reservoir close to full than Standard FC with fish flows. In general, the maximum outflow from Libby Dam increases as a result of fish flows, particularly for the scenarios where flows of powerhouse capacity plus 10 kcfs are provided for sturgeon. River levels below flood stage at Bonners Ferry increase almost without exception when compared to the flood-control-only scenarios, again with the sturgeon flows at powerhouse capacity plus 10 kcfs having the greatest impact. The level of Kootenay Lake is also likely to increase when fish flows are introduced. The typical increase is between 1 and 3 feet, depending on the flood control method (standard or VARQ) and type of fish flows provided (limited to powerhouse capacity or powerhouse capacity plus 10 kcfs from Libby Dam).

The sensitivity modeling described in Section 4.0 shows that the assumptions used in the Section 3.0 modeling are very conservative from a flood control standpoint. In nearly all cases, the modeled stages at Bonners Ferry from the sensitivity runs produced lower stages than what was modeled in Section 3.0 – even the simulations expected to establish an upper bound! The only exception to this is for the very rare events where VARQ FC with Fish Flows is used. For the 2%-chance-exceedance event using VARQ FC with Fish Flows, the sensitivity runs showed that there is about a two foot range between the upper- and lower-bound curves.

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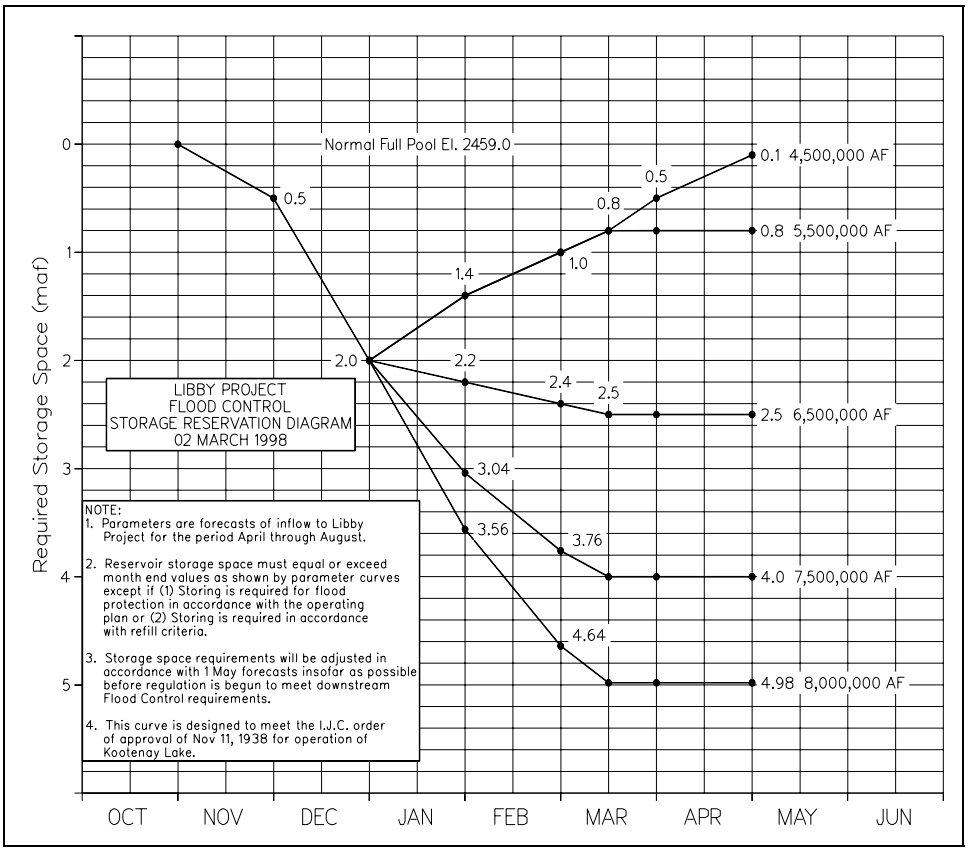
VARQ Operating Procedures at Libby Dam

INTRODUCTION. The following pages contain a description of the rules that govern the VARQ FC procedure at Libby Dam. The general rules are listed below.

Rule 1. Storage Reservation Diagram. A storage reservation diagram (SRD) for Libby Dam (see figure below) guides the evacuation of space for flood control. Required space is a function of the April-August runoff volume forecast at Libby Dam. Following the evacuation period, the project is required to maintain this space until the initiation of refill. During evacuation and up until the initiation of refill, outflows should be limited to hydraulic capacity of the powerhouse to the best extent possible. However, situations such as the loss of hydraulic capacity or rapidly changing forecasts may require spill to meet flood control requirements.

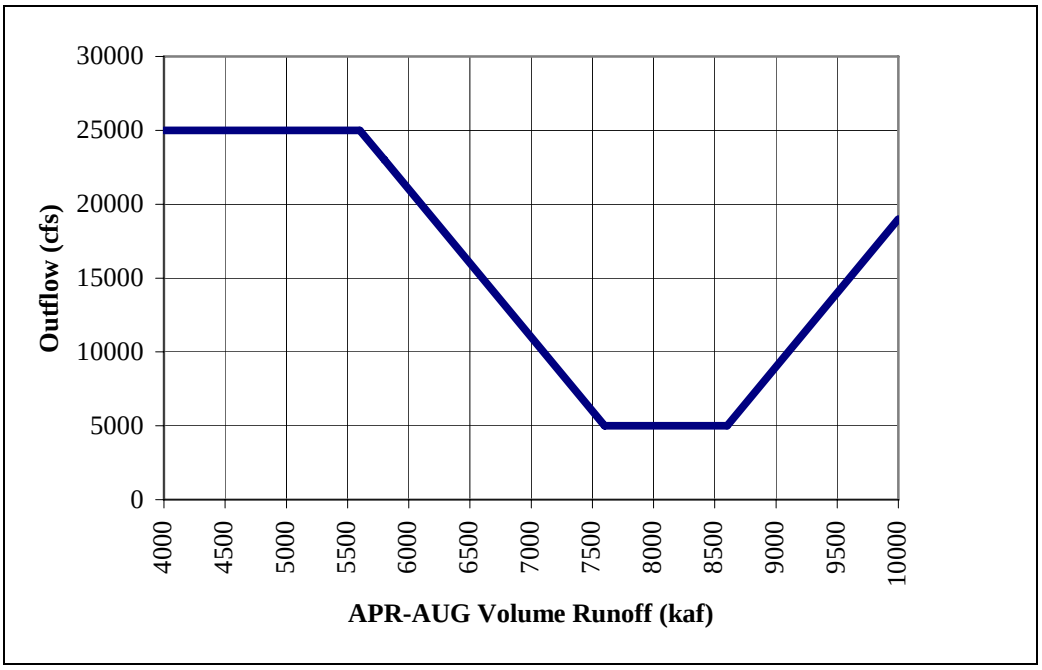


VARQ Storage Reservation Diagram for Libby Dam

Rule 2. Initiation of Refill. Initiation of refill is determined by the operating procedures for system flood control on the lower Columbia River. These procedures are described in *Columbia River Treaty, Flood Control Operating Plan, October 1972*. At Libby Dam, refill is initiated approximately ten days prior to when streamflow forecasts of unregulated flow are projected to exceed the Initial Controlled Flow (ICF) at The Dalles,

Oregon. This criterion applies most of the time: however, if the reservoir intersects with its flood control refill curve (FCRC) prior to ICF being reached, then refill is initiated at that time. The FCRC is a refill curve that fills the reservoir with 95 percent confidence at minimum outflow.

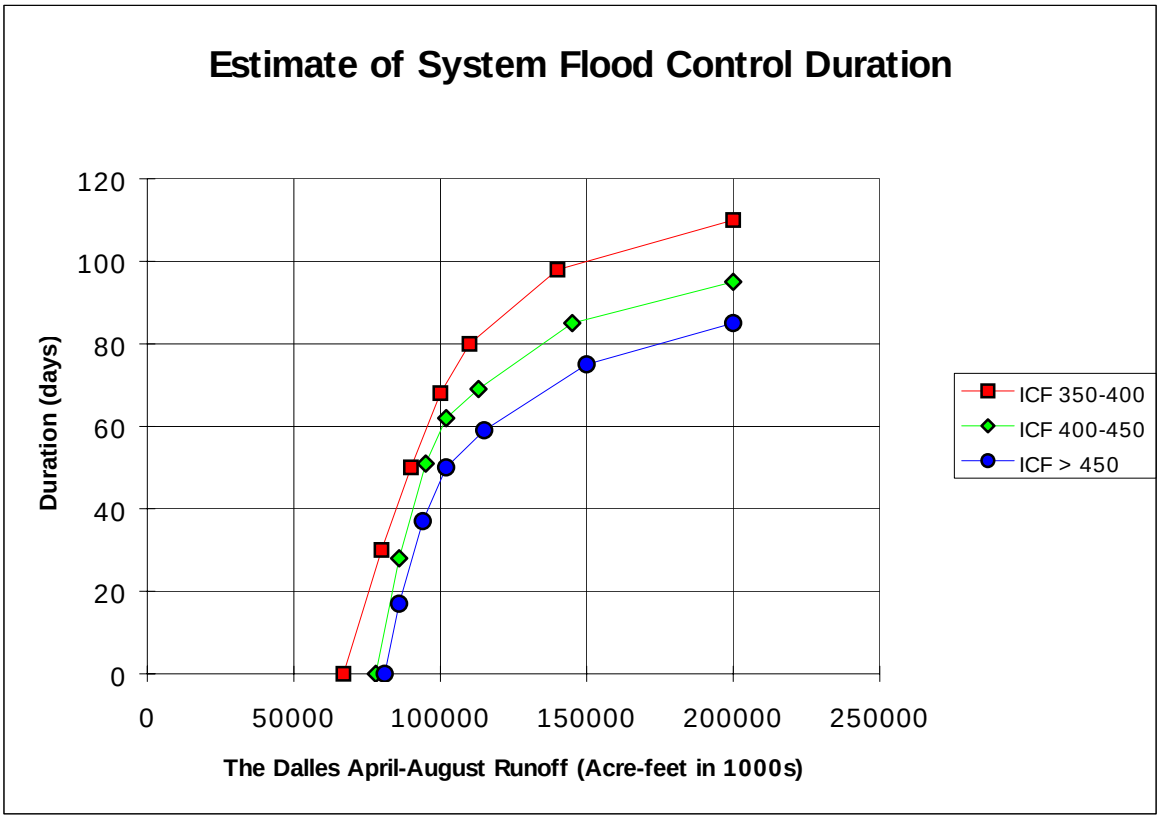
Rule 3. Initial VARQ Outflow. Use the figure below to determine an initial VARQ outflow for Libby Dam.



VARQ Outflows at Libby Dam

Rule 4. Adjusting VARQ Outflows for Delta Storage. Adjust the initial VARQ outflow, if necessary, to compensate for any storage difference between the actual reservoir level and the space required for flood control. This difference can reflect under or over-drafted conditions (Delta). This is done in the following manner:

- Estimate the duration of the system flood control operation (Duration) using the figure below. Select the appropriate curve based on the level of the latest projected control flow at The Dalles (ICF).



Estimate of System Flood Control Duration

- From the selected curve determine the flood control duration using the April-August runoff forecast for The Dalles.
- Compute the VARQ storage adjustment:

  ADJSTO = [Delta(kaf) x 0.5(ksfd/kaf)] / Duration(days)

- Compute the new VARQ outflow:

  VARQ(new) = VARQ(initial) + ADJSTO

If the runoff forecast at The Dalles is less than 85 million acre-feet, it is likely that system flood control of any significant duration will not be necessary for the lower Columbia River. Use streamflow forecasts to adjust VARQ outflows, if necessary, to compensate for any storage difference between the actual reservoir level and the space required for flood control. Reduce the VARQ outflows as necessary to provide protection against local flooding and to improve the likelihood of refill.

<u>Rule 5. Adjusting VARQ Outflows for Prior VARQ Releases.</u> VARQ releases are seasonal in nature, generated using seasonal runoff forecasts.

- This rule accounts for the difference in outflows released since the initiation of refill and the new VARQ outflows developed using the updated runoff forecast:

  ADJDUR = [VARQ(new) – VARQ(prior)] x [Prior Release(days) / [New Duration(days) – Prior Release(days)]]

- Compute final VARQ outflow:

  VARQ(final) = VARQ(new) + ADJDUR

Rule 6. Inflows Less than VARQ Outflows. At the initiation of refill, if inflows are less than the VARQ outflow, pass inflow until inflows rise to the VARQ level. Thereafter, if inflows drop below the VARQ outflow, pass inflow until they rise again to the VARQ level.

Rule 7. Updating VARQ Outflows During Refill Season. Update VARQ outflows throughout the refill season as new runoff forecasts are developed. Use streamflow forecasts to evaluate the performance of the VARQ outflows in meeting system and local flood control objectives. Reduce VARQ outflows if necessary to provide protection from local flooding. Return to VARQ outflows once local flooding is over.

Rule 8. Final Stages of Refill. Increase outflows during the final stages of refill to avoid overfilling and unwanted spill. Likewise, decrease outflows during the final stages of refill if the present outflow would otherwise not fill the reservoir. Use streamflow forecasts and engineering judgment to select the appropriate outflows.

APPENDIX C

Kootenai River Sand Transport

Appendix C KOOTENAI RIVER SAND TRANSPORT

C.1 Introduction

A sand transport analysis was undertaken as part of the Corps' sturgeon recovery efforts on the Kootenai River. It is intended specifically to inform the NEPA evaluation (Upper Columbia Alternative Flood Control [VARQ] and Fish Flow Environmental Impact Statement, or UCEIS) being performed for a long-term decision on implementation of VARQ alternative flood control and on flows for sturgeon, bull trout, salmon and steelhead from Libby and Hungry Horse dams. This analysis focuses on flows from Libby Dam to the Kootenai River.

Sand transport and deposition are important factors in the selection and design of dam operations or river modifications that are intended to improve reproductive success of Kootenai River white sturgeon. This analysis provides an initial estimate of the effects various Libby Dam flow regulation scenarios could have on annual suspended sand transport in the Kootenai River downstream of Bonners Ferry, river mile (RM) 152[1].

C.2 Flow Regulation Scenarios

Six flow regulation scenarios were used in this analysis. Each scenario provides flood control (FC), with four also providing supplemental flows (fish flows) intended to benefit sturgeon, bull trout, and salmon. Four of the scenarios are NEPA alternatives in the UCEIS; the other two are benchmark operations that provide a basis for comparison to derive the direct effects of fish flows in the UCEIS. The flow regulation scenarios are described below and the corresponding flow duration curves are shown in Figure C-1. Compared to the benchmark Standard flood control scenario without fish flows, the other scenarios all shift water from the low flow periods to the high flow period, especially the spring freshet.

[1] The river mile locations in this report are based on the Columbia Basin Inter-Agency Committee River Mile Index for the Kootenai/Kootenay River. This system assumes that RM 0 is located at the mouth of the Kootenay River, where it joins the Columbia River near Castlegar, BC.

- The benchmark Standard flood control scenario (LS) is the flow regulation currently authorized for long-term use and was used prior to and through calendar year 2002. It is also referred to as Standard FC or "BASE-CRT63". The Standard FC storage reservation diagram is used in combination with Libby's seasonal water supply forecasts to determine how much space needs to be made available by 15 March for flood control. During refill, it is assumed that the outflow from Libby Dam will be a steady 4 kcfs. There are no flow augmentations for fish in this scenario.
- The benchmark VARQ flood control scenario (LV) is the flood control method currently being used on an interim basis at Libby Dam, and recommended for long-term implementation in both the USFWS Biological Opinion and the NMFS Biological Opinion. This interim operation began in January 2003. Similar to Standard FC, VARQ FC also requires a storage reservation diagram in conjunction with the water supply forecast to determine the flood control space needed. However, compared to the Standard FC scenario, VARQ FC requires less flood control space in years with low to moderate runoff predictions. During refill, the outflow from Libby Dam is variable and is almost always greater than 4 kcfs. There is no flow augmentation for fish in this scenario.
- The no-action alternative Standard FC with fish flows to powerhouse capacity (LS1), follows the Standard FC rules, and provides supplemental fish flows as follows: First, provide a tiered volume of water during the spring freshet for sturgeon spawning and recruitment, using only the maximum powerhouse capacity (about 25 kcfs). Next, make sure Libby outflow is greater than or equal to the minimum bull trout flow during July and August. Finally, draft the pool to elevation 2439 feet (20 feet from full) for salmon flow augmentation during July and August.
- The preferred alternative, VARQ FC with fish flows to powerhouse capacity (LV1), resembles the LS1 alternative, except the VARQ flood control procedure is followed instead of the Standard FC procedure. This alternative has been implemented on an interim basis, beginning January 2003 and pending a long term decision based on the decision from the UCEIS.
- Alternative LS2, Standard FC with fish flows up to 10 kcfs above powerhouse capacity, provides fish flows similar to alternative LS1, except sturgeon flows are provided using the powerhouse capacity plus an additional 10 kcfs of release capacity.
- Alternative LV2, VARQ FC with fish flows up to 10 kcfs above powerhouse capacity, is similar to LV1, except sturgeon flows are provided using the powerhouse capacity plus an additional 10 kcfs of release capacity.

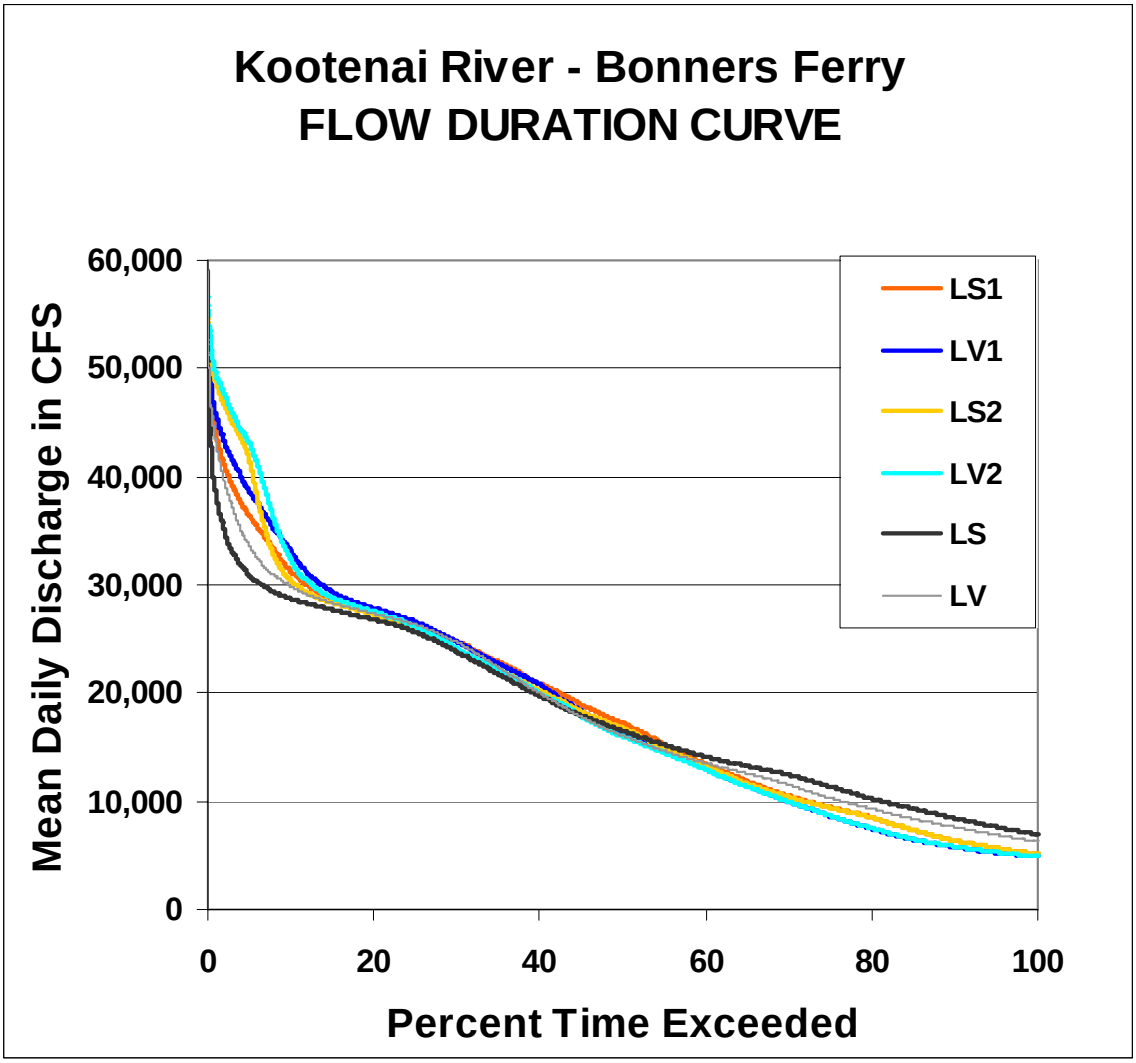


Figure C-1. Alternative flow duration curves for the Kootenai River at Bonners Ferry, RM 152.

C.3 Sand Transport Analysis

The magnitude of the average annual sand transport is an important factor in the behavior of a river. It is also important in the selection and design of dam operations or river modifications. The six flow duration curves presented above were combined with a computed suspended sand load curve to calculate average annual sand transport for each flow regulation scenario.

C.3.1 Suspended Sand Load Curve

In sand bed rivers, such as the Kootenai River between Bonners Ferry, RM 152, and the Canadian border, RM 106, suspended sand transport is directly related to the hydraulic

conditions in the channel. As a result, several empirical equations have been developed that use selected hydraulic parameters to calculate suspended sand transport. These equations can be used to calculate suspended sand transport in situations where there is hydraulic information but little or no sand transport data.

On the Kootenai River there is little useful sand transport data. Over the past 40 years the USGS has collected some suspended sediment data, even publishing daily total suspended sediment (TSS) data for the Kootenai River from 1966 to 1983. However, measurements were routinely collected on a monthly schedule without concentrating on the high discharge periods when most sand transport occurs. The available suspended sand data alone is not adequate to reliably define the sand load curve, but is useful in comparing computed sand load curves. Recently, at the direction of the Kootenai Tribe of Idaho using Bonneville Power Administration funding, the USGS has collected data and is modeling sediment transport in the Kootenai for purposes of determining characteristics of existing sturgeon spawning and rearing habitat and how it may be modified. The report from that effort is unavailable at the time of this draft.

For this analysis, Yang's sand transport equation and hydraulic data for RM 142.6 [2] from the Corps' "Kootenai River Geomorphic Assessment" (TetraTech and Perkins Geosciences 2004) were used to calculate an initial suspended sand transport curve. That initial sand transport curve was then compared to the available suspended sand and total suspended sediment transport data collected by the USGS. After this comparison, a power function, best-fit curve for the initial Yang data points was selected as the most representative suspended sand load curve. The chosen sand load curve is shown on Figure C-2 as the "Power" trend line; also shown are selected total suspended sediment trend lines and individual suspended sand data points. The high ends of the 1972, 1975, and 1980-82 curves are not well defined because the maximum discharges for those years were less than 60, 40, and 45 kcfs respectively. However, the 1966-68 curve is better defined as it includes data for discharges as high as 95 kcfs. As can be seen in Figure C-2, the chosen sand load curve provides a good match to not only the initial Yang curve, but also to the available suspended sand data.

[2] RM 142.6 is designated as RM 36.97 in the TetraTech/Perkins Geosciences report, which assumes that RM 0 is located at the Canada-US border rather than at the mouth of the Kootenay River.

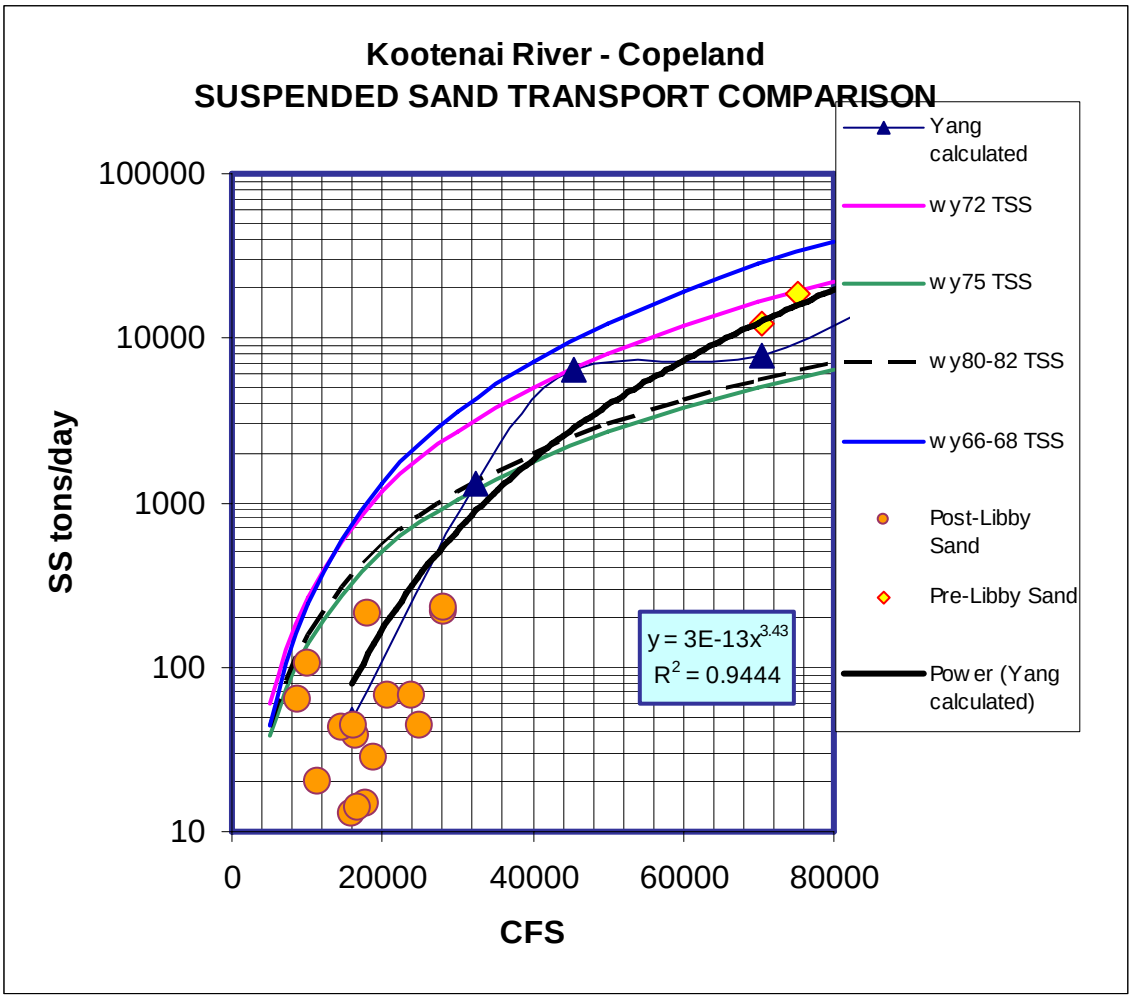


Figure C-2. Initial and chosen suspended sand load curves and measured total suspended sediment trend lines and suspended sand data points for the Kootenai River near Copeland. Trend lines have been used for clarity because of the large number of available total suspended sediment data points.

C.3.2 Average Annual Suspended Sand Transport

The flow duration curves were integrated with the chosen suspended sand load curve to calculate the average annual suspended sand transport for each alternative and benchmark scenario at Bonners Ferry. The calculated average annual suspended sand transport volumes are listed in Table C-1. As the scenarios shift more water to the high discharge period the sand transport increases, even though the annual peak discharge has been held constant at 59 kcfs in each scenario. The effects on suspended sand transport from shifting more water to the high flow period can also be seen in the sand discharge duration curve presented in Figure C-3. That figure shows that the increased sand

transport occurs during the 10 to 15 percent of the year with the highest discharges and that the reductions occur during the 40 percent of the year with the lowest discharges.

An unregulated sand discharge was not calculated as part of this analysis, but is believed to be much higher than any of the scenarios because of the higher peaks and larger volumes of the natural freshets.

Table C-1. Average annual suspended sand transport in the Kootenai River near Copeland.

Alternative		Sand Transport (tons/year)
LS1		113,000
LV1		126,000
LS2		130,000
LV2		142,000
Benchmark		
LS		87,000
LV		102,000

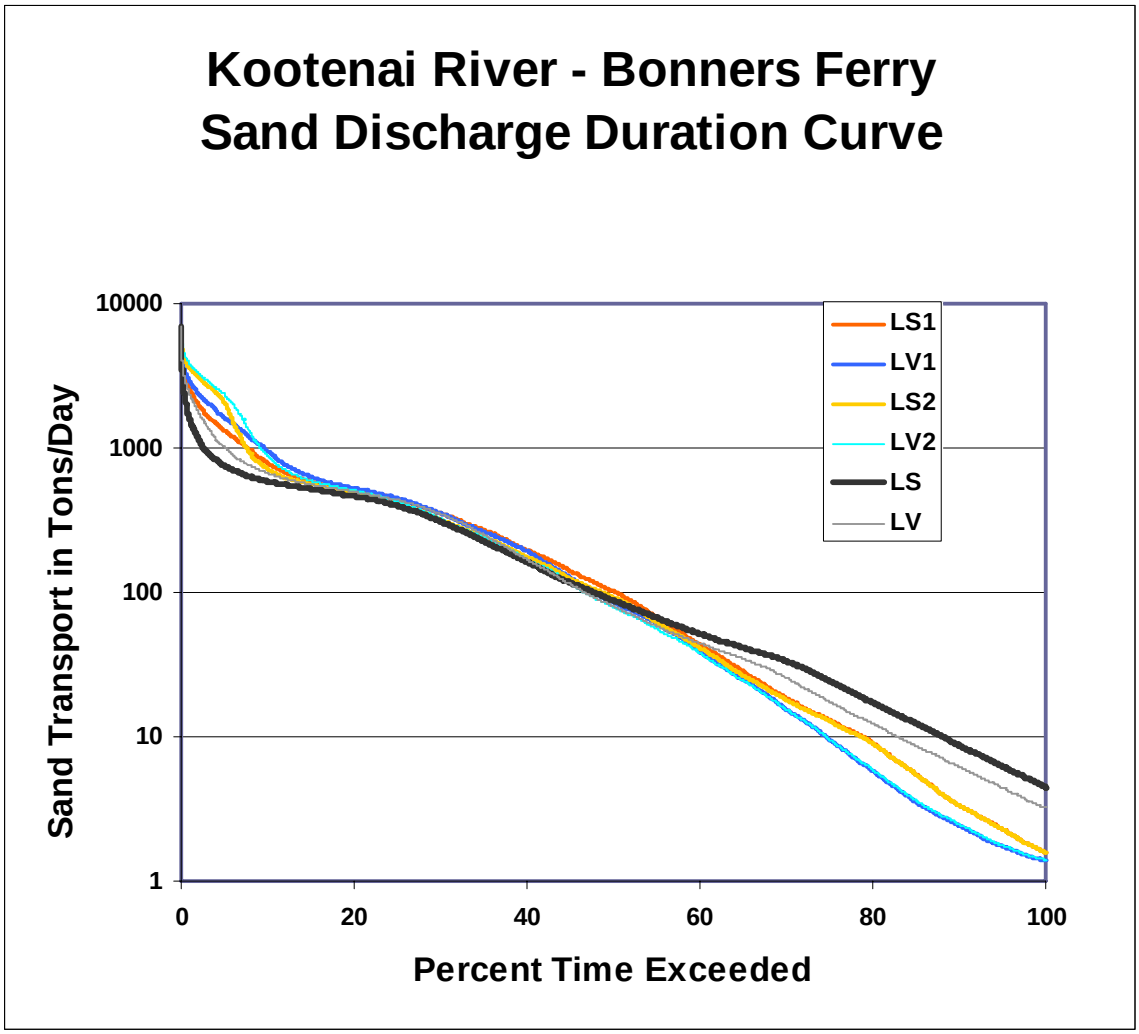


Figure C-3. Sand discharge duration curves based on the calculated daily transport rates. The effects of releasing more water during the high discharge times of the year are reflected in the higher transport rates that occur.

C.4 Limitations

This analysis provides good estimates of average annual suspended sand transport for each of the six flow regulation scenarios. However, it does not present a complete description of the existing Kootenai River sand budget. Bedload transport and inflowing sand discharges would need to be analyzed to complete a sand budget. Bedload may also transport a significant volume of sand, but was not included in this analysis. Sand inflows are necessary to determine if the Kootenai River downstream of Bonners Ferry is aggrading, degrading, or in a state of dynamic equilibrium. The lack of available data would greatly limit the reliability of any attempt to calculate bedload or sand inflow volumes.

C.5 Conclusions

Altering the flow regulation patterns at Libby Dam by shifting more water to the spring freshet will result in increased sand transport in the Kootenai River downstream of Bonners Ferry (RM 152). The scenarios included in this analysis increased suspended sand transport by 17 to 63 percent above the Standard FC condition without fish flows. Given the steep, high-energy channel between Libby Dam and Bonners Ferry, the most likely source of additional sand is the riverbed downstream of Bonners Ferry. If all the increase in sand transport were to come from the first mile of river downstream of Bonners Ferry, it could equate to 0.2 to 0.7 ft/yr of channel erosion. However, if it occurred over the 10 miles of riverbed between Bonners Ferry and Shorty's Island, it would equate to an average of only between 0.02 and 0.07 ft/yr of channel erosion.

APPENDIX D

Modeling of Biological Effects in Montana

Notice Sheet—
Upper Columbia Alternative Flood Control (VARQ) and Fish Operations EIS –
Biological responses to alternative flood control strategies at Hungry Horse and Libby dams, Montana

Nomenclature Corrections

To be consistent with the naming conventions for the different dam operations in the EIS, this report has been revised from the original that was submitted by the contractor. Other than the nomenclature revisions, the content and technical details have not been changed.

Appendix D KOOTENAI RIVER SAND TRANSPORT

Executive Summary

The Biological Opinions recommended implementation of a variable discharge flood control strategy (VARQ) at the two northwestern Montana dams. The biological consequences of these alternative dam operation strategies were analyzed using computer models that were calibrated for each reservoir and river using field measurements. Hydrologic data provided by the U.S. Army Corps of Engineers (Corps) and Bureau of Reclamation (Reclamation) were used to assess six dam operating strategies at Libby Dam and two alternatives at Hungry Horse Dam. Nine years ranging from medium dry to medium wet (20th to 80th percentile water years) were selected for analysis at each dam.

Model analyses comparing Standard flood control (FC) to variable discharge (VARQ) FC strategies revealed that VARQ FC operations generally improved biological conditions in reservoirs compared to Standard FC operations. Benthic insect production increased when the annual reservoir drawdown was minimized and substrate containing benthic insect larvae remained continually inundated. Phytoplankton and zooplankton production, and the deposition of terrestrial insects, was greatest when the surface remained at or near full pool during the biologically productive warm months. Loss of plankton through the dam turbines was proportional to the vertical distribution of plankton production in the reservoir and sensitive to the volume and depth of water withdrawal. Environmental conditions under VARQ FC were more conducive for fish growth (kokanee at Libby and westslope cutthroat trout at Hungry Horse) than the Standard FC in most water years. Exceptions were examined.

Downstream of the dams, unnatural flow fluctuations caused by dam operations disrupt natural processes and reduce biological productivity. Impacts can be mitigated by restoring a more natural spring freshet and by stabilizing river flow during the productive summer and fall months. VARQ FC operations that provided specific flows for fish recovery generally increased benthic biomass production in the Flathead and Kootenai Rivers downstream. Biological benefits moderated with distance downstream due to inflows from unregulated streams. The productive portion of the river channel is limited by the lowest flow during the preceding 30 or 40 days. Benthic biomass does not recover until substrate has been continually inundated for a month or two, so short-term flow reductions should be avoided.

Implementing VARQ FC at Hungry Horse Dam had minimal effect on Flathead Lake operation over the range of flows modeled. Model simulations in the driest and wettest water years may reveal greater differences between the alternatives than were found during this study. Additional simulations could provide greater insight into the effect of VARQ FC operations during drought and flood conditions.

Introduction

Computer models developed by Montana Fish, Wildlife & Parks (MFWP) and Montana State University (MSU) for Hungry Horse Dam (HRMOD) and Libby Dam (LRMOD) were used to assess biological effects in the reservoirs. The reservoir models were designed in three components: hydrologic physical framework, temperature regime, and biological trophic levels (Marotz *et al.* 1996). Each component in the models was assessed for reliability by comparing results with observed empirical measurements. Additionally, the models were peer reviewed by independent scientists, including Dr. James Anderson and Dr. Gordie Swartzman of the Fisheries Research Institute, Seattle, Washington. The models were also critiqued and refined by the Independent Scientific Advisory Board (ISAB).

Natural Solutions developed a conceptual model to assess biological responses associated with alternative operational scenarios in the Flathead and Kootenai Rivers. The river model (RivBio) was calibrated using channel cross-section measurements collected by MFWP in the Kootenai and South Fork Flathead Rivers immediately downstream of Hungry Horse and Libby dams and the reach just upstream of Bonners Ferry, ID. Calibration data for the Flathead River at Columbia Falls, Montana were collected by Miller Ecological Consultants, Inc. using hydroacoustic survey techniques (Miller *et al.* 2003). RivBio calculates the amount of wetted perimeter each day during a simulation, and then tracks the duration each depth zone remains wet and productive. Alternatives were subsequently ranked based on time-series analyses of the growth and decay of benthic biomass.

Objectives

The specific objectives were to:

1. Simulate current dam operation strategies for Hungry Horse and Libby Reservoir models (HRMOD and LRMOD; Marotz *et al.* 1996), including VARQ flood control (FC), flow augmentation for fish restoration, and seasonal limits to dam discharge.

2. Establish the hydrologic mass balance for the different dam operations.

3. Calculate biological productivity in the reservoir biota under each dam operation alternative. Specifically, calculate primary productivity and loss through the dam turbines, zooplankton production and washout losses, benthic insect production, terrestrial insect deposition, and fish growth (kokanee at Libby; westslope cutthroat at Hungry Horse).

4. Perform model simulations for Hungry Horse and Libby Reservoirs to assess the biological responses to two alternative flood control scenarios that are being considered in the UCEIS (listed in 7 below).

5. Assess biological productivity in the Flathead and Kootenai Rivers using the Wetted Perimeter (WETP) technique for various dam operation scenarios in the Flathead and Kootenai Rivers, and rank the alternatives using existing wetted perimeter-discharge relationships and comparisons of the area of the zone of flow fluctuation, *varial zone.*

    a) Specific to the analysis of Libby Dam operations, use mass balance equations in LRMOD to simulate file data provided by the Corps for river flows at Bonners Ferry, Idaho. Reconfigure the model to simulate the tiered flow strategy for Kootenai white sturgeon and summertime flow augmentation for bull trout and anadromous fish in the lower Columbia River.

    b) Specific to the analysis of Hungry Horse Dam operations, assess biological productivity in Hungry Horse Reservoir using HRMOD, and reconfigure the model to mimic VARQ FC and summertime flow augmentation for bull trout and anadromous fish in the lower Columbia River.

    c) For Flathead Lake, update HRMOD to incorporate current operations of Kerr Dam using Reclamation data. Based on hydrological results, infer biological effects, if any, resulting from different Hungry Horse operations.

6. Evaluate biological results of each alternative flood control strategy (listed below). For each operation, analyze representative water years (as ranked by seasonal water supply or other representative parameter) as follows: three years from the 2nd quintile, three years from the 3rd (middle) quintile, and three years from the 4th quintile (Table 1).

Model simulations for Libby Dam included six different operations:

- Standard Flood Control (Benchmark LS);
- VARQ Flood Control (Benchmark LV);
- Standard Flood Control w/ fish flows, including sturgeon flows up to
- powerhouse capacity (Alternative LS1);
- VARQ Flood Control w/ fish flows, including sturgeon flows up to powerhouse capacity (Alternative LV1);
- Standard Flood Control w/ fish flows, including sturgeon flows up to 10,000 cfs over powerhouse capacity (Alternative LS2); and
- VARQ Flood Control w/ fish flows, including sturgeon flows up to 10,000 cfs over powerhouse capacity (Alternative LV2).

Libby Dam operations LS1, LS2, LV1 and LV2 are NEPA alternatives considered by the EIS; whereas benchmarks LS and LV (flood control only) are for comparison, to isolate the effects of the fish flows.

Model simulations for Hungry Horse Dam compared two alternative operations:

- Standard Flood Control w/ fish flows (HS); and
- VARQ Flood Control w/ fish flows (HV).

Both are NEPA alternatives; the effects of the flood-control-only operations were defined in the System Operations Review EIS finalized in 1995, and as with Libby, those are not being evaluated as NEPA alternatives for the UCEIS.

Table 1. Water year selection for phase 1 and 2 of the analysis.

Hungry Horse Dam	Phase 1			Phase 2		
	Tier[a]	Water year	Percentile[b]	Tier	Water year	Percentile
	2 Low	1937	20.50	2 Low	1980	30.10
	3 Average	1993	41.00	2 Low	1969	39.70
	3 Average	1981	58.90	3 Average	1979	50.60
	4 High	1943	79.40	4 High	1932	60.20
				4 High	1952	69.80
Libby Dam	Phase 1			Phase 2		
	Tier	Water year	Percentile[c]	Tier	Water year	Percentile
	2 Low	1983	29.40	2 Low	1989	23.50
	3 Average	1955	56.80	2 Low	1957	37.20
	4 High	1965	60.70	3 Average	1968	41.10
	4 High	1971	78.40	3 Average	1963	50.90
				4 High	1981	70.50

[a] Tiers represent quintiles of water availability from very low (Tier 1) through very High (Tier 5).
Tier 2 (low)=20<x≤40 percent, Tier 3(Average)=40<x≤60 percent, Tier 4(High)=60<x≤80 percent.
[b] Percentiles are based on historic inflow volumes (May through September) from 1929 through 2002.
[c] Percentiles are based on historic inflow volumes (April through August) from 1949 through 1999.

Methods

Reservoir Modeling

Hydrologic data (reservoir inflows, surface elevations and discharge) for Libby Dam were provided by the Corps (UCEIS Kootenai River Nov. 14, 2003) and Reclamation provided hydrologic data for Hungry Horse Dam and Flathead Lake (Reclamation VARQ FC Analysis March 8, 2004)

Trophic responses in Hungry Horse and Libby Reservoirs resulting from various dam operation strategies were analyzed using the quantitative biological models (HRMOD and LRMOD, respectively) developed by MFWP and MSU (Marotz *et al.* 1996). The reservoir models are public domain computer programs; however, the original models were updated and refined specifically for the current analyses. We updated the original models to simulate current dam operating practices, including VARQ FC, flow augmentation for fish restoration, seasonal minimum and maximum river flows, Flathead Lake operation and Kerr Dam discharge limits.

Flathead Lake Component

Hydrologic data for Flathead Lake were provided by Reclamation. For comparison, HRMOD was used to calculate Flathead Lake elevation and Kerr Dam discharge as a function of Hungry Horse Dam operation and Kerr Dam operational criteria (MPC and Corps 1962). The Memorandum of Understanding (MOU) states: "Conditions permitting, the [Flathead] lake will be drawn down to elevation 2883 feet...by April 15 and will be raised to elevation 2890 feet by Memorial Day (May 30th) and to elevation 2893 feet...by June 15th. When the lake reaches elevation 2886 feet, in moderate or major flood year, the Licensee will gradually open its spill gates to maintain free flow and will not close the gates until after the danger of exceeding elevation 2893 feet has passed." In reality, Flathead Lake seldom reaches the minimum elevation of 2883. The MOU also acknowledges that during "…natural floods in the past, unaffected by any regulation, [the surface elevations of Flathead Lake] have exceeded an elevation of 2893 feet."

The Flathead Lake component did not include biological calculations, although some biological responses could be inferred from seasonal lake levels and Kerr Dam discharges. The Flathead River and Lake components were updated to include the most current operating requirements at Hungry Horse Dam and Kerr Dam.

Reservoir Trophic Responses

Once the hydrologic mass balance and reservoir thermal structure was established, the biological models calculated primary productivity, zooplankton biomass, aquatic insect emergence, terrestrial insect deposition, and fish growth (Marotz *et al.* 1996).

Primary Productivity

The biological response of primary producers (suspended algae or *phytoplankton*) in Hungry Horse and Libby Reservoirs was modeled using empirical data collected by MFWP and MSU from 1986 through 1989. Nutrient inputs to the reservoirs were assumed to have remained constant since the models were calibrated. Field and laboratory techniques were identical at both reservoirs. Primary productivity and chlorophyll a were measured longitudinally and at depth (0, 1, 3, 5, 10, 15, 20 and 25 m) using light and dark bottle arrays and carbon^{14} liquid scintillation techniques following Priscu and Goldman (1983). Samples were taken at buoyed sites in three locations along each reservoir. Production and seasonality of phytoplankton biomass was correlated with simultaneous measurements of solar input, light attenuation at each depth and water temperature at each depth (Marotz *et al.* 1996; May *et al.* 1988). Environmental variables including solar input, air temperature, and cloud cover and opacity exhibit short-term variability, but vary little between years. The reservoir heat budget, by comparison, responds gradually to the long-term climatic trends used to calibrate the thermal model. Similarly, the depth of the reservoir euphotic zone follows a predictable annual cycle associated with seasonal trends in river flow and turbidity. As a result, the model is sensitive mainly to reservoir surface area, volume and water temperature at each depth. The model calculates the longitudinal and vertical distribution of carbon fixation and relates these values to volumetric production rates (mgC/m^3/d) in each reservoir.

The loss of primary producers through the dams was calculated based on the monthly vertical distribution of C^{14} fixation in the forebay of each dam (Marotz *et al.* 1996). Since the distance from the reservoir surface to the outlet depth varies with dam operation, the estimated loss depends on surface elevation and depth of withdrawal. This relationship was simulated using a negative exponential, based on the data ($r^2 = 0.69$):

$$\%PP = {}_{exp}(2.57315 - 0.03459*DEPTH).$$

Production within in each 3 m depth zone in the forebay was calculated as a percentage of the water column total on each day of the simulation. The result was applied to the daily discharge volume. For all simulations, the selective withdrawal thermal models were configured to withdraw water from the correct depth stratum to meet established seasonal temperature targets in the dam discharge.

Zooplankton Biomass

Monthly zooplankton densities were assessed along the length of Hungry Horse and Libby reservoirs using triplicate 30-meter vertical Wisconsin plankton net tows (May *et al.* 1987 and 1988; Chisholm *et al.* 1989). Seasonal shifts in zooplankton vertical distribution were estimated using duplicate Schindler trap (Schindler 1969) series from the water surface to 15 m in 3 m intervals, then 5 m intervals to 30 m. Zooplankton genera and size fractions were examined in the laboratory (May *et al.* 1987), and zooplankton biomass was calculated from dry weights (Bottrell *et al.* 1976).

The models calculated gross zooplankton production based on the relationship of energy transfer from the phytoplankton community to zooplankton (Ulanowics and Platts 1985). Bias introduced using this technique remains constant from one simulation to the next, which allowed us to compare alternative dam operations without the need to conduct further investigations of zooplankton population dynamics (Marotz *et al.* 1996).

HRMOD partitioned total zooplankton production by genera based on the relative biomasses of each genera captured in monthly zooplankton tows. The model calculated monthly and annual estimates of production of *Daphnia, Bosmina, Diaptomus, Cyclops, Epischura* and *Leptodora.* For each genus, the model describes zooplankton production (ZP) for each day (*i*) of the year as a linear function of primary production (PP):

$$ZP_i = a * PP_i * (b * SG_i * VOL_i + c).$$

The coefficients a and b and the constant c were derived from regression from observed primary production values and zooplankton standing stock values. SG is a seasonality factor developed for the genera based on the observed abundance of the genera throughout the year. VOL is the volume of the reservoir containing zooplankton, and was calculated over the upper 30 m of the reservoir water column. LRMOD performs a similar calculation for zooplankton.

Loss of zooplankton through Hungry Horse Dam was calculated (by discharge volume) based on the vertical distribution of zooplankton and depth of water withdrawal (Cavigli *et al.* 1998). This function had limited effect on the results of this analysis, however, because the selective withdrawal depth was configured to achieve the optimal temperature in the dam discharge in all simulations.

Benthic Insect Production

Model calculations for benthic insect production in the reservoirs were calibrated by triplicate dredge samples from established reservoir depth zones. Larvae sieved from dredge samples and corresponding adults captured in surface insect emergence traps were collected monthly during the ice–free period from 1985 through 1990 (May and Weaver 1987; May *et al.* 1988; Chisholm *et al.* 1989; Marotz *et al.* 1996). Benthic production was calculated as insect emergence based on a linear regression of standing stock of dipteran larvae at each sampling depth and dipteran emergence (per unit biomass) at each reservoir bottom elevation. Insect emergence was used as the measure of benthic production because aquatic Diptera become available as food for fish upon emergence as pupae or adults. Larvae were rarely observed in fish stomach contents. For each day of a simulation, biomass and emergence were calculated in five-foot depth increments from the water surface to the reservoir bottom.

The original models were modified for this analysis to allow for single year simulations. This was necessary because larval densities at depth are dependent on the minimum pool elevation during the previous season. During reservoir drawdown, desiccated substrate becomes devoid of aquatic insects within a few days, which essentially “resets” the

vertical distribution of aquatic insect larvae from year to year. The empirically derived depth distribution of benthic larvae was, therefore, adjusted up or down based on the minimum reservoir elevation during the previous year. Standing stock estimates were then calculated based on the minimum pool elevation during the simulated water year .

Terrestrial Insect Deposition

Insects from the landscape surrounding the reservoirs become available to fish as they are deposited on the water surface. Triplicate, monthly surface-tow data from nearshore (< 100 m) and offshore areas in both reservoirs showed that the four main orders of insects differed in distance from shore and seasonal abundance ($P \leq 0.05$) (Marotz *et al.* 1996). Coleoptera and Hemiptera have limited flight capability and were deposited near shore ($P \leq 0.05$), whereas Hymenoptera and Homoptera were more randomly dispersed throughout the reservoirs. The abundance of Coleoptera on the reservoir surfaces peaked in July (present April through October); Hemiptera in August and September (present July through October), Homoptera in August (present June through November) and Hymenoptera peaked in August (present July through September). The models calculated nearshore and offshore zones separately. Insects captured in surface tows do not provide a measure of insect deposition rates because insects deposited on the surface are eaten by fish or sink. Therefore, the abundance and seasonality of insect captured in surface tows was used to develop a seasonal index used to calculate the percentage of the maximum possible at full pool:

$$\text{Density (number/acre)} = \text{MAX}\ [0.0,\ \text{mean} + \text{AMP}^* \sin(\text{period} + \text{phase shift})].$$

Where MAX[0.0, X] resets all values of X below zero to zero or greater.
AMP = amplitude of the sine wave. Shift = the sine wave was shifted temporally to correspond to the time period when each insects were active, as observed in surface tows and deposition traps. Each order was modeled on the mean date, AMP and phase shift of observed densities. The Coleoptera model was reset to zero during periods when ice forms on the reservoir surface.

Westslope Cutthroat Trout Growth – Hungry Horse Reservoir

During model development, factors unrelated to dam operation were isolated where possible. Dependence on previously described trophic models increases the uncertainty of fish growth calculations, resulting in a model that is conservative and sensitive only to gross changes in reservoir conditions. Bias introduced by the underlying model calculations was consistent in all simulations of the dam operation alternatives, so that the relative ranking of the various operations was not affected by compounded error (Marotz *et al.* 1996).

Westslope cutthroat growth was assumed to be proportional to the product of water temperature and food availability. The water temperature term in the calculation represents the maximum daily reservoir temperature up to the optimal temperature for trout growth. The empirically calibrated thermal model calculated the vertical thermal profile on each day of the simulation. This describes the annual development of the

thermocline and fall turnover as stratification weakens. Only food items found in stomach content analyses were used in the analysis (May *et al.* 1988; Chisholm *et al.* 1989). Fish growth during model development was calculated based on fish scale annuli (Weisberg 1986) and seasonal increments in otolith growth (Brothers 1986), and growth models were verified using additional data (Brothers 1987 and 1988; see also Weisberg and Frie 1987).

The model did not address fish population dynamics because density dependent and independent factors that control fish populations in tributary streams could not be isolated. Population size and age structure were, therefore, held constant in the model to remove the effects of density dependant growth. Only fish that emigrate to the reservoir at age III (migrant class III) are represented in the model output. Daily growth was modeled for three years (age III through V) using established water temperatures and food schedules. This strategy was adequate to meet the goal of comparing dam operating strategies without the expense of further research. Coefficients represent the best model of available data. The equation for growth in mm/day is:

$$GROWTH_i = FAC_j * Min(TEMP, 11.9° C) * (0.37 * DAPHNIA_i + 15.34\ EPISHURA_i + 0.060 * COLEOPTERA_i + 0.00015 * HEMIPTERA_i + 0.020 * HOMOPTERA_i + 0.00011 * HYMENOPTERA_i + 0.55\ BENTHOS).$$

Where, FAC_j is a scaling factor for each fish age, and 11.9° C represents the temperature of maximum trout growth efficiency. Scaling factors for each yearclass were calculated to scale the model to observed growth data (FAC = 0.0405, 0.0155 and 0.005449 for ages III, IV and V, respectively).

Growth in length (total length [TL] mm) was converted to weight (g) based on measurements from 7,813 westslope cutthroat trout used to calibrate the model:

$$WEIGHT = 0.00001146 * TL^{2.962}$$

The weight calculation solved 98.9 percent of the total variation. Model output included monthly growth (TL) and weight (g) of fish at age III through V.

Kokanee Growth – Libby Reservoir

Kokanee growth (age II and III) was described by the annual thermal regime in the reservoir and food availability. Empirical growth measurements varied with zooplankton availability and water temperature. Although growth increments, scale annuli and otoliths were available, catch data from monthly net surveys provided a larger data set of incremental kokanee growth for model calibration. Empirical growth was derived from the mode of kokanee lengths in each age class captured in monthly net samples (Chisholm *et al.* 1989; Marotz *et al.* 1996). Since zooplankton production is dependant on phytoplankton production, which varies directly with solar input and water temperature, the vertical thermal profile (thermocline) of the reservoir (to a depth of 64

m) was the most significant factor that influenced kokanee growth. Linear regression analyses showed that growth was higher for age I+ kokanee as compared to age II+ fish ($R^2 = 0.95$ and $R^2 = 0.88$, respectively).

Weight (g) calculations specific to kokanee in Libby Reservoir was based on the following relationship:

$$\text{WEIGHT(g)} = 3.16255\ E^{-6} * TL^{3.19262}$$ Where TL is the Total length (mm).

River Modeling

Hungry Horse Dam was retrofit with a selective withdrawal system in August 1996, which enables dam operators to control water temperatures in the tailrace and mimic pre-dam thermal conditions (Christenson *et al.* 1996; Marotz *et al.* 1996). MFWP quantified zooplankton vertical distribution in the reservoir forebay and entrainment through the turbine penstocks in 1995 and 1996 to provide recommendations for operating the system to minimize zooplankton entrainment (Cavigli *et al.* 1998). The selective withdrawal system can control water temperatures and zooplankton entrainment in the dam discharge regardless of which flood control strategy is implemented. Therefore, all model simulations were configured to optimize temperature targets in the dam discharge.

Researchers are currently developing empirical instream flow models for the Kootenai and Flathead Rivers that estimate bull trout and westslope cutthroat trout habitat availability at various operational flow regimes (Muhlfeld *et al.* 2003 and 2003b; Miller and Geise 2003; Hoffman *et al.* 2002). Although this research will provide a rigorous estimate of biological impacts associated with dam operations, results were not available for this project. Therefore, we used the wetted perimeter technique (WETP) to estimate biological productivity in the rivers because it was the most descriptive methodology available for this analysis (MFWP 1982; Leathe and Nelson 1986). WETP is a measure of the length of inundated river bottom across the river, similar to a chain draped over the substrate in the bottom of each channel cross-section.

RivBio

The WETP analysis was performed using the river model "RivBio" developed for this analysis. RivBio was programmed in Visual Basic (VB) using channel morphology data and river flows to calculate an index of benthic biomass for each alternative dam operation. Biological productivity in the Flathead and Kootenai Rivers was assessed using annual input files of daily dam discharge for each river reach. Daily discharges were used to calculate WETP on each date during an annual model simulation based on survey data specific to each river reach (Hoffman *et al.* 2002; Marotz and Muhlfeld 2000; Miller and Geise 2003). RivBio linked the daily river flow data to the WETP-discharge relationship for each river reach.

In the Kootenai River, WETP relationships were developed using 26 transects surveyed by MFWP in each of two river reaches (Hoffman *et al.* 2002). WETP results for each transect were averaged to derive a composite transect representing the channel morphology within each river reach. Reach 1 included transects located directly downstream of Libby Dam (Figure 2). Reach 2 included transects located immediately upstream of Bonners Ferry, Idaho, in the portion of the Kootenai River that is not influenced by the regulation of Kootenay Lake, British Columbia (Figure 3). The Kootenai River WETP relationship was calibrated at flows from 3 kcfs to 40 kcfs. Since the hydrologic data provided by the Corps contained daily flows slightly less than 3 kcfs and greater than 40 kcfs, survey results were inferred to lower and higher flows by extrapolating the tails of the WETP relationship. This relationship is linear below 3 kcfs, and data provided by the Corps seldom extended into this range. Error caused by flows greater than 40 kcfs had little effect on the model results because substrate in the highest portion of the river channel is not inundated long enough to become biologically productive.

RivBio analyzed benthic biomass growth and decay in two river reaches in the Flathead Watershed. Reach 1 includes the South Fork Flathead River immediately downstream of Hungry Horse dam (Figure 4). The WETP relationship for the South Fork Flathead River was developed using standard survey techniques (Leathe and Nelson 1986; Marotz and Muhlfeld 2000). Reach 2 is the mainstem Flathead River near Columbia Falls (Figure 5, Segment 1). Channel morphology data in reach 2 were obtained using a boat-mounted GPS hydroacoustic system (Miller *et al.* 2003).

The river model computes the size of the zone of water fluctuation, or "*varial zone*", for the various operating strategies. Depth zones varied in size depending upon the WETP relationship at various river flows.

The index of benthic biomass productivity or *"biomass units"* was computed in four steps. First, a "*status index*" was established to track wet and dry periods in the different depth zones. Beginning on the first day of a simulation, if the input flow datum was equal to or higher than the flow on the previous day, the "*status index*" was increased by one day.

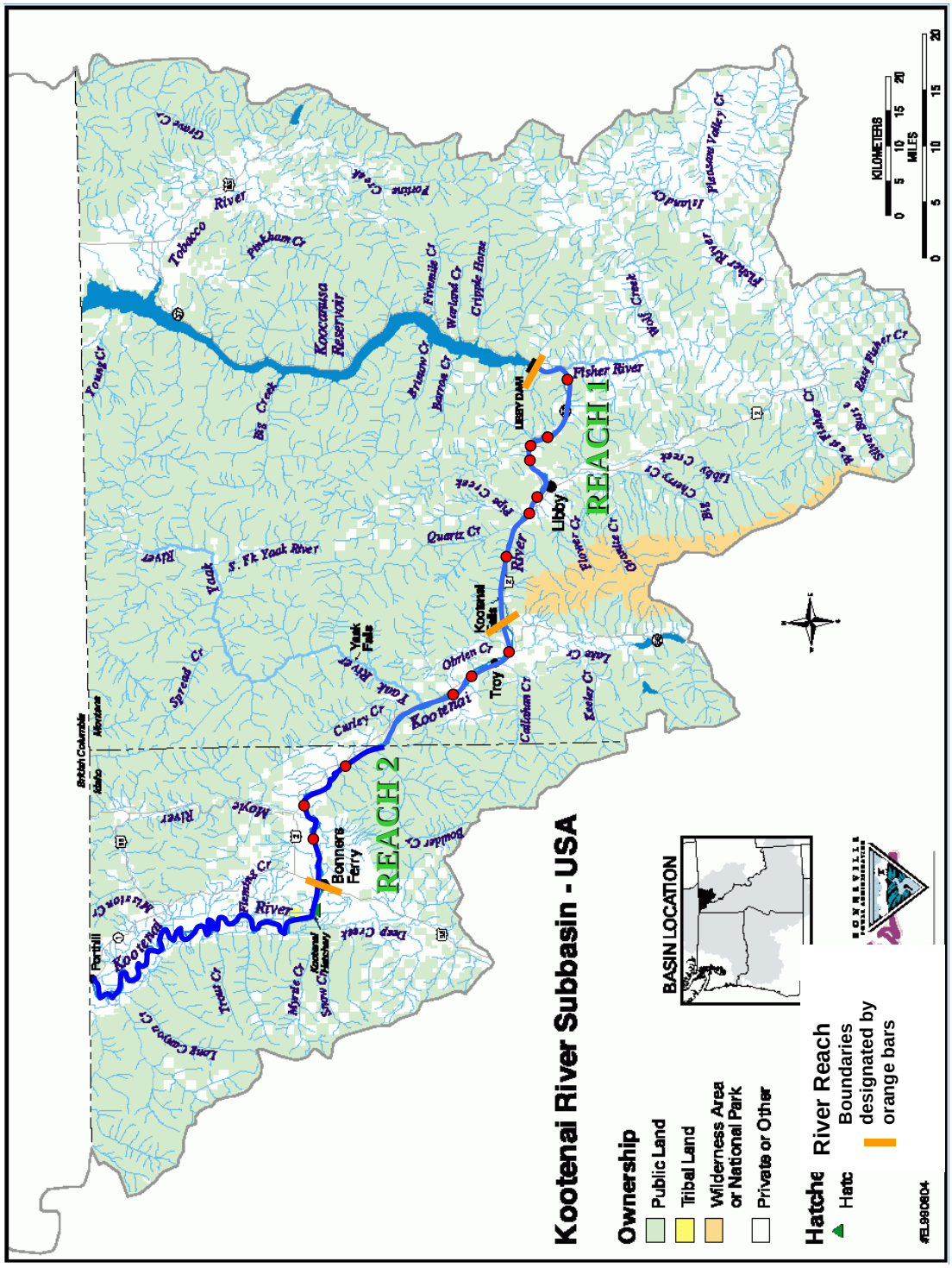


Figure 2. The Kootenai River immediately downstream of Libby Dam, Montana, was called "Reach 1" in this report. The reach just upstream of Bonners Ferry, Idaho, was "Reach 2" Sampling locations for channel cross-sections are indicated by red dots on the river channel (Source: BPA and MFWP Libby Area Office).

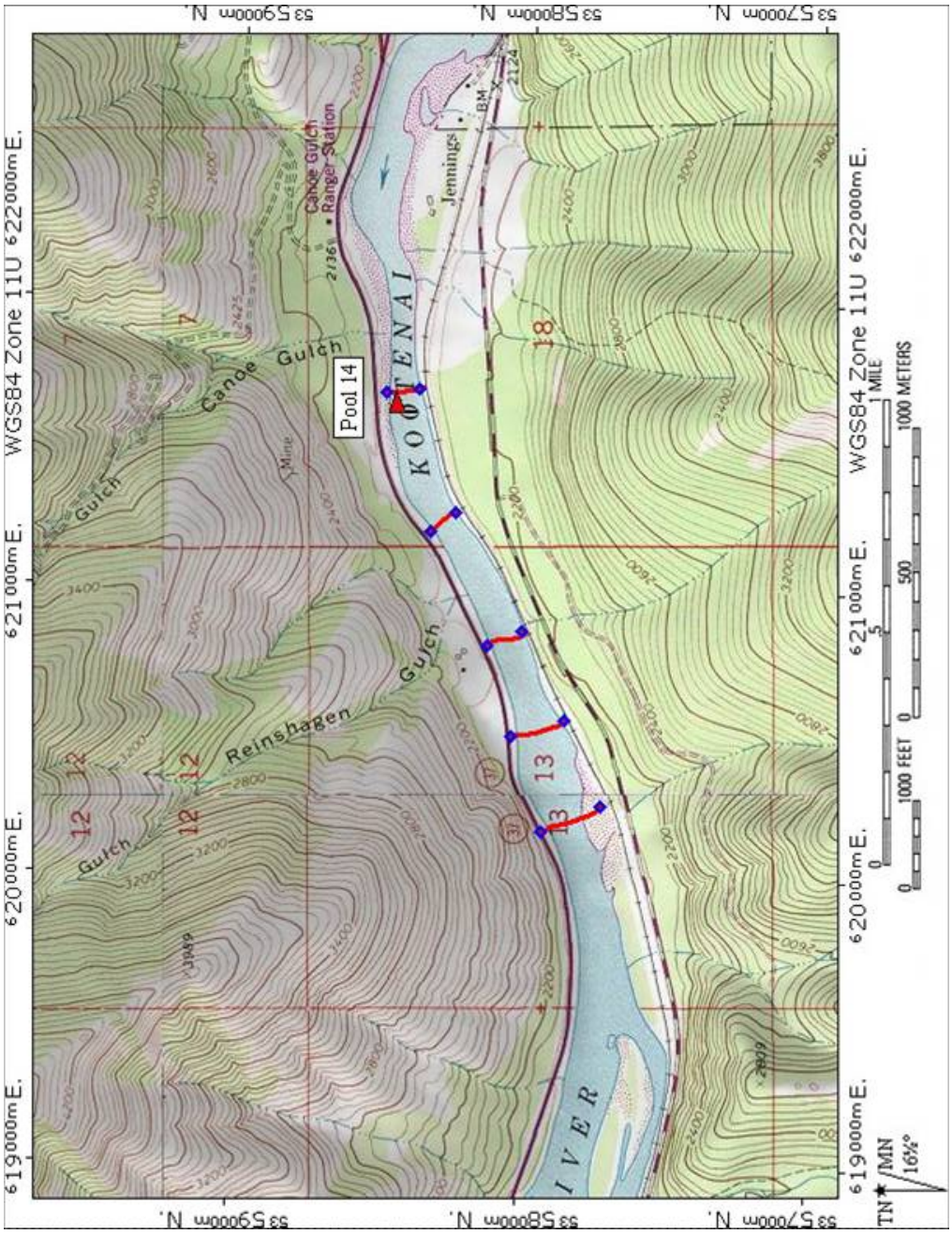


Figure 3. Each sampling location in Figure 2 represents a series of channel cross-sections that were used to calibrate RivBio. This example shows the location of transects near Jennings Rapids in Reach 1 (Source: MFWP Libby Area Office).

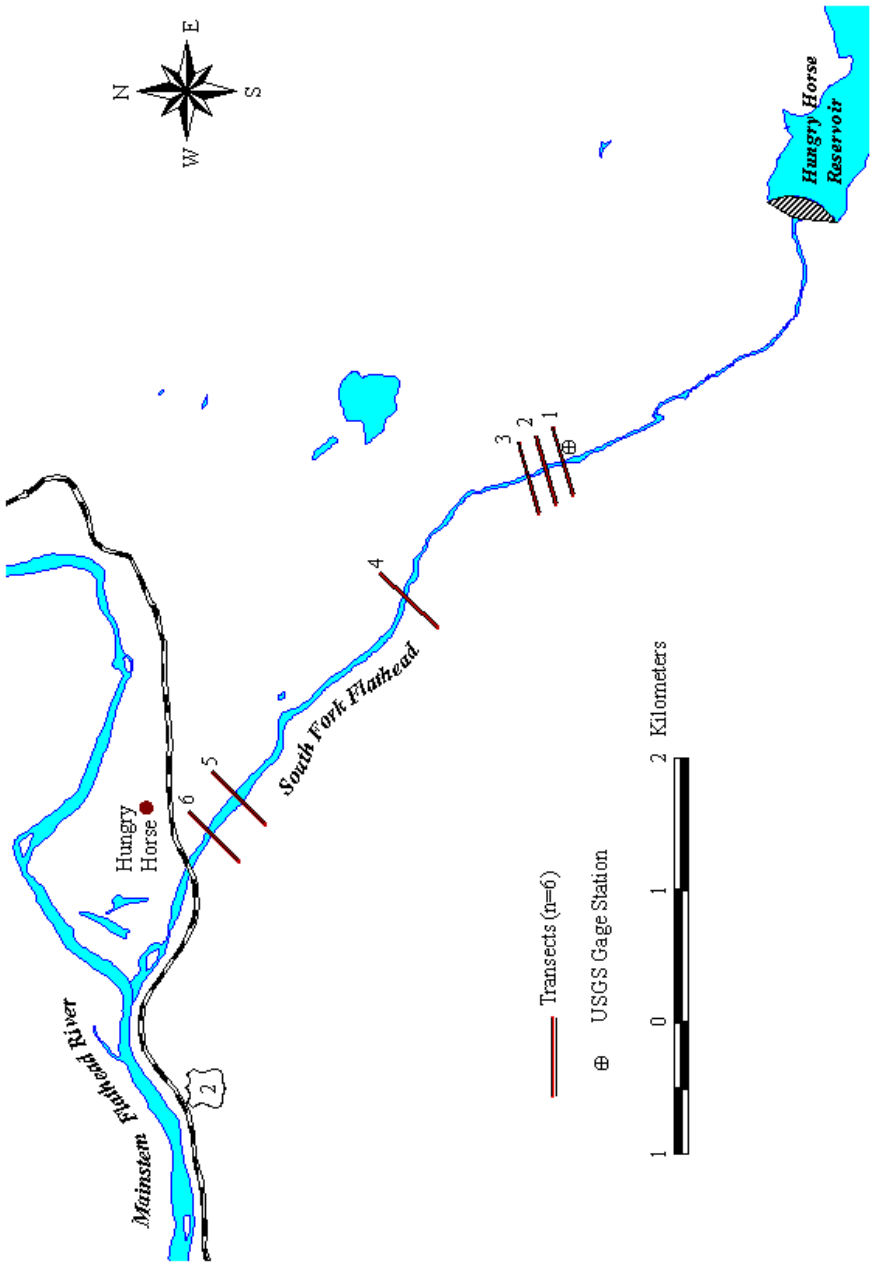


Figure 4. The South Fork Flathead River downstream of Hungry Horse Dam, Montana. The location of channel cross-sections that were used to calibrate RivBio are indicated on the map (Source: Marotz and Muhlfeld (2000) map by Steve Glutting MFWP).

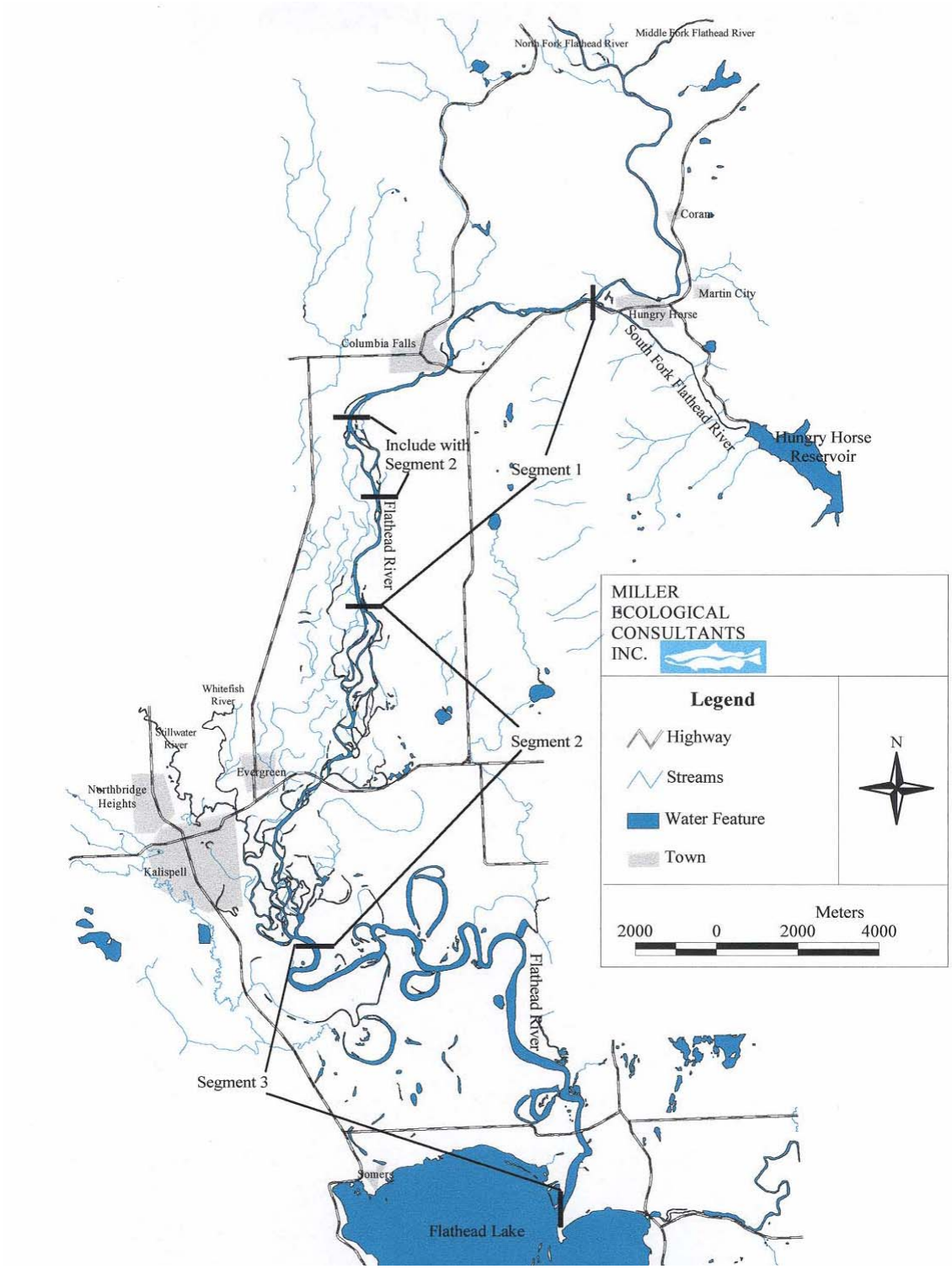


Figure 5. The Flathead River from the South Fork confluence to Flathead Lake. Segment 1 on this map includes the river near Columbia Falls, Montana, or "Reach 2" in this report. Eight representative channel cross-sections in this river reach were derived using hydroacoustic techniques (Miller and Geise 2003) and used to calibrate the river model RivBio for the Columbia Falls reach.

During each day of the RivBio simulation, the model counts the number of days each depth zone has been wet, up to a maximum number of days set by the model user (47 days was standard). Gersich and Brusven (1981) found that 47 days simulates the gradual recolonization of benthic algae and insects into newly inundated habitat. If, however, the current flow datum was less than the flow on the previous day, the status of the dewatered zone was set to –1 day. On each day, the program enumerates the number of days that a given stratum has been desiccated (up to a maximum of –5 days). All depth zones that remained wet, below the minimum flow, during a given year were considered productive (status ≥ 47 d). All depth zones that remained dry, above the maximum flow, during a particular year were scored as unproductive (status = -5 d).

Secondly, the *"condition index"* within each depth zone was scored on a relative index, scaled from 0 to 1 depending upon the zone's daily status index (0 = fully desiccated and unproductive, 1= fully recovered). The varial zone gains and loses benthic biomass throughout the year as substrate is intermittently inundated and dried. Positive status values correspond with biomass gains and negative status scores correspond with biomass losses. The "Condition matrix" inputs the daily status of each depth zone and compares it to the previous day, then adjusts the condition index based on the growth and decay curves. Daily increments or decrements in the condition index were taken directly from the growth and decay curves described in Figures 5 and 6. The rate of insect recolonization when substrate remains wet was set to 47 days. This assumption was tested using a sensitivity analysis described in the results section. Lost production was calculated as an exponential decrease over a 5-day period for each day the substrate was dry (Figure 7). The 5-day desiccation metric calculated losses in benthic biomass caused by sudden flow reductions.

Thirdly, the preliminary "*biomass index"* is calculated as the condition index in each depth zone multiplied by its wetted perimeter. The wetted perimeter relationship provides an index to the area of substrate involved. Specific biomass indices were calculated for all depth zones on each day, depending on the duration that substrate remained wet. RivBio does not have the resolution required to ascribe seasonality to the various guilds of aquatic organisms. The model did not distinguish substrate or habitat types. Insect density was assumed to be random and consistent throughout the wetted river channel after the benthos was fully recovered.

The fourth and final calculation adjusts all the raw biomass indices by the seasonality factor for each date. The model incorporated a seasonal weighting factor to describe the annual potential for biological productivity. Water temperature begins to warm in mid April and increases rapidly after the spring runoff peak in late May/early June. Water temperatures cool rapidly in October, reaching the winter low approximately in January. Benthic algae fix more carbon during the warm months as day length increases.

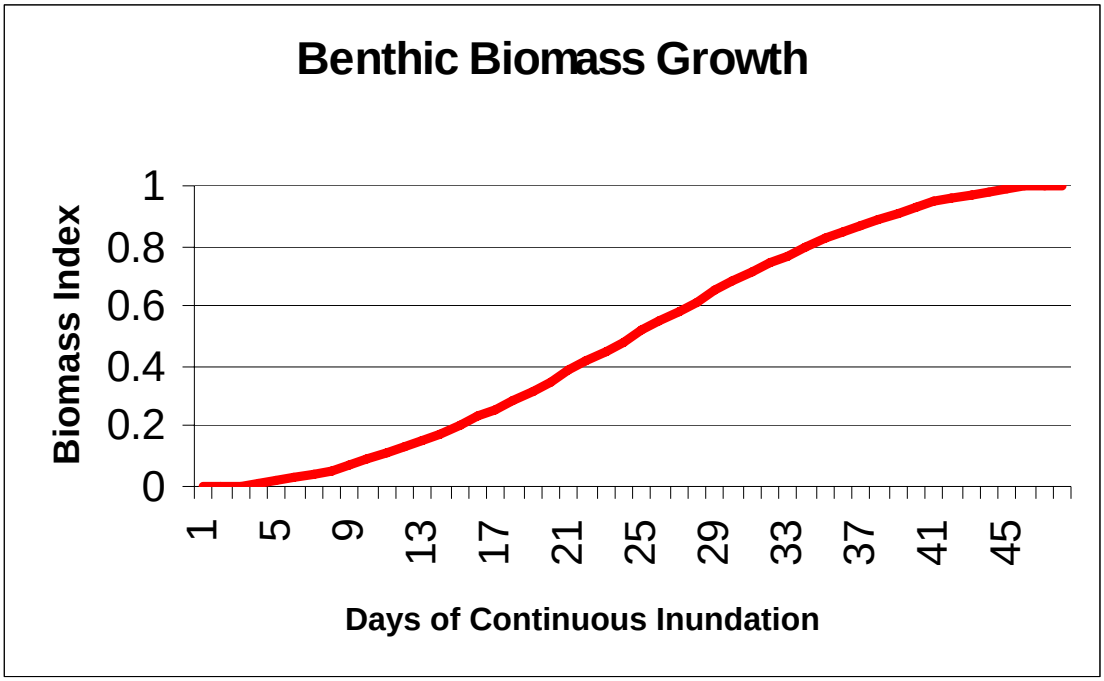


Figure 6. Sigmoid shape of biomass increase when substrate remains inundated. This index assumes a gradual increase from 0 (desiccated) to 1 (productive) over a 47-day period of continuous inundation, approximating the rate at which newly inundated substrate becomes colonized by benthic algae and aquatic insects. RivBio assumes that benthos are randomly distributed across the permanently wetted portion river bottom (score =1). Benthic biomass scores in the varial zone ranged from 0 to 1 depending on the duration substrate in each depth zone remained wet.

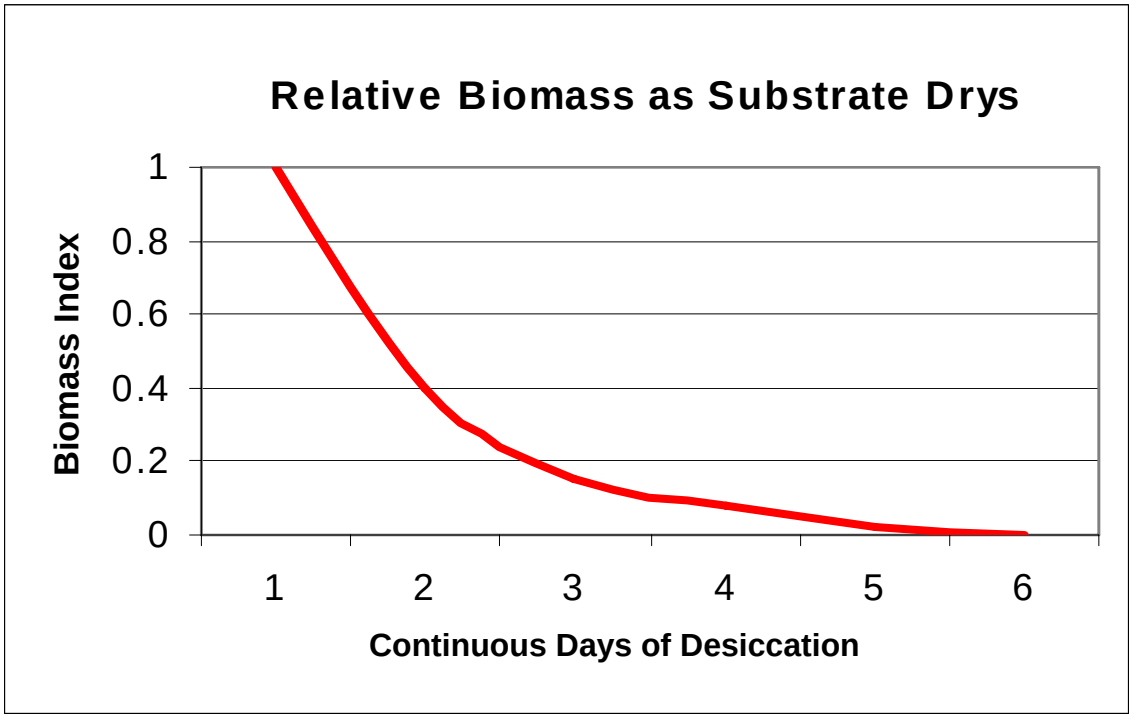


Figure 7. Exponential decay of viable biomass after productive substrate becomes dry. We assumed a complete loss of benthic productivity in each depth zone after 5 days of desiccation. All areas that remained dry for five or more days were assumed to be devoid of benthic biomass (score = 0).

Seasonality was described as a one wave-length, truncated sine wave centered on July 30 (WYD = 314; Figure 8). This un-scaled index mimicked the seasonality of longer photo-period and warmer water temperatures during summer and their influence on biological productivity. Insect emergence follows a similar annual pattern (Perry 1984; Perry *et al.* 1986; Hauer *et al.* 1994; Hauer *et al.* 1997). Although many large aquatic insects have life cycles of a year or more, multivoltic species can have more than one reproductive cycle in a growing season. For example, caddis flies emerge during the entire ice-free period providing a continuous food supply for fish, and mayflies and stoneflies have spring and fall forms and large species that emerge in early summer.

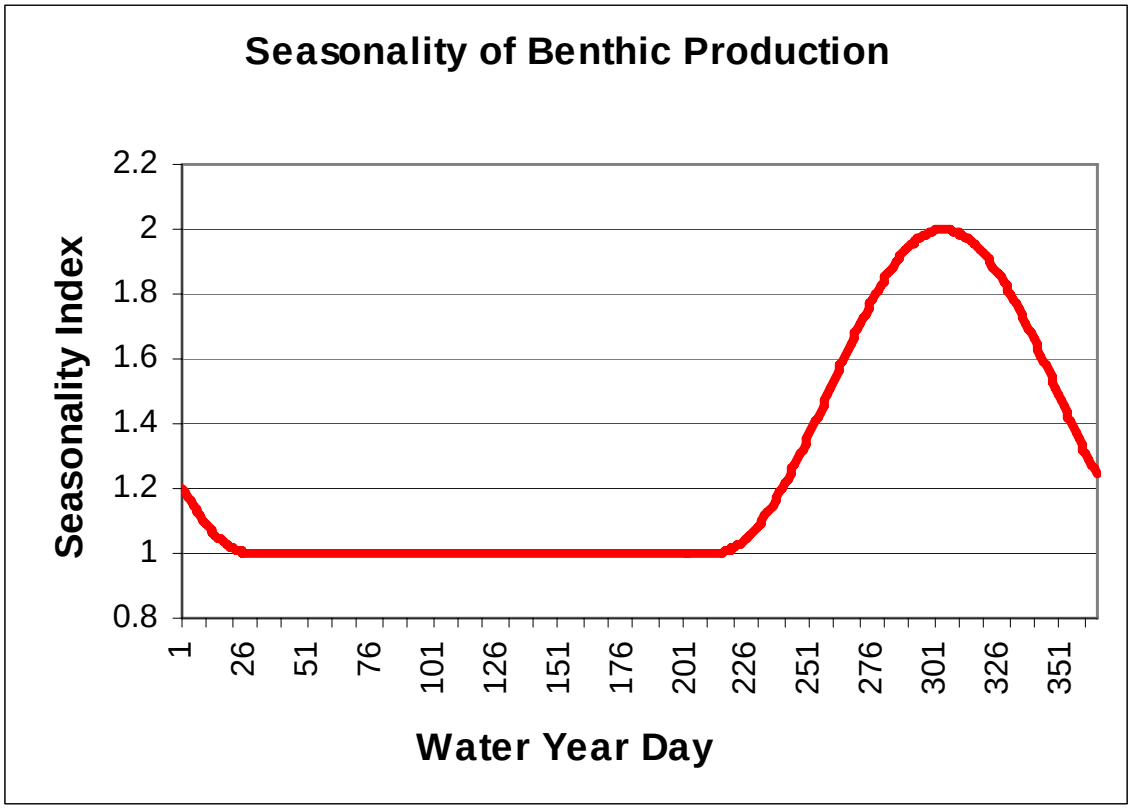


Figure 8. The seasonal index of benthic productivity was modeled as a one wave-length, truncated sine curve has the peak centered on July 30th. This un-scaled index assumed that benthic production was twice as great during summer as compared to winter to mimic the seasonal effects of photo-period and water temperature.

Ranking the relative biological potential of each alternative was performed using time series analysis on the amount of substrate that remains wet and biologically productive. Different seasons and different days have differing values depending upon how much surface had been inundated and for how long. The net of losses and gains of benthic biomass units were used to rank the alternatives. The total for each period of the year was derived by summing productivity scores for all days and depth zones, which provided the relative rank of each alternative. In this analysis, we compared relative values during the period March 1 through September 30 in the Kootenai and annual totals in the Flathead. The Corps requested that the river production calculations in the Kootenai River be limited to this period (WYD 152 to 365) because the simulated power operations during the fall and winter may vary temporally from actual operations.

We used RivBio to calculate the following physical and biological parameters:

1. Physical index: a) range of WETP range and b) range of stage variation during a given period or year;

2. Biological indices:

    a. Index of biomass gains over the year including: a) total units by depth zones, b) total units by days, and c) annual (or partial year) grand totals calculated from the amount of productive wetted perimeter; and

    b. 3. Index of the amount of potentially productive biomass achieved (or not achieved).

We report biological responses for Hungry Horse and Libby Reservoirs, the South Fork Flathead River, and Kootenai River downstream of the dams and points downstream, including the Flathead River at Columbia Falls, Flathead Lake and Bonners Ferry. Results are reported for three years in each of three categories of water availability: slightly dry, average, and slightly wet water years (Table 1). For the reservoirs, results describe trophic responses by primary producers, zooplankton, insects and fish for each year of the simulation (Figure 9).

River operations were ranked based on benthic biomass, flow seasonality and the range of fluctuation. Data sets are summarized in the report for brevity. The entire set of output files and can be viewed electronically using the accompanying compact disk (See Model Output files for each watershed).

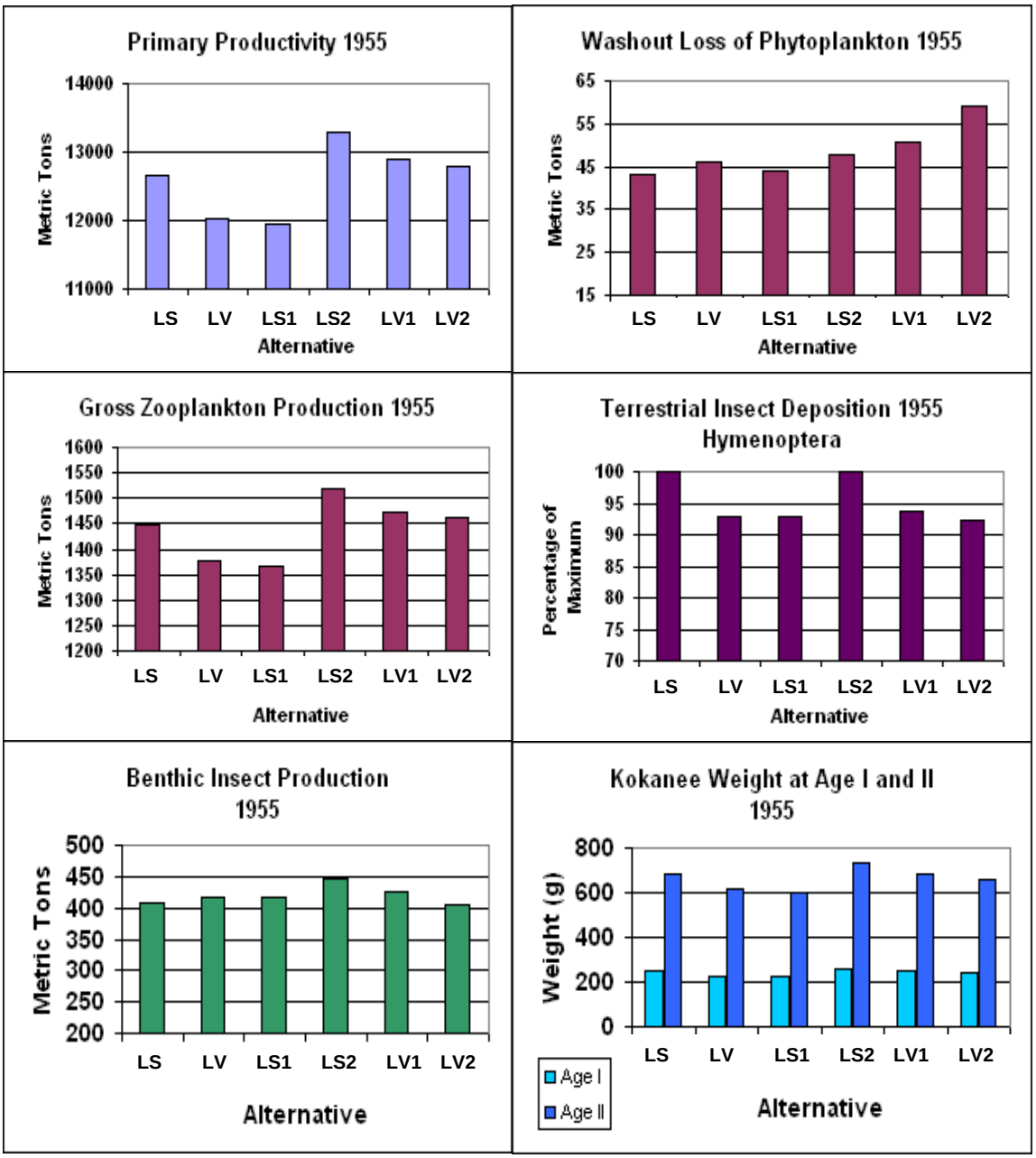


Figure 9. Example of biological results for six model simulations comparing biological responses in Libby Reservoir. Annual results for each year are named "Biol9**.xls" in folders for each simulated water year (see accompanying CD).

Modeling Assumptions

- Certain model functions were held constant during annual simulations of alternative flood control and fisheries strategies to avoid bias in model results. During all simulations, the selective withdrawal thermal control structures on Hungry Horse and Libby Dams were configured to seasonal temperature targets. Water was discharged from the appropriate layer of the reservoirs to remain within the designated minimum and maximum seasonal targets.
- The thermal structure in the reservoir forebay, calculated by the thermal model, was extrapolated throughout the reservoir. This assumption was supported by longitudinal thermal profile measurements by MFWP.
- Meteorological parameters (i.e. inflow water temperature, air temperature, humidity wind speed, cloud cover and opacity) were modeled using modified sine waves fit to 11 years of daily records from local weather and gauging stations, correlated to measurements at each dam (Marotz *et al.* 1996). Weather effects were held constant in all model simulations.
- Water temperature in the dam discharge equals the temperature in the reservoir forebay at the depth of water withdrawal.
- All model simulations conformed to flow ramping rates and seasonal minimum and maximum flow targets specified in the NOAA-Fisheries and USFWS 2000 Biological Opinions.
- According the Corps Environmental Coordinator for this project, simulated power discharges during the winter period at Libby Dam may differ from actual operations. Therefore, we analyzed biological conditions in the Kootenai River during the period March 1 through September 30 only.
- Nutrient loading to the reservoirs has not changed significantly since the models were calibrated in 1996.
- All discharge water was assumed to pass through the turbines (no spill) and the selective withdrawal system even when default model specifications had to be superseded to accurately portray the hydrologic data provided by the Corps and Reclamation.
- Operating alternatives for Libby Dam contained fish flows as high as maximum existing turbine capacity plus 10 kcfs. Model simulations did not differentiate turbine and spillway discharge. Temperature effects of potential surface water release through the spillway could not be assessed.
- Total zooplankton production was proportional to primary productivity, minus a loss function established for plankton communities in oligotrophic, temperate waters.
- Total zooplankton production at Hungry Horse Reservoir was subdivided into estimates of production within each zooplankton genus, based on the relative biomass of zooplankton genera captured in monthly sampling series (1983-1991) (May *et al.* 1988).
- Estimated washout of zooplankton from Hungry Horse Reservoir, per discharge volume through the selective withdrawal structure (which became functional in August 1995), was assumed to be proportional to the measured density at each withdrawal depth (Cavigli *et al.* 1996).

- The vertical distribution of Chironomid larvae in the reservoir substrate was assumed to be proportional to triplicate dredge samples in each depth zone (May *et al.* 1988; Chisholm *et al.* 1989). This distribution is adjusted up or down to reflect the minimum reservoir elevation during the previous year at the beginning of each annual simulation.
- Annual water year simulations at Libby Dam are initiated at full pool elevation 2459 in benchmarks LS and LV, and 20 feet below full pool in all the alternatives (LS1, LV1, LS2, LV2).
- Annual water year simulations at Hungry Horse are initiated at the elevation specified in data provided by Reclamation.
- The seasonality and relative abundance of terrestrial insects trapped in the reservoir surfaces were assumed to be proportional to captures in duplicate surface tow nets in nearshore (<100 m) and offshore (>100 m) zones (Chisholm *et al.* 1989; May *et al.* 1988).
- Fish population sizes and relative abundance were assumed to be static for all simulations. The model design focused on the relative effects of various dam operations on fish growth in target species (westslope cutthroat trout (WCT) at Hungry Horse and kokanee (KOK) at Libby).
- Fish growth estimates assumed identical dam operations during each year of the fish's life cycle. WCT at ages IV+ and V+ and KOK at ages I+ and II+ assumed constant operation for 2 and 3 years, respectively.
- Benthic insect productivity in the river channel recovers within 47 days after dry substrate becomes inundated (Gersich and Brusven 1981). The rate of recovery in a given depth zone after inundation follows a sigmoid curve, scaled from zero to one with one being fully recovered.
- Benthic biomass was assumed to be randomly dispersed throughout the river channel; all depth zones in the wetted perimeter were considered equally productive after recovery.
- Benthic biomass in the river channel declines exponentially to zero five days after productive substrate becomes dry.
- Biological productivity in the rivers occurs on an annual cycle that approximates a one wave-length truncated sine curve centered on the end of July. To simulate a seasonal effect, benthic biomass was assumed to be twice as great during summer than during mid winter (see seasonality of measured productivity in the reservoirs).

Results

Libby Reservoir

Primary productivity

Primary production (carbon fixation) by phytoplankton was limited by changes in reservoir surface area and the volume and average temperature within each depth stratum. The model calculated the longitudinal and vertical distribution of carbon fixation and related these values to volumetric production rates (mgC/m^3/d) for each operating alternative. Model output included daily schedules of carbon fixed by phytoplankton (see example in Figure 10). Totals for the four alternatives and two benchmark operations were summarized by water year (Figures 11). The benchmark operations (LS and LV) begin the water year at full pool (elevation 2459) on October 1, so results were plotted separately from all other alternatives that begin the simulation 20 feet below full pool (elevation 2439).

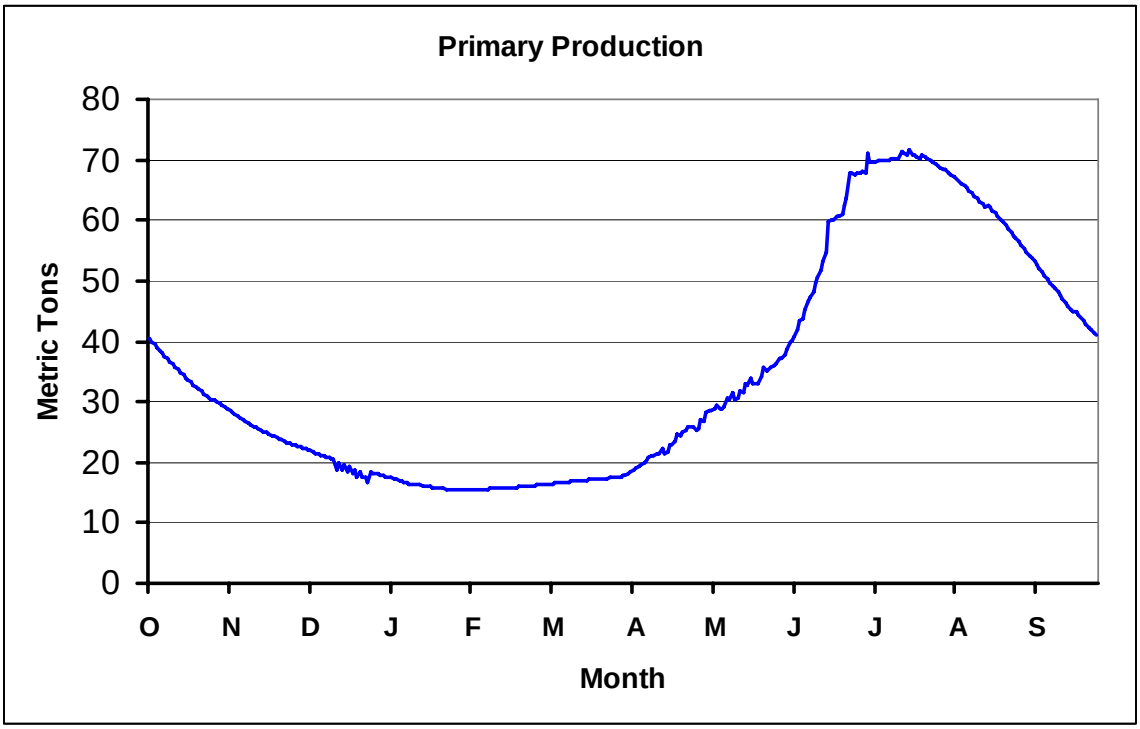
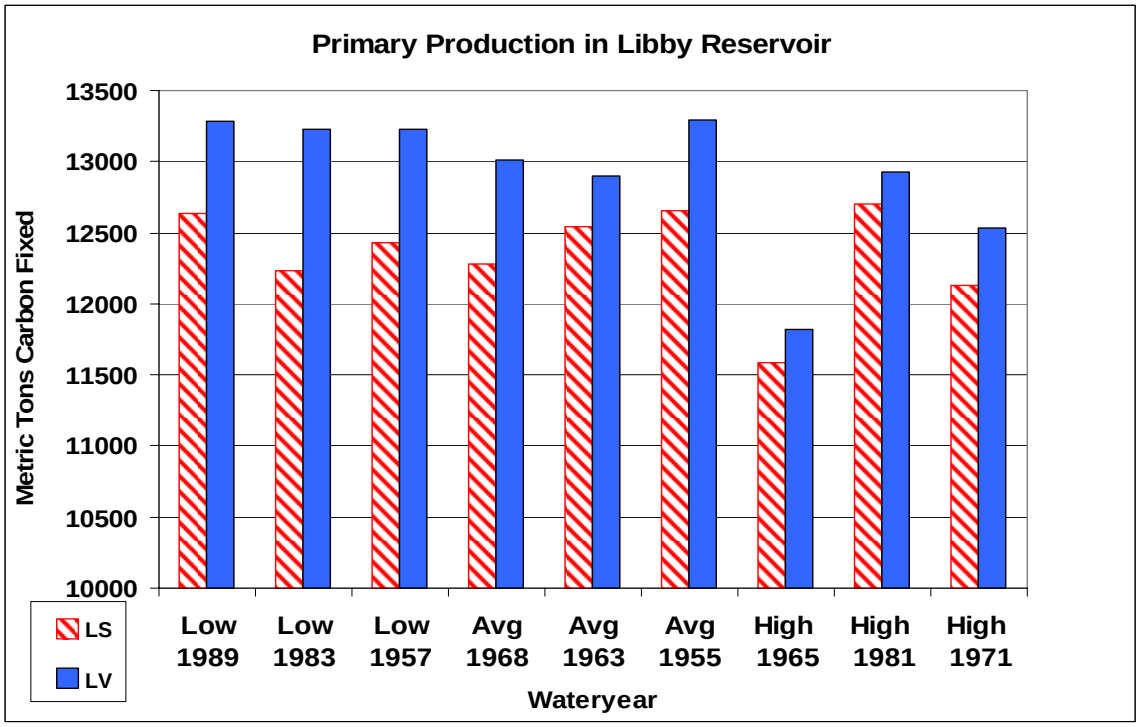


Figure 10. This annual schedule of primary production in Libby Reservoir shows model results from the 1955 benchmark LS (standard flood control without fish flows). Vertical and longitudinal distribution of primary production in the reservoir was calibrated using light and dark bottle arrays and liquid scintillation measurements of C^{14} uptake. The shape follows annual trends in water temperature and solar input.



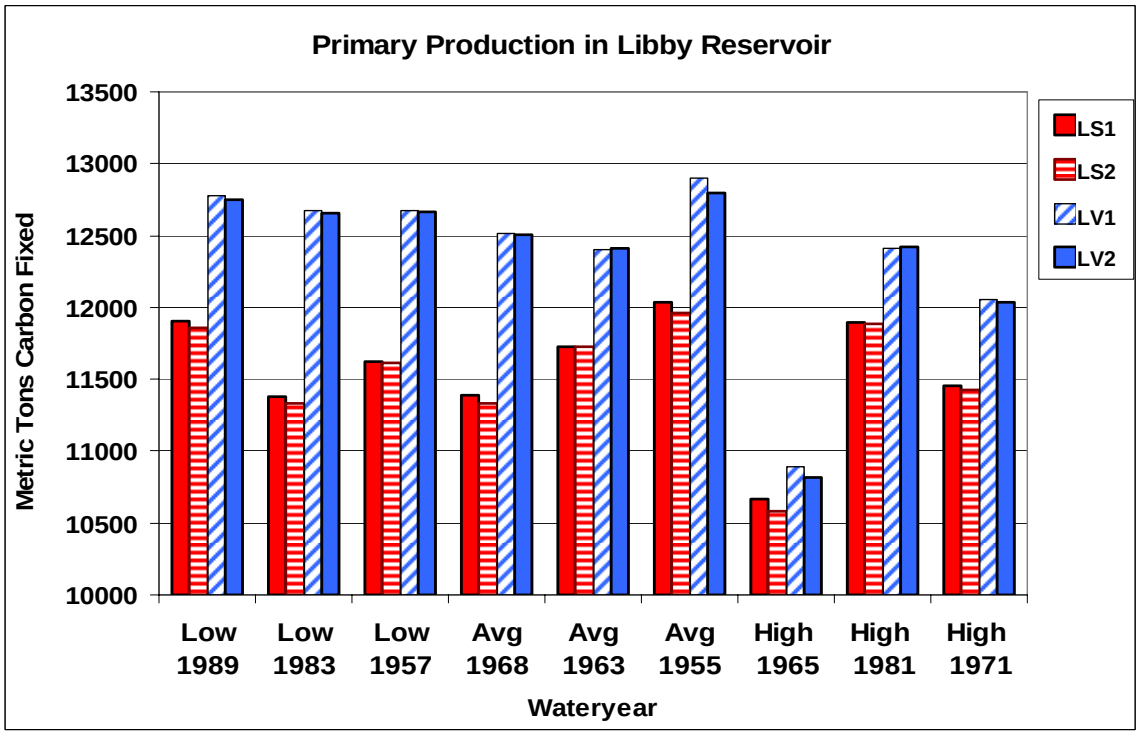


Figure 11. Primary production calculations (metric tons of carbon fixed by phytoplankton) were calculated for each of the six alternative dam operation strategies. Benchmarks LS and LV initiated at full pool, whereas the other alternatives began 20 feet below full pool, so were plotted separately. Results were arranged by water availability during each water year in order from low (X-axis left) to high water years (X-axis right).

Model calculations of primary production ranged from 10,578 to 13,289 metric tons under the six alternative dam operation strategies. Benchmarks LS and LV produced more phytoplankton because Libby Reservoir remained at or near full pool during the productive warm months. All alternatives (LS1, LS2, LV1, and LV2) provide fish flows and remained 20 feet from full pool during late-summer and fall. The VARQ FC benchmark operation without fish flows provided reservoir conditions that produced the highest values of primary production. When fish flows were added, Alternative LV1 resulted in slightly greater primary productivity than LV2 during seven of the nine water years, and LS1 produced more phytoplankton than LS2 during all nine years.

Loss of phytoplankton through the dam turbines was controlled mainly by the discharge volume and the vertical distribution of phytoplankton relative to the depth of water withdrawal. The thermal model was configured in all simulations to release reservoir water from the appropriate depth to meet the specified seasonal temperatures in the Kootenai River. This caused the depth of withdrawal, as measured from the reservoir surface, to remain relatively constant between alternatives, thus limiting the difference between the alternatives. The differing starting elevation in the simulations had little effect on results, so all alternatives were plotted on the same graph. Differences in the annual schedule of primary productivity in the reservoir and the seasonality of dam discharge volumes influenced washout losses (Figure 12). Results would differ if the selective withdrawal structure was operated differently.

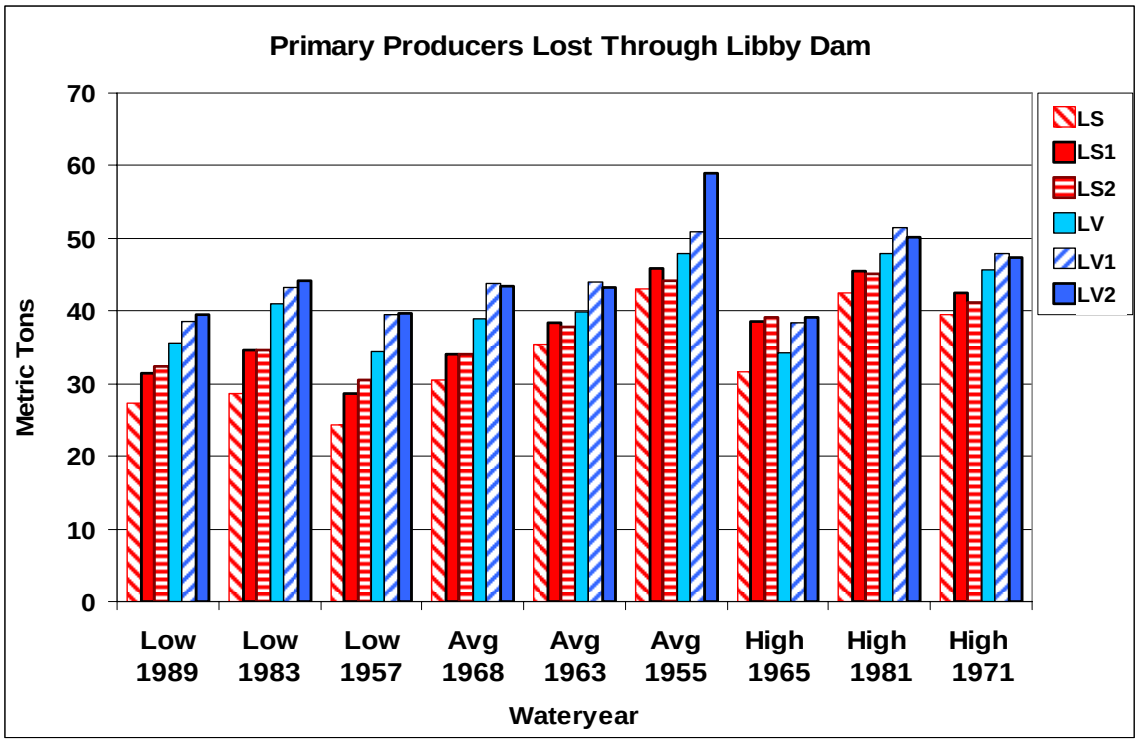


Figure 12. Estimated loss of primary producers through the dam turbines resulting from each alternative. Withdrawal depths were automated for consistency in all simulations. Therefore, loss calculations were most sensitive to production in the reservoir and the seasonality of discharge volumes.

Seasonal flows and the depth of water withdrawal influence washout of primary producers through the turbines of Libby Dam. Because selective withdrawal was modeled the same way in all simulations, the seasonal discharge volume was the strongest controlling factor in this analysis. Still, the water withdrawal depth remains an important factor determining to amount of plankton discharged through the dam. Results indicate that VARQ FC alternatives result in greater washout loss of primary producers than the Standard FC alternatives. As expected, operations that provide "fish flows" passed more phytoplankton through the dam than their respective LS or LV "flood control only" benchmarks. Alternatives LV1 and LV2 ranked highest during eight of nine water years, and LV2 had the highest losses in five of the years simulated. Losses were proportional to the level of production in the reservoir stratum at the outlet depth influenced by penstock turbulence. When more primary production occurred in the reservoir, more phytoplankton was lost through turbine penstocks. Washout losses represent a small fraction of the overall production in Libby Reservoir and provide a trophic gain to the Kootenai River.

Zooplankton Production

The annual schedule of zooplankton production was a function of phytoplankton production calibrated to reported energy transfer efficiencies as zooplankton graze on phytoplankton. Not surprisingly, a plot of the seasonality of zooplankton production is shaped very similarly to the annual schedule for primary productivity (Figure 13).

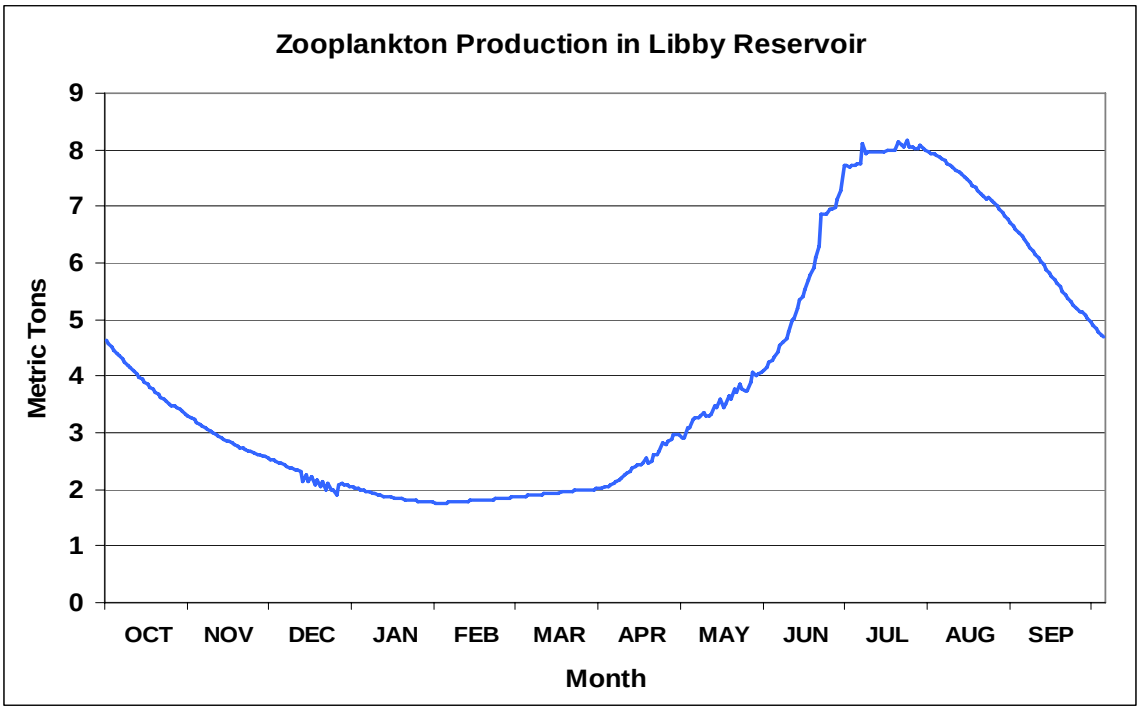
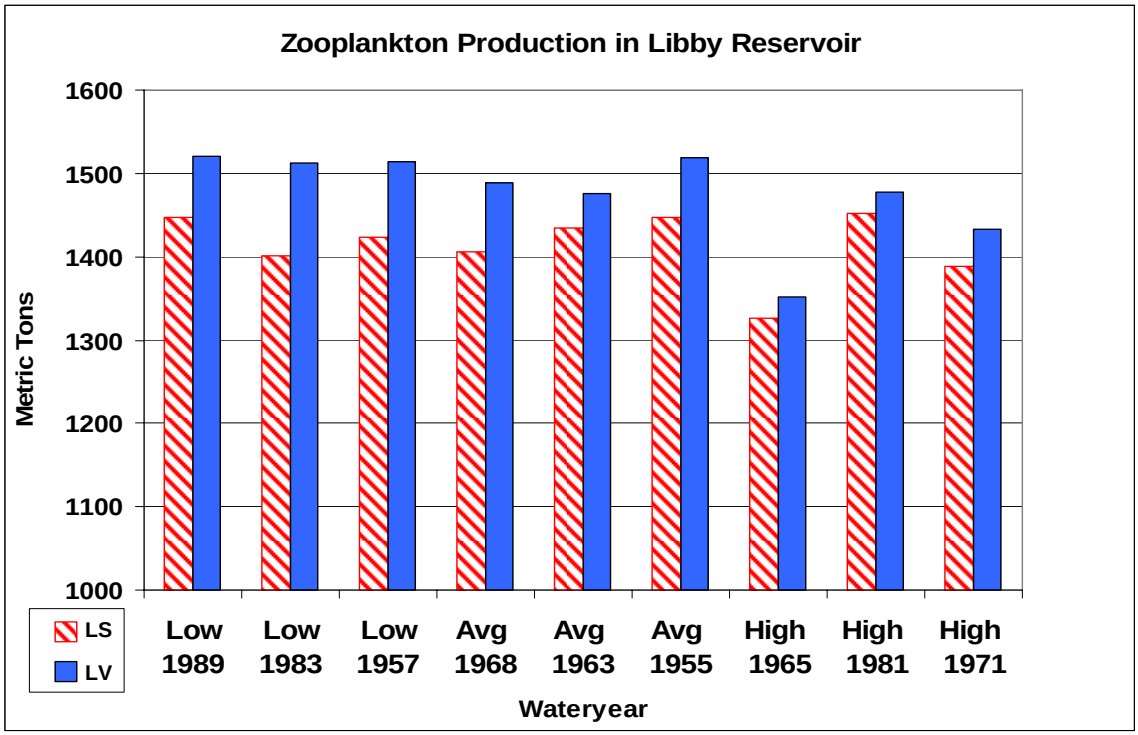


Figure 13. An example annual simulation of a zooplankton production for 1955 Benchmark LS. ASCII text files for each simulation are named Biol9**.dat, where "**" represents the last two digits of the year. This example is from an Excel file named Biol955-b.xls located in the \Libby Reservoir\1955\ folder.

Once produced, zooplankton survive in the reservoir for an indefinite period until they are eaten by predators (e.g. fish, Leptodora), die from natural causes and sink, or lost through the dam. Enough individuals survive through fall and winter that zooplankton provide the primary winter food for fish species that do not prey on fish (including westslope cutthroat trout and juvenile bull trout). Zooplankton are the primary food supply utilized by kokanee throughout their lives. Model estimates of zooplankton production under the six alternative operating strategies reflected differences in surface area and volume at depth during each simulated water year (see folders for each year containing Excel files named Biol9**.xls on the CD).

Zooplankton production estimates ranged from 1209 to 1521 metric tons across all years and alternatives. Benchmarks LS and LV began at full pool on October 1 and were not drafted during the biologically productive summer months to augment flows downstream. Operations that maximized surface area and volume during summer produced the most zooplankton. In general, the Standard FC alternative had lower reservoir elevations during spring as compared to the VARQ FC alternative, which resulted in a slower build up of zooplankton biomass in the Standard FC alternatives (Figure 14). Conversely, reduced reservoir drawdown during spring under the VARQ FC operation created a larger volume of optimal temperature water as zooplankton production increased toward the summer maxima. Alternative LV1, VARQ FC with fish flows, produced slightly more zooplankton than did LV2 during 6 of the 9 years. During the two highest water years, LV2 produced more zooplankton. Additional simulations are required to determine if a trend exists between the two VARQ FC alternatives. Logically, since LV2 increases fish flows by an additional 10 kcfs, the downstream washout of zooplankton would be greater. Further, the accelerated water exchange rate in the reservoir should delay production as the reservoir fills. Zooplankton washout under LV1 and LV2 would become more similar during high water years, as alternative operations converge (Figure 11, also see plots of all input variables in \H-Input\ for Hungry Horse and \L-Input\ for Libby). As water supply increases, the alternative operations become more similar. This is presumably because as water availability increases, Libby Dam can only regulate a progressively smaller percentage of the annual water budget.

Zooplankton washout losses could be managed to some extent using the selective withdrawal system at Libby Dam. Such control, however, may not be warranted because once zooplankton are produced they remain available to fish until they sink or wash through the dam. Although washout losses increase with higher dam discharges, the loss is a small fraction of the overall reservoir productivity. Another mitigating factor is that zooplankton swept through Libby Dam provides a trophic gain to the Kootenai River. The amount of zooplankton available as food for kokanee is therefore mainly influenced by the amount of zooplankton produced in the reservoir. Food availability is largely controlled by reservoir surface area and volume during the productive summer months.



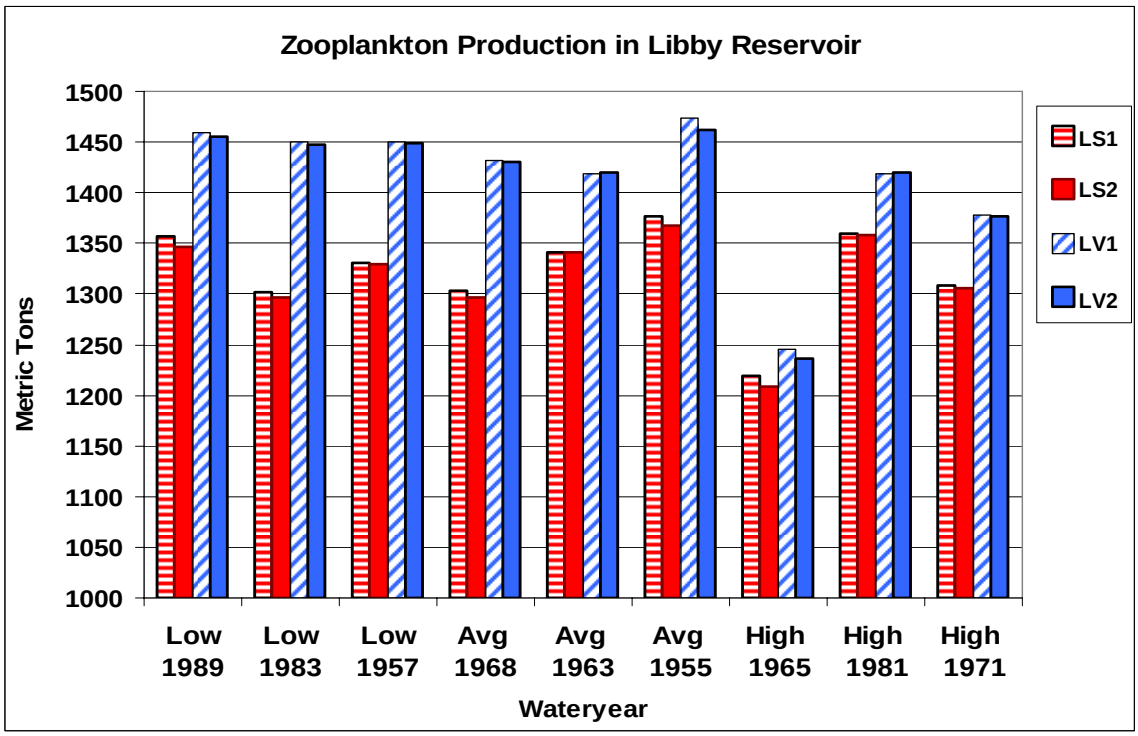


Figure 14. Zooplankton production (metric tons) in Libby Reservoir under each alternative was plotted for comparison. The "flood control only" benchmarks LS, Standard FC, and LV, VARQ FC, initiate at full pool on October 1. The "flood control with fish flows" alternatives LS1, LS2, LV1 and LV2 initiate at 20 feet below full pool, so were plotted separately. Graphs of annual reservoir surface elevation schedules can be found in "All Years Lsurf.xls".

Benthic Insect Production

Impoundment of the Kootenai River by Libby Dam and annual operations have greatly simplified the diversity of aquatic insects in Libby Reservoir by reducing insects that are adapted to flowing water (e.g. stoneflies, mayflies and caddis flies). Aquatic diptera dominate the existing reservoir insect community. Larger, long-lived species dominate the permanently wetted zone, whereas the varial zone contains mainly small, short-lived *multivoltic* species. Larvae recolonize previously dewatered substrates as the reservoir fills, and shoreline areas are dominated by multivoltic dipterans that produce cohorts throughout the warm summer months (May 1988; Chisholm *et al.* 1989).

Annual production schedules are controlled by the substrate area of each depth zone (digitized from topographic maps) and the duration each zone remains wet and productive as the reservoir refills and drafts. The model calculated daily estimates of benthic insect production during the water year (Figure 15). Annual production totals were compared between alternatives for each simulated water year and summarized for each category of water availability (Figure 16).

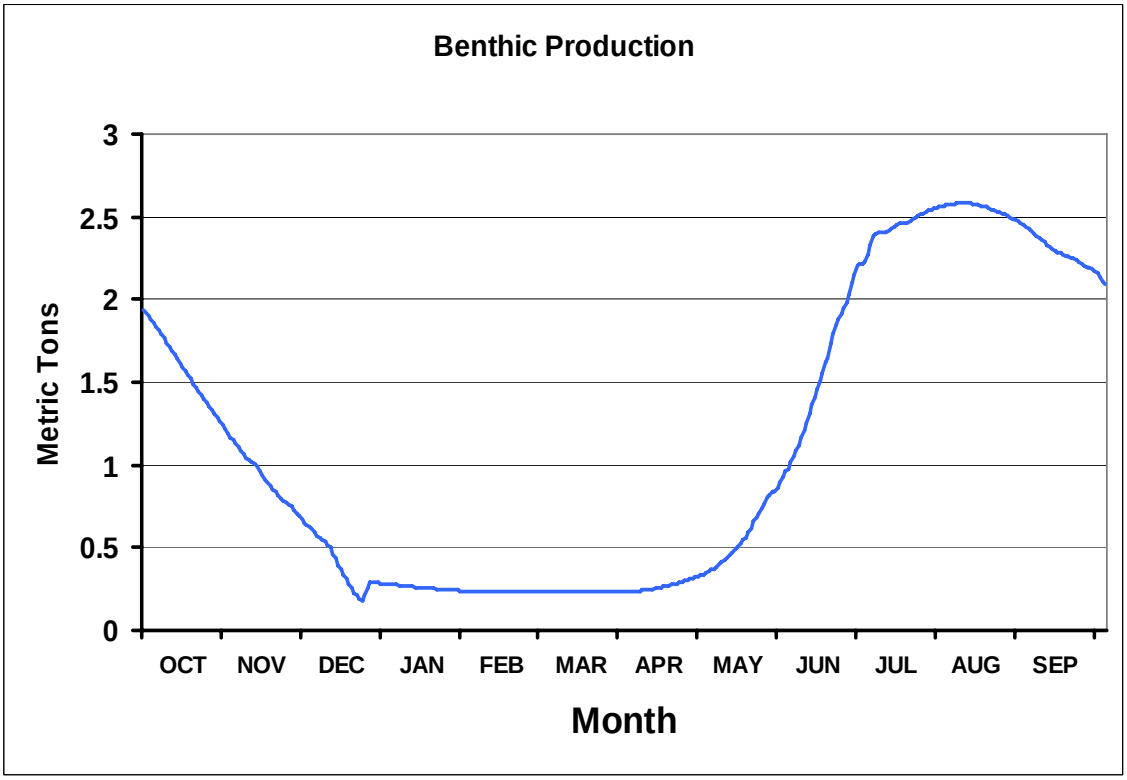
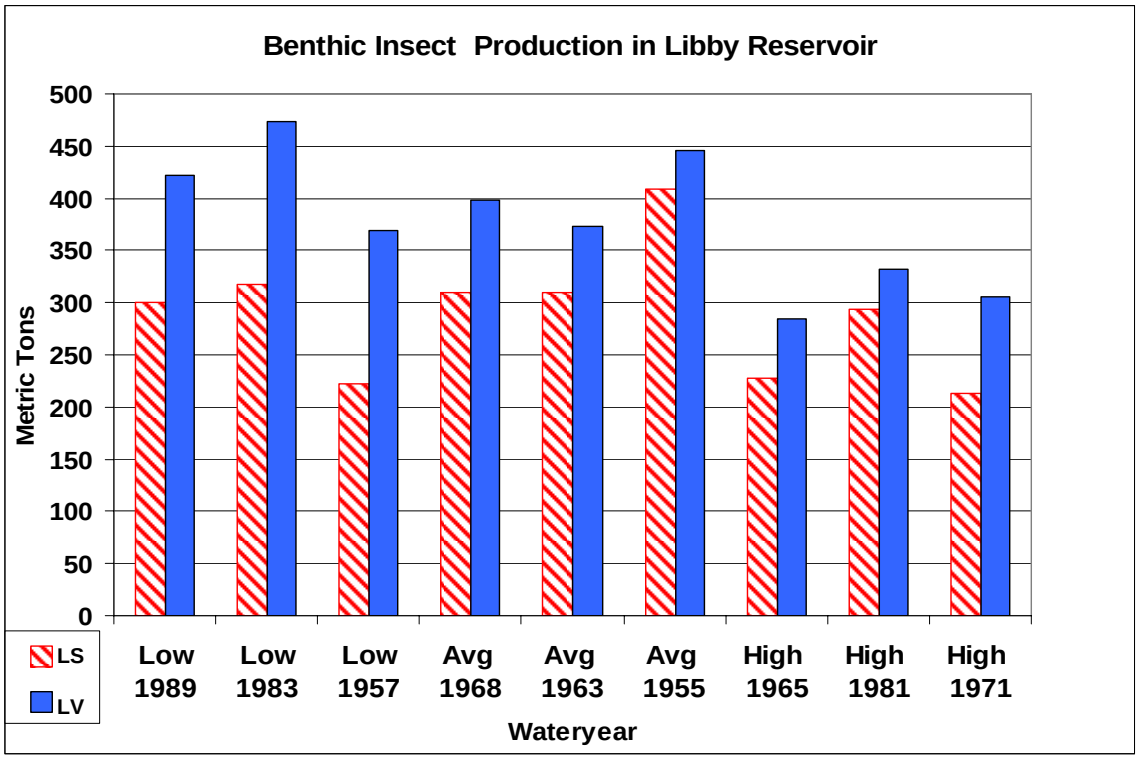


Figure 15. Daily simulations of benthic dipteran production were calibrated using dredge samples of larval distribution at depth and emergence rates from surface trapping at varying distances from shore. Results were controlled mainly by the wetted substrate area in each reservoir depth zone. The vertical distribution of larvae was adjusted to the minimum pool during the previous water year. This example is 1955, Benchmark LS. The complete data are named biol9**-*.txt in folders containing output for each year (e.g. \1955\biol955-b.txt).



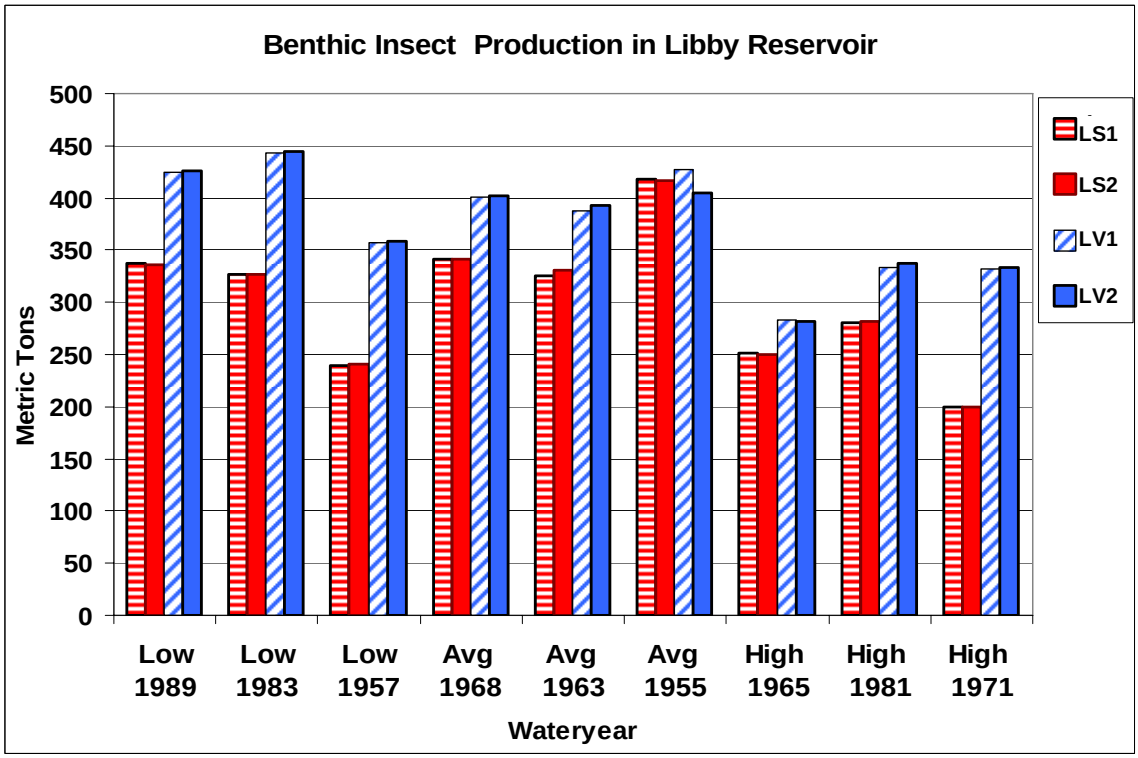


Figure 16. Estimates of benthic biomass production in Libby Reservoir were summarized for each alternative by year and category of water availability. Benchmarks LS and LV initiated at full pool on October 1, whereas all other alternatives began the water year at 20 feet below full pool.

Estimates of benthic insect production ranged from 199.7 to 473.7 metric tons across all water years and alternatives. Results indicate that benthic production is enhanced by the VARQ FC operation as compared to standard flood control. Since the vertical distribution of dipteran larvae is reset by the minimum pool during the previous water year, production values represented the build up from the existing state during each simulation. Operations that prevented substrates containing high larval densities from being desiccated and killed ranked high (LV, LV1, and LV2), whereas deep reservoir drawdowns resulted in lower production totals (LS, LS1, and LS2) (See "All Years Lsurf.xls"). "Fish flow" alternatives LV1 and LV2 ranked higher than LS1 and LS2 during all water year except 1955 when only LV1 ranked higher.

Terrestrial Insect Deposition

Of the four orders of terrestrial insects captured in near shore (< 100 m) and offshore surface tows, Hymenoptera were the most abundant by weight in surface tows and by numbers in trout stomach contents (Chisholm *et al.* 1989). During each simulation, the model calculated insect deposition as the percentage of the maximum possible deposition if the reservoir remained at full pool when each insect order is active (Figure 17). Results were also calculated for Hemiptera, Homoptera and Coleoptera (Figures 18-20).

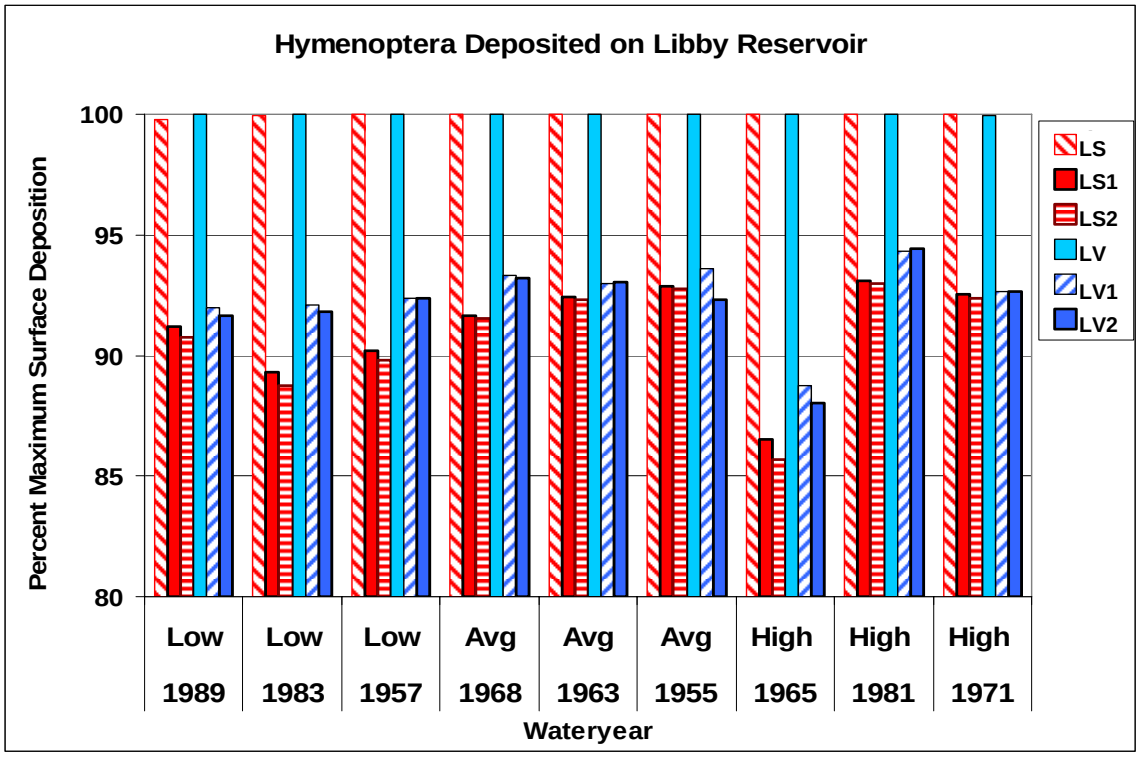


Figure 17. Deposition of Hymenoptera on the surface of Libby Reservoir. Alternatives were summarized by water year and each category of water availability. Benchmarks LS and LV remain at full pool during the entire period that Hymenoptera are active, so nearly 100 percent of the maximum were deposited on the surface. Alternatives that draft Libby Reservoir 20 feet to provide summer flow augmentation trap fewer insects, and consequently less food is available for insectivorous fish.

Hymenoptera exhibit good flight capability and are deposited in nearly equal proportions in nearshore and offshore (>100 m) areas. The amount deposited is proportional to surface area. Flood control benchmarks LS and LV remained at full pool while Hymenoptera are active, so insects are deposited and trapped by the large surface area. Alternatives that drafted the reservoir during summer to augment flows for fish in the Columbia River had a smaller surface area, thus trapped fewer Hymenoptera.

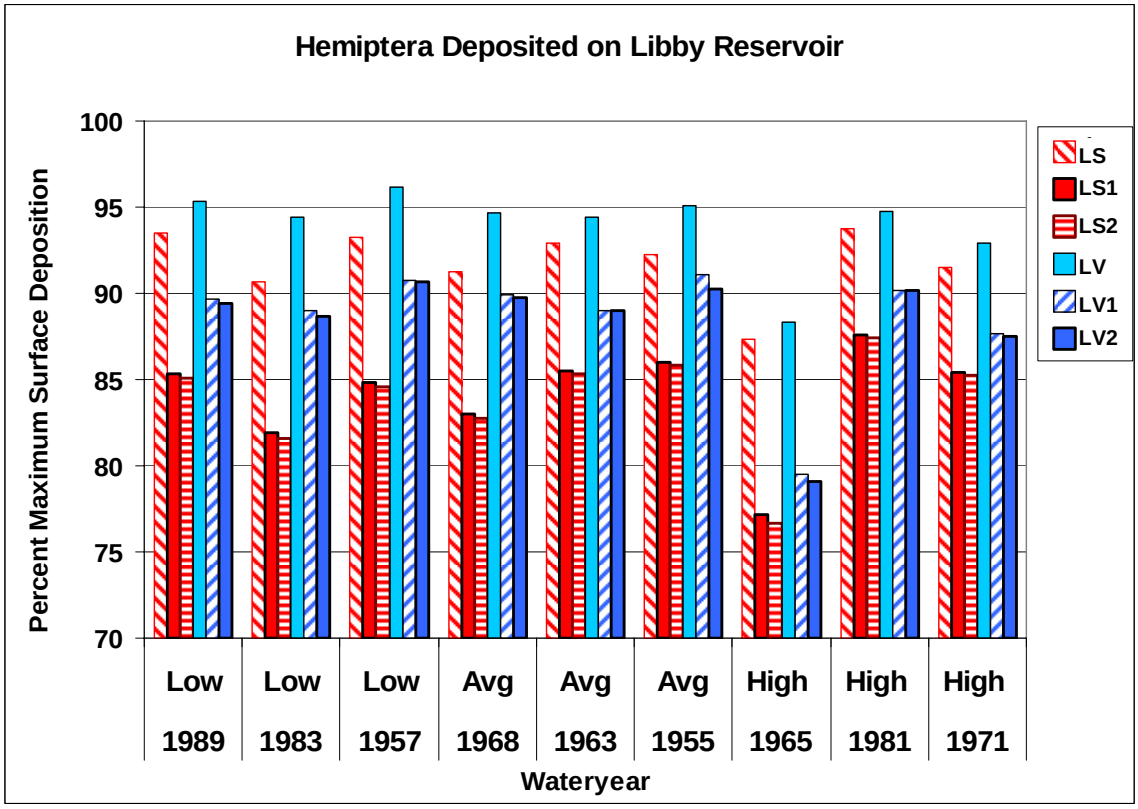


Figure 18. Hemiptera are deposited on the surface of Libby Reservoir in proportion to surface area. Benchmarks LS and LV remain near full pool during a portion of Hemipteran activity, so trap a larger percentage of available insects. Conversely, all alternatives provide water for fish flow augmentation and reservoir surface shrinks during periods of insect activity.

The VARQ FC alternatives trap more Hemiptera than their respective Standard FC counterparts. Hemipterans are deposited in significantly greater numbers within 100 m of shore. As a result, reservoir operations that caused the water to recede from shoreline vegetation during period of Hemipteran activity ranked lowest. Benchmarks LS and LV remained near full pool during the period of Hemipteran activity thus ranked highest. Of the alternatives that provided fish flows, LV1 trapped slightly more insects than LV2 during eight of the nine water years. The difference was likely caused by slightly lower reservoir elevations during late summer and fall under LV2. The Standard FC alternatives drafted Libby Reservoir deeper during spring, which delayed the refill process. Also, the reservoir remained near full pool for a shorter duration. Consequently, the reservoir surface receded from the shoreline and fewer insects were captured. Alternative LS1 trapped slightly more insects than LS2 during all water years. This is logical because LS2 released an additional 10 kcfs, reducing the reservoir surface area. Volumetrically, this effect increased as the reservoir volume decreased.

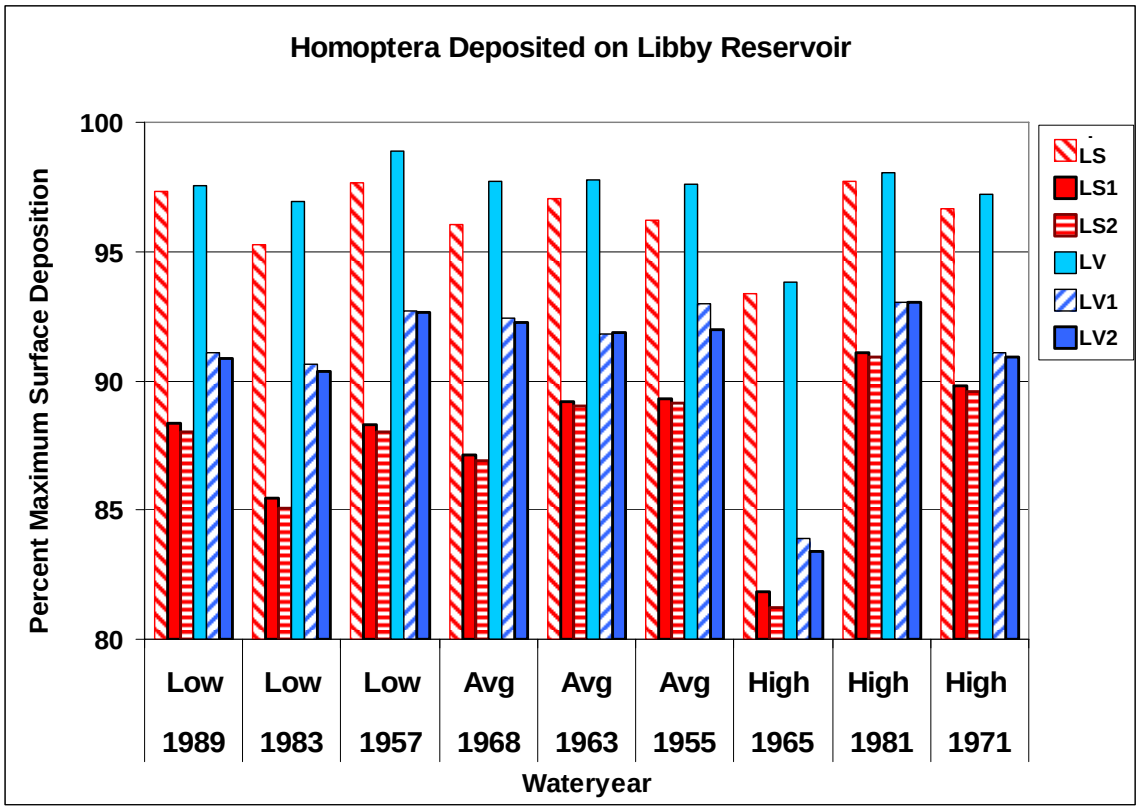


Figure 19. Homoptera deposited on the surface of Libby Reservoir summarized for each alternative and water year. Surface elevations in benchmarks LS and LV begin at full pool each year. Other alternatives begin 20 feet below full pool.

Homoptera were deposited in nearly the same amounts in nearshore and offshore areas; deposition is proportional to reservoir surface area. Benchmarks LS and LV began at full pool each water year and remained near full pool during the period of peak Homopteran activity. As a result, benchmark LV ranked the highest followed by benchmark LS, which produced a higher score than the "fish flow" alternatives that begin at 20 feet below full pool during all water years. Of the alternatives that provided flow augmentation for fish recovery, LV1 ranked the highest in seven of nine water years and LV2 ranked the highest in the remaining two years. VARQ FC alternatives remained closer to full pool and had shallower annual drafts than the Standard FC alternatives. Alternative LS1 trapped slightly more insects than LS2 during all water years.

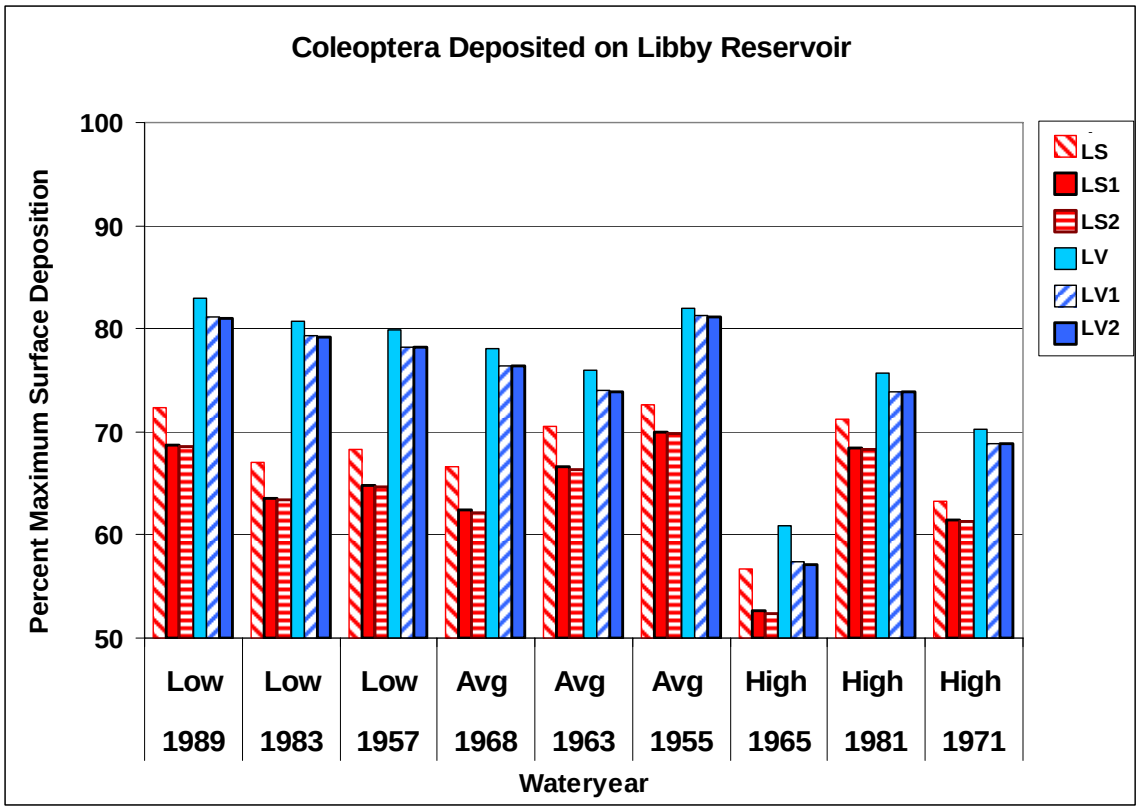


Figure 20. Coleoptera deposition on the surface of Libby Reservoir under each alternative by water year. Surface elevations in benchmarks LS and LV begin at full pool each year. Other alternatives begin 20 feet below full pool.

Coleoptera are deposited in significantly greater numbers within a 100 m of shore. As a result, dam operations that caused the water to recede from shoreline vegetation during period of Coleopteran activity ranked lowest. Benchmark LV remained closer to full pool and ranked the highest during all water years. Of the alternatives that provided fish flows, LV1 trapped slightly more insects than LV2 during six of the nine water years, and LV2 ranked higher the remaining three years. This difference was likely caused by slightly lower reservoir elevations during late summer and fall under LV2 during most average or lower water years. The Standard FC alternatives drew Libby Reservoir down to a greater depth during spring, which delayed the refill process. Also, the reservoir remained near full pool for a shorter duration. Consequently, the reservoir surface recedes from the shoreline and fewer insects are captured. Alternative LS1 trapped slightly more insects than LS2 during seven of nine water years. This is logical because LS2 released an additional 10 kcfs, reducing the reservoir surface area.

Kokanee Growth

Model calculations of kokanee growth are sensitive to food availability and the volume of water at optimal temperatures for fish growth. Kokanee diet is almost exclusively zooplankton (*Daphnia, Diaptomus* and *Bosmina*) and dipteran pupae are also consumed in trace quantities. Kokanee select the largest available zooplankton, then shift to smaller sizes as larger zooplankton are depleted (Chisholm *et al.* 1989). The model calculated

gross zooplankton production in metric tons and assumed an average proportion based on observed relative abundances of the zooplankton genera in Libby Reservoir.

Annual simulations assumed identical reservoir conditions for kokanee growth during age I and II. Kokanee population size and age structure were assumed to be constant so that alternatives could be compared without the confounding influence of density dependant growth. Growth trajectories for age I and II kokanee were calculated during each simulation, then summarized into annual growth in length (mm) and weight (g) (Figure 21; also see files named lmfg9**.txt. Files are identified by alternative after the hyphen in the file name (for example lmfg955-b.txt is benchmark LS ["b"] during 1955). Results compare each alternative/benchmark by water year and were summarized across categories of water availability (Figures 22 and 23).

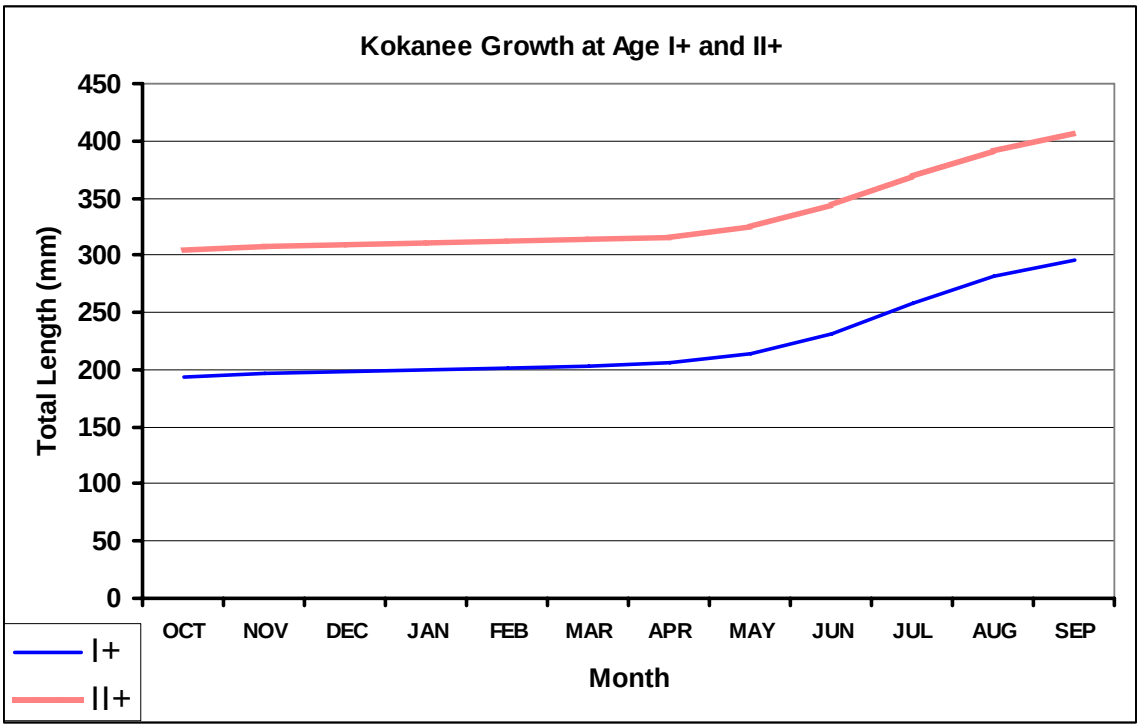
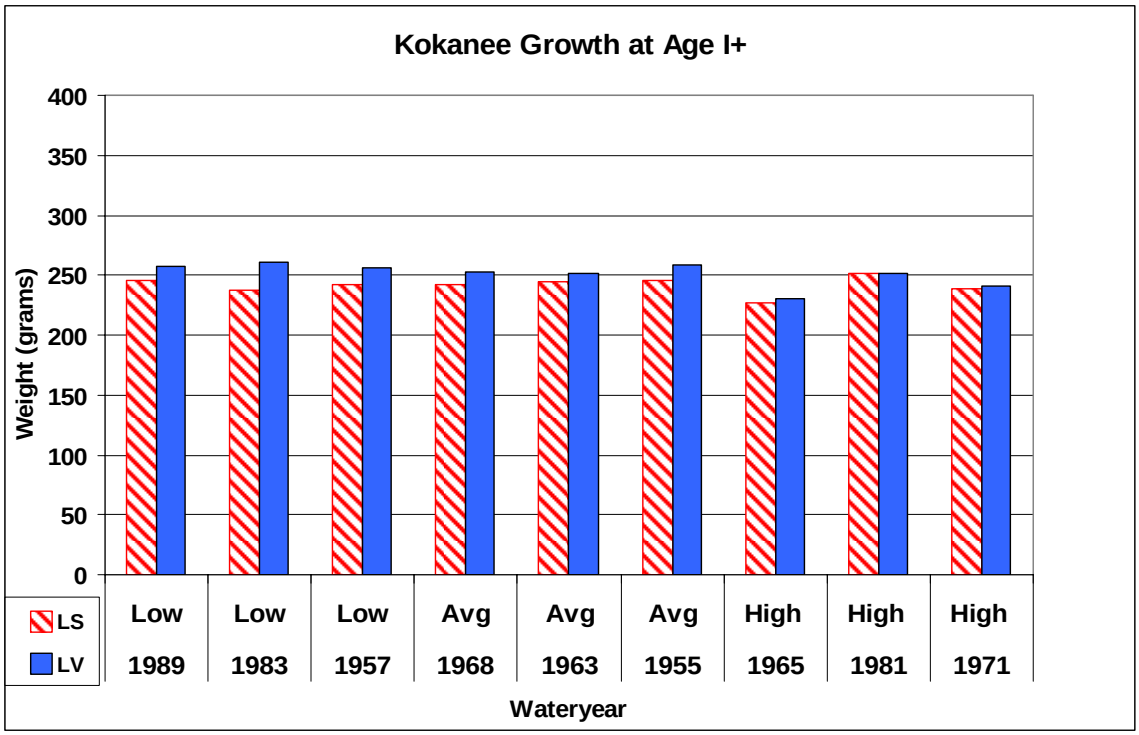


Figure 21. An example of the annual growth (total length) trajectory for age I+ and II+ kokanee. Monthly results for growth in total length (mm) and weight (g) are presented in tabular format in files named lmfg9**-*.txt for each year and alternative.



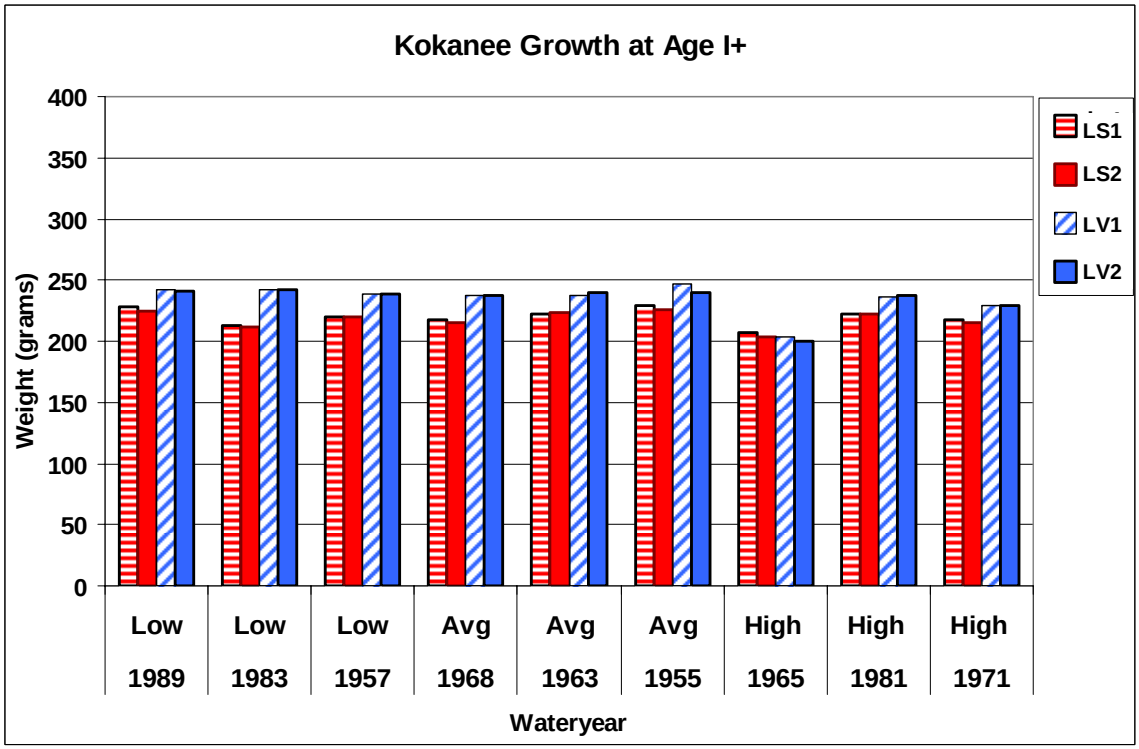
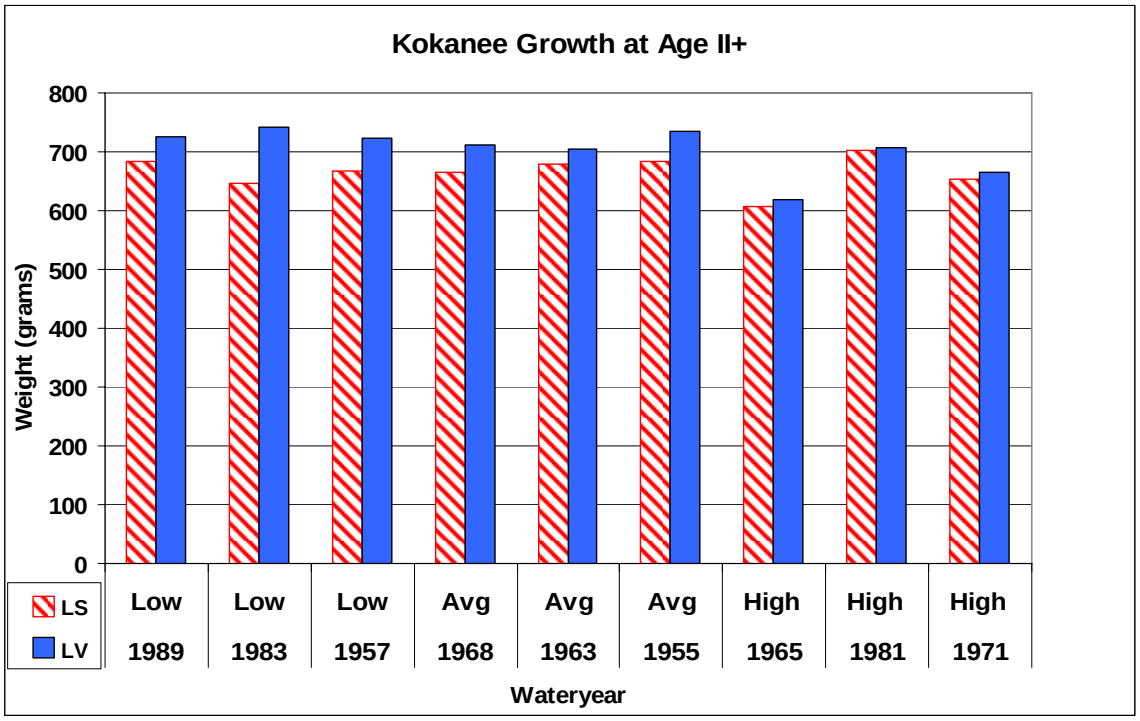


Figure 22. Comparison of kokanee growth in weight (g) at age I+ in Libby Reservoir under six alternative dam operation strategies. Bars are grouped by water year, and span categories of water availability from medium-low to medium-high. The kokanee growth model is sensitive only to gross changes in reservoir conditions. The VARQ FC alternatives ranked higher than their Standard FC counterparts during all years.



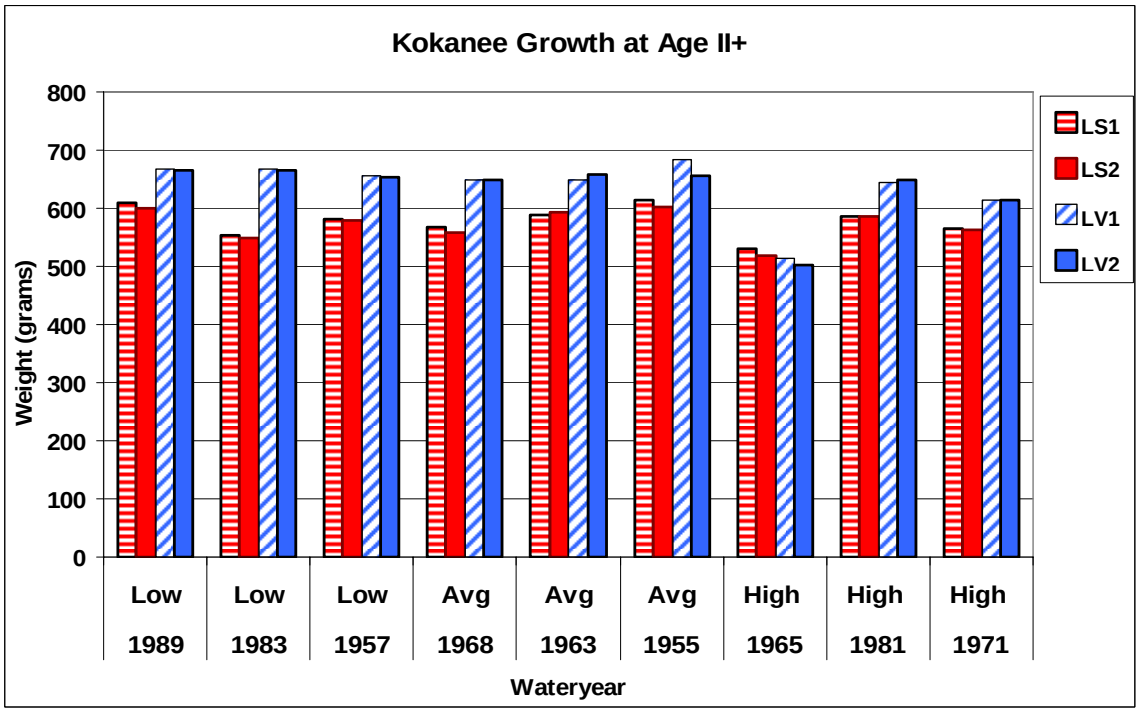


Figure 23. Comparison of age II+ kokanee growth in weight (g) at Libby Reservoir during all water years and categories of water availability. The model is sensitive only to gross changes in reservoir conditions. The VARQ FC operations ranked higher than their Standard FC counterparts during all years. Benchmarks LS and LV initiate at full pool elevation so were plotted separately.

The fish growth model assumes identical environmental conditions in the reservoir when calculating the growth of age I and II kokanee in total length (mm) and weight (g). Alternatives that provided a large surface area for zooplankton production and a large reservoir volume of optimal water temperatures for fish growth ranked highest. Benchmarks LS and LV began at full pool on October 1 each water year and maintained a relatively large surface area and volume during the productive warm months. Growth was greater under benchmark LV because reservoir drawdown was shallower than benchmark LS. The VARQ FC simulations produced greater kokanee growth than their respective Standard FC counterparts in eight of nine years.

Hungry Horse Reservoir

Primary production

Primary production (carbon fixation) by phytoplankton was controlled by reservoir surface area and volume and mean temperature within each depth stratum. The model calculated the longitudinal and vertical distribution of carbon fixation and related these values to volumetric production rates (mgC/m^3/d) for each operating alternative. Model output included daily schedules of primary production (Figure 24) and annual totals, summarized by year and overall by water year category (Figure 25).

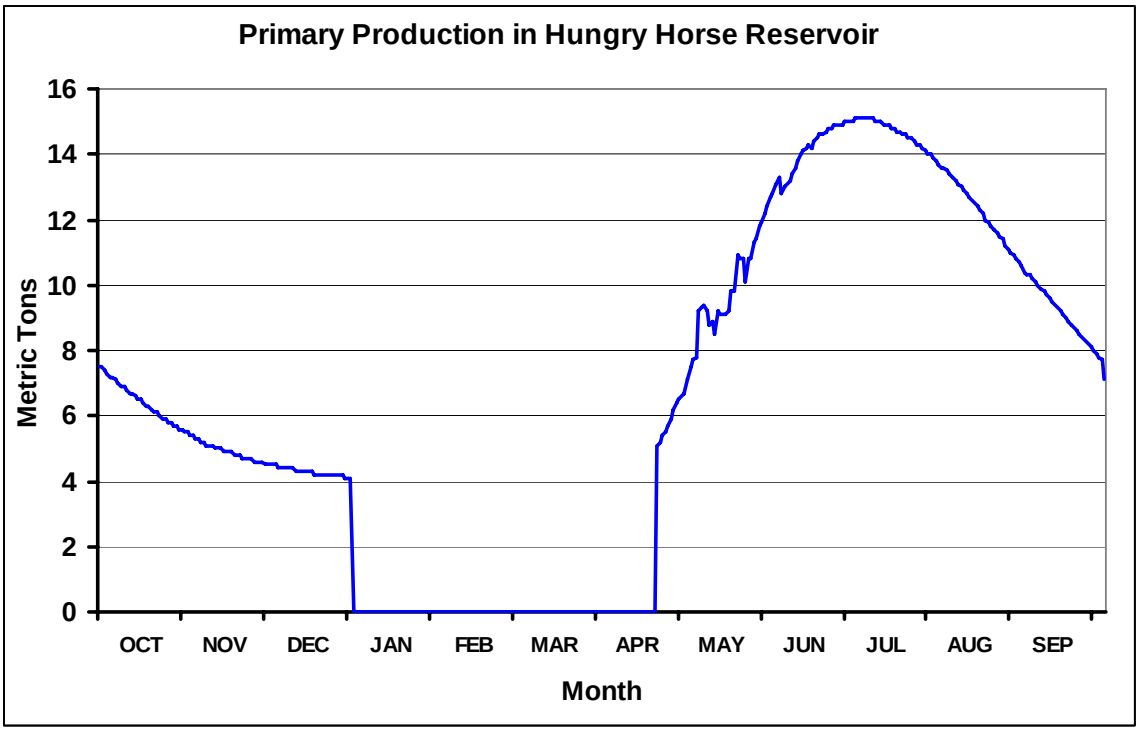


Figure 24. The annual schedule of daily primary production (metric tons of carbon fixed) in Hungry Horse Reservoir shows the biological importance of the summer growing season. Productivity drops to zero when solar input declines during periods of ice formation and snow cover. Data for each water year and operating alternative are named MPrimProd9**-*.txt. This example is MPrimProd832-v.txt representing HV (VARQ FC) in 1932.

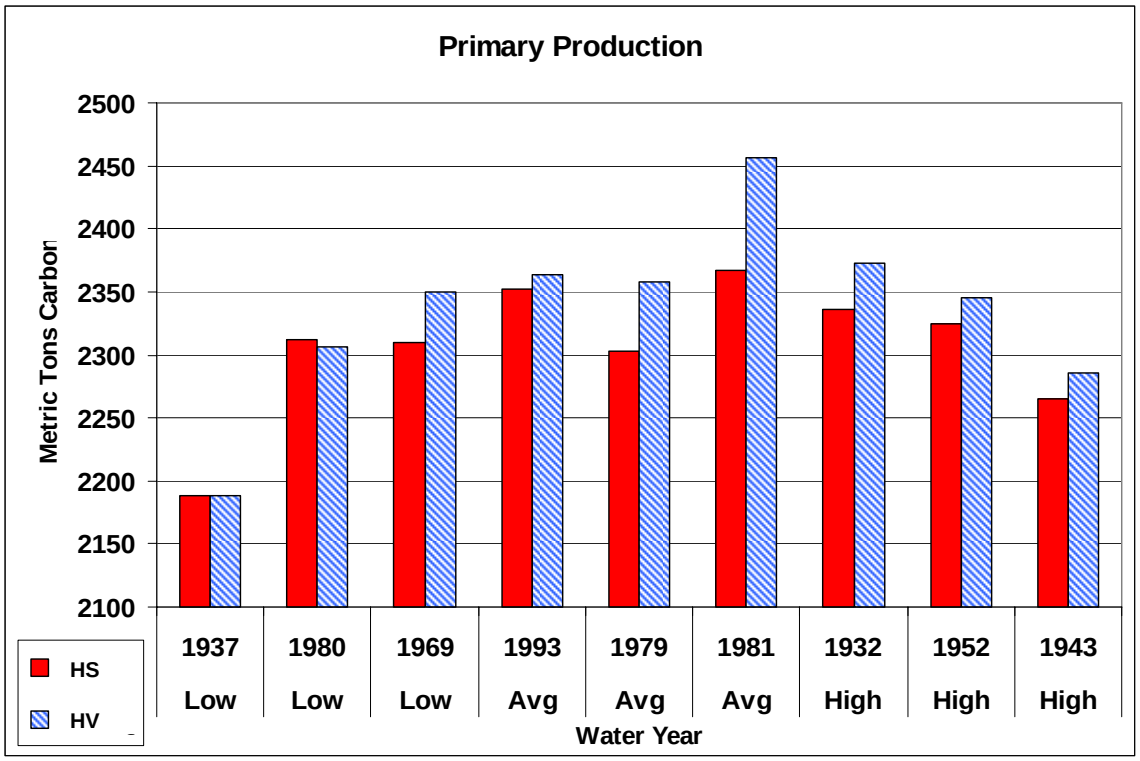


Figure 25. Total annual primary production in Hungry Horse Reservoir under the HS (Standard FC with fish flows) and HV (VARQ FC with fish flows). The X-axis is arranged by water year from medium-low (left) to medium-high (right) water years.

It is important to note that there was no difference between the alternative operating strategies for the year 1937. Primary production under HV was slightly greater than HS during all other simulated water years. Reservoir drawdown was typically greater under HS (see comparisons of surface elevations resulting from the HS and HV alternatives in \H-Input\HH Surface Elev.xls). Differences between the alternatives were offset somewhat because much of the period of low reservoir elevation correlates with the period of ice formation, when primary productivity approaches zero.

Loss of phytoplankton through the dam turbines was controlled mainly by the discharge volume and the density of phytoplankton at the depth of water withdrawal. The Hungry Horse Reservoir selective withdrawal model was configured in both alternatives to withdraw water from the appropriate depth to achieve the target temperatures in the South Fork and mainstem Flathead River. This caused the depth of withdrawal, as measured from the reservoir surface, to remain relatively constant between alternatives, thus limiting the difference between the alternatives. Differences in the annual schedule of primary productivity in Hungry Horse Reservoir resulted from changes in reservoir volume and surface area. Differences in the seasonality and volumes of dam discharge influenced washout losses (Figure 26). Results would differ if the selective withdrawal structure was operated differently.

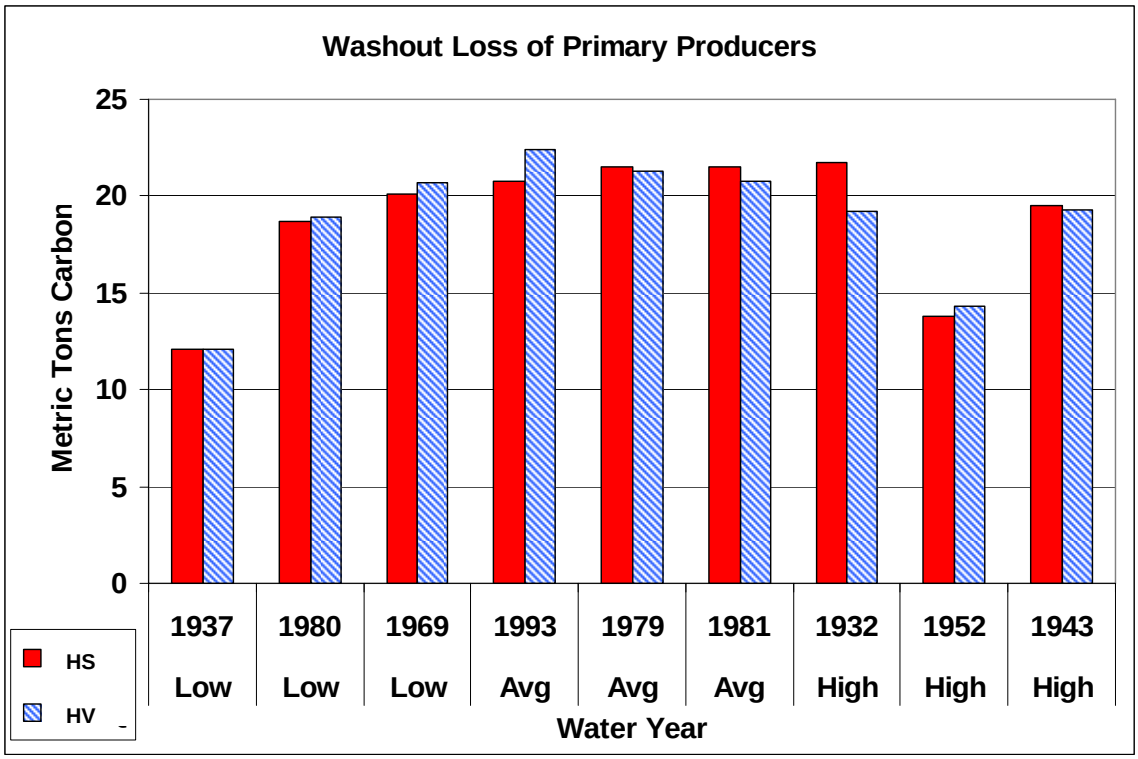


Figure 26. Washout losses through the turbines of Hungry Horse Dam are similar under the HS and HV alternatives. The X-axis is arranged by water year from medium-low water availability through medium-high water years.

Washout of primary producers through the turbines of Hungry Horse Dam was strongly influenced by seasonal discharges because selective withdrawal was standardized in all simulations. Losses were calculated in proportion to seasonal schedule of reservoir productivity and vertical distribution in the forebay. When more primary production occurred in the reservoir, more phytoplankton were lost through turbine penstocks. Model calculations of downstream losses of phytoplankton revealed little difference between HS and HV during these nine water years. However, there appears to be a trend of greater losses under HV during less than average water years and, except for 1952, greater losses during high water years under HS. More annual simulations are required to determine if this trend is supported by additional data.

The depth of water withdrawal remains an important factor that controls washout losses. Although selective withdrawal may provide a tool to control washout losses, such control may not be warranted because washout losses amounted to less than one percent of the overall production in the reservoir. Phytoplankton entrained through Hungry Horse dam provides a trophic gain to the Flathead River.

Zooplankton Production

The annual schedule of zooplankton production was calculated as a function of phytoplankton production to mimic published energy transfer efficiencies as zooplankton graze on phytoplankton (Figure 27).

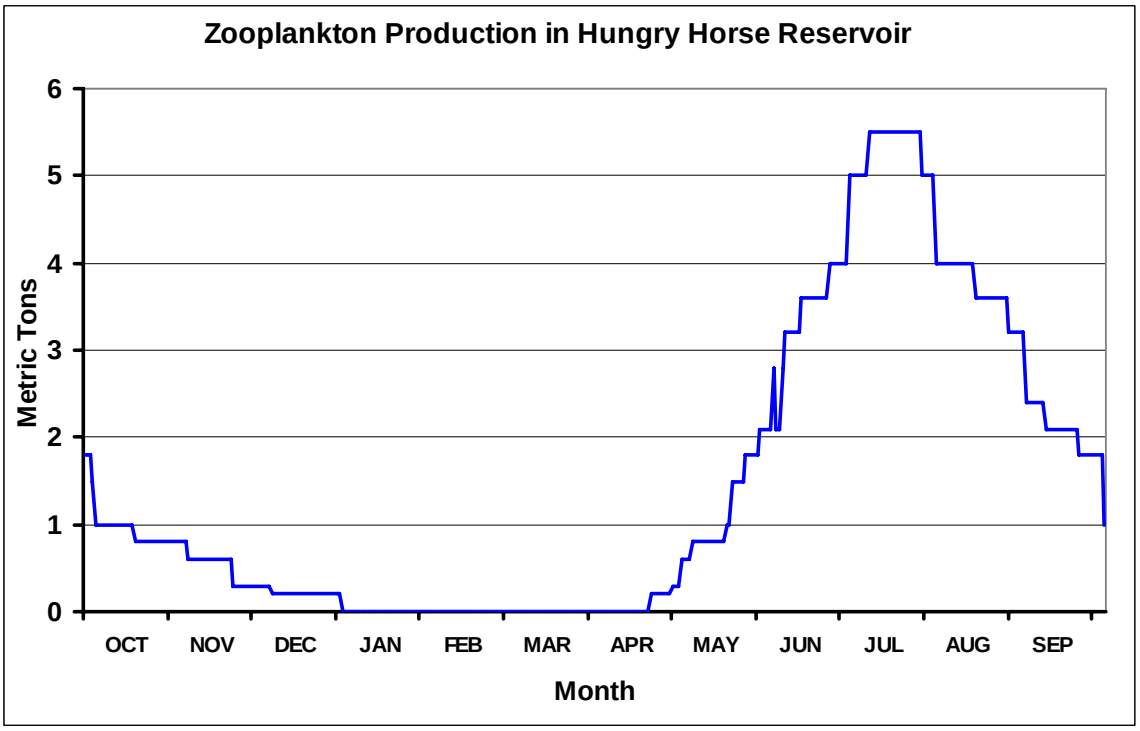


Figure 27. An example of an annual simulation of daily zooplankton production in Hungry Horse Reservoir. Data files for each simulation are named Mzooplankton9**.txt, where "**" represents the year and the final letter (b for HS, or v for HV) signifies the alternative. This is Mzooplankton932v.txt from the Hungry Horse Reservoir\1932\ folder. Data represent HV during 1932. Files contain two columns A and B. Metric tons = A*(10*B).

After hatching, zooplankton survive for an indefinite period until they are eaten by predators, die of natural causes and sink, or washed through Hungry Horse Dam. Enough individuals survive that zooplankton is the primary winter food for fish species that do not prey on fish (including westslope cutthroat trout and juvenile bull trout). Model estimates of zooplankton production under the two alternative operating strategies reflected changes in surface area and the volume at depth during each day of the simulated water year. Results were summarized for each water year and category of water availability (Figure 28).

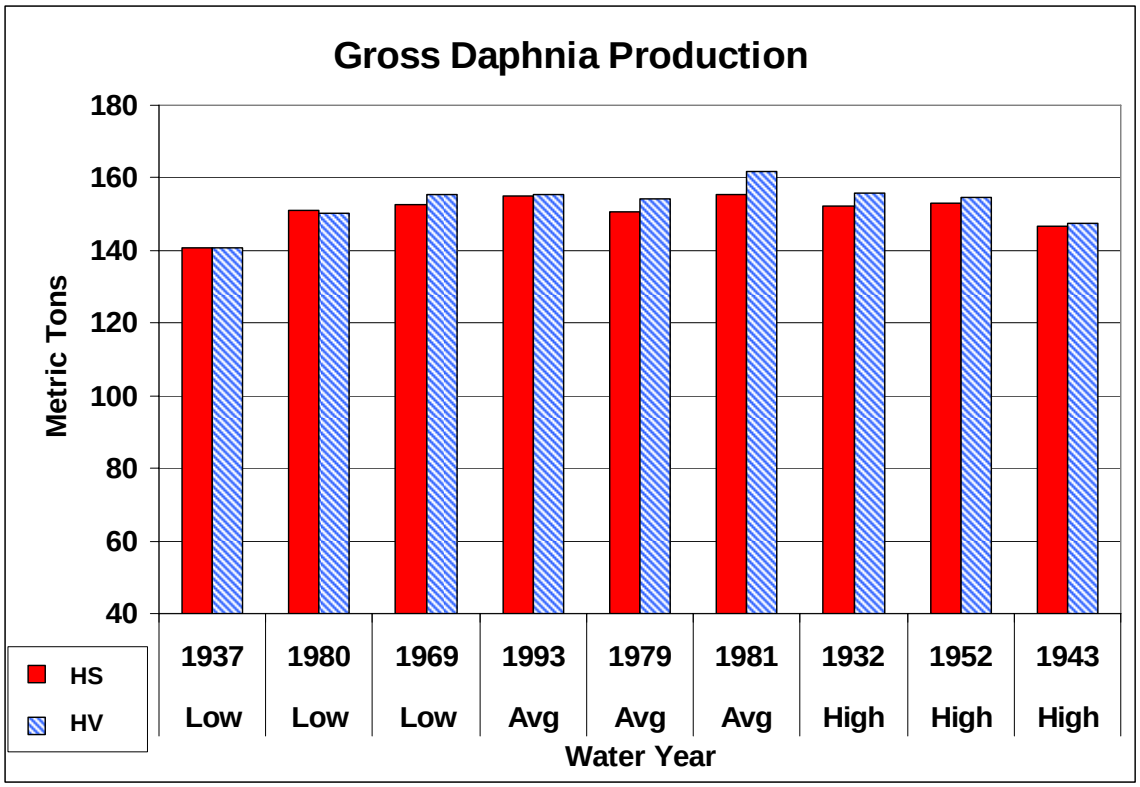


Figure 28. Calculations of Daphnia production (metric tons) in Hungry Horse Reservoir under each alternative were plotted for comparison. See complete files of reservoir surface elevations, named \H-input data\HH Surface Elev.xls.

Model results indicate that HV produced slightly more Daphnia during seven of the nine water years. Operations that maximized reservoir volume and surface area during the biologically productive summer months produced more phytoplankton, and therefore more food for zooplankton. Zooplankton production is enhanced by large volumes of optimal water temperatures during the warm months.

Zooplankton densities in Hungry Horse Reservoir were low compared to Libby Reservoir, as indicated by measuring density in numbers per m^3 in Hungry Horse, versus numbers per L in Libby Reservoir. These low densities warrant controlling the amount of zooplankton lost through the selective withdrawal device (Figure 29). Zooplankton washout losses can be managed to a limited extent using the selective withdrawal system at Hungry Horse Dam. Slide gates located 50 feet below the top of the control gate can be gradually opened during the summer to intake cool water from beneath the strata containing high zooplankton densities. In this way, warm and cool water can be mixed to achieve an intermediate tailwater temperature while minimizing zooplankton entrainment (Cavigli *et al.* 1998). Stratifying the withdrawal depth allows dam operators to reduce zooplankton entrainment, while providing optimal water temperatures downstream in the South Fork Flathead River. Such control is warranted because zooplankton production is very low in Hungry Horse Reservoir due to oligotrophic nutrient conditions. Once produced, zooplankton remain available as prey to fish until they sink or wash through the dam. Although washout losses increase with higher dam discharges and represent a

substantial fraction of the overall reservoir productivity, these results do not incorporate stratified withdrawal, so actual losses may be less than predicted. Zooplankton swept through Hungry Horse Dam provides a trophic gain to the Flathead River.

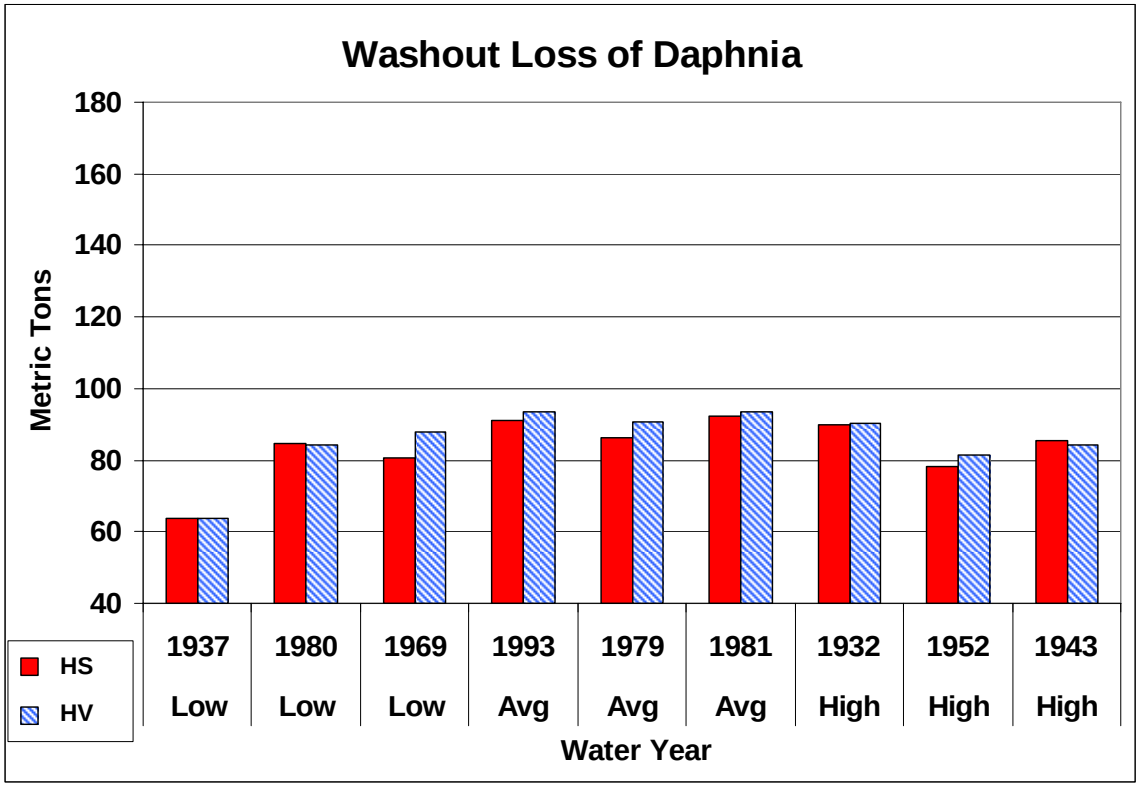


Figure 29. Washout of Daphnia through the turbines of Hungry Horse Dam was calculated for the two alternative operation strategies. Daphnia are the most important zooplankton genus in fish stomach contents. Results are proportional to total zooplankton washout.

Results indicate that zooplankton loss through Hungry Horse Dam was slightly higher under HV during six of the nine water years simulated. Since the selective withdrawal model was automated, the depth of water withdrawal differed little between the alternatives in any given year. Zooplankton washout was, therefore, most sensitive to discharge volume, especially during summer. Results are proportional to calculated production values in the reservoir pool; when more zooplankton were produced, more were washed through the dam. It is important to note that these results are sensitive to the specified withdrawal depths and that results would change if selective withdrawal was operated differently.

Benthic Insect Production

Impoundment of the South Fork Flathead River by Hungry Horse Dam and reservoir operations have greatly simplified the diversity of aquatic insects in the reservoir by reducing species adapted to flowing water (e.g. stoneflies, mayflies and caddis flies). Aquatic Diptera dominate the existing reservoir insect community. Larger, long-lived species dominate the permanently wetted zone, whereas the varial zone contains mainly small, multivoltic species. Larvae recolonize previously dewatered substrates as the

reservoir fills, and shoreline areas are dominated by multivoltic dipterans that produce cohorts throughout the warm summer months (May *et al.* 1988). Annual production schedules are controlled by the substrate area of each depth zone and the duration each zone remains wet and productive. The model calculates daily estimates of benthic insect production during the water year (Figure 30).

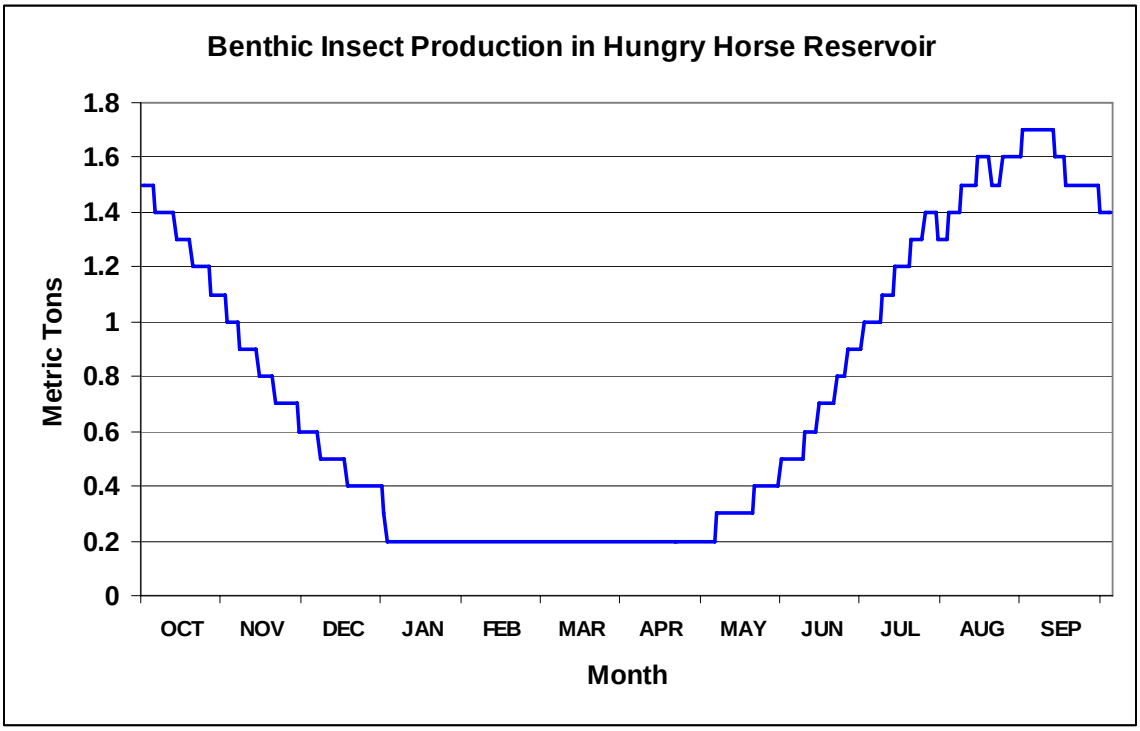


Figure 30. Daily simulations of benthic dipteran production were calibrated using dredge samples of larval distribution at depth, and emergence rates from surface trapping at varying distances from shore. Results were controlled mainly by the wetted substrate area in each reservoir depth zone. Vertical distributions of larvae were adjusted to the minimum pool during the previous water year. This example is HV in 1932. ASCII text files containing these data were named Mbenthos9**-*.txt in folders containing output for each year (e.g. \1932\ Mbenthos932-v.txt).

Benthic insects are the primary food item for westslope cutthroat trout during spring. Factors controlling benthic insect production include maximum reservoir drawdown, duration at maximum pool, and the amount of time substrate remains wet and productive. The minimum pool elevation during the previous year "resets" the vertical distribution of larval densities as reservoir drawdown desiccates substrate containing dipteran larvae. Larger, long-lived forms are dominant in the permanently wetted zones, whereas smaller, multivoltic species are more common in the zone of water fluctuation. Larvae swarm during spring as the reservoir refills. Larvae distribute randomly and their survival depends on finding suitable habitat to continue their life cycle. Larvae then pupate and ascend to the surface buoyed by air bubbles in their case. Fish prey predominantly on pupae, emerging adults and adults; however, few larvae were found in fish stomach contents in Hungry Horse Reservoir (May *et al.* 1988). Benthic insect production was, therefore, measured in units of dipteran emergence. Annual production totals were

compared between the two alternatives during each simulated water year, and then summarized for each category of water availability (Figure 31).

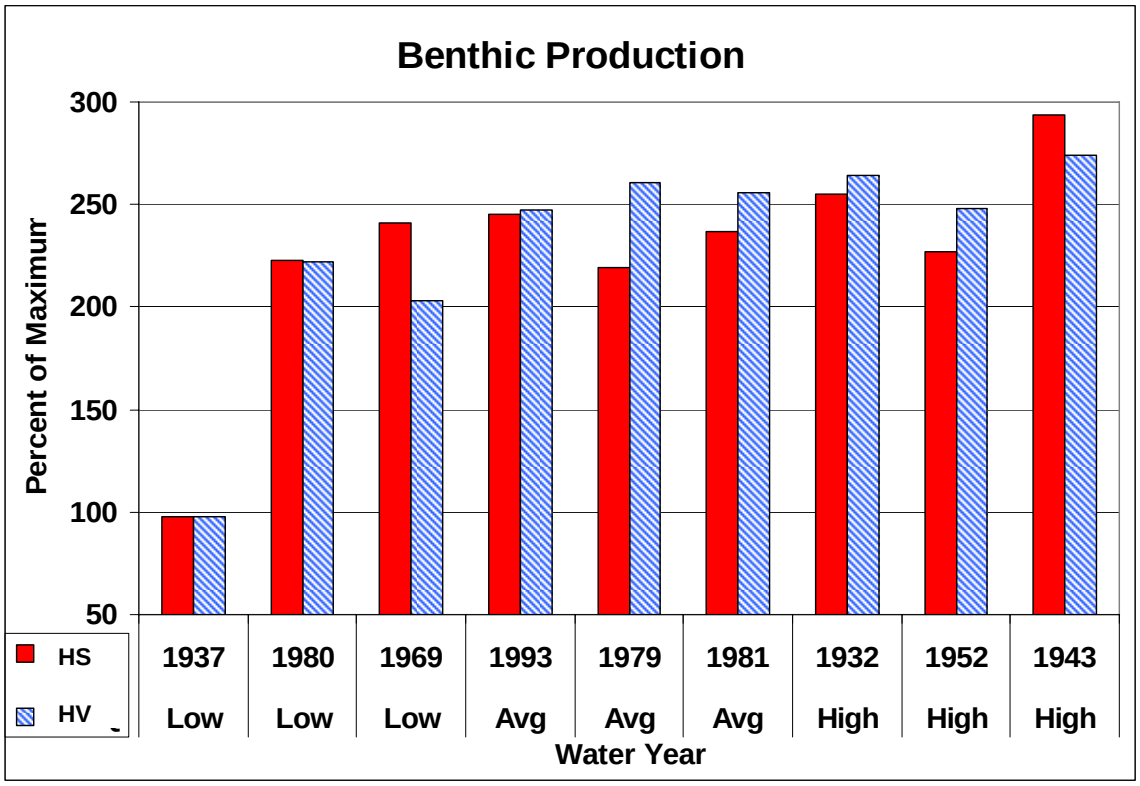
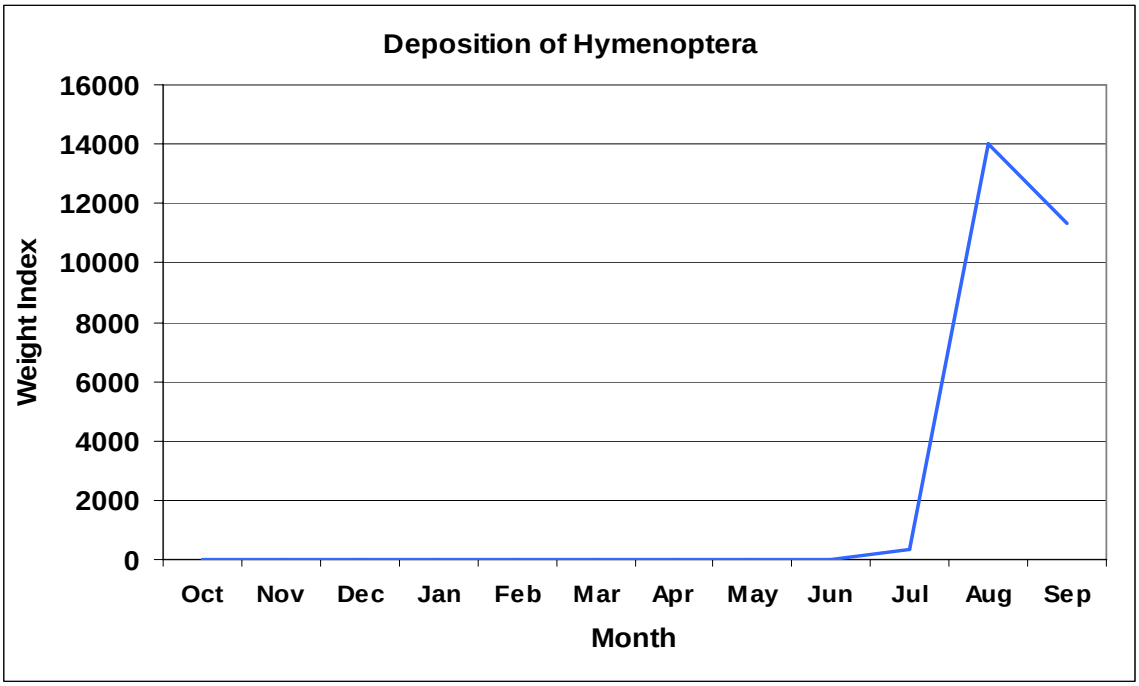


Figure 31. Estimates of benthic biomass production in Hungry Horse Reservoir was summarized for each alternative by year and category of water availability.

HV produced more benthos than HS during seven of the nine water years simulated. During 1969, HS maintained higher reservoir elevations during the fall while benthic production remained high. Although HS reached a deeper minimum pool elevation, benthic production was at the seasonal low during that period. During 1943, reservoir elevations under HS were slightly higher than HV during the reservoir refill period (see plots of Hungry Horse Reservoir elevation schedules in \H-input\ HH Surface Elev.xls).

Terrestrial Insect Deposition

Of the four orders of terrestrial insects captured in near shore (< 100 m) and offshore surface tows, Hymenoptera were the most abundant by weight in surface tows and by numbers in fish stomach contents in Hungry Horse Reservoir (May *et al.* 1988). The seasonality was significantly different among the insect orders (Marotz *et al.* 1996) and modeled accordingly (Figure 32). During each simulation, the model calculates insect deposition as a percentage of the maximum possible if the reservoir were at full pool during the period insects are active. Results were calculated for Hymenoptera, Hemiptera, Homoptera and Coleoptera (see Biological Summary.xls for Hungry Horse Reservoir). Of the four insect orders, only the deposition of Coleoptera differed between the two alternatives (Figure 33).



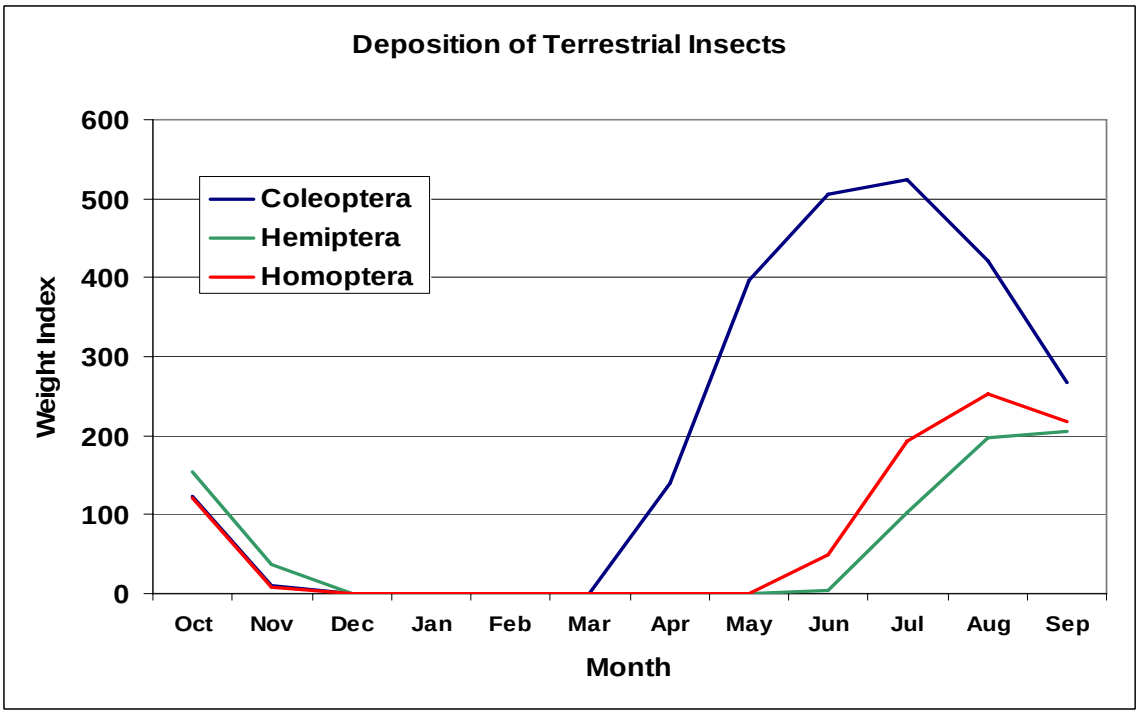


Figure 32. Seasonal periods of insect abundance differ significantly between the four main orders of insects deposited on the surface of Hungry Horse Reservoir. Hymenoptera deposition is an order of magnitude greater than the other insect orders, so was plotted separately.

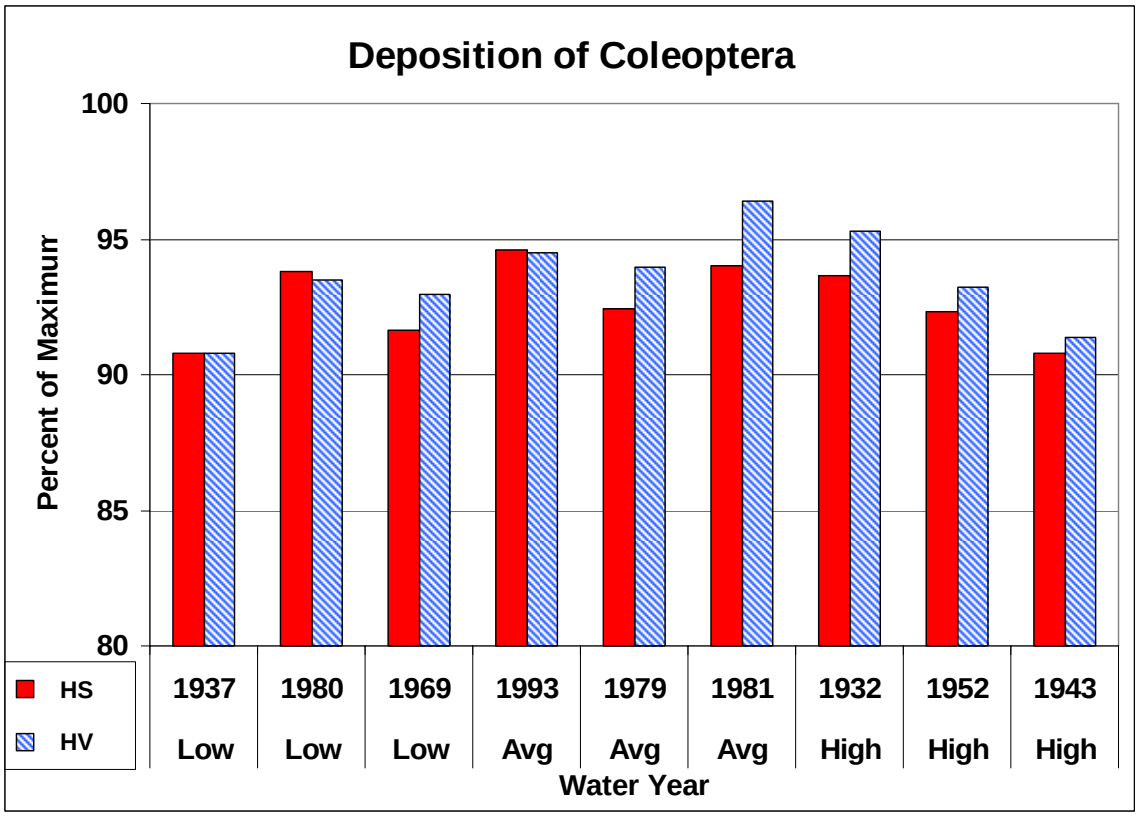


Figure 33. Deposition of Coleoptera on to the surface of Hungry Horse is charted to allow comparison of the two alternative dam operations. The x-axis arranges the water years from medium-low through medium-high categories of water availability.

As weather warms in spring and snowmelt begins to refill Hungry Horse Reservoir, westslope cutthroat trout shift their diet from benthic Diptera to terrestrial insects (May *et al.* 1988). Terrestrial insects deposited and trapped on the surface of Hungry Horse Reservoir are the primary food source for insectivorous fish between late-June and mid-November, or when freezing weather ends most terrestrial insect activity. Afterwards, zooplankton become the primary winter food of reservoir fish species that do not eat other fish.

Model results revealed no differences in the amount of Hymenoptera, Hemiptera and Homoptera deposited on the reservoir among the alternatives. However, Coleoptera deposition differed between HV and HS. Coleoptera are deposited in significantly greater numbers within 100 m of shore (May *et al.* 1988). Therefore, when surface elevation recedes from shoreline vegetation, fewer beetles are trapped on the surface and fish food availability is reduced. HV trapped as many or more beetles than HS during seven of the nine simulated water years. However, during 1980 and 1993, HS filled slightly faster and the larger surface area trapped more insects. HS resulted in greater reservoir drawdown during all years except 1937 when the alternatives did not differ. Deep drawdown slows the reservoir refill process, so the surface area remains smaller and further from shoreline vegetation and fewer beetles are trapped on the surface.

Westslope Cutthroat Trout Growth

Trout growth is controlled primarily by water temperature and food availability. Little growth occurs when water temperature is less than 6° C or greater than 18° C. For example, growth efficiency in sockeye salmon (*Oncorhynchus nerka*) peaks between 9 and 14° C, depending on food availability (Brett *et al.* 1969). Growth efficiency was optimal at lower water temperatures when food was limiting. Conversely, trout can sustain more efficient growth at higher temperatures when food is unlimited. These relationships were used to calculate growth in westslope cutthroat trout.

Westslope cutthroat trout growth was calculated using multivariate analyses of measured growth rates. Equations included water temperature and seasonal food habits. Annual growth calculations at age III, IV and V assumed that reservoir conditions remained the same during each year. Differences between the alternative operating strategies influenced the reservoir thermal structure and the production of food categories used by the growth equations. Results reflected differences in the reservoir thermal structure, and production values for zooplankton, benthic insects and Coleoptera. Growth trajectories were calculated over each water year (Figure 34, also see files for each year named Mhhtrout9***.txt, where "***" is the two digit year and the alternative code b = HS, v = HV).

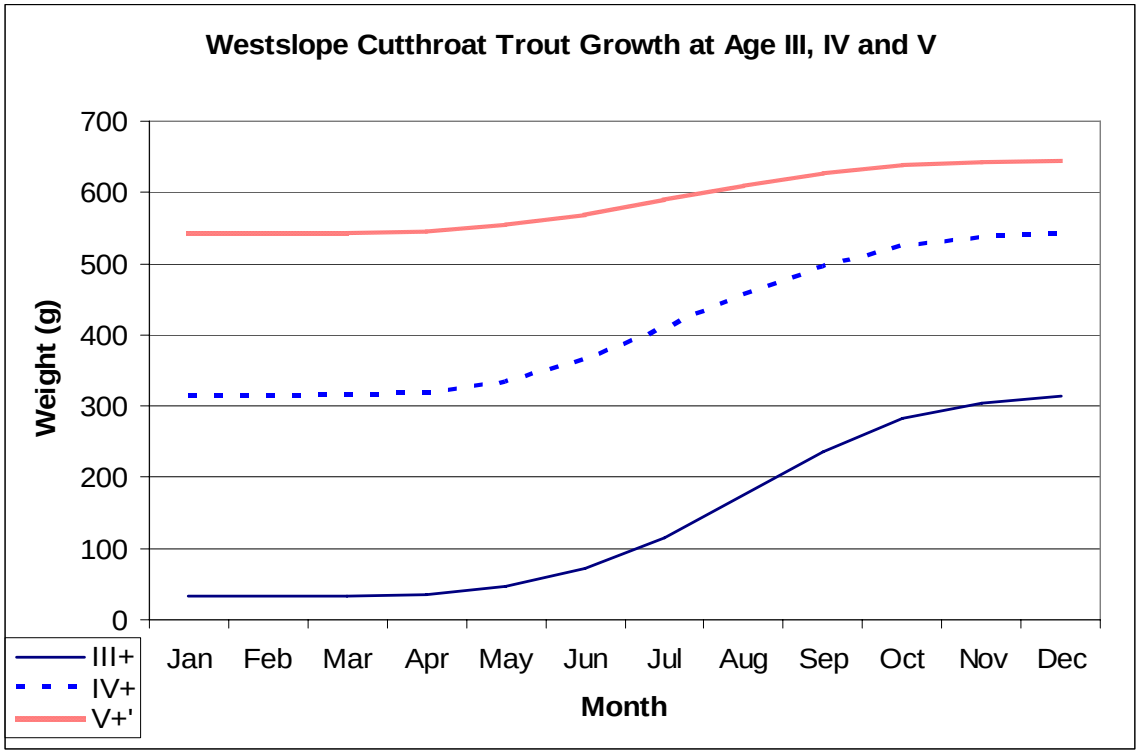


Figure 34. Annual growth trajectories for age III, IV and V westslope cutthroat trout in Hungry Horse Reservoir. This example is for the Standard alternative in 1969 (Mhhtrout969b.txt).

The total annual growth of westslope cutthroat trout was compared between the alternative operation strategies (Figure 35).

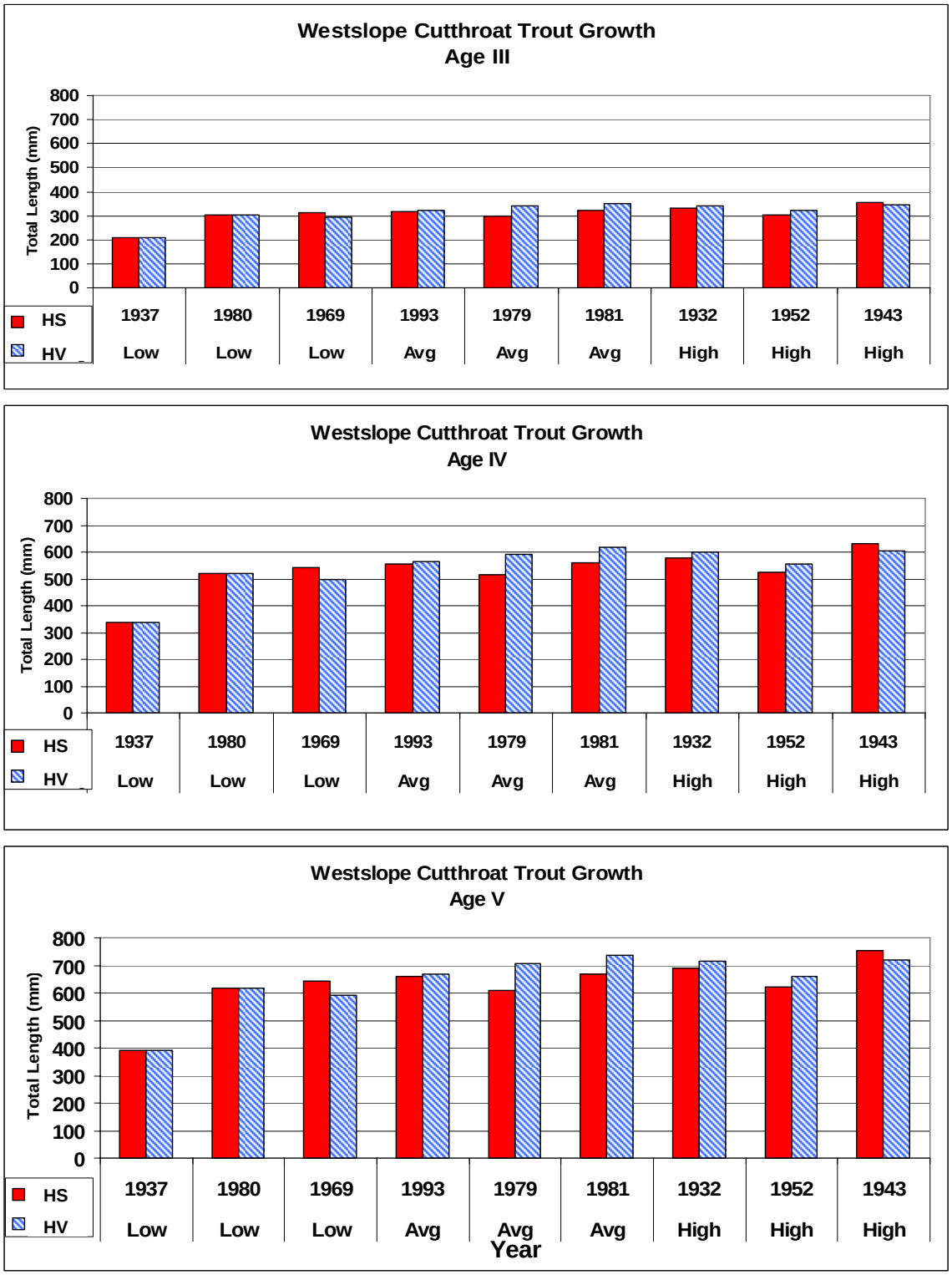


Figure 35. Westslope cutthroat trout growth (weight in grams) at age III, IV and V in Hungry Horse Reservoir. Bars in each water year compare growth under two alternative dam operation strategies.

Model results revealed slightly higher growth for all three age classes of westslope cutthroat trout under HV in five of the nine water years simulated. During the three average and the lower two high water years, HV produced greater food production in the lower trophic levels due to the large volume of reservoir at optimal water temperatures. Food availability was a primary factor that influenced trout growth. Although the availability of terrestrial insects is an important factor, model results predicted no difference in the deposition of three of the four insect orders, including Hymenoptera that is a primary food item in the diet of westslope cutthroat trout.

Westslope cutthroat trout growth was higher under HS for the two years simulated (1969 and 1943). During 1969, primary productivity and zooplankton production were slightly higher under HV, and washout losses were less compared to HS. Although HS reached a deeper minimum pool elevation, reservoir elevations remained higher during the previous fall when trout growth potential remained high (see plots of Hungry Horse Reservoir elevation in \H-Input\ All Years Hsurf.xls). During 1943, reservoir elevations under HS were slightly higher than HV during the reservoir refill period. Primary production was slightly greater under HS, whereas zooplankton production was slightly greater under HV. Washout losses of Daphnia were slightly higher under HS. The availability of terrestrial beetles was lower under HS, but due to the relatively low biomass associated with Coleoptera, growth calculations for the alternatives were not offset by this factor. Most importantly, benthic production during both years was substantially greater under HS (by 38 metric tons in 1969 and 20 metric tons in 1943) during the seasonal growth period. Benthic insects are the primary food source for westslope cutthroat trout during spring and the importance of this trophic level is weighted accordingly in the growth equation. This single factor largely resulted in better growth under HS during these two water years.

River Modeling

We conducted a sensitivity analysis to determine if the assumed rate of benthos recolonization (47 days) influenced the relative ranking of the alternative dam operation scenarios. The rate at which benthos recovers after dry substrate becomes inundated is variable depending on several factors including flow variability, water temperature, trophic state, stream morphology and insect species diversity (Armitage 1984; Cushman 1985). Gersich and Brusven (1981) found that benthic recolonization is delayed when flows vary rapidly (66 days) as compared to unregulated streams (47 days). Brusven and Trihey (1978) observed that it took a minimum of 28 days for benthic stream communities to become productive. Given this uncertainty, 144 paired simulations were performed with the benthos growth curve set at 30 days and 100 days to determine if the relative ranking of alternatives was influenced by the benthos recovery interval.

In Kootenai River simulations, the relative ranks in 96 of 108 simulations did not change when the benthic recovery interval varied from 30 to 100 days. As expected, the total sum of benthic biomass units accrued by each alternative, reduced as the duration of benthic recovery was increased. Six transpositions of rank occurred. In 1955, alternative LV2 (VARQ FC with fish flows plus 10 kcfs) was lower than predicted when the benthic recovery interval was increased from 30 to 100 days. In 1957, benchmark LV (VARQ FC without fish flows) was higher than predicted when the benthic recovery interval was increased from 30 to 100 days. In 1963, alternative LV1 (VARQ FC with fish flows) was lower than predicted when the benthic recovery interval was increased from 30 to 100 days. In 1981, benchmark LV was higher than predicted when the benthic recovery interval was increased from 30 to 100 days. In 1963, alternative LV1 (VARQ FC with fish flows) was lower than predicted when the benthic recovery interval was increased from 30 to 100 days. In 1989, alternatives LV1 and LV2 were lower than predicted when the benthic recovery interval was increased from 30 to 100 days.

Additional simulations were performed by increasing the benthic recovery interval in 10-day increments to determine when the rank transposition occurred in these alternatives. Results indicated that the ranking of alternatives remained consistent when the benthic recovery interval was set between 30 and 70 days. Ranking results remain the same between this range. Thus, our results suggest that our assumed benthic recovery interval of 47 d did not influence the relative ranking of alternatives (see RivProd (KR1-sensitivity).xls on the accompanying CD).

In Flathead River simulations, the relative rank of 34 of 36 simulations did not change when the benthic recovery interval varied from 30 to 100 days. As expected, the total sum of benthic biomass units accrued by each alternative reduced as the duration of benthic recovery increased. Only one transposition of rank occurred. In 1979, the total sum of benthic biomass units under HS was higher than under HV when the benthic recovery interval was 65 days or greater. Ranking once again remained consistent at recovery rates less than 65 days. These data suggest that the benthic recovery interval of 47 days used in this analysis did not influence the relative ranking of alternatives (see RivProd (C Falls sensitivity).xls).

Flood control operations limit high spring flows and result in physical changes to river morphology. Control of periodic flood events removes the hydraulic energy required for channel maintenance and resorting of river sediments. This generally occurred during spring runoff on average or greater water years. Under regulated conditions, frequent flow fluctuations exceed natural variability and cause extensive bank instability and erosion as water repeatedly flows into and out of the banks. Excess sediments increase substrate embeddedness and reduce interstitial habitat required by aquatic insects (Armitage 1984).

Flow regulation disrupts natural processes governing the growth of riparian vegetation. Aquatic and terrestrial vegetation that would normally provide secure habitat for fish and wildlife along the river margins, and stabilize soils, cannot fully reestablish each summer, and fine sediment materials are more easily eroded and swept back into the channel (Jamieson and Braatne 2001; Marotz *et al.* 2002).

Macroinvertebrate communities are adapted and arranged to capitalize on stream energy (velocity), such that a continuum occurs where downstream forms benefit from the inefficiency of upstream forms (Vannote *et al.* 1980; Stanford *et al.* 1988; Stanford and Ward 1989; Hauer *et al.* 1989). Flow fluctuations caused by hydropower dams impact physical habitat and biological production (Ward and Stanford 1979). Rapid flow reductions desiccate bottom substrates and may strand aquatic insects, zooplankton, fish, and fish eggs (Kroger 1973; Cushman 1985), and increase downstream drift of benthic invertebrates (Minshall and Winger 1968; White *et al.* 1981; Poff and Ward 1991). Loss of habitat due to power peaking operations results in reduced insect production and food availability for fish (Gislason 1983).

Hungry Horse and Libby Dam operations increased annual flow variability causing the zone of fluctuation, or *varial* zone, to widen (Figure 36) and become biologically unproductive (Stanford and Hauer 1978; Hauer and Stanford 1982; Fraley and Graham 1982; Shepard *et al.* 1984; Fraley and Decker-Hess 1987; Hauer *et al.* 1994; Hauer *et al.* 1997). Since 2000, ramping rate practices consistent with the 2000 U.S. Fish and Wildlife Service Biological Opinion have helped reduce rapid flow fluctuations. Many of the insect species in the Flathead and Kootenai Rivers that are sensitive to changes in flow velocity were relatively low in abundance following the installation of Hungry Horse and Libby Dams (Hauer and Stanford 1991; Hauer *et al.* 1994; Hauer and Stanford 1997). Most slow-growing univoltine insect species that are grazers or collectors/gatherers have declined and been replaced by species with short life spans (e.g., multivoltine), are sessile, or predaceous. Rapid flow reductions from Hungry Horse Dam resulted in the desiccation and/or freezing of stonefly nymphs concentrated in the lateral margins of the channel (Stanford 1975). Hauer and Stanford (1982) observed large limnephilid caddisfly larvae stranded on gravel bars and pools in summer after declining flow releases from Hungry Horse Dam, thus increasing the likelihood of desiccation and predation by birds.

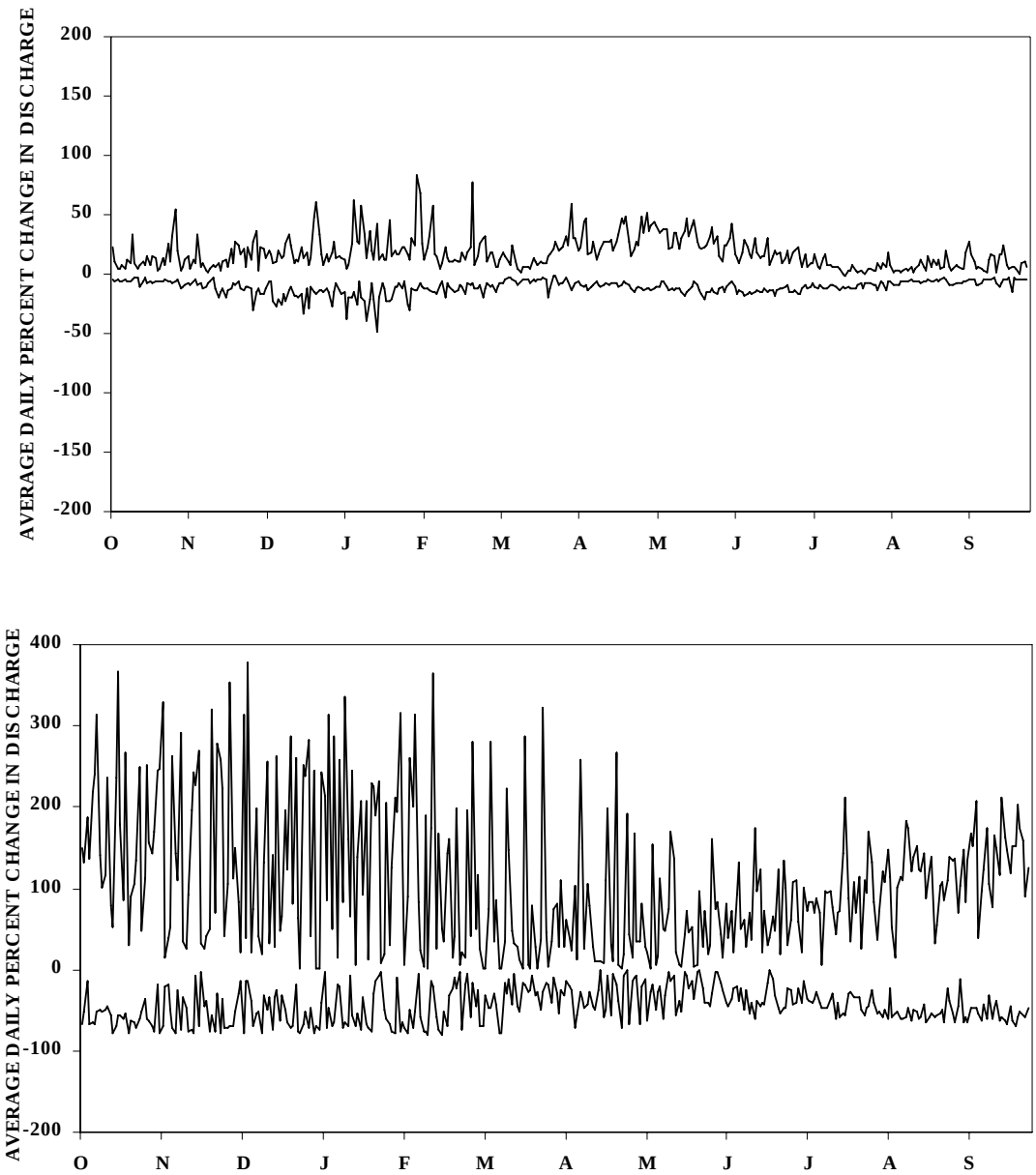


Figure 36. The analogous example of the change in daily discharge before and after regulation by hydropower operations is from the Kootenai River. Daily variance is less prior to dam installation (water year 1952 through 1971 (top)) and greater after Libby Dam began regulating flows (water years 1975 through 1995 (bottom); Hauer 1997). Intermittent fluctuations create a wide varial zone that becomes biologically unproductive.

Kootenai River

Benthic biomass calculations are presented for the Kootenai River in Reach 1 immediately downstream of Libby Dam and Reach 2 just upstream of Bonners Ferry, Idaho. Annual simulations used input files provided by the Corps for the six alternatives and nine water years. Reach 1 analyses used daily Libby Dam discharge data, and daily flow data from Bonners Ferry were used in Reach 2 calculations. The model RivBio was calibrated using survey transects specific to each river reach. For each simulation, model output included daily schedules of benthic biomass units, totals for each depth zone in the channel, and totals for the period March 1 through September 30. Comparisons of the alternatives were summarized. All output files can be examined on the accompanying CD.

Reach 1 - Downstream of Libby Dam

The effect of hydropower operations was most apparent in the Kootenai River immediately downstream of Libby Dam. Inflowing water from unregulated sources progressively moderates the influence of dam operation with distance downstream. Results reveal an increasing trend in benthic biomass with increasing water availability (Figure 37).

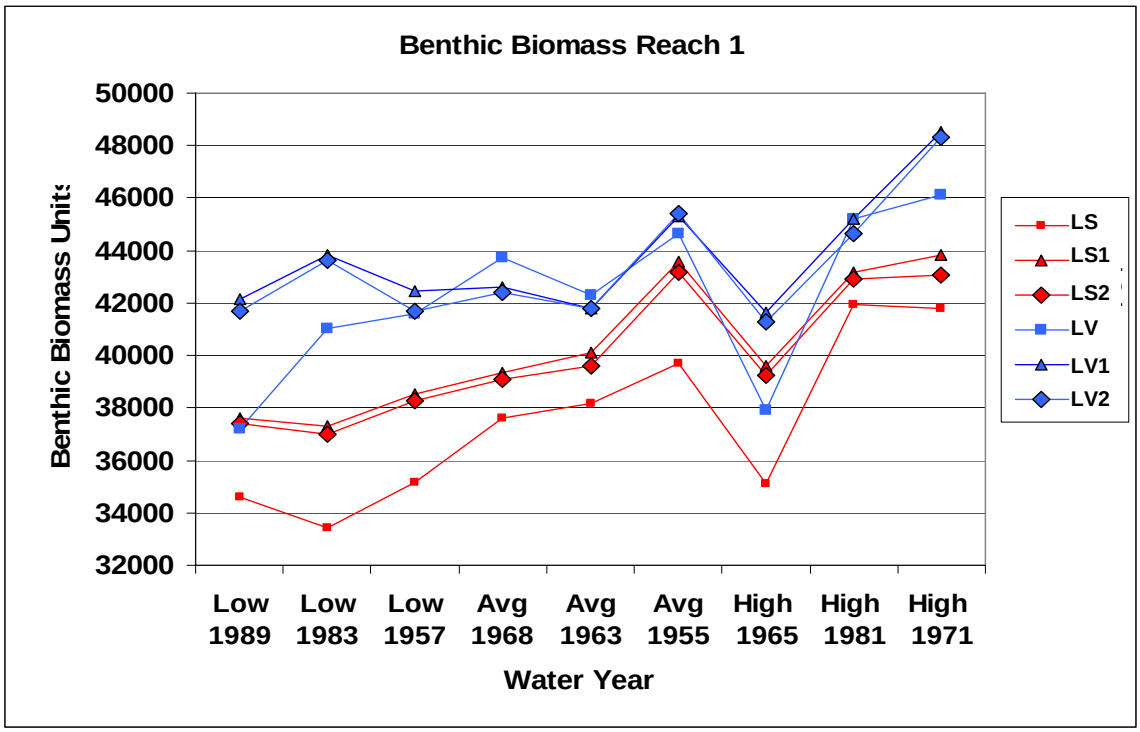


Figure 37. Model calculations of benthic biomass units accrued during the period March 1 through September 30 in the Kootenai River downstream of Libby Dam. Water years on the X-axis are arranged from driest to wettest, left to right. The four alternatives and two benchmarks are color-coded: red = Standard FC, blue = VARQ FC and identified by point symbols. Alternative LS = Standard FC only, LS1 = Standard FC with fish flows, LS2 = Standard FC with fish flows plus 10 kcfs. LV through LV2 follow the same convention for VARQ FC.

The VARQ FC alternatives and benchmark generally accrued more benthic biomass units than standard flood control alternatives and benchmark. However, in water years 1965 and 1989, benchmark LV accrued less benthic biomass than alternatives LS1 and LS2. The reason for these results is apparent in the corresponding hydrographs (Figures 38 and 39).

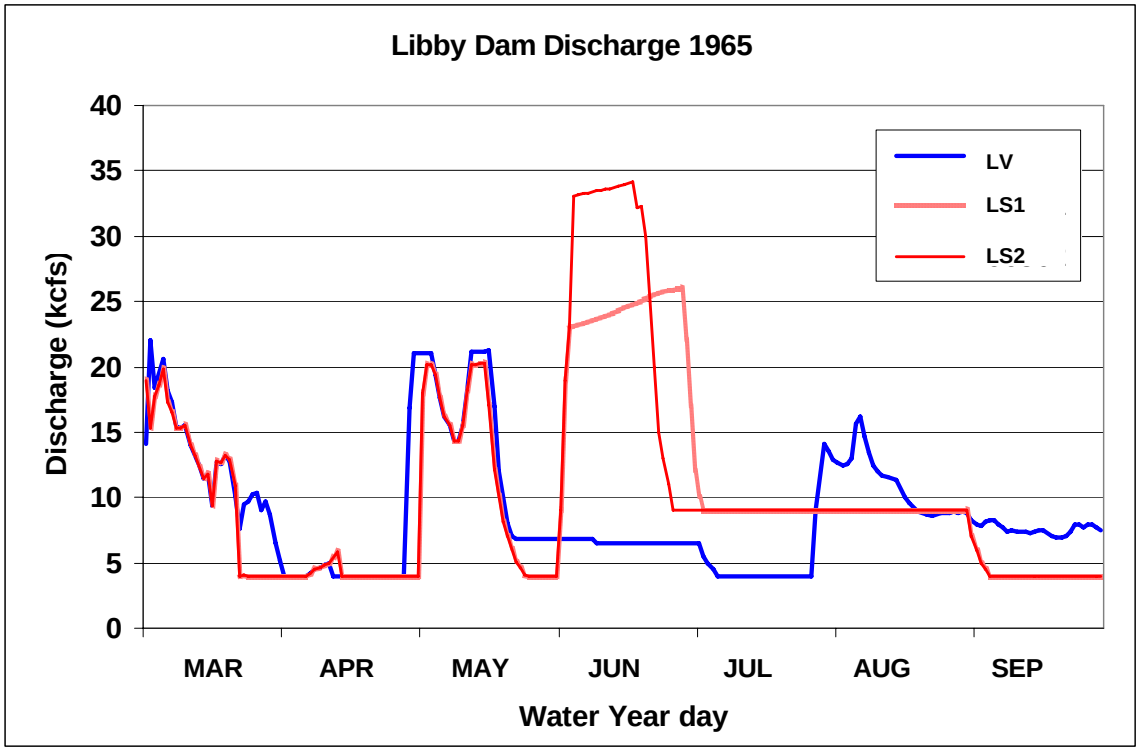


Figure 38. Comparison of Libby Dam discharge hydrographs for three alternative dam operations in 1965. Dam discharges under benchmark LV (blue line) decline toward minimum flow (4,000 cfs) during July, dewatering substrate, and then fluctuate with minimums approaching 7 kcfs. Alternatives LS1 and LS2 remain stable at 9 kcfs throughout the biologically productive summer months. Operation LV during September produces more benthic biomass than LS1 and LS2 that reduce flows to the minimum.

In 1965, the VARQ FC alternatives LV1 and LV2 produced nearly a natural hydrograph, whereas benchmarks LV and LS result in a "double peak" during spring. During the spring peak, a sudden flow reduction dewaters substrate and "resets" the benthos to the lowest flow during the preceding 30-d period. Benthic productivity was limited during brief periods of high discharge because substrate inundation was of short duration. Wetted perimeter remained wet and biologically productive during the summer months in alternatives LV1 and LV2 as flows stabilized above 11 kcfs. Summer production was also protected by alternatives LS1 and LS2 that stabilized at 9 kcfs through August. Conversely, wetted perimeter was rapidly lost in benchmark LV as flows approached minimum flow (4 kcfs) during July. This "double peak" first dewaters productive habitat, then floods substrate again during late July and August. Fluctuations during fall in benchmark LV limited benthic production to the zone that remained wet at 7 kcfs.

Benthic production during September was greater under benchmark LV as flows in LS1 and LS2 declined toward the minimum flow of 4 kcfs.

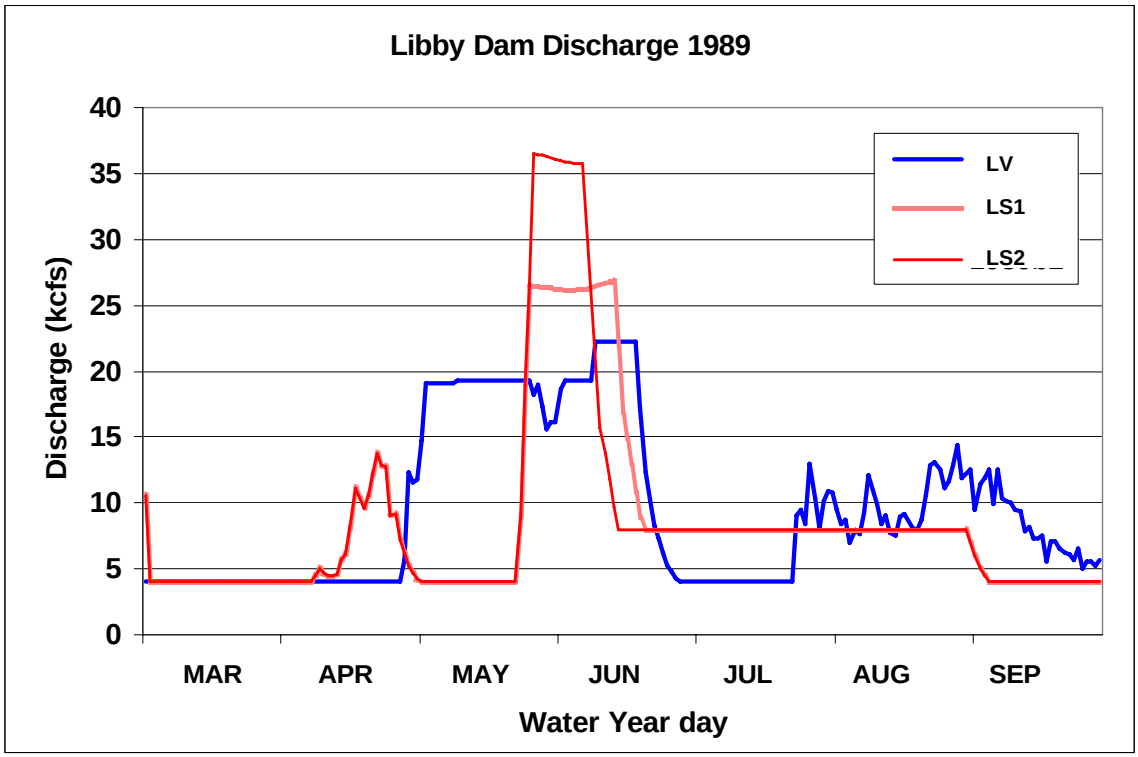


Figure 39. Discharge hydrographs for three alternative dam operations at Libby Dam in 1989. Hydrographs compare benchmark LV (VARQ FC with no fish flows) to the Standard FC alternatives LS1 (with fish flows) and LS2 (with fish flows plus 10 kcfs). Comparison of Lines superimpose until early-April. Dam discharges under LV (blue line) decline toward minimum flow (4,000 cfs) during July, dewatering substrate, and then fluctuate with minimums approaching 7 kcfs. Alternatives LS1 and LS2 remain stable at 8 kcfs throughout the biologically productive summer months. Benchmark LV during September produces more benthic biomass than LS1 and LS2 that reduce flows to the minimum.

In 1989, benthic productivity was limited in May and June during the brief high flows under alternatives LS1 and LS2. The fairly stable and prolonged spring freshet in benchmark LV facilitates the development of benthic biomass, but this potential is lost, or "reset" as substrate dries as flows reduce to minimum flow (4,000 cfs) in late-June. Benthos are maintained in riffle areas that remain wet at 8,000 cfs in alternatives LS1 and LS2 because flows are held constant at 8 kcfs during the productive summer months June through August. Conversely, benchmark LV dewaters a large percentage of riffle habitats with 4 kcfs minimum flows during July. Brief pulses above 7 kcfs in late August under benchmark LV produces a limited gain in productivity, failing to offset previous losses. Benthic production in benchmark LV exceeds the amount provided by the Standard FC operations during September as flows gradually decline from 10 to 5 kcfs.

Reach 2 – Kootenai River at Bonners Ferry

We used 26 survey transects to establish the relationship between flow and wetted perimeter (WETP) in the Kootenai River upstream of Bonners Ferry, Idaho. Stream flow data for the six alternative dam operation scenarios were examined using the river model, RivBio, to estimate benthic biomass production resulting from the various discharge schedules. The effect of Libby Dam operation is moderated in this river reach. The channel in Reach 2 has a lower gradient and is generally wider than Reach 1. Unregulated inflows from tributaries entering the Kootenai River downstream of Libby Dam dilute and mask the effects of short-duration operational changes. Results for the period March 1 through September 30 are presented in Figures 40-41.

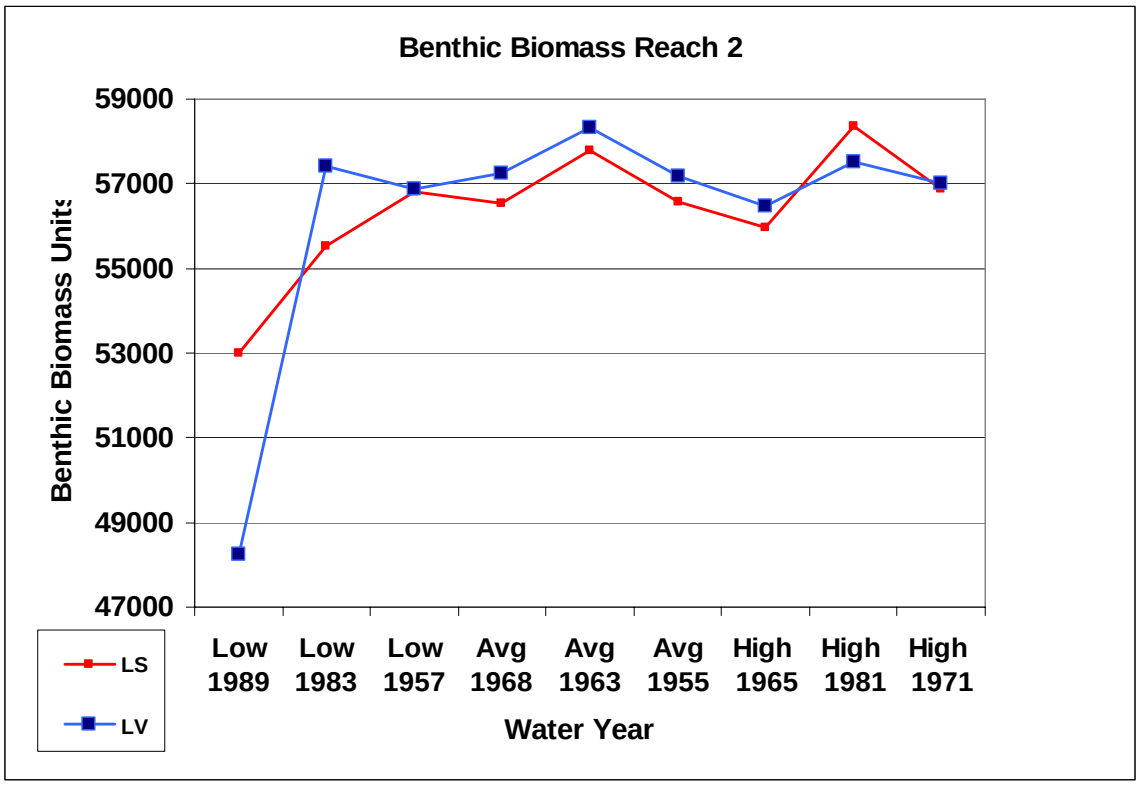


Figure 40. Benthic biomass units accrued during the period March 1 through September 30 in the Kootenai River upstream of Bonners Ferry, Idaho under the Standard FC benchmark LS and VARQ FC benchmark LV. Neither alternative provides "fish flows" for Kootenai white sturgeon, bull trout or anadromous species in the Columbia River.

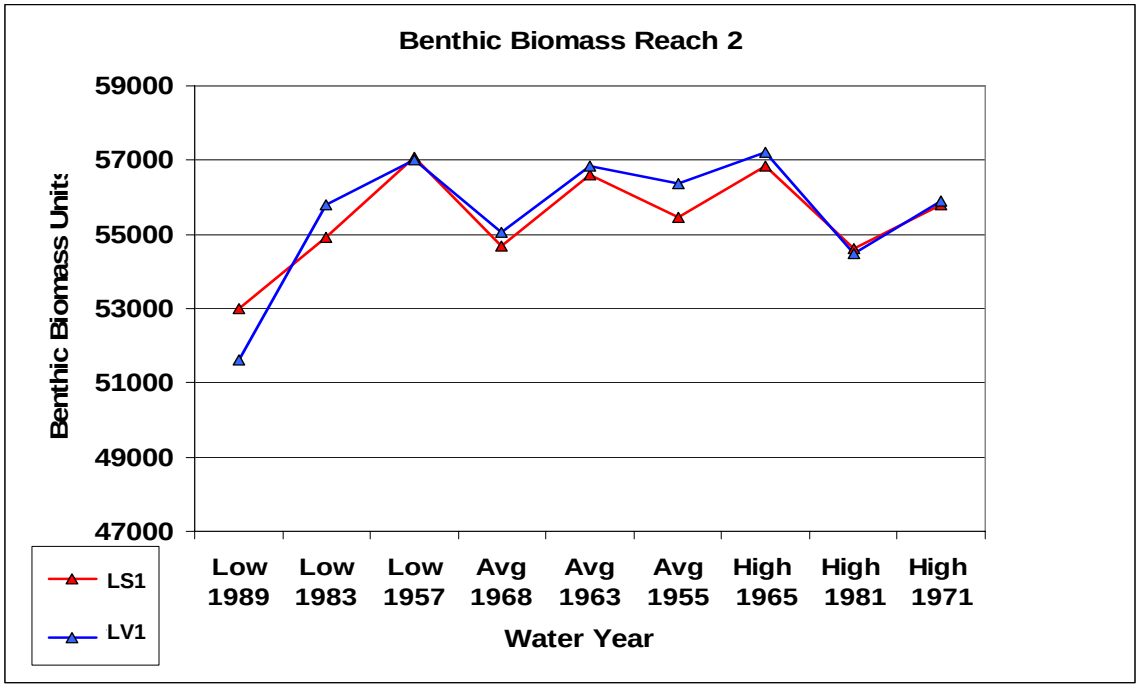


Figure 41. Benthic biomass units accrued during the period March 1 through September 30 in the Kootenai River upstream of Bonners Ferry, Idaho under alternatives LS1 and LV1. Both alternatives provide "fish flows".

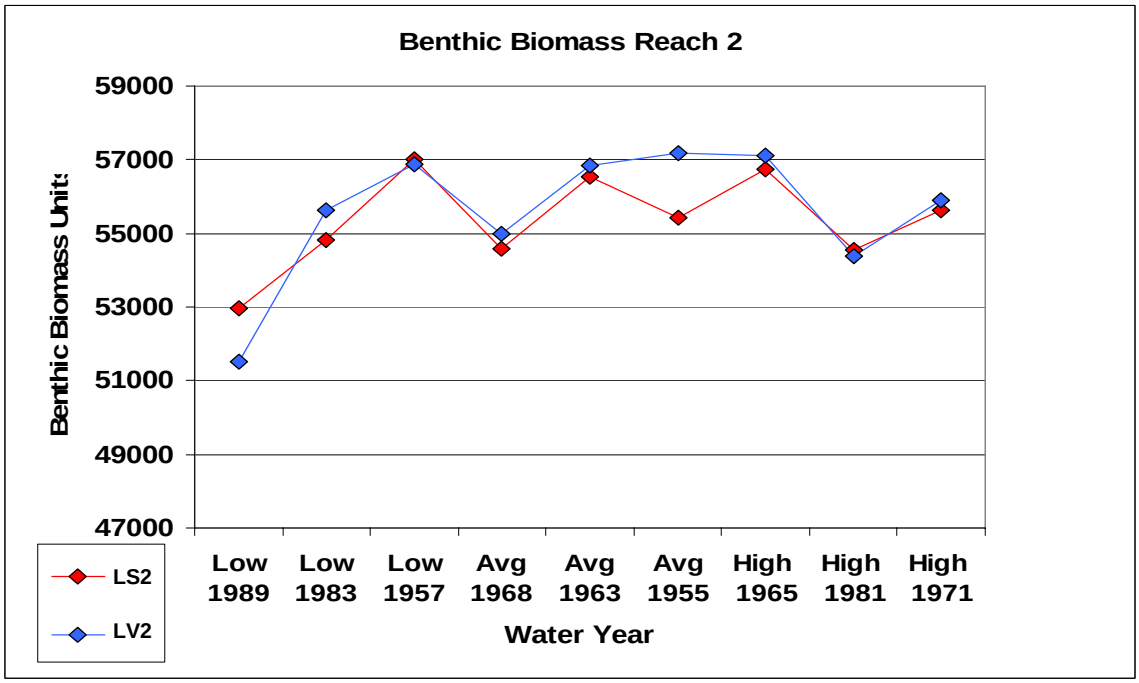


Figure 42. Benthic biomass units accrued during the period March 1 through September 30 in the Kootenai River upstream of Bonners Ferry, Idaho under the LS2 and LV2. Both alternatives provide "fish flows" for anadromous species in the Columbia River and bull trout, "plus 10 kcfs" for Kootenai white sturgeon.

The VARQ FC alternatives resulted in greater benthic biomass than the Standard FC during all years except 1989 and 1981. During 1989, flows under the VARQ FC alternatives declined toward the minimum during July and benthic organisms desiccated along the channel margins. Even after flow conditions improved, benthic biomass impacted earlier by the low flows rebounded slowly. The period totals remained lower than the Standard FC alternatives (Figure 43).

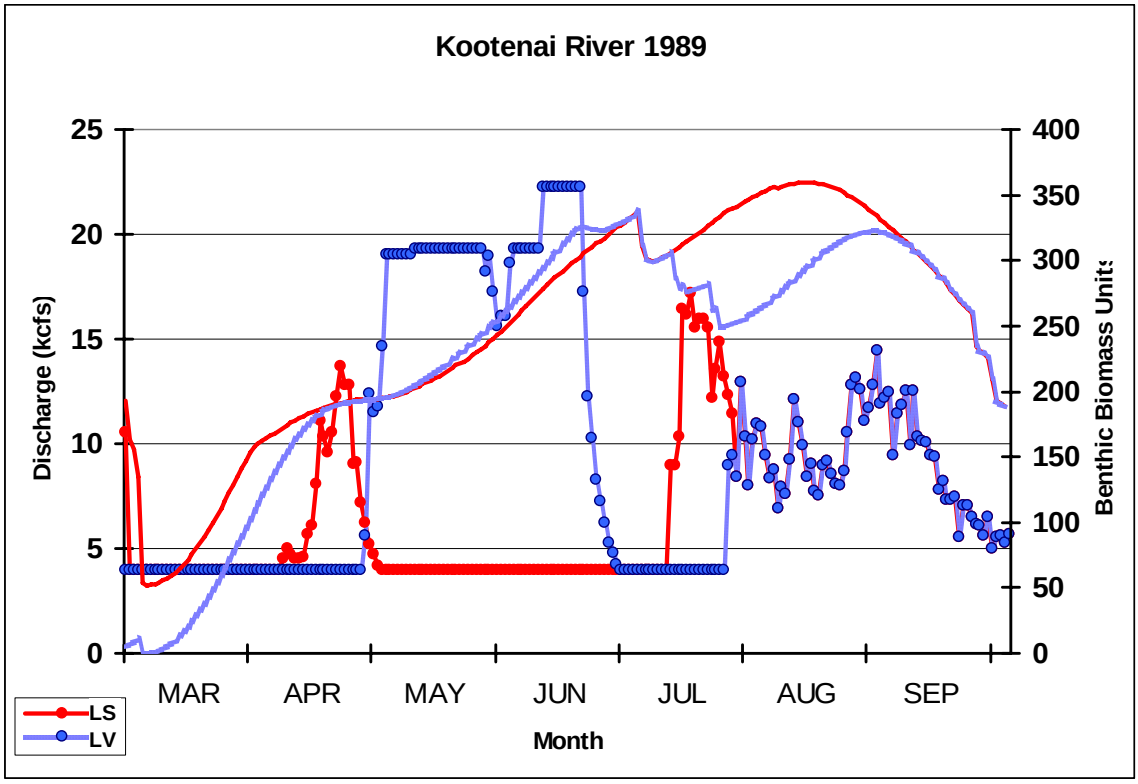
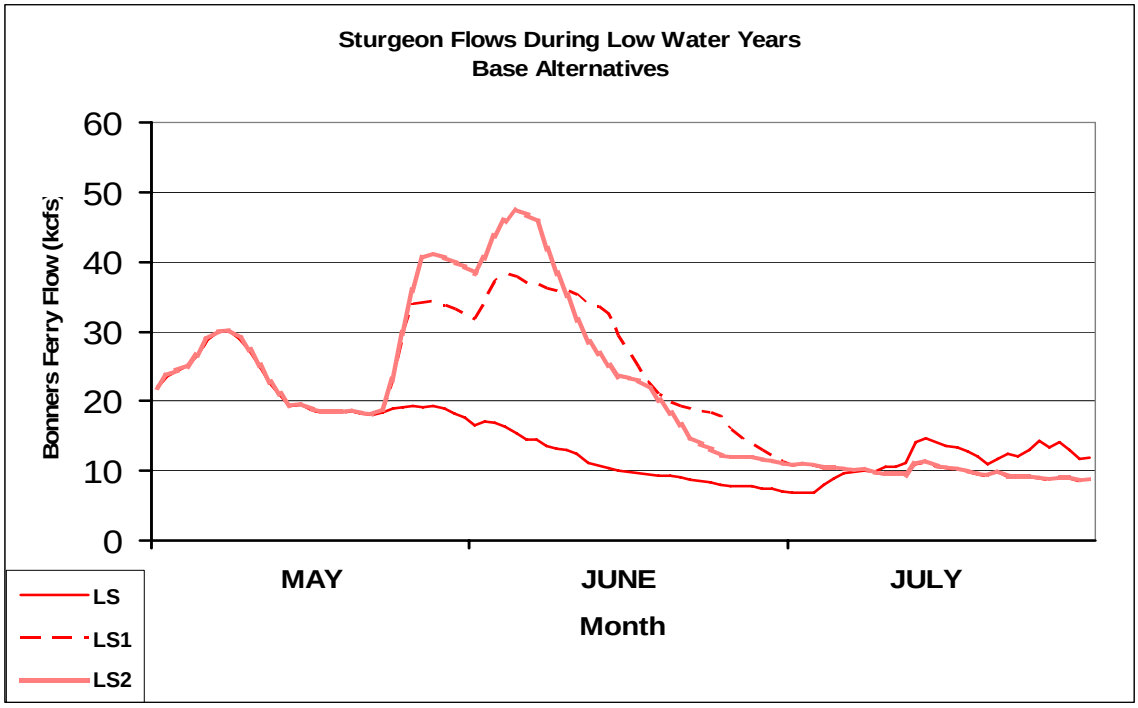


Figure 43. The daily accumulation of benthic biomass units compared to flow (kcfs) in the Kootenai River upstream of Bonners Ferry, Idaho. Lines with data points represent flow. In this example for 1989, benthic production in benchmark LV (blue) is "reset" to a lower level when Libby Dam discharges are reduced in July. The dewatered substrate later recovers, although the period total remains lower than Benchmark LS.

Flow Augmentation for Kootenai White Sturgeon

The USFWS 2000 Biological Opinion on the operation of Columbia River Dams contains reasonable and prudent alternatives for the recovery of the Kootenai white sturgeon. Flow data for the Kootenai River upstream of Bonners Ferry were summarized to determine the relative amount of flow provided by the alternatives during the sturgeon's critical spawning and early rearing phase. Differences between the alternatives that provided fish flows "LS1, LS2, LV1 and LV2" were most apparent during low water years (Figure 44, also see the complete set of plots named Bonners Flow (sturgeon flows).xls).



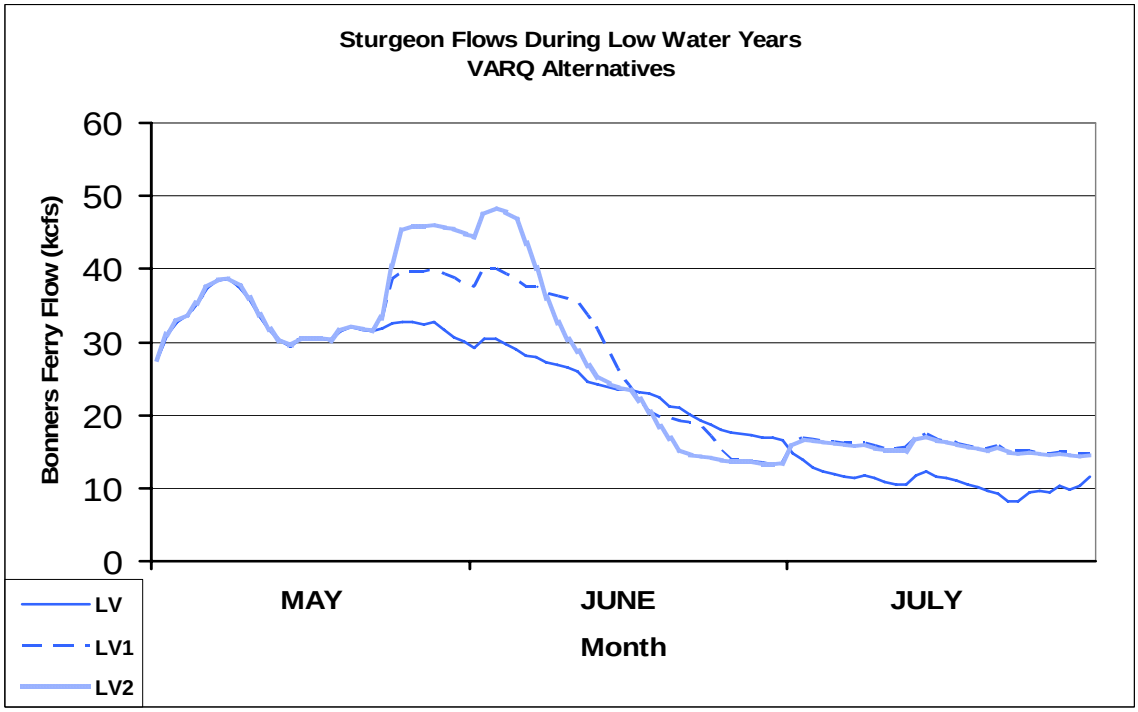


Figure 44. Average flows provided for Kootenai white sturgeon during low flow years under LS and LV benchmarks compared to "fish flow" alternatives LS1 and LV1 and the "fish flows plus 10 kcfs" alternatives LS2 and LV2.

The difference in sturgeon flows provided by the alternatives was most apparent during average and low water years. The VARQ FC alternatives LV1 and LV2 released more water during May and early June, and maintained flows at a higher stage during July.

Flathead River

Benthic biomass calculations are presented for the South Fork Flathead River immediately downstream of Hungry Horse Dam (Reach 1) and mainstem Flathead River at Columbia Falls, Montana (Reach 2). Annual simulations used input files provided by Reclamation for two alternatives and nine water years. Reach 1 analyses used daily Hungry Horse Dam discharge data. Daily flow data from Columbia Falls were used in Reach 2 calculations. The model RivBio was calibrated using survey transects specific to each river reach. For each simulation, model output included daily schedules of benthic biomass units, totals for each depth zone in the channel and totals for the year. Comparisons of the alternatives are summarized here. All output files can be examined on the accompanying CD.

Reach 1 - Downstream of Hungry Horse Dam

RivBio was calibrated using WETP survey data provided by MFWP. The reach immediately downstream of the dam has many deep runs and pools and only three riffles. This was reflected in a composite WETP versus flow relationship that was derived by averaging data from six survey transects (Figure 45).

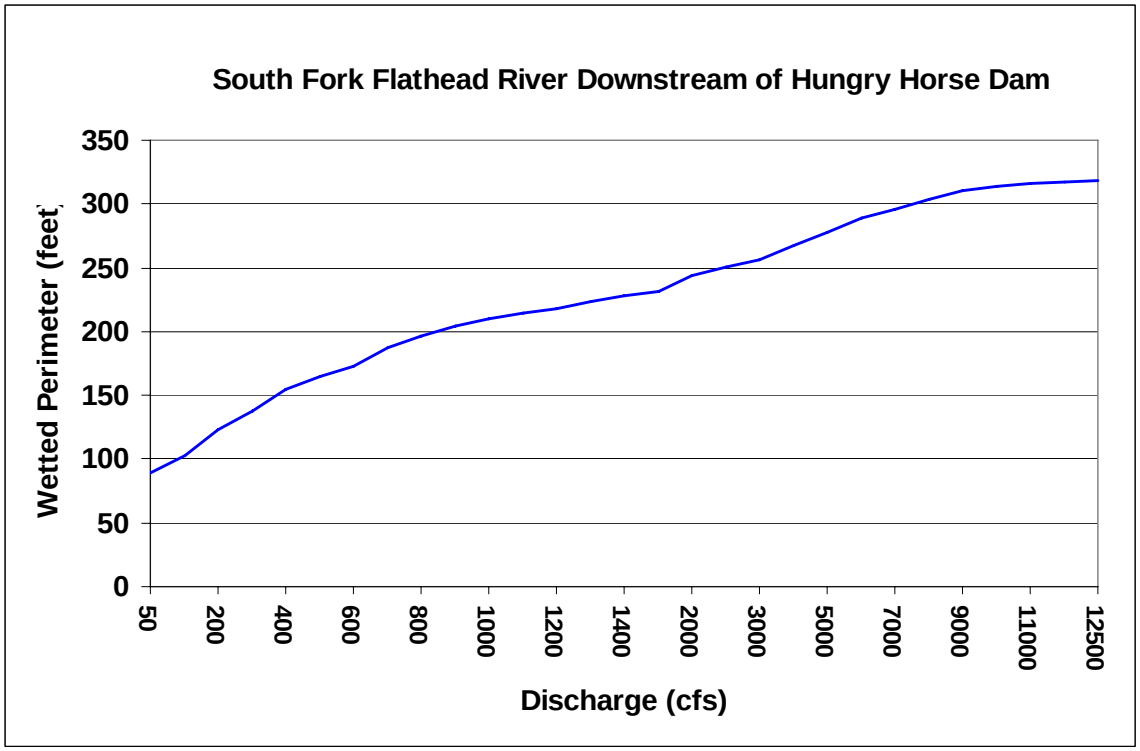


Figure 45. Wetted Perimeter and flow relationship for the South Fork Flathead River immediately downstream of Hungry Horse Dam (source: Marotz and Muhlfeld 2000).

Minimum flows in the South Fork Flathead River were established with a sliding scale to adjust to varying annual water availability. Flows of 900 cfs protect aquatic productivity in the majority of riffle areas and shallow runs. During the driest water years, the

minimum flows may be reduced to 400 cfs (Marotz and Muhlfeld 2000). Discharge data provided by Reclamation adhere to these limits and so there is little difference between the HS and HV during periods at minimum flow.

The effect of hydropower operations is most apparent in the South Fork Flathead River immediately downstream of Hungry Horse Dam. Inflowing water from the unregulated North and Middle Forks of the Flathead Rivers and the Stillwater River progressively moderates the influence of dam operation with distance downstream. Results reveal an increasing trend in benthic biomass with increasing water availability (Figure 46).

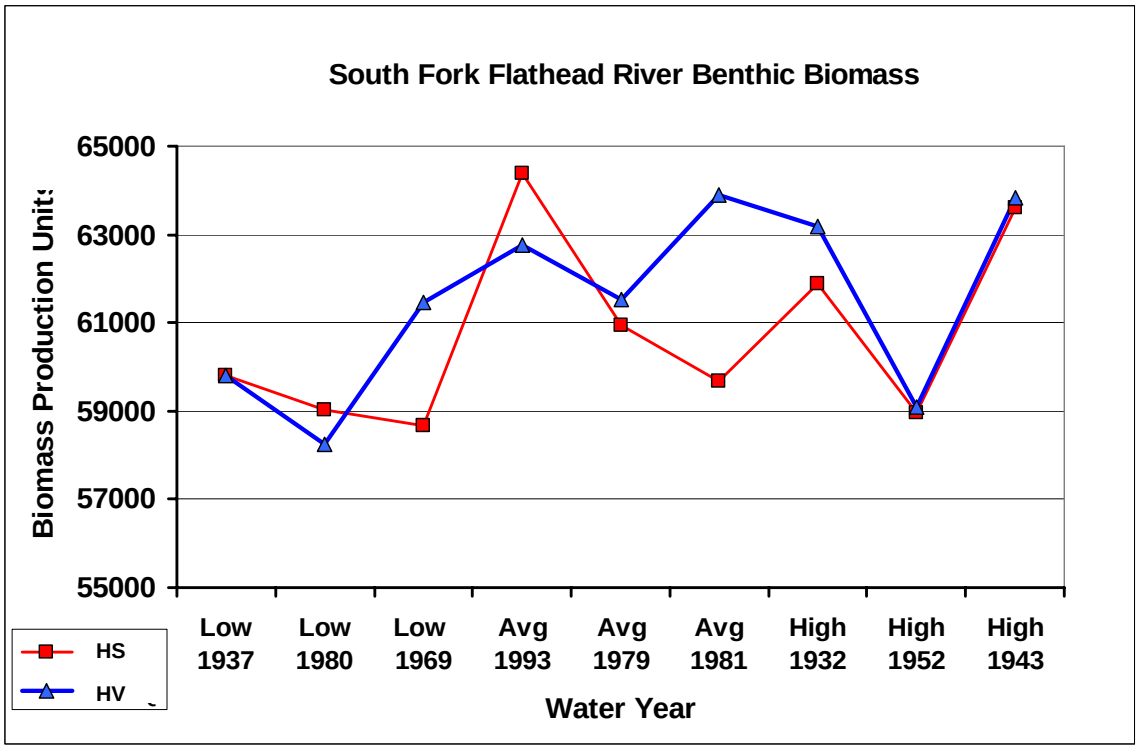
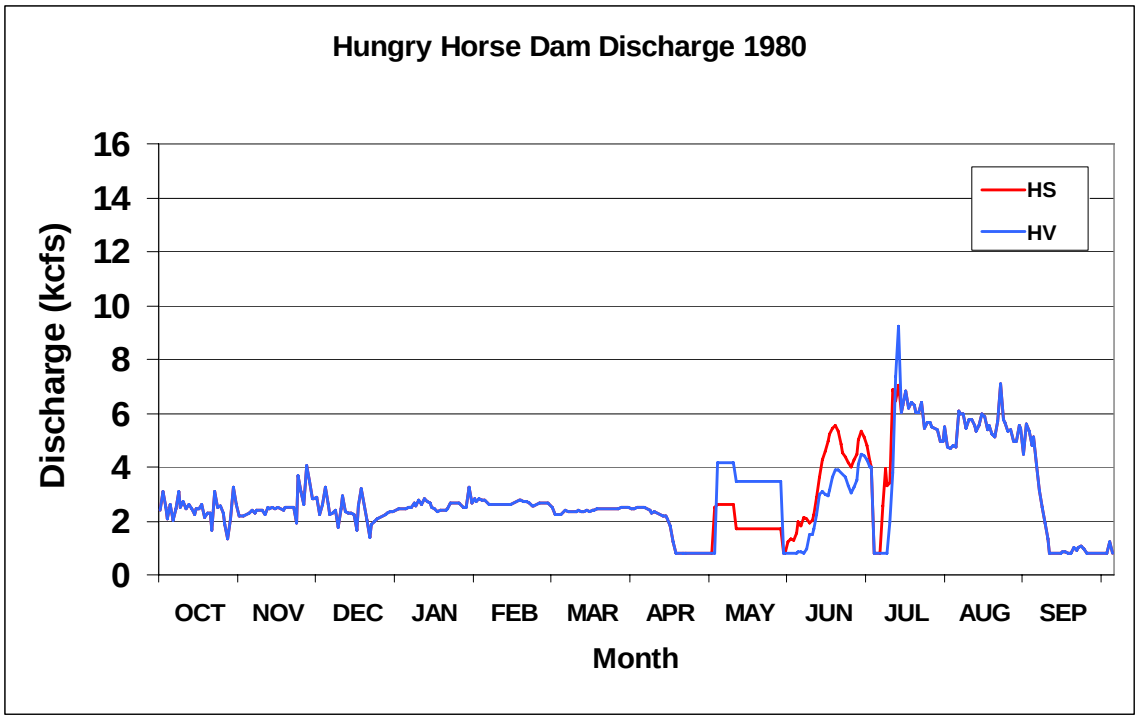


Figure 46. Benthic Biomass accumulated in the South Fork Flathead River under the HS and HV during each water year.

Benthic biomass production under HV was equal to or greater than HS during seven of the nine years. HS provided more favorable conditions for benthic production during 1980 and 1993. The reason for HS ranking higher in these two years is apparent in a comparison of the hydrographs produced by the two alternatives during these two years (Figure 43, also see plots of discharge data in the file named "HH Outflow (All Alternatives).xls").



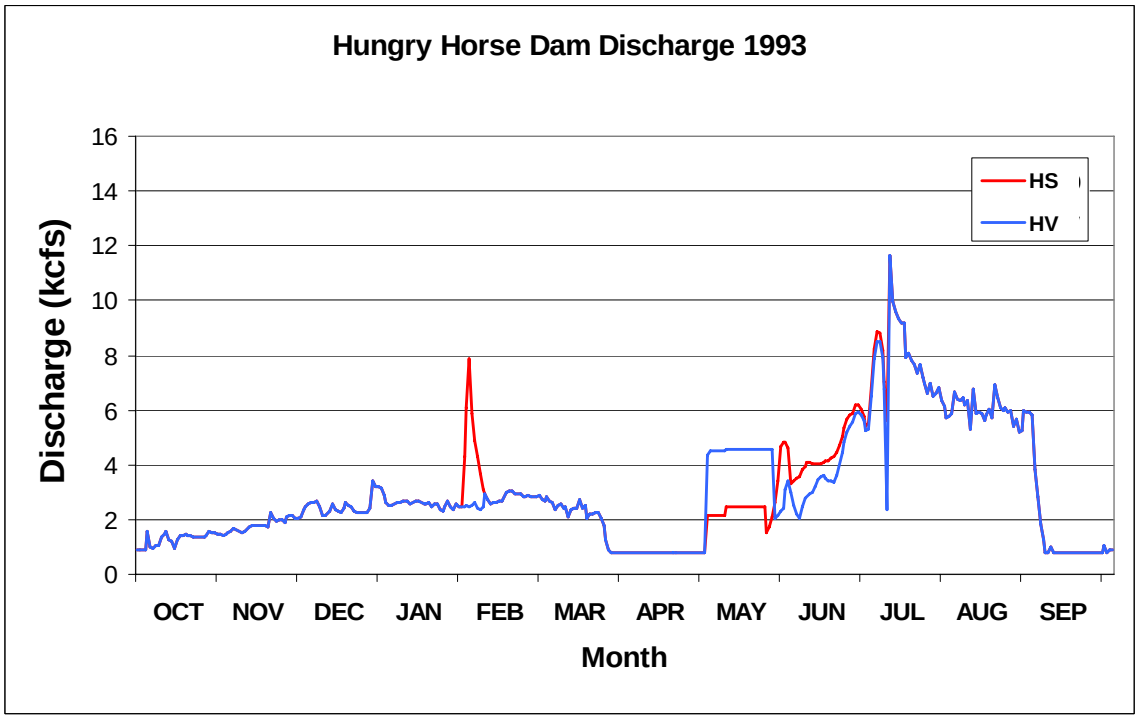


Figure 47. Hungry Horse Dam discharge (kcfs) under HS and HV operations during 1981 and 1993. Note that in both years, flows under the HS (red) were higher during June and early July. Flow increases produced by HV (blue) during May, provided little benefit to benthic production because the pulse was too brief to allow benthic recovery, then flows reduced in late-May desiccating productive substrate.

Alternatives that provided stable flows during the productive warm months produce more benthic biomass units during the water year. Sudden flow reductions "reset" the productive zone to the lowest river stage during the preceding 30-40 days.

Reach 2 – Flathead River at Columbia Falls

The wetted perimeter (WETP) methodology used 8 transects developed using hydroacoustic techniques by Miller *et al.* (2003). Transect data were averaged to establish the relationship between flow and WETP in the Flathead River at Columbia Falls, Montana. Stream flow data for the two alternative dam operation scenarios were examined using RivBio to estimate benthic biomass production resulting from the various discharge schedules. The effect of Hungry Horse Dam operation is moderated in the mainstem by unregulated flows from the North and Middle Forks of the Flathead River. Reach 2 is lower gradient and generally wider than Reach 1. Unregulated inflows from the Middle and North Forks dilute and mask the effects of short-duration operational changes. Annual results for HS and HV are presented in Figure 48.

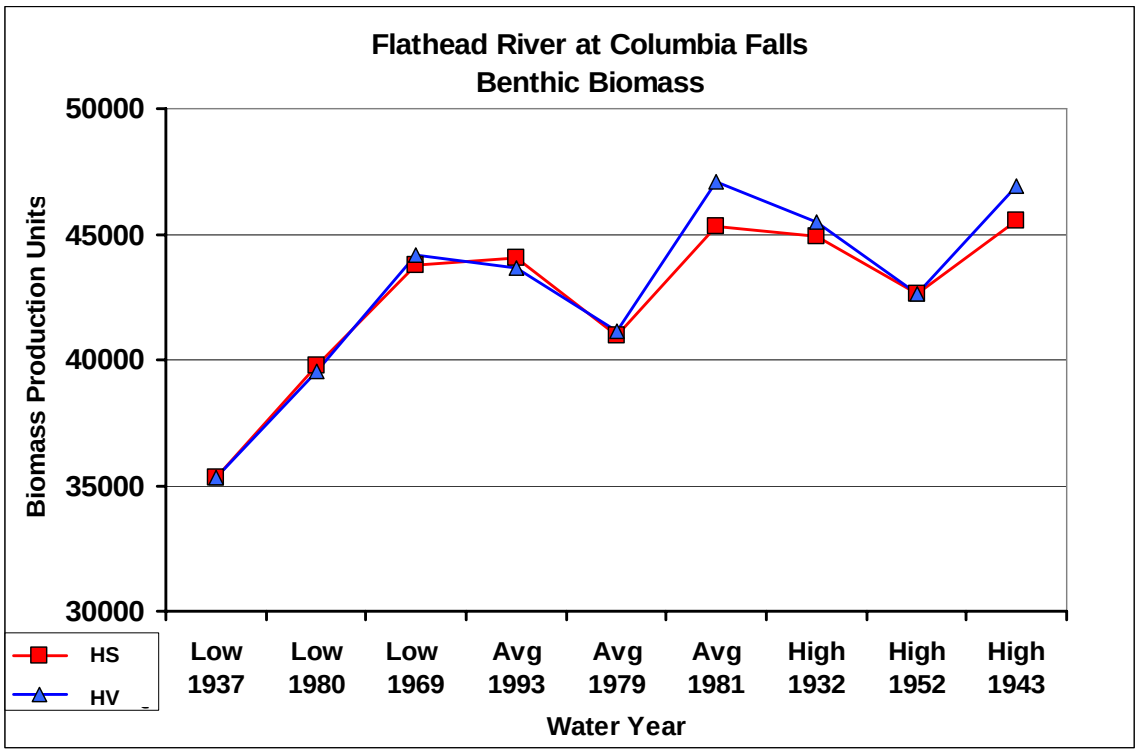


Figure 48. Benthic biomass units accrued in the Flathead River at Columbia Falls during each water year. The plot compares benthic biomass production under HS and HV. Both alternatives provide "fish flows" for bull trout in the Flathead River and anadromous species in the Columbia River.

The effects of Hungry Horse Dam operations on river biota were moderated by minimum flows established for the South Fork and the annual minimum flow limit at Columbia Falls (3,500 cfs). Since HS and HV adhere to these limits, the depth zones protected by

minimum flows remained productive in both scenarios. The remaining differences were also moderated in Reach 2 by unregulated flows from the North and Middle Forks. Given this, HV produced more benthic biomass than HS in five of the nine years simulated. The two years in which HS produced more benthos, Flathead River flows were greater than HV during June and early July as explained earlier in reference to the South Fork Flathead River.

Short-term flow fluctuations for weekly load following continue to impact river biota and should be mitigated, especially during low flow periods, by reducing the rate of change or *"ramping rate"* (Marotz *et al.* 2002). Benthos are reset to the lowest flow during the preceding 30 or 40 days, so short-term flow reductions should be avoided. Bull trout and westslope cutthroat trout in the Flathead River trout are impacted indirectly by dam operation by decreased food availability and directly by habitat loss. Sporadic flow fluctuations are especially harmful to bull trout that require shallow areas along the channel margins at night (Muhlfeld *et al.* 2003). The highly variable flows apparently stress native salmonids as they move from day to night habitat locations based on depth and velocity characteristics. Miller *et al.* (2003) provides a visual characterization of habitat and Arcview project data.

Flathead Lake

During the water years selected for this analysis, conditions in Flathead Lake were minimally influenced by Hungry Horse Dam operations. Data provided by Reclamation for Flathead Lake elevations under the two alternatives were overlaid for comparison in the file: "Flathead Lake Elevations (mod comp).xls" (Figure 49) .

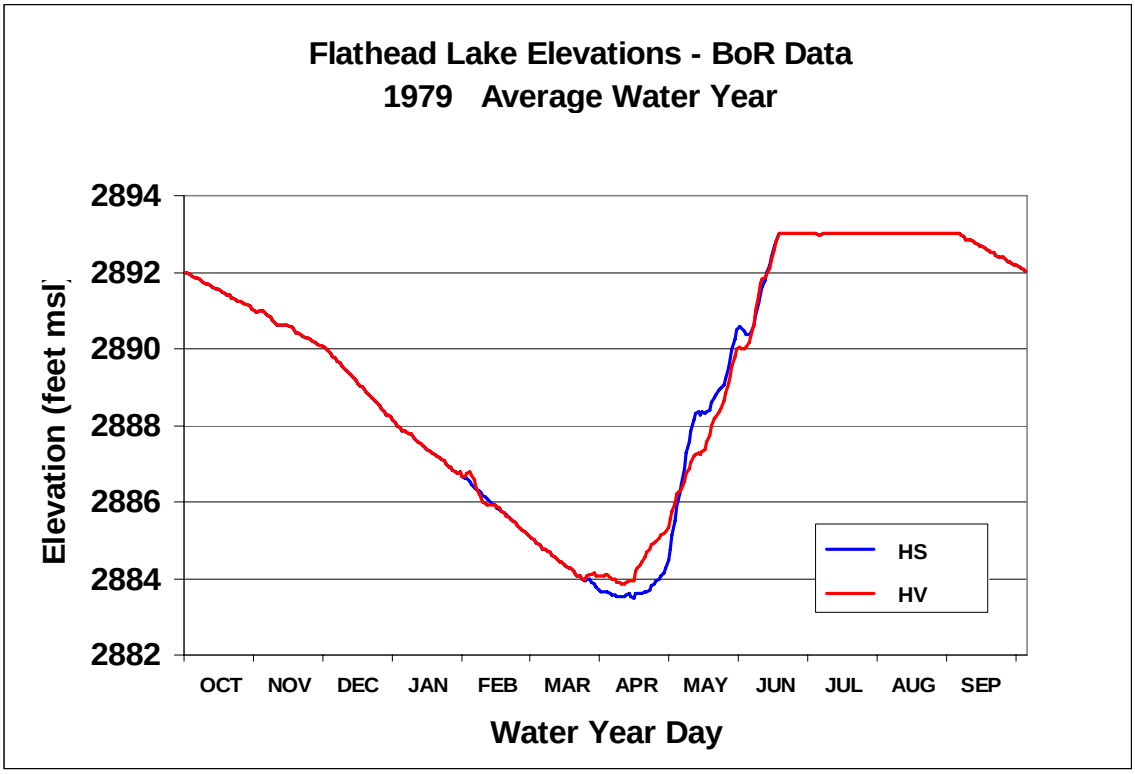


Figure 49. An example of the minimal effect of HS and HV on Flathead Lake.

Results from the Reclamation model and HRMOD were very similar. Neither model revealed a notable difference in Flathead Lake operations during water years with medium-low to medium-high water availability. Model simulations in the driest (lowest 20th percentile) and wettest (highest 20th percentile) water years may reveal greater differences between the alternatives than were found during this study. Additional simulations during the lowest and highest water years could provide greater insight into the effect of VARQ FC operations during drought and flood conditions.

Conclusions

Based on model analyses of biological responses to Standard and VARQ FC strategies, VARQ FC operations that provided fish flows generally resulted in improved biological conditions in the rivers downstream. Biological benefits in the Flathead and Kootenai rivers were moderated with distance downstream due to inflows from unregulated streams. VARQ FC alternatives also improved biological conditions in reservoirs compared to Standard FC alternatives during most years. Reservoir biota benefit when the annual reservoir drawdown is reduced and the surface remains at or near full pool during the biologically productive summer months.

Dam operations that maximize surface area and volume in the euphotic zone during the warm months produce more phytoplankton and zooplankton. Zooplankton are the primary food of non-predacious fish species during winter. At Libby Reservoir, the VARQ FC alternatives produced greater plankton production in all water years simulated. Benchmarks LS and LV that initiated at full pool produced more plankton than alternatives that began the year (October 1) 20 feet below full pool. Benchmark LV ranked highest, followed by LV1, which produced more phytoplankton than LV2 during seven of the nine years and more zooplankton during six of the nine years. At Hungry Horse Reservoir, HV resulted in greater phytoplankton and zooplankton production during seven of the nine water years. Loss of phytoplankton through the dam turbines, however, differed very little between the alternatives because the selective withdrawal was automated the same way in all alternatives. Loss of Daphnia through the turbines was higher under HV during six of the nine water years, presumably due to greater Daphnia production in the reservoir resulting from HV.

Benthic insects are the primary food for insectivorous fish species during spring. Benthic insect production is enhanced when the depth of the annual reservoir drawdown is reduced and when depth zones containing high densities of dipteran larvae remain in the euphotic zone during the productive warm months. At Libby Reservoir, benchmark LV produced more benthos than benchmark LS during all years. Of the alternatives that provided fish flows, LV1 produced more benthic insects than the Standard FC alternatives during all years. Alternative LV2 produced more benthos than the Standard FC alternatives during eight of nine water years. At Hungry Horse Reservoir, benthic production was greater under HV in five of the nine years, whereas HS produced more benthos in three of the nine water years.

Terrestrial insects become available to fish when they are deposited on the reservoir surface from the surrounding landscape and are the primary food for insectivorous fish during the summer and fall. The number of terrestrial insects captured on the reservoir surface is dependant on reservoir surface area and distance from shoreline vegetation to the water. Alternatives that remain at or near full pool during the months when terrestrial insects are active capture more insects than operations that draw the reservoirs down during summer. At Libby Reservoir, benchmarks LS and LV began at full pool and the reservoir remained full during most of the summer and fall. Benchmark LV captured more insects than any other alternative, while LS was a close second for all insect orders

except Coleoptera. Of the alternatives that provided fish flows, the VARQ FC alternatives captured more terrestrial insects than the Standard FC alternatives during all water years. Alternative LV1 captured slightly more insects than LV2 with few exceptions. Similarly, LS1 nearly always captured more insects than LS2. Apparently, LS2 reduced surface area during most years and trapped fewer terrestrial insects. At Hungry Horse Reservoir, terrestrial insect deposition was nearly the same in both alternatives. Of the four insect orders, only the deposition of Coleoptera differed between the alternatives. HV captured more beetles during six of the nine water years. Deep reservoir drawdowns delay the reservoir refill process and result in a smaller surface area and greater distance from the water to shoreline vegetation. Operations that fail to refill trap fewer terrestrial insects.

VARQ FC provided environmental conditions more conducive for fish growth than Standard FC during most water years. At Libby reservoir, benchmark LV resulted in greater kokanee growth than LS during all years. Of the four alternatives that provided fish flows, the VARQ FC alternatives resulted in greater kokanee growth during eight of the nine years. Alternative LV1 produced greater kokanee growth than LV2 during five of the nine water years, while growth under LS1 was greater than LS2 during six of nine years. At Hungry Horse Reservoir, operations did not differ between the alternatives during 1937. Of the eight remaining water years, HV resulted in greater growth of westslope cutthroat trout during six of the years.

Downstream of the dams, unnatural flow fluctuations caused by dam operations disrupt natural processes and reduce biological productivity. The effect of hydropower operations is most apparent in the rivers immediately downstream of the dams. Inflowing water from unregulated sources progressively moderates the influence of dam operation with distance downstream. Short-term flow fluctuations increase the width of the zone of fluctuation, or *varial zone*, which becomes biologically unproductive.

Biological impacts associated with hydropower operations can be mitigated by restoring normative river processes (Independent Scientific Group 1999). When flows are stabilized below hydropower projects, flood plain function can be restored, reducing deleterious effects on biological production (Marotz *et al.* 2002). The Independent Scientific Advisory Board (ISAB 1997 and 1997b) recommended restoring the most natural flow regime possible under the current management constraints to protect key ecosystem processes and maintain or restore resident fish populations. Restoration of the most natural flow regime possible can partially be achieved by establishing minimum flows and seasonal flow ramping rates. Many of these beneficial measures have already been implemented at Hungry Horse and Libby Dams. Tiered flows for restoring Kootenai white sturgeon and stable summer flows for bull trout (USFWS 1999 and 2000) were included in the Libby alternatives LS1, LS2, LV1, and LV2. Similarly, both HV and HS alternatives provided “fish flows” in the Flathead River reaches. Still, short-term flow reductions continue to impact river biota below the Montana projects and annual hydrographs differ from normative conditions. The WETP technique demonstrated the importance of avoiding short-term flow reductions, especially during the productive summer months.

The VARQ FC alternatives generally accrued more benthic biomass units than alternatives that use standard flood control. In the Kootenai, alternatives LV1 and LV2 ranked similarly high during all years and benchmark LV ranked closely behind. An exception occurred during 1965 and 1989 when LV was ranked lower than LS1 and LS2. The reason LV produced less benthic biomass was evident in the hydrographs. Benchmarks LS and LV do not provide fish flows. As a result, dam discharges under LV reduced to minimum flow during the productive summer months, whereas all the alternatives that provide fish flows (LV1,LV2, LS1 and LS2) maintain higher, stable flows throughout summer. During September, however, flows under LV protected more river productivity than LS1 and LS2 by maintaining stable flows when flows under the Standard FC alternatives reduced to minimum. Although LV created better river conditions during September, benthic production was insufficient to offset the summer losses and LV ranked lower than Standard FC operations in two years. September flows remain important to river productivity. Short-term flow reductions should be avoided between summer flows and high winter flows that result when the dams begin to generate electricity to meet high winter loads. River flows should be maintained as stable as possible during the fall transition period to maintain the maximum benthic productivity during the winter high discharge period.

Differences between the alternatives were most evident in the South Fork Flathead River immediately downstream of Hungry Horse Dam. Analysis of the South Fork Flathead River revealed that alternative HV produced more benthic biomass than HS during six of nine water years. Comparison of the HV and HS in the Flathead River at Columbia Falls produced similar results, although the effect of operation was moderated by unregulated flows from the unregulated North and Middle Forks. HV produced more benthos in the mainstem Flathead River during five of the nine years. Our river modeling indicated that HV is beneficial to river productivity when flows remain stable during the productive summer and fall months.

The influence of VARQ FC on Flathead Lake was minimal over the range of flows modeled (middle 60th percentile water years). Model simulations in the driest and wettest water years may reveal greater differences between the alternatives than were found during this study. Additional simulations could provide greater insight into the effect of VARQ FC operations during drought and flood conditions.

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APPENDIX E

Detailed Recreation Assessment

UPPER COLUMBIA ALTERNATIVE FLOOD CONTROL AND FISH OPERATIONS EIS

RECREATION AFFECTED ENVIRONMENT
Appendix E: Part 1 of 2

prepared for:

U.S. Army Corps of Engineers
Seattle District

and

Bureau of Reclamation

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May 2005

UPPER COLUMBIA ALTERNATIVE FLOOD CONTROL AND FISH OPERATIONS EIS

RECREATION AFFECTED ENVIRONMENT

TABLE OF CONTENTS

Page E-

1.0 Introduction 1
2.0 Area 1 - Kootenai River Basin 3
2.1 Lake Koocanusa 3
2.2 Kootenai River 6
2.3 Kootenay Lake 8
3.0 Area 2 - Flathead/Clark Fork/Pend Oreille River Basin 11
3.1 Hungry Horse Reservoir 11
3.2 Flathead River 14
3.3 Flathead Lake 16
3.4 Lower Flathead River 19
3.5 Lower Clark Fork 20
3.6 Lake Pend Oreille 22
3.7 Pend Oreille River - United States 26
3.8 Pend d'Oreille River - Canada 28
4.0 Area 3 - Columbia River Mainstem 30
4.1 Upper Columbia River 30
4.2 Middle and Lower Columbia River 41

LIST OF TABLES

Page E-

Table 1: Lake Koocanusa Recreational Facilities 4
Table 2: Lake Koocanusa Minimum Usable Boat Ramp Elevations 5
Table 3: Kootenai River Recreational Facilities 7
Table 4: Kootenay Lake Recreational Facilities 9
Table 5: Hungry Horse Reservoir Recreational Facilities 12
Table 6: Hungry Horse Reservoir Minimum Usable Boat Ramp Elevations 13
Table 7: Flathead River below Hungry Horse Dam Day Use Recreational Facilities 15

Table 8: Flathead Lake Recreational Facilities.....17
Table 9: Flathead Lake Minimum Usable Boat Ramp Elevations 18
Table 10: Lower Clark Fork Recreational Facilities.....21
Table 11. Lake Pend Oreille Recreational Facilities 23
Table 12: Lake Pend Oreille Minimum Usable Boat Ramp Elevations 25
Table 13: Pend Oreille River below Albeni Falls Dam Recreation Facilities 27
Table 14: Upper Columbia River Canadian Recreational Facilities.....31
Table 15: Lake Roosevelt Recreational Facilities 33
Table 16: Lake Roosevelt Minimum Usable Boat Ramp Elevations 36
Table 17: Lake Rufus Woods Recreational Facilities.....39
Table 18: Lake Rufus Woods Minimum Usable Boat Ramp Elevations 40

UPPER COLUMBIA ALTERNATIVE FLOOD CONTROL AND FISH OPERATIONS EIS

RECREATION AFFECTED ENVIRONMENT

1.0 Introduction

The Columbia River Basin hosts numerous Canadian and U.S. National parks, state/provincial parks, national forests, recreation areas, interpretive centers, wildlife refuges, hot springs, public beaches, and historic points of interest. The Basin's recreational opportunities attract both local residents and long distance visitors, drawing an estimated 18 million visitors to the basin each year and contributing substantially to local and regional economies (BPA *et al.* 1995).

The recreational features, facilities and activities that could be directly affected by changes in reservoir operations include boat ramps[1], fixed and floating boat docks, moorage, swimming beaches, and fishing. Additional land based features, facilities, and activities that could be indirectly affected are near-shore camping and campsites, sightseeing, and trails.

In this section, the affected environment regarding recreation is described by three sub-basins within the Columbia Basin, then by major river reach, lake and reservoir recreational areas, and finally by the affected recreation activity. The three regions within the Columbia Basin comprise the following areas:

- Area 1 - Kootenai River Basin from Lake Koocanusa in Montana (MT) and British Columbia (BC) through Idaho (ID) to the Columbia River in BC
- Area 2 - Flathead/Clark Fork/Pend Oreille Basin from Hungry Horse Reservoir in MT to the Columbia River in Washington (WA)
- Area 3 - Columbia River mainstem from the mouth of the Kootenai River in BC downstream to the Pacific Ocean in Oregon (OR) and WA

Area 1 – Kootenai River Basin recreational areas are:

- Lake Koocanusa in MT and BC (Extent of reservoir pool)

[1] Note that elevation data presented for boat ramps should be considered approximate as they are often not a precise measurement. These elevations do not account for all aspects of launching ability, such as the presence of mud or debris on the ramp, or exposed hazards that appear at lower water levels.

- Kootenai River[2] (Libby Dam in MT, through ID to Kootenay Lake in BC)
- Kootenay Lake in BC (Kootenay Lake to Corra Linn Dam)

Area 2 – Flathead/Clark Fork/Pend Oreille River Basin recreational areas are:

- Hungry Horse Reservoir in MT (Extent of reservoir pool)
- South Fork Flathead and Flathead River in MT (Hungry Horse Dam to confluence with Flathead Lake)
- Flathead Lake in MT (Confluence with Flathead River to Kerr Dam)
- Lower Flathead River in MT (Kerr Dam to confluence with Clark Fork)
- Lower Clark Fork (Confluence with lower Flathead River in MT to confluence with Lake Pend Oreille in ID)
- Lake Pend Oreille in ID (Confluence with lower Clark Fork to Albeni Falls Dam)
- Pend Oreille River (Albeni Falls Dam in ID to Columbia River in WA)
- Pend d'Oreille River and Pend d'Oreille Reservoir in BC

Area 3 – Columbia River mainstem recreational areas are:

- Primary Sub-basin (Kootenay River confluence in BC to Chief Joseph Dam in WA)
    - Upper Columbia River (Kootenay River in BC to Franklin D. Roosevelt Lake (Lake Roosevelt) confluence in WA)
    - Lake Roosevelt in WA (Lake Roosevelt confluence to Grand Coulee Dam)
    - Rufus Woods Lake in WA (Grand Coulee Dam to Chief Joseph Dam)
- Secondary Sub-basin in WA and OR (Chief Joseph Dam to Pacific Ocean)

[2] The Canadian spelling is Kootenay. The U.S. spelling is Kootenai.

2.0 Area 1 - Kootenai River Basin

From its headwaters to its confluence with the Columbia River, the Kootenai River Basin offers many recreational opportunities. The main recreational features of interest to this study include Lake Koocanusa, Kootenay Lake, and the Kootenai/Kootenay River itself.

2.1 Lake Koocanusa

General Information: Lake Koocanusa is an important regional recreational resource on both sides of the U.S./Canadian Border. The lake is relatively undeveloped compared to nearby reservoirs, with less transportation access, and fewer recreational facilities than those found in at Lake Pend Oreille or nearby Flathead Lake in Area 2. This is due, in part, to the large seasonal fluctuation in pool elevation that accompanies operation of the Libby Dam, which can result in a 160 foot fluctuation in water surface elevations through the year (BPA *et al.* 1995). Two provincial parks and two recreational areas are located along the lake in BC.

Recreation Management: The two primary U.S. recreational resource managers in the area are the U.S. Army Corps of Engineers (Corps) and the U.S. Forest Service (USFS). The Corps operates and maintains Libby Dam, the dam's visitor center, a campground, and a boat ramp at Lake Koocanusa. The USFS manages the Kootenai National Forest (KNF) and operates all other U.S. recreational facilities along the reservoir. Canadian recreation sites along the reservoir are managed by BC Provincial Parks and private owners.

Recreation Access: Lake Koocanusa is accessible by road. MT State Highway 37 runs along the east side of the reservoir for more than 20 miles, while the west side is accessible via USFS roads. On the Canadian side of the lake, BC Provincial Highway 3 crosses the reservoir near Wardner, BC (BPA *et al.* 1995).

Visitation: Approximately half of Lake Koocanusa recreational visitors are from MT and out of state visitors tend to come from WA, BC and Alberta. The peak recreation season is June through August (BPA *et al.* 1995). The estimated number of visitor days for the Corps' facilities at Libby Dam and Lake Koocanusa (the dam, Souse Gulch, and the Libby Dam Visitors Center) averaged 44,092 visitor days per year from 1988-1994. Over the last 10 years (fiscal years 1995-2004) visitation at these facilities increased to an average of 50,915 visitor days per year (D. Wernham, pers. comm. Dec 2004). These visitation statistics do not include visitation at USFS lake-oriented recreation sites in KNF. Visitor-day use data is not available for these sites. Visitation for the entire KNF in fiscal year 2002 was estimated at 1.1 million total visitors (USFS 2003). The most recent consolidated estimate of visitor days for water related recreation activities at Libby Dam and Lake Koocanusa was 175,400 visitor days per year (calculated over period 1987-1993). (BPA *et. al.* 1995 Appendix J).

Recreation Activities: A variety of developed and less well developed recreational sites are located on both sides of the U.S/Canadian border along Lake Koocanusa. Recreational activities at these sites include fishing, boating, camping, and swimming. Several businesses on Lake Koocanusa rent houseboats. A summary of Lake Koocanusa recreation sites is provided in **Table 1**.

Table 1: Lake Koocanusa Recreational Facilities

SITE NAME	BOATING	FISHING	SWIMMING	CAMPING
Barron Creek	●	●		●
Canyon Creek	●			●
Englishman Creek	●			●
Gateway Boat Camp	●	●		●
Gold Creek Bay	●	●	●	●
Kikomun Creek Provincial Park	●	●		●
Koocanusa Lake Campsite and Resort	●	●		●
Lake Koocanusa Resort and Marina	●	●	●	●
Mariner's Haven	●	●		●
McGillivray	●	●	●	●
Newgate Sandy Shores Resort	●			●
Peck Gulch	●	●		●
Rexford Bench Complex	●	●	●	●
Rocky Gorge	●	●		●
Souse Gulch	●			
Tobacco Plains	●	●		●
Tobacco River		●		●
Wardner Provincial Park		●	●	
Warland Flats	●			●
Yarnell Islands				●
Lake Koocanusa Visitor Center				

Boating and Fishing: Fishing on Lake Koocanusa is reported to be the primary activity at the lake, with 45% of visitors reporting that fishing or related activities were the main reasons for visiting (BPA *et al.* 1995). Most fishing on the lake requires the use of a boat and most boating on the lake is associated with fishing (Shapiro 1985). The lake is available for fishing year round, including summer angling for game fish and winter ice-fishing. Game fish present include cutthroat trout, bull trout, rainbow

trout, kokanee, mountain whitefish, and burbot (BC Adventure 2004). Bull trout are currently listed as threatened with critical habitat areas requiring specialized management. Beginning in 2004, MT has allowed limited harvest of bull trout in Lake Koocanusa. The lake is stocked with rainbow trout (BPA *et al.* 1995).

There are 13 boat launches on the U.S. side of the lake, managed by the USFS and the Corps, and five improved boat launches on the Canadian side of the border, managed by the BC Provincial Parks and private owners. Additionally, there are two private campground/marinas (Lake Koocanusa Resort and Marina, on the east side of the lake 6 miles upstream from Libby Dam, and Mariner's Haven near Rexford, MT) on the U.S. side of the lake. Moorage slips, rental cabins, a care and convenience store, rental boats, and service shop are all available. In Canada, a commercial campground, boat launch, marina and store are located on the west shore of the reservoir, opposite Kikomun Creek. **Table 2** lists the minimum lake elevations for boat ramp operations at Lake Koocanusa.

Table 2: Lake Koocanusa Minimum Usable Boat Ramp Elevations

LAKE KOOCANUSA FULL POOL ELEVATION (FT):		**2459**
BOAT RAMP	**MINIMUM USABLE BOAT RAMP ELEVATION (FT)**	**MINIMUM USABLE BOAT RAMP ELEVATION (FT BELOW FULL POOL)**
U.S. Ramps		
Tobacco River	2449	10
Gateway Boat Camp	2445	14
Warland Flats	2444	15
Tobacco Plains	2433	26
Koocanusa Lake Campsite and Resort	2420	39
Mariner's Haven	2420	39
McGillivray	2385	74
Rocky Gorge	2370	89
Rexford Bench Complex	2341	118
Lake Koocanusa Resort and Marina	2334	125
Peck Gulch	2310	149
Souse Gulch	2310	149
Barron Creek	2282	177
Canadian Ramps		
Englishman Creek	2458	1
Newgate Sandy Shores Resort	2439	20
Koocanusa Marina	2430	29
Golden Ears (Gold Creek Bay)	2427	32
Kikomun Creek Provincial Park	2396	63

Swimming: Swimming and picnicking are popular activities on Lake Koocanusa, each accounting for 25% of recreation participation while at the lake (BPA *et al.* 1995). There are two swimming beaches on the U.S. side of the lake (McGillivray and Rexford Bench). The Souse Gulch boat dock also serves as a popular swimming destination for local residents. On the Canadian side of the lake, there are swimming beaches at both Kikomun Creek and Wardner provincial parks. Swimming is a popular activity with MT residents from Libby, Eureka and Rexford. Swimming is also a side activity for the recreational boaters who will stop at small secluded beach areas (BPA *et al.* 1995).

Camping: Camping along Lake Koocanusa is a popular activity that accompanies many boating, fishing, swimming and picnicking activities. Camping facilities typically include improved campsites, picnic tables, toilet facilities, and some locations have recreational vehicle (RV) hookups. The Corps and USFS operate and maintain eleven campgrounds on the U.S. side of the lake. There are six camping areas on the Canadian side of the lake, managed by BC Provincial Parks and private owner/operators.

Other Recreational Activities and Aesthetics: At Libby Dam, tourists can visit the visitor center that is managed by the Corps and offers a viewpoint tower. Several highways in the area are identified as scenic drives. MT State Highway 37 is a scenic by-way following the Kootenai River along Lake Koocanusa. Tourists frequently drive and hike throughout the Kootenai River Basin, enjoying views of natural landscapes and local wildlife. Many of these landscapes are enhanced by the regional water features of the Kootenai River, Kootenay Lake, and Lake Koocanusa (BPA *et al.* 1995).

Typical Reservoir Operation: Current dam operations are such that in low water years, boat ramp access can be problematic when the reservoir is drawn down. Commercial marinas along Lake Koocanusa are dependent on the reservoir filling to within 10 feet of the full pool elevation of 2459 feet.

2.2 Kootenai River

General Information: Downstream from Libby Dam the Kootenai River follows a meandering course, passing over Kootenai Falls nine miles west of the town of Libby, MT. The river flows northwesterly through Troy, MT and Bonners Ferry, ID, eventually turning north and crossing the border back into BC.

Recreation Management: The Corps operates three recreation sites downstream from Libby Dam; Alexander Creek, Dunn Creek, and Blackwell Flats. ID Department of Parks and Recreation provides boating facilities. Boundary County Parks and Recreation maintains two boat launches on the Kootenai River; Deep Creek and Copeland, which provide docks for fishing. In addition, the Corps manages 448 acres downstream from the dam as habitat for big game and waterfowl. Further downstream, the U.S. Fish and

Wildlife Service manages the Kootenai National Wildlife Refuge, providing outdoor recreational opportunities. In the U.S., The Kootenai River is bordered by both the Kootenai and Kaniksu National Forests which are managed by the USFS. In Canada, the Creston Valley Wildlife Management Area (CVWMA), a non-profit regional wildlife and recreational area, is a 17,000-acre wetland adjacent to the Kootenay River, offering bird and wildlife viewing, and non-motorized boating.

Recreation Access: The Kootenai River is accessible via U.S. Highway 2, which follows the river out of MT and up to Bonners Ferry, ID. As the river turns north, it runs through the Kootenai Indian Reservation, which is paralleled by ID State Highway 1.

Visitation: The estimated number of visitor days for the three Corps' facilities on the Kootenai River averaged 6,786 visitor days per year from 1988-1994. Over the last 10 years (fiscal years 1995-2004) visitation at these facilities increased to an average of 13,121 visitor days per year (D.Wernham, pers. comm. Dec 2004).

Recreation Activities: Recreational opportunities along the river are primarily fishing, boating, camping, sightseeing and wildlife viewing. The Kootenai Flats area, downstream from Bonners Ferry, is located in the scenic Purcell trench and includes the Kootenai National Wildlife Refuge area just downstream of Bonners Ferry. Recreation facilities on the river are summarized in **Table 3**.

Table 3: Kootenai River Recreational Facilities

SITE NAME	BOATING	FISHING	SWIMMING	CAMPING
Alexander Creek				●
Blackwell Flats	●			●
Copeland	●			
Deep Creek	●			
Dunn Creek				●
Porthill	●			
Yaak River	●	●		●

Boating: Downstream from Libby Dam/Lake Koocanusa, boating opportunities on the Kootenai River are mostly related to float boating for fishing. The Kootenai is a big river and fly fishing from a boat is a popular method of fishing the river. Between Libby Dam and Kootenay Lake, there are a total of eight improved boat ramps and several unimproved boat ramp and fishing access points. Kayaking and rafting are popular activities at Kootenai Falls, MT and downstream between the Yaak River confluence in MT and the Hwy 2 bridge in Bonners Ferry, ID. (BSF 2004).

Fishing: Sportfishing opportunities primarily focus on rainbow and cutthroat trout. This reach of the river is a blue ribbon rainbow trout fishery and is a popular draw for anglers. Westslope cutthroat, bull trout and the occasional brown trout are found in this reach, but the primary sport fishery is for rainbow trout. In 1997, the freshwater world record rainbow trout was caught along this reach of the river. This stretch of the Kootenai also holds the MT state record for mountain whitefish (BSF 2004).

Other species found in this reach include the Kootenai River population of white sturgeon, which was listed as endangered in 1994 and burbot, which are also in decline, and kokanee. Fishing for white sturgeon, bulltrout and burbot is prohibited. Local guide services, outfitters, and gear shops are a growing part of the recreational economy (BPA *et al.* 1995). In 2004, there were more than five river outfitting services listed in Libby and Troy, MT. The river is primarily fished by floating, although there are some wadeable areas along the banks at certain times of the year (BSF 2004).

Camping: There are four maintained campgrounds located along the river from Libby Dam, downstream to the Canadian Border. These are shown in **Table 3**.

Other Recreational Activities and Aesthetics: Downstream of Libby Dam, the Kootenai River follows a free flowing meandering course. Nine miles west of Libby, MT the river passes over scenic Kootenai Falls. The landscape along this reach transforms from a narrow river valley near the reservoir (3 to 4 miles wide) to a wider valley through Kootenai Flats (5 miles wide or greater towards BC).Valley hillsides and nearby mountains are covered with stands of coniferous trees such as ponderosa pine, western larch, and Douglas fir. A variety of riparian plants can be found along the river. Most of the potential viewers of the reservoir and river are residents of nearby towns. Residents can view the reservoir and river from a number of locations including private property, local roads, and recreation facilities. Visitors from outside the immediate area can also view the river from roads and nearby recreation facilities. (BPA *et. al.* 1995 Appendix J)

2.3 Kootenay Lake

General Information: After crossing the border into BC, the Kootenay River flows into Kootenay Lake, which provides several river and lake-related recreational opportunities. Boating, sport fishing and camping abound in this region.

Recreation Management: Public recreation management at Kootenay Lake is provided by BC Parks of the Ministry of Water Land and Air Protection, and by the Ministry of Forests, Kootenay Lake Forest District. Some privately-operated resorts offer lake-oriented recreation activities. Kootenay Lake is bordered by several Provincial Parks, which are managed by BC Parks.

Recreation Access: Kootenay Lake is accessible from the east via Highway 3A. The Kootenay Lake Ferry offers free service across the lake, and the highway continues along the west arm of the lake to Nelson, B.C.

Visitation: In the period 1996 to 2001, annual average park visits for the BC Parks, Kootenay District was slightly less than 2.0 million visitors per year. Camping and day use continues to grow and boating use has increased substantially in the area (CRN 2004).

Recreation Activities: Many recreational activities take place on Kootenay Lake, including boating, fishing, swimming, camping, and sightseeing. Provincial and regional parks bordering the lake provide camping, hiking, and picnicking areas. Several privately-operated resorts and marinas also exist along the lake, primarily in the vicinities of Nelson, Balfour, Kaslo, and the eastern shore south of Kootenay Bay. Several marine parks, accessible only by boat, are located on the south arm of the lake. Recreation facilities on the lake are summarized in **Table 4**.

Table 4: Kootenay Lake Recreational Facilities

SITE NAME	BOATING	FISHING	SWIMMING	CAMPING
Bayshore Resort	●	●		●
Davis Creek/Lost Ledge	●	●	●	●
Drewry Point	●	●	●	●
Garland Bay	●	●	●	●
Gray Creek Auto Camp	●		●	●
Kootenay Kampsites				●
Lockhart Beach	●	●	●	●
Lockhart Creek		●	●	●
Midge Creek	●	●	●	
Mountain Shores Resort and Marina	●	●	●	
Pebble Beach				●
Pilot Bay	●	●	●	●
Pilot Bay Resorts	●	●	●	
West Arm Provincial Park		●	●	
Downstream Vista				

Boating: Several types of boating take place on the lake, including houseboating, sailing, kayaking, cruising, sightseeing and fishing. Operators, businesses and marinas located around the lake provide charter services, rentals, and boat access on the lake. In addition, there are several smaller improved boat ramp access points and campground areas along the shoreline of the lake. Overall, there are eleven recreational facilities on Kootenay Lake that provide boat access, docking, and fueling for recreational boaters. Downstream from the lake, there are several reaches of river and rapids for kayaking. Brilliant Dam operators manage flows in coordination with the boating community (TekCominco 2001).

Fishing: At Kootenay Lake, fishing takes place for Gerrard rainbow trout (with some upwards of 20 pounds in weight), Yellowstone cutthroat trout, kokanee, and Dolly Varden. Fly fishing in the late summer with floating line is particularly productive. The Yellowstone cutthroat is more common in the southern end of the lake whereas the north end of the lake is good for kokanee. Sheltered Crawford Bay provides excellent fishery for Gerrard rainbows, bull trout and largemouth bass (FishBC 2004). Fishing boat charters recommend October through May for Gerrard rainbow angling (Split-Shot 2004). Duck Lake, a managed impoundment near the south end of Kootenay Lake in the Creston Valley Wildlife Management Area, provides boating and fishing opportunities unique to the area with its sheltered waters and fishery for bass and other warmwater fish species.

Swimming: Swimming is common at several of the campsites, resorts, marinas, beaches and pocket beaches along the shoreline of the lake.

Camping: The lake has twelve campgrounds and resorts that are owned and operated by BC Provincial Parks or private operators.

Other Recreational Activities and Aesthetics: Relatively undeveloped, the Kootenay Lake Valley exhibits thickly forested mountains and pristine waters. Kootenay Lake is fed by numerous creeks and its rocky shores encompass hundreds of tiny bays and beaches that can be explored by kayak or canoe. Approximately half of the lakeshore has roads, with the balance accessible only by boat. Settlements occupy a thin lakeside band where the roads follow the lakeshore. Opportunities for wildlife viewing exist with large populations of deer, elk, moose, bear, mountain goat, cougar, and coyote. Kootenay Lake remains ice-free in winter, and wetlands at both ends of the lake and at Crawford Bay, including the 7,000 hectare (17,298 acre) Creston Valley Wildlife Management Area, host over 260 species of migrating and nesting birds. Popular area sightseeing activities include a scenic drive down the lake to Creston or a ferry ride across the lake. A network of hiking trails of varying difficulty is offered providing scenic views of the lake and surrounding mountains. (Kootenay Lake Visitors Guide 2004).

3.0 Area 2 - Flathead/Clark Fork/Pend Oreille River Basin

Area 2 is dotted with recreational opportunities, offered in areas such as the Glacier National Park and Kootenai, Flathead, Lolo, Kanisku, Coeur d'Alene and Colville National Forests. Numerous developed and undeveloped recreation facilities are located along the rivers and reservoirs, which include state parks, privately owned campgrounds and resorts, picnic areas, public beaches, scenic viewpoints and byways, historic markers, and hot springs. Many wildlife refuges, natural scenic, hiking, and wilderness areas, and wildlife management areas are also present in this area.

The relatively pristine nature of the area is one of its primary recreation attractions. In addition to the area's high scenic quality, visitors have an opportunity to view an abundance of wildlife. Threatened or endangered species in the area include the gray wolf, grizzly bear, bald eagle, peregrine falcon, and bull trout. Big game species that draw hunters into the area throughout the year include deer, elk, and moose. Migratory waterfowl, fur bearers, and non-game species are also abundant in the area (BPA *et al.* 1995).

3.1 Hungry Horse Reservoir

General Information: Hungry Horse Reservoir is located 15 miles southwest of the west entrance to Glacier National Park, 20 miles northeast of Kalispell, MT (estimated population 15,463 in 2002), and 4 miles southeast of Hungry Horse, MT (population 934 in 2000). This
34-mile-long reservoir has 133 miles of shoreline and sits at an elevation of over 3500 feet. Hungry Horse Reservoir is located within 30 miles of the Continental Divide and is surrounded by high mountain peaks.

Recreation Management: The Flathead National Forest manages 6,729 acres of land around Hungry Horse Reservoir under a 1969 Memorandum of Agreement with Reclamation (BPA *et al.* 1995). Hungry Horse Reservoir is completely surrounded by national forest lands and there are no cabins or private lands located along the lake.

Recreation Access: Approximately 115 miles of road circle Hungry Horse Reservoir and provide good access for recreation around, and just beyond the head of the reservoir. Forest Road 895 on the west side of the reservoir passes over Hungry Horse Dam and is paved for the first 11 miles to Lid Creek Campground. Forest Road 38 is a rough dirt road and travels along the east side of the reservoir. The roads meet at the head of the reservoir and continue on 6 miles to Spotted Bear which has three guest ranches and no services. A trailhead at the south end of the road provides access to the Bob Marshall Wilderness, one of the largest wilderness areas in the lower 48 states.

Visitation: Visitation figures have not been collected at Hungry Horse Reservoir for over 10 years; however, according to USFS staff, visitation appears to be steadily increasing

(Burren 2004). Visitation at Hungry Horse Dam and Reservoir was estimated at 93,500 visitor days for 1993. From 1987 to 1993 the 7-year average visitation was 79,200 visitor days (BPA *et al.* 1995). Hungry Horse Reservoir is not considered a primary recreation destination spot in the basin. As pressure increases on surrounding recreation sites, overflow use goes to Hungry Horse Reservoir. Approximately 50 percent of the visitors to Hungry Horse Reservoir live within 50 miles of the reservoir (BPA *et al.* 1995).

Recreation Activities: Primary recreation activities at Hungry Horse Reservoir are camping, fishing, and boating. Also popular is sightseeing, and non-reservoir dependent activities such as huckleberry picking and hunting. Recreation facilities on the lake are summarized in **Table 5**.

Table 5: Hungry Horse Reservoir Recreational Facilities

SITE NAME	BOATING	FISHING	SWIMMING	CAMPING
Doris	●	●		●
Lost Johnny Campground	●	●		●
Lost Johnny Point Campground	●	●		●
Wounded Bear Ob. Pt.				●
Lid Creek Campground	●	●		●
Lakeview				●
Abbot Bay	●	●		●
Emery Bay Campground	●	●		●
Riverside	●	●		●
Murray Bay Campground	●	●		●
Canyon	●	●		●
Devil's Corkscrew Campground	●	●		●
Fire Island				●
Elk Island				●

Camping: Fifteen campgrounds as well as dispersed recreation sites surround the reservoir. Facilities include approximately 174 single camp units, one group camp site with a 150 person capacity, and 27 picnic units (BPA *et al.* 1995). To some extent, the Hungry Horse campgrounds serve as overflow facilities when campgrounds at Glacier National Park are full (BPA *et al.* 1995).

Fishing: The reservoir receives relatively light angling pressure. The reservoir is low in nutrient input and primary productivity (Corps 2002). Unlike most MT reservoirs, The reservoir is not stocked with fish; however, native fish populations are currently considered good. Species present in the reservoir include bull trout, westslope cutthroat trout, and mountain whitefish. Fishing for bull trout is closed. The reservoir is open year round to fishing; however, May through November receive the greatest fishing use.

Boating: There are 10 boat ramps along the reservoir (Burren 2004). Reservoir full pool is at elevation 3560 feet. Abbot Bay, on the east side, is the longest boat ramp providing access when the reservoir is down 130 feet below full pool. Lost Johnny Point is the longest boat ramp on the west side and provides access down to 45 feet from full through a series of several high water and low water boat ramps. Lake levels are important for boating access to the reservoir. As lake levels decrease throughout the summer months, there is a potential to strand certain boat ramps above the reservoir water levels. The minimum usable boat ramp elevations are presented in **Table 6**.

Table 6: Hungry Horse Reservoir Minimum Usable Boat Ramp Elevations

	HUNGRY HORSE RESERVOIR FULL POOL ELEVATION (FT):	3560
BOAT RAMP	**MINIMUM USABLE BOAT RAMP ELEVATION (FT)**	**MINIMUM USABLE BOAT RAMP ELEVATION (FT below FULL POOL)**
Doris	3545	15
Canyon Creek	3542	18
Murray Bay Campground	3540	20
Lost Johnny Campground	3536	24
Lid Creek Campground	3529	31
Emery Bay Campground	3527	33
Devil's Corkscrew Campground	3517	43
Lost Johnny Point Campground	3515	45
Riverside	3507	53
Abbot Bay	3430	130

Other Recreational Activities and Aesthetics: The relatively pristine nature of the area is one of the primary recreational attractions, affording high scenic qualities and the opportunity to see an abundance of wildlife (Corps 2002). The primary destination for the area is Glacier National Park. The dam itself is also a major tourist draw in the area.

Hungry Horse Reservoir is not visible from US Highway 2, the major access road to Glacier National Park. Views from the shores and pool of the reservoir are confined to the river valley and adjacent mountains. The mountainous terrain adjacent to the

reservoir is steep with peaks ranging up to approximately 8000 feet in elevation. Coniferous forest surrounds the reservoir and views can extend 10 to 12 miles up and down the reservoir (BPA *et al.* 1995).

Typical Reservoir Operation: Since 1995 Hungry Horse Reservoir has been managed for flood control, minimum flows from the reservoir, minimum flows at Columbia Falls, salmon augmentation, and power production. The reservoir must refill by June 30, so except for extremely dry years where minimum flow requirements do not allow for refill, the reservoir is nearly full every summer. The reservoir is then drafted 20 feet from full by August 31 for salmon augmentation. The severe drawdowns that were common from 1987-1993 no longer occur. Since December 2000, the reservoir has been operated with ramping rates restrictions and minimum flows, so power-peaking fluctuations in water levels no longer occur.

3.2 Flathead River

General Information: The South Fork of the Flathead River flows for 5 miles below Hungry Horse Dam before joining the mainstem. Downstream from the confluence of its three forks, the Flathead River enters the Flathead Valley, and traverses predominantly cropland (Corps 2002). As the river approaches Columbia Falls, MT (estimated population 3827 in 2002) and Kalispell, MT (estimated population 15,463 in 2002), land use becomes increasingly developed and urban in character.

Recreation Management: The Flathead National Forest manages portions of federal lands below Hungry Horse Dam along the South Fork. On January 20, 2004, the USFS issued a Notice of Intent to prepare an Environmental Impact Statement to revise Forest Plans for the Bitterroot, Flathead, and Lolo National Forests. As part of this effort an *Assessment of the Management Situation* was done, and recreation was identified as one of six areas needing major changes. Release of the final revised forest plans is estimated for February 2006 (USFS 2004).

Recreation Access: The mainstem of the Flathead River runs adjacent to U.S. Highway 2, just below the confluence with the South Fork, and flows under the highway in the town of Columbia Falls, MT (BPA *et al.* 1995). Numerous day-use sites provide good river access to this 35-plus-mile reach of the river (**Table 7**).

Visitation: Although recreation use figures are not available along the Flathead River, the USFS indicates that use is steadily increasing (Burren 2004, BPA *et al.* 1995).

Recreation Activities: Primary recreation activities are fishing and boating. Other popular activities include sightseeing, camping, and picnicking. Recreation sites are present on all three forks of the river, including undeveloped boat ramps, sanitary facilities, and parking areas. There are no developed campgrounds, although camping occurs on a dispersed basis along the South Fork below the dam. Fishing is a major

recreational activity, and contributor to the local economy, that draws many thousands of visitors to the area. Recreation facilities on the river are summarized in **Table 7**.

Boating: This 35-mile stretch of the Flathead River is popular, but not crowded, for floating and boating. The current is generally fast, navigation is reasonably easy, and access is good. There are six boat ramps providing access to the river reach for fishing and boating. The boat ramps are not improved and do not have formal docks, marinas or structural access ramps. Boat access can become restricted when water levels drop.

Fishing: The South Fork and the mainstem of the Flathead River below Hungry Horse Dam are not considered great fisheries and receive low fishing pressure as compared to other MT rivers. The river itself is fed primarily by snowmelt resulting in clear, fast, cold water with fewer nutrients than many other MT rivers. The river fishery, primarily kokanee, has declined, reducing angler opportunities (BPA *et al.* 1995). The optimal discharge range for fishing along the river is 4,000 to 17,000 cfs (T.Tzeidt, pers. comm.). Cutthroat trout, whitefish, and bull trout are present in the river and northern pike can be found in the slower segments south of Kalispell.

Selective withdrawal facilities were added to Hungry Horse Dam in the mid 1990s to allow water to be drawn from any depth in the reservoir. Prior to this modification, all releases came from the bottom of the dam where the water was coldest. This very cold water had a negative affect on the fishery and aquatic hatches on the South Fork as well as the mainstem Flathead River, as well. With this modification, the dam now releases water that has the same temperature as the main stem of Flathead River. Insect hatches have improved and it is expected that fishing will also improve in time.

Table 7: Flathead River below Hungry Horse Dam Day Use Recreational Facilities

SITE NAME	BOATING	FISHING	RIVER MILE
Tea Kettle	●	●	143.6
Kokanee Bend	●	●	141.2
Pressentine Bend	●	●	136.2
Old Steel Bridge – in Kalispell, MT	●	●	128.5
Foys Bend Access Site[1]	●	●	122.0
Sportsman Bridge[1]	●	●	107.5

[1]site primarily used to access Flathead Lake

Other Recreational Activities and Aesthetics: Between Hungry Horse Dam and Flathead Lake, the Flathead River valley is largely in agricultural production or developed and includes the communities of Hungry Horse, Columbia Falls, La Salle,

and Kalispell. Within this reach, the three forks of the Flathead River join to the north of Columbia Falls. The river valley is bordered by the Flathead National Forest, offering scenic views of the Swan Range to the east and the Salish Mountains to the west. Surface roads in the area provide access to hiking, sightseeing, and wildlife viewing opportunities. The Stillwater State Game Preserve is just north of Kalispell in this reach.

3.3 Flathead Lake

General Information: Flathead Lake is the largest freshwater lake in the western United States. The lake has nearly 200 square miles of surface area and 185 miles of shoreline. Prominent communities bordering the lake include Polson (estimated population 4,308 in 2002) and Bigfork (population 1,421 in 2000). The Flathead Indian Reservation surrounds the southern half of the lake. Yellow Bay, Wild Horse Island, and Finely Point State Parks are within the reservation. Flathead National Forest lands are close, but not adjacent to the lake on both the east and west sides. Flathead Lake is ringed by summer and year-round homes; many increasingly upscale and elegant.

Recreation Management: MT Fish, Wildlife and Parks manages six areas as part of Flathead Lake State Park. The southern half of Flathead Lake is located on the Flathead Indian Reservation and is managed by The Confederated Salish Kootenai Tribes (CSKT). Flathead Lake does not have a comprehensive recreation management plan but the 2003-2007 Montana Statewide Comprehensive Outdoor Recreation Plan (SCORP) provides some general direction for recreation management. Findings of the SCORP were that fishing and boating are near the top of the list of Montanans' favorite outdoor recreation activities, and also are a tourist draw (Montana SCORP 2003). It was determined that there is generally insufficient access to the lake for water-based recreation. One of 10 goals identified by the SCORP was to "enhance access for water-based recreation activities (fishing, boating)".

Recreation Access: Paved roads surround Flathead Lake. Six units of Flathead Lake State Park provide public access. Wildhorse Island, near Big Arm Bay, is the largest island in the lake at 2100 acres. It is managed by the MT Department of Fish, Wildlife and Parks as a wildlife refuge and is open for day-use only. Open space on the shoreline includes the National Wildlife Refuge on the north shore and state land managed by the Flathead Lake Biological Station as a refuge on the south shore (Polson Bay). The southern half of Flathead Lake is located on the Flathead Indian Reservation. Tribal fishing permits are required for fishing in this area.

Visitation: Consolidated visitation numbers are not available for Flathead Lake. Flathead County's population grew over 25 percent from 1990 to 2000, almost twice MT's state average growth of 12.9 percent during that period (U.S. Census 2004). Recreation use across the Interior Columbia River Basin (which includes Flathead County) is increasing at 2.3 percent per year and is expected to double in 29 years (USFS 2004).

Recreation Activities: Popular activities on the lake are fishing and boating. Other activities include camping, swimming, hiking, biking, and horseback riding. Winter activities include ice fishing, ice skating, skiing, and snowmobiling. Recreation facilities on the lake are summarized in **Table 8.**

Table 8: Flathead Lake Recreational Facilities

SITE NAME	BOATING	FISHING	SWIMMING	CAMPING
Bigfork	●	●		
Ducharme	●	●		
Elmo	●	●		
Woods Bay	●	●		
Walstad	●	●		
Somers	●	●		
Big Arm	●	●	●	●
Finley Point	●	●	●	●
Wayfarers	●	●	●	●
West Shore	●	●	●	●
Wild Horse Island		●	●	
Yellow Bay	●	●	●	●
Arrowhead Park and Marina	●	●	●	●
Marina Cay Resort and Conference	●	●	●	
Bayshore Resort	●	●	●	
Averills Ranch	●	●	●	

Boating: On Flathead Lake, eleven public sites have boating facilities. Additional private boat ramps and docks are located on the lake. Typically, facilities include access ramps, docks, marinas, fueling stations, mooring and camping areas. Boating on Flathead Lake is primarily for fishing. Sailing, cruising and waterskiing are also popular activities. Several commercial companies offer guided fishing trips, boat rental and scenic cruises on Flathead Lake. Minimum operable boat ramp elevations are presented in **Table 9**.

Table 9: Flathead Lake Minimum Usable Boat Ramp Elevations

	FLATHEAD LAKE FULL POOL ELEVATION (FT):	2893
BOAT RAMP	**MINIMUM USABLE BOAT RAMP ELEVATION (FT)**	**MINIMUM USABLE BOAT RAMP ELEVATION (FT below FULL POOL)**
Ducharme (MFWP)	2893	0
Averills Ranch	2892	1
Arrowhead Park and Marina	2891	2
Marina Cay Resort and Conference Center	2891	2
Bigfork (MFWP)	2890	3
Finley Point (MFWP)	2890	3
Bayshore Resort	2886	7
Walstad (MFWP)	2885	8
Woods Bay (MFWP)	2884	9
Note: Ramp elevations were provided by Jim Vashro of Montana Fish, Wildlife and Parks (MFWP) for the MFWP ramps through personal communications in 2004. The remaining ramps in Table 9 are privately operated and elevations were obtained through personal communications with facility managers in 2004.		

Fishing: Flathead Lake is considered one of the premiere fishing lakes in MT, attracting many thousands of anglers annually. Fishing is popular for cutthroat trout, yellow perch, lake trout, kokanee, and whitefish. The State of MT controls waters on the northern half of the lake, while CSKT control the southern end of the lake waters.

Swimming: The lake offers ten recreational facilities with swimming amenities. These sites include Big Arm, Finley Point, Wayfarers, West Shore, Wild Horse Island, Yellow Bay, Arrowhead Park and Marina, Marina Cay Resort and Conference Center, Bayshore Resort, and Averills Ranch.

Camping: Around the lake, there are seven state-run campground facilities, and many more private resorts offering lodging and camping facilities. Camping facilities offer a variety of campsites, picnic areas, boat access, RV hookups, swim beaches, toilets and showers.

Other Recreational Activities and Aesthetics: A 90-mile scenic paved loop road around the lake provides panoramic views and access to the campgrounds, picnic areas, hiking trails, and orchards. Narrated scenic cruises of the lake are also commercially available during the summer season. Visual quality is high, key observation points are numerous, and public sensitivity to changes is great. Mixtures of forest, rangeland, cropland, orchards, and pasture/meadow areas, as well as residential, commercial, and recreational development surround the lake (Corps 2002).

Typical Lake Operation: Regulation of outflow by Kerr Dam maintains the lake's level between 2883 and 2893 feet above sea level. The lake level is typically brought to 2890 feet by the end of May and to full pool (elevation 2892.75) by June 15. From 1951

through 2000, the average summer elevation was 2892.75 (Flathead Lakers 2004). During low water years parts of the lake shoreline can become exposed, making boat access difficult.

3.4 Lower Flathead River

General Information: The lower Flathead River flows out of Flathead Lake from Kerr Dam, downstream through Polson, MT to its confluence with the Clark Fork near Paradise, MT. Recreational opportunities on the lower Flathead are more limited than other sections of the river. This lower Flathead stretch has a low gradient and primarily warmwater fishery known for a variety of trout, northern pike and some largemouth bass.

Recreation Management: The majority of the lower Flathead River lies within the Flathead Indian Reservation, and is managed by CSKT.

Recreation Access: MT State Highway 200 parallels the lower Flathead River from Dixon, MT to the confluence with the Clark Fork in Paradise, MT.

Visitation: Recreation use statistics are not available along the lower Flathead River.

Recreation Activities: Recreational activities include boating and fishing. Fishing on the lower Flathead is less desirable for most anglers compared to sections of the Flathead upstream of the lake (FFC 2004). Another recreational opportunity along the lower Flathead is whitewater kayaking and rafting.

Boating: Downstream from Kerr Dam, kayaking is popular along the Buffalo Rapids reach. This section of the Flathead flows through lightly forested canyon and offers good whitewater and the big waves and holes of Buffalo Rapids. At flows above 20,000 cfs, many of the rapids wash out, though powerful currents and suctions can be hazardous. Also, this river stretch becomes more difficult at low to moderate flows when large waves and holes develop and some sharp drops and rocks appear (Allaboutrivers 2004).

Fishing: The lower Flathead River offers limited fishing opportunities. River navigation is difficult directly downstream from Kerr Dam through Buffalo Rapids. Fish species found in the lower Flathead include mountain whitefish, five species of trout including rainbow, bull, brown, cutthroat and brook, as well as non-native northern pike and largemouth bass. Expectations are that northern pike and largemouth bass fishing will become more popular in this reach as their availability becomes more generally known (BPA 1983).

Other Recreational Activities and Aesthetics: The lower mainstem Flathead River drains from the southwest corner of Flathead Lake and draws waters from an arid valley basin throughout its 75-mile course. The Flathead River empties into the Clark Fork at Paradise, MT. Most of this scenic reach of the river flows through a narrow valley bordered by scenic mountains within the Flathead Indian Reservation. A

diversity of fish and wildlife complement the land and water resources, and contribute to both the natural and cultural values of the lower Flathead river environment. (MFWP 2004a) Recreational boaters along the lower Flathead River have opportunity to view many birds of prey and waterfowl. (E-Raft 2004).

3.5 Lower Clark Fork

General Information: Three reservoirs on the lower Clark Fork provide recreation opportunities between Kerr Dam and Lake Pend Oreille. Thompson Falls, Noxon Rapids, and Cabinet Gorge are run-of-the-river reservoirs providing fishing, camping, picnicking, boating, water skiing, and other recreation activities.

Recreation Management: Recreation facilities are provided by MT Fish, Wildlife and Parks; Kanisku and Kootenai National Forests; and Avista Corporation. In 2001, Avista Corporation began a renewed 45-year license to operate Noxon Rapids Dam and Cabinet Gorge Dam collectively as the Clark Fork Project. The relicensing process led to new recreation resource management plans and improvements to numerous recreation sites along both reservoirs and the lower river.

Recreation Access: MT State Highway 200 parallels the Clark Fork from its confluence with the lower Flathead River in Paradise, MT to the ID border. The highway continues as ID State Highway 200 following the river to its confluence with Lake Pend Oreille, in ID.

Visitation: No visitation data is available for the lower Clark Fork.

Recreation Activities: Recreation opportunities include fishing, camping, boating, picnicking, swimming and sightseeing along the lower Clark Fork. This reach of the river is much different than the upper reaches of the upper and middle Clark Fork. Water flows more slowly and deeply along this reach, due in part to the backwater effects of the dams and reservoir areas. Dispersed recreation areas adjacent to the river and lake areas take advantage of the natural beauty provided by the water environment. These recreation areas have a range of facilities including unimproved and constructed boat ramps, parking, drinking water, flush and pit toilets, camping, RV hookups, picnic shelters, swimming beaches, including some with disabled access. A planned recreation element is the expansion of a trail system along the river and lake areas (Avista 2003). Recreation facilities on this reach are summarized in **Table 10**.

Table 10: Lower Clark Fork Recreational Facilities

SITE NAME	BOATING	FISHING	SWIMMING	CAMPING
Thompson Falls State Park	●	●	●	●
Flatiron Ridge Boat ramp	●	●		
Finley Flats Recreational Area	●	●		●
Trout Creek Community Park	●	●	●	
North Shore Campground	●	●	●	●
Marten Creek Recreational Area	●	●		●
Pilgrim Creek Recreational Area		●		
Noxon Park	●	●		
Triangle Pond			●	
Bull River Campground	●	●	●	●
Heron Boat Launch	●			
Noxon Rapids Viewpoint				
Cabinet Gorge Dam Viewpoint				

Boating: There are nine boat ramp facilities along the lower Clark Fork. Most of these are unimproved ramps (access only), and a few have marina and docking facilities. Boat ramps are typically used for scenic float trips and float fishing (MFWP 2004).

Fishing: The lower Clark Fork reach flows through Noxon Rapids Reservoir and Dam, and the Cabinet Gorge Reservoir and Dam before entering Lake Pend Oreille. This reach is considered a big-water fishery with deeper, slower moving water. The fishery includes mountain whitefish, westslope cutthroat trout, rainbow trout, brook trout, brown trout, as well as northern pike, rainbow trout, smallmouth bass, and yellow perch.

The Cabinet Gorge Fish Hatchery is located on this reach between the Cabinet Gorge Dam and Lake Pend Oreille. The primary species production is kokanee salmon, which are released each June into Lake Pend Oreille. The hatchery also breeds rainbow trout, westslope cutthroat and fall Chinook salmon.

Camping: There are five campground areas along the lower Clark Fork. Many of these camping areas are located along the shoreline of Cabinet Gorge and Noxon Rapids Reservoirs.

Other Recreational Activities and Aesthetics: From the confluence with the Flathead River, the Clark Fork flows north and west 350 miles through broad, semi-arid valleys, high mountain ranges, and steep-sided valleys; and terminates in Lake Pend Oreille, Idaho. The lower Clark Fork flows through sedimentary formations and a landscape sculptured by the massive outflows of glacial Lake Missoula. The river valley is narrow; bordered by mountains within the Lolo National Forest in the Upper two thirds of the reach and the Kanisku National Forest in the lower third. Good up-close viewing of bighorn sheep is available at the U.S. Forest Service KooKooSint Sheep Viewing Area (up river about 8 miles from Thompson Falls), especially in the March-May and November-December time frames. Three dams/reservoirs exist in the reach; Thompson Falls Dam, Noxon Rapids Dam & Reservoir, and Cabinet Gorge Dam and Reservoir. (Travel Montana 2005).

The Thompson Falls Dam located in town on the Clark Fork is a popular attraction for visitors. The Thompson Falls area has outstanding access to millions of acres of national forest lands. These lands offer a wide range of recreational possibilities including hiking, mountain biking, fishing, camping, and hunting. Winter provides backcountry skiing and snowmobiling. Sightseeing adventures include trails in old growth timber, wild flowers, waterfalls, mountain lakes, creeks, rivers, and wildlife such as deer, elk, moose, big horn sheep, mountain goats, bears, and many varieties of birds. (Travel Montana 2005a). Noxon Rapids Dam is located in a heavily wooded area of Western Montana. This area is rich with natural beauty and wildlife. It is not uncommon to see bighorn sheep, elk, turkey, deer, and eagles while on the water. (Montana B.A.S.S. Federation 2005) Cabinet Gorge Dam is located outside of Clark Fork, Idaho. Scenic views of the reservoir can be found along the Pend Oreille Scenic Byway (ID Highway 200). (IDP 2005)

3.6 Lake Pend Oreille

General Information: The lower Clark Fork flows into Lake Pend Oreille, which is a major recreational resource for northern ID. It is the largest and deepest lake in ID, being 43-miles long and a maximum of 1200 feet deep, with 111 miles of shoreline. Lake Pend Oreille offers trophy fishing, as well as sailing, swimming, and water-skiing in summer. Winter sports include cross-country skiing on groomed trails, and nearby skiing and snowmobiling. The discussion of recreation in this section also includes recreation resources along the Pend Oreille River between Lake Pend Oreille, downstream to Albeni Falls Dam.

Recreation Management: There are 27 developed recreation sites around the shoreline (BPA *et al.* 1995). Camping and day use opportunities are provided by the Corps, USFS, City of Sandpoint, ID, IDFG, and ID Department of Parks and Recreation (IDPR). Farragut State Park, located at the southern tip of the lake, is one of the largest state parks in ID, covering 4000 acres with 184 campsites. Farragut State Park has hosted many large gatherings including several Boy Scout Jamborees and Girl Scout Roundups attended by thousands of people. There are also numerous private marinas and resorts

offering a full range of services around the lake. Along the Pend Oreille River between Lake Pend Oreille and Albeni Falls Dam, 8 recreation areas are operated by the Corps, including 4 developed campgrounds and day-use areas, 2 day-use only areas, and 2 primitive access areas (Corps 2004a).

Recreation Access: Lake Pend Oreille is easily accessible, located only 50 miles from Spokane, WA, and 48 miles from Coeur d'Alene, ID. U.S Route 2 runs from the dam to Spokane, while Interstate 90 and U.S. Route 95 provide access from Coeur d'Alene, ID. Jet service is available to the Spokane, WA Airport, and Amtrak serves Sandpoint, ID (BPA *et al.* 1995).

Visitation: Between 1987 and 1993, Lake Pend Oreille recreation visitation was estimated to average 175,400 visitor days per year (BPA *et al.* 1995). More current visitation statistics are not available. The estimated number of visitor days for the Corps' facilities at Lake Pend Oreille averaged 131,953 visitor days per year from 1987-1994. Over the last 10 years (fiscal years 1995-2004), visitation at these facilities decreased to an average of 118,460 visitor days per year (Brengle, pers comm. Dec 2004). Approximately 75 percent of the recreation use at the lake occurs during the months of May through September (BPA et al. 1995).
Recreation Activities: Swimming, boating, fishing, camping, sightseeing, picnicking, hiking, horseback riding, hunting, and snowmobiling are popular activities. Recreation facilities at the lake include numerous boat ramps; moorage slips at 11 separate marinas; over 100 picnic sites; and more than 300 camp sites (BPA *et al.* 1995). Recreation facilities on the lake are summarized in **Table 11**.

Table 11. Lake Pend Oreille Recreational Facilities

SITE NAME	BOATING	FISHING	SWIMMING	CAMPING
Albeni Cove Recreation Area	●	●	●	●
Bayview Marina	●	●		
Beyond Hope Resort	●	●		●
Bottle Bay Marina	●	●		
Buttonhook	●	●		
Cedar Creek	●	●		
Evans Landing	●	●		
Farragut State Park	●	●	●	●
Floating Restaurant	●			
Garfield Bay	●	●	●	●

SITE NAME	BOATING	FISHING	SWIMMING	CAMPING
Granite Creek	●	●		
Hudson Bay Resort	●	●		
Hope Boat Basin	●	●	●	
Idaho Country Resorts	●	●		●
Island View Resort	●	●	●	●
Johnson Creek	●	●		
Lakeview Landing	●	●		
McDonalds Hudson Bay Resort	●	●	●	●
Morton Slough Access Area	●	●		
Northbay Landing	●	●		
Pend Oreille Shores	●	●		
Priest River Recreation Area	●	●	●	●
Pringle Park	●	●		
Red Fir Resort	●	●	●	
Riley Creek Recreation Area	●	●	●	●
Sandpoint Marina and City Beach	●	●	●	
Sam Owen Park	●	●	●	●
Springy Point Recreation Area	●	●	●	●
Talache	●	●		
Trestle Creek Recreation Area	●	●	●	
Whiskey Rock	●	●		

Boating: There are more than twenty-eight boating related facilities on Lake Pend Oreille. These include federal, state and city owned parks and campground facilities, as well as private resorts and marinas. Typically, these facilities have access ramps, docks, marinas, fueling stations, mooring and camping areas (ISPR 2004). There are also several charter boat and fishing outfitters who provide boat access to the lake. Minimum operable boat ramp elevations are presented in **Table 12.**

Table 12: Lake Pend Oreille Minimum Usable Boat Ramp Elevations

LAKE PEND OREILLE FULL POOL ELEVATION (FT):		2062.5
BOAT RAMP	**MINIMUM USABLE BOAT RAMP ELEVATION (FT)**	**MINIMUM USABLE BOAT RAMP ELEVATION (FT below FULL POOL)**
Beyond Hope Resort	2060	2.5
Island View Resort	2060	2.5
Springy Point Recreation Area	2059	3.5
Samowen Park	2056	6.5
Albeni Cove Recreation Area	2055	7.5
Buttonhook	2054	8.5
Farragut State Park	2054	8.5
MacDonald's Hudson Bay Resort	2054	8.5
Trestle Creek Recreation Area	2054	8.5
Idaho Country Resorts	2053	9.5
Bitter End Marina	2051.5	11
Garfield Bay	2051.5	11
East Hope	2048	14.5

Fishing: Over fourteen species of game fish inhabit Lake Pend Oreille, including Gerrard rainbow trout (kamloops), kokanee, whitefish, perch, crappie, bluegill, largemouth bass, rainbow, brown and brook trout (BPA *et al.* 1995). The world-record kamloops (37 pounds) was caught in the lake (IDPR website).

Camping: Lake Pend Oreille has nine campground areas that are owned and operated by both public and private entities. Two major camping areas are the Farragut State Park and Springy Point Recreation Area.

Swimming: Thirteen recreational sites with swimming beaches exist on Lake Pend Oreille.

Other Recreational Activities and Aesthetics: Lake Pend Oreille is situated at the foot of the Coeur d'Alene Mountains in the Bitterroot Range in a scenic forest setting of lodgepole pine, ponderosa pine, white pine, Douglas fir, poplar, western larch and grand fir. Most of Lake Pend Oreille is located adjacent to the Coeur d'Alene and Kaniksu National Forests and much of the shoreline is undeveloped. City Beach in downtown Sandpoint, ID offers hundreds of feet of sand beach with a sweeping view of the Cabinet Mountains east across the lake. Commercial sightseeing cruises are offered on the lake, and homes and businesses have been located to take advantage of lake views. Viewers of the reservoir include residents of local communities, recreationists and tourists, travelers on U.S. Routes 2 and 95 and ID State Highway 200, and Amtrak riders who can view the north and east sides of the reservoir.

Lake Pend Oreille provides a focal point for the current upward trend in recreational based tourism economy for the northern ID area. Additional recreational

opportunities near Lake Pend Oreille include sea kayaking, boat plane tours, and a drive around the Lake Pend Oreille scenic byway. The Corps of Engineers operates a visitor's facility at the Albeni Falls Dam (BPA *et al.* 1995).

Typical Reservoir Operation: Typical operations of Albeni Falls Dam regulate Lake Pend Oreille Lake levels for flood control and winter target elevations. Winter operations at Albeni Falls dam involve operating for three years at elevation 2055 feet and one year at elevation 2051 feet to aid in kokanee spawning.

3.7 Pend Oreille River - United States

General Information: The Pend Oreille River from Albeni Falls Dam to the Columbia River is impounded by a series of run-of-river dams. This has created a series of four long reservoirs along the reach, including two in the U.S., Box Canyon (55-miles long), and Boundary (17-miles long).

Recreation Management: Downstream from Albeni Falls Dam, the Pend Oreille River is a large flatwater river that travels from western ID, through the northeastern corner of WA, then briefly through BC to the confluence with the upper Columbia River, south of Trail, BC. Box Canyon Dam is owned and operated by Pend Oreille Utility District. Boundary Dam is owned and operated by Pend Oreille Utility District and Seattle City Light with some recreation lands manged by the Bureau of Land Management (BLM). The Colville National Forest operates 3 campgrounds along this reach of the Pend Oreille River in WA. Also, the WA Department of Fish and Wildlife manages the LeClerc Wildlife Area on the east side of the Pend Orielle River in this reach.

Recreation Access: U.S. Route 2 runs along the north side of the Pend Oreille River, from Sandpoint, ID to the WA border. As the river turns North, WA State Highway 20 follows along the western side to Tiger, WA. Then, WA State Highway 31 follows the western side of the river to Metaline Falls, where it crosses to the eastern side as the river flows into Canada.

Visitation: Visitation data is not available for recreation sites along the Pend Oreille River downstream of Albeni Falls Dam.

Recreation Activities: Recreation activities include fishing, boating, camping, picnicking, and sightseeing. Road access to both sides of the river is generally good, providing for numerous dispersed and some developed recreation opportunities. The Corps also operates a visitor center near Albeni Falls Dam. Recreation facilities on the river are summarized in **Table 13**.

Table 13: Pend Oreille River below Albeni Falls Dam Recreation Facilities

SITE NAME	BOATING	FISHING	SWIMMING	CAMPING
Pioneer Park	●	●		●
Blueside Resort	●	●		●
Metaline Falls	●	●		●
Bonner Park West	●	●		
Dock-n-Shop	●	●		
Laclede	●	●		
LeClerc Creek	●	●		●
Thama	●	●		
Town of Ione	●	●		
Edgewater Campground	●	●		●
Willow Bay Marina	●			●

Boating: Downstream from Lake Pend Oreille, boating activities on the Pend Oreille River, Box Canyon reservoir and Boundary Dam reservoir are primarily related to fishing; but power boating, cruising, sightseeing as well as kayaking and camping are all popular activities along this reach. There are eleven sites documented as providing boat access, fuel, docks, marina and/or other boating related services.

Fishing: The Pend Oreille River offers a year-round fishery that includes brook trout, brown trout, rainbow trout, cutthroat trout, largemouth bass, walleye, whitefish, spiney ray, and panfish (WDFW 2004a). Most fishing is oriented toward warmwater species along this reach of river (WDFW 2004a). The Kalispel Tribe of Indians stocks the river with largemouth bass from its hatchery.

Camping: Downstream from Albeni Falls Dam, six campground facilities are located along the Pend Oreille River.

Other Recreational Activities and Aesthetics: The WA reach of the Pend Oreille River is bordered primarily by the Colville National Forest to the east and by the Coleville and Kaniksu National Forests on the west. The nearby WA towns of Newport, Ione, and Metaline Falls have resource-based economies. The towns continue to develop recreational opportunities, many of which are related to the scenic beauty of the river. The LeClerc Creek Wildlife area offers opportunities to view local flora and fauna in a natural setting. Scenic views can be enjoyed along the Selkirk Loop, a designated scenic route in WA, ID, and Canada (Selkirk 2005).

3.8 Pend d'Oreille River - Canada

General Information: The River is spelled "Pend Oreille" in the U.S. and "Pend d'Oreille" in Canada. There are two dams and reservoirs on the river in Canada; Seven Mile Reservoir (9-miles long) and Waneta Reservoir (less than 5 miles in length). The reservoir impounded by Seven Mile Dam includes the Pend d'Oreille Recreation Area, southeast of Trail, BC.

Recreation Management: BC Hydro Manages Seven Mile Dam and the Pend d'Oreille Reservoir Recreation Area. Tek Cominco manages Waneta Dam.

Recreation Access: Highways 3B and 22A are major highways that connect Trail and Waneta, BC; and provide access to the Pend d'Oreille Recreation Area.

Visitation: No visitation data is available for the Pend d'Oreille Reservoir and Recreation Area.

Recreation Activities: Recreational opportunities include camping, picnicking, swimming, boating, canoeing, wildlife viewing and fishing. There are two developed recreation opportunities, Buckley Campground and Seven Mile Dam Viewpoint (BC Hydro 2004). Buckley Campground provides boat access, fishing, swimming, and camping. Fishing is popular downstream of Waneta Dam near the confluence with the Columbia River.

Boating: Pend d'Oreille Reservoir has a gravel boat launch and parking area for day-use boating at Buckley Campground, which is open from May 1 through Sept. 30 (BC Hydro 2004).

Fishing: The fishery includes several freshwater species including rainbow trout, walleye, burbot, whitefish and bull trout. There are several outfitting guides in the area, and many locals frequent the reach of the Pend d'Oreille River just downstream from Waneta Dam to the confluence of the Pend d'Oreille and Columbia Rivers (TekCominco 2001).

Camping: There is one campground at the Buckley Recreational Area on Pend d'Oreille Reservoir behind Seven Mile Dam north of the U.S. border.

Other Recreational Activities and Aesthetics: The Canadian section of the Pend d'Oreille River basin is virtually uninhabited. The nearest major city is Trail, approximately 20 km to the northwest. There are two dams (Waneta and Seven Mile) in this reach. The Pend d'Oreille Recreation Area is situated on Pend d'Oreille Reservoir, near BC Hydro's Seven Mile Dam, southeast of Trail. Recreational opportunities include camping, picnicking, swimming, boating, canoeing, wildlife viewing and fishing. The tailrace viewpoint is open year round. An additional scenic

viewpoint is located on top of the dam. There are opportunities for viewing many species of wildlife, including deer, bears and cougars in the recreation area. (BCHydro, 2004; and Wipperman 1996).

4.0 Area 3 - Columbia River Mainstem

The area of the mainstem Columbia River that is likely to be most affected by variations in discharge volume and timing from Libby and Hungry Horse Dams is the reach from the mouth of the Kootenay River in BC to Grand Coulee Dam in WA. It is anticipated that the operation of the Grand Coulee Dam will re-regulate variations in volume from those two upstream dams, thus minimizing any potential effects on recreation opportunities on the mainstem Columbia River downstream of Grand Coulee Dam.

For this report the Columbia River mainstem was divided into two segments for evaluation. The upstream reach is referred to in this report as the "upper Columbia River," and corresponds to the river from the Kootenay River confluence to Chief Joseph Dam. Because it is possible that there may be the potential for minor or indirect effects on recreation opportunities to occur downstream of the upper Columbia River Reach, recreation below Chief Joseph Dam is also discussed. For this discussion this reach is referred to as the "middle and lower Columbia River Reach".

4.1 Upper Columbia River

The discussion of the upper Columbia River includes three river segments: (a) an "upper Columbia River in Canada" segment from the confluence of the Kootenay River in BC to the U.S. Border, (b) Lake Roosevelt in the U.S. (from the border to Grand Coulee Dam), and (c) Lake Rufus Woods (from Grand Coulee Dam to Chief Joseph Dam).

4.1.1 Upper Columbia River in Canada

General Information: The scenic and recreational resources of the upper Columbia reach are unique in the Columbia River Basin. The area provides a unique sport fishery, is part of a critical winter range for wildlife, includes several ancient Indian village sites along the shores, and is part of the longest navigable inland waterway in the western U.S. (BPA et. al. 1995).

Recreation Management: In Canada, groups responsible for management of recreational sites including the Castlegar Historical Society, the cities of Trail and Castlegar, BC, and the Ministry of Environment, Lands and Parks. Beaver Creek Provincial Park borders the upper Columbia River in BC. The Colville National Forest, managed by USFS, borders the upper Columbia River in the WA.

Recreation Access: In the U.S., WA State Route 25 runs along the eastern side of the upper Columbia River and Lake Roosevelt. River access in BC is good with roads close to the river and improved boat ramps at multiple locations.

Visitation: Although tourist traffic is low, the upper Columbia River is used extensively for recreation by local residents. Visitation at this segment of the river has been estimated at approximately 155,000 visitor days per year (BPA *et. al.* 1995).
Recreation Activities: The most popular forms of recreation in the area are sightseeing, picnicking, and fishing for a wide variety of species, including trophy sized rainbow trout. Other popular activities include hiking and swimming. Boating is popular for local residents and other boaters who travel up from Lake Roosevelt. Boat and drag-boat races are held annually during the summer festivals at Trail and Castlegar, BC (BPA *et. al.* 1995). Recreation facilities on the upper Columbia River reach are summarized in **Table 14**.

Fishing: The recreational fishery includes wild and stocked rainbow trout, walleye, kokanee, mountain and lake whitefish, burbot, brook trout, and brown trout. Primary use of the fishery is by local residents. (BPA *et. al.* 1995)

Swimming: Swimming is a popular recreation activity in this reach of the river. While swimming occurs throughout the area, concentrated swimming occurs at Gyro Park in Trail, BC and Pass Creek Park near Castlegar, BC.

Boating: River boating occurs throughout this reach of the river. Most boating is in conjunction with fishing. Access for boaters to the river is good with several improved boat ramps usable at low, medium and high water levels at Beaver Creek, Indian Eddy and Robson. While most boaters are local, some travel up from Lake Roosevelt. Canoeing, kayaking, waterskiing and rafting also take place in summer.

Table 14: Upper Columbia River Canadian Recreational Facilities

SITE NAME	BOATING	FISHING	CAMPING	SWIMMING
Beaver Creek Provincial Park	●	●	●	
Indian Eddy Boat Launch	●	●		
Waterloo Eddy	●	●		
Zuckerberg Island Historical Park	●	●		
Robson Boat Launch	●	●		
Gyro Park		●		●
Pass Creek Park		●	●	●

Other Recreational Activities and Aesthetics: The scenic and recreational resources of the upper Columbia River reach are unique within the Columbia River Basin. The reach offers the sight of one of the few accessible, big free-flowing rivers left in Western North America. In addition to the fishing swimming, and boating activities

described above, sightseeing and picnicking are also popular activities in this reach. Sightseeing is accomplished both from vehicles and by foot. The area is marked with many distinct natural and manmade vistas, including an excellent view of area mountains and high rock bluffs, old abandoned orchards and semi-rural landscapes, waterfalls, park land, and forested hills. Many people take advantage of the numerous opportunities to see wildlife in its natural habitat. Bird-watching is popular, with opportunities to view osprey, bald and golden eagles, turkey vultures, great blue herons, many species of ducks, as well as many other species o birds throughout the year. (BPA *et al.*, 1995, Appendix J)

4.1.2 Lake Roosevelt

General Information: Lake Roosevelt offers a wide variety of recreation opportunities on a 154-mile-long lake extending from Grand Coulee, WA, to the Canadian border. For most of its length, the lake is a deep gorge between ½- and 1-mile-wide, and is bordered by 513 miles of shoreline. Lake Roosevelt is one of the few large lakes in the region that has an extensive amount of shoreline and adjacent lands that are publicly owned and available for public recreation. Recreation activities include camping, sightseeing, fishing, hiking, boating and picnicking. The Colville National Forest, Colville Indian Reservation, and Fort Spokane are adjacent to the Columbia along Lake Roosevelt.

Recreation Management: The Lake Roosevelt National Recreation Area (LRNRA) was established in 1946, and management of Lake Roosevelt is shared by National Park Service (NPS), Bureau of Reclamation (Reclamation), Bureau of Indian Affairs (BIA), The Spokane Tribe of Indians (STI), and The Confederated Tribes of the Colville Reservation (CCT), as delineated in the Lake Roosevelt Cooperative Agreement (NPS 2002b). A management agreement was signed in 1990 confirming and establishing management authority of the CCT and STI for project lands within their respective reservations. The Tribes now administer approximately 45 percent of the project lands and waters (BPA et al. 1995). These lands are adjacent to the respective reservation boundaries on both sides of the reservoir. LRNRA is managed under the direction of the Lake Roosevelt National Recreation Area General Management Plan completed in January 2000.

LRNRA is the portion of Lake Roosevelt managed by the National Park Service (NPS). The LRNRA includes about 312 miles of shoreline, 47,438 acres of water surface (at full pool) and 12,936 acres of land (NPS 2002b). LRNRA also includes shoreline along about 29 miles of the Spokane River arm of the lake, and about 7 miles along the Kettle River arm (NPS 2002b).

The shorelands of LRNRA consist primarily of a narrow band of land above the maximum water surface elevation (1290 feet) that was originally purchased by Reclamation for construction of the reservoir. In most cases, the minimum amount of shorelands is determined by the 1310-foot contour, while the maximum ranges up to almost ½-mile from the water's edge in a few locations. The norm is a narrow strip of land that is just a few hundred feet wide (NPS 2002b).

Recreation Access: Most of the northern half of Lake Roosevelt is easily accessible by roads. WA State Route 25 parallels 70 miles of the east shore from Fort Spokane to Northport. The west shore has good road access from Inchelium north to Barstow via paved county roads, State Highway 20, and U.S. Highway 395. Two ferries operate on the lake; at Inchelium-Gifford, and Keller. Both ferries carry normal highway traffic, and are free. The ferry between Inchelium and Gifford is managed by the CCT, and provides access to the Colville Indian Reservation from WA State Route 25. This ferry cannot operate at lake elevations below 1225 feet (Corps 2002). The Keller Ferry, part of WA State Route 21, crosses the Columbia River at its confluence with the Sanpoil River, from Ferry County, WA and the Colville Indian Reservation on the north bank to Lincoln County, WA on the south. It can operate through the operating range of the lake, from elevation 1208 to 1290 feet, but when the normal terminal is affected by low water, the ferry must utilize an old road bed nearby to come ashore (Corps 2002).

Visitation: Annual visitation at LRNRA has been between 1.3 and 1.5 million people for the last several years (NPS 2002a). Visitation at LRNRA is affected by a variety of factors, including weather, fuel costs, and lake level fluctuations (NPS 2002a). The peak period of use is May to September. A 1996 visitor use survey found that WA residents made up 74 percent of the visitors, 13 percent were from Canada and 5 percent from other Pacific Northwest states (NPS 2002b).

A recent NPS study projected potential recreation use at LRNRA from 1998 to 2010. Projections based on a high rate of growth (7 percent compounded annually) predicted the visitor use of LRNRA would double in about 10 years. Projections based on a medium growth rate estimated that an additional 500,000 recreation visits would occur in about the same period of time. Annual visitor use is generally expected to increase to near the 2–million mark within the next 15-20 years from the year 2000's level of 1.4 million (NPS 2002b).

Recreation Activities: Of the approximately 1.4 million visitors that the park receives annually, over 70 percent participate in camping or fishing (NPS 2002a). The most popular activities include camping, swimming, motor boating, and fishing, followed by family gatherings, picnicking, sightseeing, and water skiing. These uses and other day-use recreational opportunities are primarily located in 28 developed areas easily reached by multiple access points (NPS 2002a). Recreation facilities on the lake are summarized in **Table 15**.

Table 15: Lake Roosevelt Recreational Facilities

SITE NAME	BOATING	FISHING	SWIMMING	CAMPING
Abraham Cove	●	●		
Barnaby Island	●	●		
Barnaby Creek		●		

SITE NAME	BOATING	FISHING	SWIMMING	CAMPING
Bradbury Beach	●	●	●	
Blackberry Cove				●
Blacomb's Landing				●
Chief 3 Mountain				●
China Bend	●	●		
Cloverleaf	●	●		●
Crescent Bay	●	●		
Crystal Cove	●			●
Daisy	●			
Detillion	●	●		●
Enterprise	●			●
Evans	●	●		●
Fort Spokane	●	●	●	●
French Rocks	●			
Gifford	●			●
Goldsmith	●			●
Haag Cove	●			●
Halverson Canyon	●			●
Hanson Harbor	●			
Hawk Creek	●			●
Hidden Beach			●	●
Hunters Camp	●			●
Inchelium Ferry	●			
Jones Bay	●			●
Kamloops	●			●
Keller Ferry Marina and Park	●	●	●	●

SITE NAME	BOATING	FISHING	SWIMMING	CAMPING
Kettle Falls Marina and Campground	●	●		●
Kettle River				●
Lincoln Mill	●			
Locust Grove				●
Lower Columbia	●	●		●
Maggie Shoup				●
Marcus Island	●			●
McCoy's Marina	●			
McGuire's Place				●
No Name				●
Napolean Bridge	●			●
North Gorge	●			●
Penix Canyon	●			●
Plum Point	●			●
Ponderosa	●			●
Porcupine Bay	●	●	●	●
Reynold's Resort				●
Roger's Bar				●
Sand Creek				●
Seven Bays Marina	●			●
Snag Cove Camp	●			●
Spring Canyon Marina	●			●
Sterling Point	●			●
Summer Island	●			●
Two Rivers Marina	●			●
Upper Columbia	●			●

SITE NAME	BOATING	FISHING	SWIMMING	CAMPING
Wilmont Creek				●
Raccoon Cove (picnic area)				
Grand Coulee Dam Visitors Center				

LRNRA facilities include 22 boat launch ramps with adjacent trailer and vehicle parking lots; 28 campgrounds (18 drive-in and 10 boat-in) containing 640 individual campsites as well as several group campsites, 10 developed swim areas, and three concessionaire-operated marinas (NPS 2002b). There is a visitor center at Fort Spokane, WA, and there are visitor contact stations at Kettle Falls and Coulee Dam, WA. Lakewide, there are over 40 campgrounds. More than half of the LRNRA's shoreline is maintained in a natural condition (NPS 2002b). STI maintains 11 campgrounds and 2 marinas (BPA *et al.* 1995). CCT maintains 7 campgrounds (BPA *et al.* 1995).

Boating: NPS estimates 112,498 boats visited LRNRA in 2002 (NPS 2002a). Park staff estimate personal watercraft (PWC) use is 4 percent of boating activity. PWC are banned from the Kettle River. Renting houseboats is growing in popularity at Lake Roosevelt and rental houseboats are available at several locations. The Concession Management Plan for Lake Roosevelt sets the maximum allowable number of rental houseboats on the lake at 200 (CODA 1998). Powerboating is a major recreation activity, while sailing is somewhat limited due to the lack of consistent wind during summer months. The popularity and growth of recreational boating on Lake Roosevelt is expected to continue (NPS 2002a). The STI operates the Two Rivers Marina, which is operable down to lake elevation 1280 feet. **Table 16** summarizes mimimum elevations for boat ramp operations at Lake Roosevelt.

Table 16: Lake Roosevelt Minimum Usable Boat Ramp Elevations

	LAKE ROOSEVELT FULL POOL ELEVATION (FT):	1290
BOAT RAMP	**MINIMUM USABLEBOAT RAMP ELEVATION (FT)**	**MINIMUM USABLE BOAT RAMP ELEVATION (FT below FULL POOL)**
Jones Bay	1282	8
Hawk Creek	1281	9
Marcus Island	1281	9
Evans	1280	10
North Gorge	1280	10
Two Rivers (marina)	1280	10
Napoleon Bridge	1280	10
Snag Cove Camp	1277	13
China Bend	1277	13
Crescent Bay	1265	25
Daisy	1265	25
French Rocks	1265	25

	LAKE ROOSEVELT FULL POOL ELEVATION (FT):	1290
BOAT RAMP	**MINIMUM USABLEBOAT RAMP ELEVATION (FT)**	**MINIMUM USABLE BOAT RAMP ELEVATION (FT below FULL POOL)**
Hansen Harbor	1253	37
Barnaby Island	1251	39
Bradbury Beach	1251	39
Gifford	1249	41
Fort Spokane	1247	43
Lincoln Mill	1245	45
Porcupine Bay	1243	47
Kettle Falls (marina)	1234	56
Hunters Camp	1230	60
Keller Ferry (marina)	1229	61
Seven Bays (marina)	1227	63
Spring Canyon	1222	68

Fishing: The primary sport fishery on Lake Roosevelt include walleye, rainbow trout, kokanee, smallmouth bass and perch. The Spokane Tribal Hatchery and cooperative net-pen culture operations located throughout the reservoir raise trout to yearling catchable size then release them to the reservoir in May through June (Corps 2002). Annually, over 500,000 rainbow trout and 500,000 kokanee are stocked in the lake. Other common sport fish include large and smallmouth bass, walleye, and perch. Several fishing tournaments are held at the lake each year. (LRF 2004c).

Swimming: Swimming at Lake Roosevelt accounts for a major portion of visitor day use. The NPS maintains six swimming areas with lifeguards in the more popular areas. Picnicking is frequently a companion activity to swimming with picnic areas located adjacent to the swim beaches. Swimming is highly affected by changes in reservoir levels. As reservoir levels are reduced, the access to the lake from swimming beaches becomes difficult due to unsafe topography and bottom composition (BPA *et al.* 1995).

Camping: The NPS operates over 17 campgrounds accessible by car and 10 campgrounds accessible by boat (LRF 2004b). Shoreline camping is permitted within a distance of ¼ mile from NPS campsites. STI maintains 11 campgrounds and CCT maintain 7 campgrounds. In addition some camping opportunities are provided by private operators and resorts. A 1996 visitor survey found camping in developed campgrounds to be the most popular visitor activity at Lake Roosevelt accounting for 16% of the total use-days. The use of recreational vehicles is the most popular form of camping. Tents are commonly used at developed and undeveloped areas along the lakeshore. Houseboats are popular for overnight stays on the reservoir (NPS 2002b).

Other Recreational Activities and Aesthetics: Sightseeing is a popular recreational activity at Lake Roosevelt. Many visitors come to the Grand Coulee Dam visitor center to view the largest dam in the U.S. Recreationists visiting the lake are principal viewers of the lake, and much of the viewing is done from boats on the lake. Views of

the lake are possible from a few small communities, including Grand Coulee and Seven Bays, WA in the southern section of the reservoir and Kettle Falls and Marcus, WA to the north (BPA *et al.* 1995). A popular laser light show plays nightly across the face of the dam during the tourist season and is visible from several points below the dam.

The visual amenities at Lake Roosevelt are one of the primary attractions for most visitors. The landscape adjacent to Lake Roosevelt is relatively natural and undeveloped except for occasional farms and small communities. In the northern section of the reservoir, the river valley is shallow and visitors to the reservoir are afforded views of both the valley and the mountains beyond. Coniferous forests cover the hills and line the shores. In the southern section of the reservoir (Fort Spokane, WA to the dam) the forested areas thin out and the predominant vegetation changes to sagebrush, bitterbrush, and other arid species. In this portion of the reservoir, the canyon walls rise from the shoreline and views from the reservoir are frequently restricted to basalt cliffs and narrow terraces within the canyon rim.

Reservoir Operation: Lake Roosevelt is drawn down 30 to 80 feet by May 1 to make room for high spring flows and prevent downstream flooding. During years when high spring run-off is expected, recreational access to the lake is limited from January through May due to low lake elevations. Since 1995, the lake levels have been lower in August due to efforts to increase downstream flow for salmon. All facilities are operable from full pool (1290 feet) to five feet of drawdown. If the reservoir is drawn down more than 5 feet, some swimming areas and boat launch ramps become inoperable (BPA *et al.* 1995). The lake is drafted 10 to 12 feet between August 1 and August 31. These summer adjustments in lake level reduce recreation access and use during the primary season (NPS 2002).

4.1.3 Lake Rufus Woods

General Information: Downstream from Grand Coulee Dam, Chief Joseph is the next dam on the Columbia River System. Chief Joseph Dam is a run of the river facility, and has much less developed recreational facilities. Facilities include Bridgeport State Park, Brandt's Landing, Rocky Flats and viewpoints at the dam.

Recreation Management: The Corps is the primary federal agency responsible for managing recreation lands at Lake Rufus Woods. Corps-managed facilities include the visitor center, viewpoints, and fishing access sites. The Corps cooperates with the WA State Parks Department in the operation of Bridgeport State park, the only major recreation site on the lake. This state park includes a campground, day-use park, and golf course on the lake. Other local entities such as Douglas County, WA and the town of Bridgeport, WA cooperate in managing other recreation facilities including boat ramps, swimming beaches, campgrounds, picnic areas, golf course, and interpretive sites.

Recreation Access: Road access is available to Bridgeport State Park, the Visitor Center, viewpoints, and the Brandt's Landing Recreation Site. The state park offers an improved boat launch.

Visitation: Available visitation data shows an average annual visitation at Corps recreation facilities at Lake Rufus Woods of 30,800 visitor days over the period 1987-1993, and 47,900 at Bridgeport State Park over the period 1989-2003 (BPA *et al.* 1995).

Recreation Activities: Boating, sightseeing and fishing are the primary recreational activities, with less participation in swimming and camping activities (BPA *et al.* 1995). Recreation facilities on the river are summarized in **Table 17**.

Table 17: Lake Rufus Woods Recreational Facilities

SITE NAME	BOATING	FISHING	SWIMMING	CAMPING
Rocky Flats	●			●
Brandt's Landing	●	●		●
Bridgeport State park	●	●	●	●
Upstream Boat Ramp	●			
Seaton's Grove Boat Ramp	●			
River Mile 581	●			
Chief Joe Dam Visitors Center				

Boating: Most of the boating on Rufus Woods Lake is for fishing and water skiing. Most boaters remain close to the vicinity of the put-in, whereas in other areas along the mainstem Columbia, boaters will travel further up and downstream from their entry/exit point. Four boat ramps were identified on Lake Rufus Woods. Two of the ramps (Bridgeport State Park on the north shore and the Upstream Boat Ramp on the south shore) are near Chief Joseph Dam. The other two ramps are the Seatons Grove Boat Ramp and the River Mile 581 Boat Ramp (Corps 2004c). The River Mile 581 ramp is a gravel launch; the other listed ramps are paved. Minimum usable boat ramp elevations at the lake are listed in **Table 18**.

Table 18: Lake Rufus Woods Minimum Usable Boat Ramp Elevations

LAKE RUFUS WOODS FULL POOL ELEVATION (FT):		956
BOAT RAMP	**MINIMUM USABLE BOAT RAMP ELEVATION (FT)**	**MINIMUM USABLE BOAT RAMP ELEVATION (FT below FULL POOL)**
River Mile 581	952	4
Seatons Grove Boat Ramp	950	6
Bridgeport State Park	937	19
Upstream Boat Ramp	930	26

Fishing: At Lake Rufus Woods, people fish primarily for walleye, rainbow trout, and kokanee, and some other small populations of sportfish (WDFW 2004a).

Swimming: Swimming at Rufus Woods Lake takes place at Bridgeport State Park and at Marina Park in Bridgeport, WA. All of the swim beaches along Lake Rufus Woods are sensitive to changes in flow operations or conditions with respect to the swimming facilities. The swimming beach at Bridgeport State Park is accessible down to elevation 945 feet (BPA *et al.*, App. J, 1995).

Camping: At Rufus Woods Lake, there is camping at Bridgeport State Park, Marina Park, upstream shorelines areas and a newly opened boat-in campsite named Rocky Flats (WA Parks 2004).

Other Recreational Activities and Aesthetics: Chief Joseph Dam and Lake Rufus Woods are located in a relatively remote portion of central WA. The north side of the valley rises sharply to the Okanogan Highlands, 1,000 feet or more above the Columbia River. The south side of the valley rises in a series of terraces and benches climbing to the Columbia Plateau surface. The majority of the shoreline is treeless with a dry land shrub-steppe cover. Numerous canyons and deep draws support isolated stands of pine and deciduous trees and shrubs. Irrigated orchards on upland benches and 6 irrigated wildlife mitigation sites along the lakeshore provide islands of greenery.

Many visitors are attracted to the impressive engineering features of the dam, which is the second largest power producing dam in the United States. The dam includes visitor facilities and viewpoints. Hiking and sightseeing are popular activities at Lake Rufus Woods. The project includes multiple trails. The North Shore Trail extends two miles from the Orientation Area, through the Tower Trailhead to the Dunes Trailhead on the boundary of Bridgeport State Park. A spur trail connects to the Spillway Viewpoint at the north end of Chief Joseph Dam. The trail is fully paved and has many rest areas. The South Shore Trail is a gravel trail that goes around the Debris Basin, connecting to the Upstream Boat Ramp. Hunting is also a popular recreational activity in the vicinity of Rufus Woods Lake. Animals sought include Canada goose, ducks, chukar, gray partridge, ring-necked pheasant, California quail, mourning dove, coyote, and mule deer. (Corps 2002a)

4.2 Middle and Lower Columbia River

General Information: Downstream from Chief Joseph Dam, the Columbia River passes through the flatlands of central Washington, also called the channeled scablands. The area is hot and dry in the summer, making it an excellent area for rock climbing, boating, sunbathing, and cultural, geological, and historic interpretation. As the river passes through the Columbia River Gorge, the surrounding areas become more heavily urbanized, and a greater number of year-round recreational opportunities are available. In the Columbia River Gorge, climatic conditions create an excellent location for windsurfing, and Hood River, OR has become a choice windsurfing destination (WTHR 2004).

Recreation Access: U.S. Route 97 parallels the river from Brewster to just north of Wenatchee, WA. Downstream of Wenatchee, WA State Route 28 follows the river to Trinidad, WA. There is intermittent local access downstream to the Interstate 90 crossing just south of Vantage. Downstream of the I-90 crossing, WA State Route 243 follows the river to the WA State Highway 24 crossing at Vernita Bridge. Downstream of this crossing, the River is surrounded by the United States Department of Energy Hanford Site to the south, and the Saddle Mountain National Wildlife Refuge and the Wahluke Wildlife Refuge to the north. Multiple access points are offered in the vicinity of Richland/Pasco/Kennewick WA Tri-Cities Area, just downstream of the Hanford site. U.S. Route 12 follows the river from Tri-Cities to Wallula Junction, WA. U.S. Route 12 follows the river from Wallula Junction to Interstate 84. Both Interstate 84 and Highway 14 parallel the Columbia River and provide direct access to many developed recreation recreational areas along the river.

Recreation Activities: Rocky Reach Dam and Rock Island Dam are operated by the Chelan Public Utility District (PUD). Grant County PUD operates Wanapum Dam and Priest Rapids Dam (Grant PUD 2004). Camping, picnicking, swimming, boating and fishing are common recreation activities associated with the Chelan and Grant County, WA PUD projects (Chelan PUD 1999). Further downstream the Corps and BPA facilities include McNary Dam, John Day Dam, The Dalles Dam, and Bonneville Dam. There are many recreational facilities and areas including boat ramps, camping areas, picnic areas, and hiking trails associated with these dams and reservoirs (Corps 2004c). Overall this vast region has a wide variety of recreational opportunities at several hundred recreation-related facilities. This is especially true within the Columbia River Gorge National Scenic Area (CRGNSA). Congress created the Columbia River Gorge National Scenic Area (CRGNSA) in 1986.

The Portland, OR/Vancouver, WA tourist industry is largely based on the Columbia and Willamette Rivers. Steamboat tours, kayaking trips, fishing, boating, hot spring use, and hiking are all popular year-round activities. During the summer, sailing, boating, swimming and camping are common along this reach of the Columbia River.

Boating: Boating along the mainstem Columbia includes powerboating, waterskiing, cruising, navigating the lock and dam systems, and fishing.

Fishing: The lower and middle Columbia River have historically had some of the world's largest runs of salmon and steelhead. The middle Columbia fishery includes walleye, salmon, sturgeon, bass, perch and whitefish. Sturgeon caught upstream of Priest Rapids Dam are required to be released. Summer Chinook and steelhead angling may be allowed, depending upon the size and composition of the runs. The lower Columbia fishery includes sturgeon, shad, winter and summer steelhead, sea-run cutthroat trout, bass, crappie and walleye, plus salmon during open seasons. All chum, wild cutthroat, wild steelhead, and wild coho must be released (WDFW 2004a). In recent years, bounty programs for northern pikeminnow have encouraged fisherman to target this species during the spring and summer.

Swimming: Swimming is a popular activity along the mainstem Columbia. There are numerous swim beaches at recreational areas and campsites and swimming is also done in conjunction with boating along the shores of the river (BPA *et al.* 1995).

Camping: Downstream from Chief Joseph Dam numerous locations provide campsites along the banks, overlooking scenic sections of the Columbia River. Camping areas are found along the shores of the river behind many of the dams. The reach includes several designated state parks with camping, RV hookup, and trail facilities.

Other Recreational Activities and Aesthetics: The upper part of this reach includes Wells, Rocky Reach, and Rock Island reservoirs operated by WA Public Utility District (PUD). Here scenic driving is popular, with highways providing access to vistas of natural features, such as the east Cascade Mountains, cliffs paralleling the river canyon, tributary rivers and streams, and WA fruit orchards. The numerous fish hatcheries and fish ladders at the PUD projects are also popular visitor attractions.

Below Rock Island Dam, the river moves east away from the mountains, the climate is dryer, and the river canyon becomes wider. Land uses bordering the river include hydroelectric dams, suburban residential areas, resorts, wildlife areas, an Indian village, an Army base, agricultural acreage, and a variety of recreational developments. The Wanapum Indian village at Priest Rapids Dam and the Army's Yakima Firing Center occupies much of the west shore of the river between Priest Rapids Dam and Sentinel Gap

The Hanford Reach, located between Priest Rapids Dam on the north and the upper end of Lake Wallula (McNary Dam pool) on the south, is unique in being the last undammed reach of the Columbia River in the U.S. The Hanford Reach and adjacent wildlife refuge/recreation areas provide year round recreational opportunities, including nature viewing and hunting. Public use and access is restricted in the Hanford Reservation and in the Saddle Mountain National Wildlife Refuge located to the north of the river.

The lower Columbia River reach encompasses the four Corps run of the river reservoir projects McNary Dam (Lake Wallula), John Day Dam (Lake Umatilla), The Dalles (Lake Celio), and Bonneville Dam (Lake Bonneville). The scenic and recreational amenities of the lower Columbia River have gained national and international renown. In recognition of those amenities, Congress created the CRGNSA. Scenic driving is a popular form of sightseeing in the reach. Area highways provide access to majestic vistas of natural features including forests, mountains, cliffs, rivers, streams, and waterfalls.

In the CRGNSA, there are a variety of recreational related tourist activities. Windsurfing is identified as an extremely popular recreational activity and the Hood River area is known as the windsurfing capital of the U.S. The Gorge offers thousands of maintained forest service hiking and backpacking trails, including the Pacific Crest Trail, which crosses the Columbia River at the Bridge of the Gods near the Cascade Locks. Wineries and fruit orchards are also present along the river. Many visitors to the region are attracted to the engineered dams, navigation locks, hatcheries, and fish ladders of the lower Columbia River. The region is also rich in history and pre-history. Features such as Native American petroglyphs, the route of the Lewis and Clarke Expedition and the Oregon Trail, and historic navigation locks can be viewed and interpreted. (BPA et. al. 1995, Appendix J)

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RECREATION IMPACT ANALYSIS
Appendix E: Part 2 of 2

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RECREATION IMPACT ANALYSIS

TABLE OF CONTENTS

Page E-

1.0 Introduction **55**
2.0 Recreation Impact Analysis Methodology **56**
3.0 Area 1 – Kootenai River Basin Recreation Impacts **58**
3.1 Lake Koocanusa – U.S. 58
3.2 Lake Koocanusa – Canada 61
3.3 Kootenai River 63
3.4 Kootenay Lake 65
4.0 Area 2 – Flathead/Clark Fork/Pend Oreille River Basin Recreation Impacts ... **70**
4.1 Hungry Horse Reservoir 70
4.2 Flathead River 72
4.3 Flathead Lake 75
4.4 Lower Flathead River and Clark Fork River 77
4.5 Lake Pend Oreille 80
4.6 Pend Oreille River – U.S. 81
4.7 Pend d'Oreille River – Canada 82
5.0 Area 3 – Columbia River Mainstem Recreation Impacts **83**
5.1 Upper Columbia River 83
5.2 Lake Roosevelt 83
5.3 Lake Rufus Woods 85
5.3 Middle and Lower Columbia River 86

LIST OF TABLES

Table 1. Lake Koocanusa Month-End Average Stage (feet) 58
Table 2. Lake Koocanusa Average Usable Boat Ramp Days/Month – U.S. 59
Table 3. Lake Koocanusa Average Swimming Days/Month – United States 59
Table 4. Lake Koocanusa Average Days/Month with Lake Level > 2439 feet – U.S.....60
Table 5. Lake Koocanusa Average Days/Month with Lake Level > 2409 feet – U.S.....60
Table 6. Summary of Quantified Recreation Impacts at Lake Koocanusa – U.S. 61
Table 7. Lake Koocanusa Average Usable Boat Ramp Days/Month – Canada 62
Table 8. Lake Koocanusa Average Swimming Days/Month – Canada.....62
Table 9. Summary of Quantified Recreation Impacts at Lake Koocanusa – Canada.....63
Table 10. Libby Dam Monthly Average Discharge (cfs) 63
Table 11. Kootenai River Average Shore Fishing Days.....64
Table 12. Kootenai River Average Boating and Boat Fishing Days 65
Table 13. Summary of Quantified Recreation Impacts at the Kootenai River 65
Table 14. Kootenay Lake Month-End Average Stage (feet) 66
Table 15. Kootenay Lake Average Days/Month between Elevations 1740 and 1754 Feet67
Table 16. Kootenay Lake Average Days/Month at or above Elevation 1744 Feet 67
Table 17. Kootenay Lake Average Days/Month at or above Elevation 1744 Feet 68
Table 18. Kootenay Lake Average Days/Month < Elevation 1749 Feet.....68
Table 19. Summary of Quantified Recreation Impacts at Kootenay Lake 69
Table 20. Hungry Horse Reservoir Month-End Average Stage (feet).....70
Table 21. Hungry Horse Reservoir Average Usable Boat Ramp Days/Month 71
Table 22. Hungry Horse Dam Monthly Average Discharge (cfs) 72
Table 23. Flathead River at Columbia Falls Monthly Average Discharge (cfs) 73
Table 24: Average Days > 4,000 cfs, Flathead River at Columbia Falls 74
Table 25. Flathead River at Columbia Falls Average Days between 4,000 & 17,000 cfs 74
Table 26. Summary of Quantified Recreation Impacts at the Flathead River 75
Table 27. Flathead Lake Month-End Average Stage (feet) 75
Table 28. Flathead Lake Average Usable Boat Ramp Days/Month.....76
Table 29: Average Days/Month with Beach Access on Flathead Lake.....76
Table 30. Summary of Quantified Recreation Impacts at Flathead Lake.....77
Table 31. Kerr Dam Monthly Average Discharge (cfs) 78
Table 32. Lower Flathead River Average Kayaking Days/Month 79
Table 33. Lower Flathead River Average Days between 4,000 and 17,000 cfs.....79
Table 34. Summary of Quantified Recreation Impacts at Lower Flathead River and Lower Clark Fork.....80
Table 35. Lake Pend Oreille Month-End Average Stage (feet).....80
Table 37. Albeni Falls Dam Monthly Average Discharge (cfs) 81

Table 39. Lake Roosevelt Month-End Average Stage (feet).....84
Table 40. Lake Roosevelt Average Usable Boat Ramp Days/Month.....84
Table 42. Grand Coulee Dam Monthly Average Discharge.....85

UPPER COLUMBIA ALTERNATIVE FLOOD CONTROL AND FISH OPERATIONS EIS

RECREATION IMPACT ANALYSIS

1.0 Introduction

This document presents the findings of an assessment of potential recreational impacts associated with different alternatives for Libby and Hungry Horse Dams as described in Section 2. The potential impacts were examined for each of three study areas.

- Area 1 - Kootenai River Basin from Lake Koocanusa in Montana (MT) and British Columbia (BC) through Idaho (ID) to the Columbia River in BC
- Area 2 - Flathead/Clark Fork/Pend Oreille Basin from Hungry Horse Reservoir in MT to the Columbia River in Washington (WA)
- Area 3 - Columbia River mainstem from the mouth of the Kootenai River in BC downstream to the Pacific Ocean in Oregon (OR) and WA

Water-related recreation resources in the three study areas are associated with either reservoir/lake recreation or river recreation. The recreation activities potentially most affected in the three areas include boating, fishing, swimming, camping, and aesthetics. The primary recreation use season for all study areas is the summer (May through September). Winter recreation appears to be less affected by water levels.

For reservoir/lake-based recreation, pool elevation during the summer season is one of the most influential factors on recreation and aesthetics. Full pool is ideal for most forms of reservoir recreation, and water levels are particularly important for the function of boat ramps. For river-based recreation, river flows below flood stage and above minimum flows are generally best for recreation. Extreme high and low flows are generally not good for river-based fishing and boating.

A discussion of potential recreation impacts for each area is presented below, preceded by a brief description of the general methodologies used to assess and evaluate these impacts.

2.0 Recreation Impact Analysis Methodology

Potential recreation impacts associated with alternative flood control and fish flow operations were evaluated. Two operations without fish flows, referred to as "benchmark operations[3]," were evaluated:

- Standard Flood Control Operations *without* Fish Flows (LS)
- VARQ Flood Control Operations *without* Fish Flows (LV)

The two benchmark operations were evaluated to facilitate assessment of the potential recreational impacts of fish flows that have been implemented in response to the 2000 U.S Fish and Wildlife Service and National Marine Fisheries Service Biological Opinion.

In addition to the two benchmark operations, four other operational alternatives were evaluated in Area 1 that include fish flows.

- Standard Flood Control Operations *with* Fish Flows up to Powerhouse Capacity at Libby Dam (LS1)
- VARQ Flood Control Operations *with* Fish Flows up to Powerhouse Capacity at Libby Dam (LV1)
- Standard Flood Control Operations *with* Fish Flows up to 10,000 cfs above Powerhouse Capacity at Libby Dam (LS2)
- VARQ Flood Control Operations *with* Fish Flows up to 10,000 cfs above Powerhouse Capacity at Libby Dam (LV2)

In Area 2, two operational alternatives were evaluated.

- Standard Flood Control Operations (HS)
- VARQ Flood Control Operations (HV)

To evaluate the effects that the Area 1 and Area 2 operational alternatives and benchmarks have in Area 3, the following combinations were addressed:

- HS + LS1 (no-action)
- HV + LV1
- HS + LS2
- HV + LV2
- HS + LS (benchmark combination)
- HV + LV (benchmark combination)

[3] A "benchmark operation" does not meet the purpose and need of the action and provides a basis for comparison of the incremental impacts of the fish flows at Libby.

The methodology used to evaluate the recreational impacts of the different alternatives and benchmarks involved the following approach:

1) River-related recreation resources were identified and documented in the Recreation Affected Environment report.

2) "Threshold" water surface elevations or recreation resource characteristics were identified for different recreational activities in each subarea. These thresholds are the data points at which the recreation activity becomes affected by changes in water levels or discharge volumes.

3) To identify impacts, the identified thresholds were compared with hydrologic model outputs for all alternatives and benchmarks in each study area. In Areas 1 and 2, daily stages for the two lakes and daily discharges for the river reach were simulated. In Area 3, average monthly stages and discharges were simulated. Area 1 and Area 3 simulations were over a 53-year period for all four alternatives and two benchmarks. Area 2 simulations were over a 74-year period for the two alternatives evaluated in Area 2. The data from these simulations were used to calculate average end-of-month stages, average monthly discharges, and average number of days per month above or below identified threshold elevations. Impacts were quantified where possible, and in cases where available data was insufficient for quantification, a qualitative evaluation of potential impacts was performed. Quantification of impacts typically involved documenting the number of days in the respective recreation season that the recreational activity would be available with each alternative/benchmark.

3.0 Area 1 – Kootenai River Basin Recreation Impacts

Three subareas in Area 1 were evaluated: Lake Koocanusa, the Kootenai River, and Kootenay Lake. The analysis for Lake Koocanusa is further divided between the U.S. and Canadian portions of the lake.

3.1 Lake Koocanusa – U.S.

The primary recreational activities at Lake Koocanusa that could be affected by changes in lake levels include boating, fishing, swimming, and camping. Average end-of-month stages at the lake during the high use summer recreation months of May-September are presented in **Table 1** for each of the four alternatives and two benchmarks.

Table 1. Lake Koocanusa Month-End Average Stage (feet)

Month	LS1 (No-Action)	LV1	LS2	LV2		LS benchmark	LV benchmark
May	2393	2406	2391	2404		2400	2410
June	2431	2440	2429	2439		2449	2450
July	2443	2448	2442	2447		2459	2459
August	2438	2439	2437	2439		2459	2459
September	2435	2436	2434	2436		2438	2438

For each of the standard flood control alternatives and benchmark modeled (LS, LS1, and LS2), the change to VARQ (LV, LV1, and LV2; respectively) results in an increase in average end-of-month stage at Lake Koocanusa during May, June, and July. The higher stages result in more recreational opportunities by increasing the number of days that boat ramps and swimming beaches are functional. Additionally, the higher stages can benefit the quality of recreation activities through improved aesthetics. In August and September, there is little to no change between standard flood control operations and VARQ. Average end-of-month stages are higher in all months for the benchmarks without fish flows (LS and LV) compared to the alternatives with fish flows (LS1, ALT 2, LS2, and LV2).

3.1.1 Lake Koocanusa Fishing and Boating – U.S.

Fishing was identified as the prime recreational activity on Lake Koocanusa. Since most fishing on Lake Koocanusa is done by boat and most boating on the lake is associated with fishing, impacts to these two linked recreational activities were evaluated together. The most important limiting factor for lake fishing/boating is boat access to the lake, which can be affected by lake drawdown. Thirteen boat ramps were identified and evaluated.

The total number of days that each ramp was functional over the 53-year period of simulation was calculated and converted to an average annual value. The average annual days of availability were then summed across all ramps at the lake to calculate the average number of usable boat "ramp days" per month. **Table 2** shows the average number of ramp days per month at Lake Koocanusa. Reference the **Exhibits** at the end of this report for results of average end-of-month and average daily elevation analysis for each ramp.

Table 2. Lake Koocanusa Average Usable Boat Ramp Days/Month – U.S.

Month	LS1 (No-Action)	LV1	LS2	LV2		LS benchmark	LV benchmark
May	171	199	171	198		174	201
June	244	269	239	265		290	300
July	327	360	321	355		398	399
August	323	337	321	333		403	403
September	274	303	298	303		362	362
Total:	1,340	1,467	1,351	1,454		1,627	1,665

3.1.2 Lake Koocanusa Swimming – U.S.

The primary swimming season at Lake Koocanusa is June through August. Two improved swimming beaches were identified on the U.S. side of the lake: the McGillivray and Rexford Bench recreation areas. In addition, the Souse Gulch boat dock serves as a popular swimming location during high water levels. Low water elevations result in disconnection of the improved beaches or dock from the water. Swimming at McGillivray is possible down to lake elevation 2444 feet; at Rexford Bench to elevation 2439 feet. Swimming from the dock at Souse Gulch is possible down to elevation 2441 feet. **Table 3** presents the sum of usable swimming days at the three swimming sites on the U.S. side of the lake.

Table 3. Lake Koocanusa Average Swimming Days/Month – United States

Month	LS1 (No-Action)	LV1	LS2	LV2		LS benchmark	LV benchmark
June	10	19	9	18		32	36
July	52	69	41	65		91	92
August	45	62	43	59		93	93
Total:	107	150	92	141		216	221

3.1.3 Lake Koocanusa Camping - U.S.

Camping use becomes affected when the lake elevation drops below 2439 feet (20 feet below full pool). At lake levels between 2439 feet and 2409 feet, camping is expected to become more concentrated at the recreation sites with longer boat ramps that provide access to the lake at lower pools. Increased demand on these facilities could result in reduced quality of the camping experience for campers at those sites. At elevations below 2409 feet, more extensive impacts on camping could result as a result of increased concentration of campers and potential camping on the dry lake bed that could result in poor sanitation, lack of privacy, and increased litter. **Tables 4 and 5** show the number of days per month in the recreation season that pool levels would be at or above these two threshold elevations (2439 feet and 2409 feet).

Table 4. Lake Koocanusa Average Days/Month with Lake Level ≥ 2439 feet – U.S.

Month	LS1 (No-Action)	LV1	LS2	LV2		LS benchmark	LV benchmark
May	0	0	0	0		0	0
June	4	8	4	7		12	14
July	17	25	16	24		31	31
August	22	29	21	28		31	31
September	2	3	1	2		28	28
Total:	45	65	42	61		102	104

Table 5. Lake Koocanusa Average Days/Month with Lake Level ≥ 2409 feet – U.S.

Month	LS1 (No-Action)	LV1	LS2	LV2		LS benchmark	LV benchmark
May	3	9	3	9		4	11
June	18	25	16	23		25	27
July	31	31	31	31		31	31
August	31	31	31	31		31	31
September	31	31	30	31		31	31
Total:	113	126	112	124		122	130

3.1.5 Summary of Lake Koocanusa Recreation Impacts – U.S.

Quantified recreation evaluation criteria for Lake Koocanusa included boat ramp days, swimming days, camping days above the initial impact threshold of 2439 feet, and camping days above the more extensive impact threshold of 2409 feet. The total number of days for each criterion and each alternative/benchmark are summarized in **Table 6**.

Table 6. Summary of Quantified Recreation Impacts at Lake Koocanusa – U.S.

Recreation Evaluation Criteria	LS1 (No-Action)	LV1	LS2	LV2		LS benchmark	LV benchmark
Total Boat Ramp Days (May-Sep)	1,340	1,467	1,351	1,454		1,627	1,665
Swimming Days (Jun-Aug)	107	150	92	142		217	221
Camping Days above 2439 feet (May-Sep)	45	65	42	61		102	104
Camping Days above 2409 feet (May to Sep)	113	126	112	124		122	130

Additional non-quantified effects included impacts on aesthetics. Higher pool elevations are more aesthetically pleasing for viewing and sightseeing than low pool elevations due to the presence of exposed stumps, banks, and flats with drawdown. As presented in **Table 1**, the two benchmark operations (LS and LV) maintain the highest water surface elevations. VARQ flood control operations (LS, LS1, and LS2) provide higher pool elevations than do standard flood control operations (LV, LV1, and LV2) in all months. Additionally, the Libby Dam Visitor center could receive higher visitation with VARQ flood control due to the increased general lake visitation associated with increased days of availability for boating, swimming, and camping resulting from the higher pool levels.

3.2 Lake Koocanusa – Canada

Table 1 includes the average end-of-month stage for each month in the summer recreation season for Lake Koocanusa. As with the U.S. side of the lake, for each standard flood control operations modeled (LS, LS1, and LS2), the change to VARQ flood control operations (LV, LV1, and LV2, respectively) results in an increase in average end-of-month stage at Lake Koocanusa during May, June, and July. The higher stages benefit recreational activities at the lake by increasing the number of days that boat ramps and swimming beaches are functional and by improving aesthetics. In August and September, there is little to no change between VARQ and standard flood control operations. From June through September, there is no change in end-of-month stage between benchmarks LS and LV. Average end-of-month stages are higher in all months for the benchmarks without fish flows compared to the alternatives with fish flows. Expected effects for each primary recreational activity in Canada are presented below.

3.2.1 Lake Koocanusa Boating and Fishing - Canada

The most influential limiting factor for Lake Koocanusa fishing and boating is access to the lake. Five boat ramps were identified on the Canadian side of the lake for evaluation of their functionality under conditions with each of the four alternatives and two

benchmarks. The methodology applied to identify average annual usable boat ramp days was the same as described for the U.S. portion of the lake. **Table 7** shows the average number of ramp days per month at Lake Koocanusa for the Canadian side of the lake. Reference the **Exhibits** at the end of this report for results of average end-of-month and average daily elevation analysis for each ramp.

Table 7. Lake Koocanusa Average Usable Boat Ramp Days/Month – Canada

Month	LS1 (No-Action)	LV1	LS2	LV2		LS benchmark	LV benchmark
May	8	19	8	18		10	20
June	44	65	41	61		76	83
July	99	116	96	114		141	142
August	112	122	110	121		154	154
September	89	92	88	91		122	122
Total:	352	414	343	404		503	522

3.2.2 Lake Koocanusa Swimming - Canada

The primary swimming season at Lake Koocanusa is June through August. Two improved public swimming beaches were identified on the Canadian side of the lake. The sites are Kikomun Creek Provincial Park and Wardner Provincial Park. An additional private swim beach is provided at the Newgate Sandy Shores Resort. Swimming at Kikomun Creek is possible down to lake elevation 2452 feet; at Wardner to elevation 2444 feet. Newgate Sandy Shores Resort indicated that the facility's gradually sloping beach was not affected by drawdown. **Table 8** presents the sum of usable swimming days at the two public improved swimming sites at the lake.

Table 8. Lake Koocanusa Average Swimming Days/Month – Canada

Month	LS1 (No-Action)	LV1	LS2	LV2		LS Benchmark	LV benchmark
June	4	7	3	6		13	14
July	17	30	14	27		56	57
August	9	14	8	12		62	62
Total	29	51	25	45		131	133

3.2.3 Lake Koocanusa Camping - Canada

With lower pools, the quality of the recreation experience at Canadian campsites on the lake could be diminished due to loss of swimming opportunities and diminished aesthetics. Generally, the highest pool levels are associated with the benchmark operations. Fish flows result in lower pools during the camping season which can be

partially offset by moving from standard flood control operations (LS, LS1, and LS2) to VARQ flood control operations (LV, LV1, and LV2).

3.2.5 Summary of Lake Koocanusa Recreation Impacts - Canada

Quantified recreation evaluation criteria for Lake Koocanusa included boat ramp days and swimming days. The total number of days for each criterion and each alternative/benchmark are summarized in **Table 9**.

Table 9. Summary of Quantified Recreation Impacts at Lake Koocanusa – Canada

Recreation Evaluation Criteria	LS1 (No-Action)	LV1	LS2	LV2		LS Benchmark	LV benchmark
Total Boat Ramp Days (May-Sep)	352	414	343	404		503	522
Swimming Days (Jun-Aug)	29	51	24	45		131	133

Additional non-quantified effects included impacts on camping and aesthetics. Higher stages are generally preferable for camping and aesthetics at the lake. As the pool is lowered, more mudflat in the Canadian portion of the lake becomes exposed resulting in diminished quality of the scenic resources. As identified in **Table 1**, the highest stages during the summer recreation season are associated with LS and LV, the benchmark operations without fish flows. Once fish flows are added, stages go down. This is partially although not completely offset by implementing VARQ flood control operations (LV, LV1, and LV2) as compared to standard flood control operations (LS, LS1, and LS2).

3.3 Kootenai River

The primary recreational activities associated with the Kootenai River that are potentially affected by changes in discharge from Libby Dam include boating, fishing, and camping. The average monthly discharge rates for all months from Libby Dam in cubic feet per second (cfs) are presented in **Table 10** for each alternative/benchmark modeled.

Table 10. Libby Dam Monthly Average Discharge (cfs)

Month	LS1 (No-Action)	LV1	LS2	LV2		LS Benchmark	LV benchmark
January	20,405	12,562	20,402	12,562		20,596	12,663
February	13,795	9,728	13,795	9,728		13,795	9,728
March	7,529	6,721	7,529	6,721		7,529	6,721
April	5,684	6,425	5,684	6,425		5,685	6,425
May	9,776	14,344	10,862	15,337		5,965	12,071

Month	LS1 (No-Action)	LV1	LS2	LV2		LS Benchmark	LV benchmark
June	18,016	18,346	17,946	18,338		9,222	13,832
July	14,095	16,958	13,664	16,461		14,918	15,429
August	13,619	16,111	13,202	15,738		9,670	9,764
September	8,606	8,982	8,581	8,909		22,272	22,279
October	6,852	7,005	6,790	6,998		7,394	7,421
November	6,350	6,426	6,334	6,426		6,657	6,639
December	16,885	17,104	16,841	17,081		17,699	17,742

Compared to standard flood control operations (LS, LS1, and LS2), VARQ flood control operations (LV, LV1, and LV2) result in an increase in discharge from Libby Dam during the summer recreation season (May-September). Fish flows result in higher discharges in May, June and August and lower discharges in September and October when compared to the non-fish-flow benchmarks. Discharges in other months (November through April) are similar or the same.

3.3.1 Kootenai River Fishing and Boating

Discharge ranges accommodating recreational fishing were identified for both shoreline and boat fishing on the river. The optimal range for shoreline fishing was identified as 4,000 to 10,000 cfs. **Table 11** shows the days per month of the summer recreation season with optimal flows for shore fishing for each of the alternatives/benchmarks.

Table 11. Kootenai River Average Shore Fishing Days

Month	LS1 (No-Action)	LV1	LS2	LV2		LS Benchmark	LV benchmark
May	21	10	21	10		26	11
June	10	10	13	12		20	10
July	10	3	10	4		9	9
August	11	4	11	5		19	19
September	24	23	24	23		0	0
Totals	77	50	80	54		74	48

The optimal range for boat fishing was identified as 8,000 to 25,000 cfs, which also corresponds to the optimal discharge rate for use of boat launches along the Kootenai River. From 5,000 to 7,000 cfs, only small drift boats, canoes, and kayaks can be launched. At flows below 5,000 cfs, the boat launches are not usable. **Table 12** shows the days per month that river flows are between 8,000 and 25,000 cfs for each alternative/benchmark.

Table 12. Kootenai River Average Boating and Boat Fishing Days

Month	LS1 (No-Action)	LV1	LS2	LV2		LS Benchmark	LV benchmark
May	8	18	7	19		6	23
June	12	12	13	14		10	22
July	28	29	28	30		22	23
August	28	30	28	30		21	21
September	12	13	11	13		27	27
Totals	88	101	88	105		85	115

3.3.3 Kootenai River Camping

No impacts from the modeled discharges were identified for campsites along the Kootenai River.

3.3.4 Summary of Kootenai River Recreation Impacts

Quantified recreation evaluation criteria for the Kootenai River included shore fishing days and boating/boat fishing days. The total number of days for each criterion and each alternative/benchmark are summarized in **Table 13**.

Table 13. Summary of Quantified Recreation Impacts at the Kootenai River

Recreation Evaluation Criteria	LS1 (No-Action)	LV1	LS2	LV2		LS Benchmark	LV benchmark
Shore Fishing Days (May-Sep)	77	50	80	54		74	48
Boating and Boat Fishing Days (May-Sep)	88	101	88	105		85	115

No impacts to camping along the river were identified. Higher flow rates are generally more aesthetically pleasing than lower flow rates. Generally, the VARQ flood control operations (LS, LS1, and LS2) result in higher flow rates during the summer recreation season. From May through August, the increase in flows with LV1 is large enough to be perceptible to recreation users.

3.4 Kootenay Lake

Boating, fishing, swimming and camping were identified as the primary recreational activities at Kootenay Lake that could potentially be affected by changes in lake levels.

Table 14 presents average end-of-month water surface elevations for Kootenay Lake for all twelve months.

Table 14. Kootenay Lake Month-End Average Stage (feet)

Month	LS1 (No-Action)	LV1	LS2	LV2		LS Benchmark	LV benchmark
January	1744	1744	1744	1744		1744	1744
February	1742	1742	1742	1742		1742	1742
March	1739	1739	1739	1739		1739	1739
April	1741	1741	1741	1741		1741	1741
May	1747	1748	1747	1748		1746	1747
June	1747	1747	1747	1747		1746	1747
July	1744	1744	1744	1744		1744	1744
August	1743	1743	1743	1743		1743	1743
September	1745	1745	1745	1745		1745	1745
October	1745	1745	1745	1745		1745	1745
November	1745	1745	1745	1745		1745	1745
December	1745	1745	1745	1745		1745	1745

Average end-of-month stage at Kootenay Lake is similar with all alternatives and benchmarks in all summer recreation season months (May-September). Average end-of-month stages are one foot higher with VARQ flood control operations (LV, LV1, and LV2) during May as compared to standard flood control operations (LS, LS1, and LS2).

3.4.1 Kootenay Lake Recreation

Canadian stakeholders identified lake elevations of between 1740 and 1754 feet as non-detrimental for most recreational resources at the lake. Average end-of-month stages are within the non-detrimental range for all months in the main summer recreation season (May to September) with all alternatives and benchmarks. Average end-of-month stages are also within the non-detrimental range for all non-summer months excluding March; where all alternatives and benchmarks have average end-of-month stages of 1739 feet, one foot below the lower threshold of 1740 feet. No average end-of month elevations in any months of the year exceeded the upper threshold of 1754 feet.

Additional daily analysis of pool elevations in the 53 years of simulation for all alternatives and benchmarks found that there was no difference in the number of days in the detrimental recreational range during the summer recreation season. In the period of May-September, the only month with days in the detrimental range was May with a monthly average of two days under the lower threshold elevation of 1740 feet for all alternatives and benchmarks. Non-summer months with days below 1740 feet include February, March, and April. In these months there is little to no difference in lake level across all alternatives and benchmarks. No days in any months of the year exceeded the upper threshold of 1754 feet.

Table 15 shows the number of days within the non-detrimental range of lake elevations for recreation at Kootenay Lake.

Table 15. Kootenay Lake Average Days/Month between Elevations 1740 and 1754 Feet

Month	LS1 (No-Action)	LV1	LS2	LV2		LS benchmark	LV benchmark
May	28	27	28	27		28	27
June	18	17	17	16		25	22
July	28	28	29	28		28	28
August	31	31	31	31		31	31
September	30	30	30	30		30	30
Total	135	132	134	132		142	139

3.4.2 Kootenay Lake Boat Moorage (Pilot Bay Resorts)

In addition to the non-detrimental recreational range evaluated in section 3.4.1, Pilot Bay Resorts, a private recreation facility, indicated detrimental impacts to boat moorage at lake elevations below 1744 feet. Problems were cited during the low water season (January-May). **Table 16** shows the average number of days per month that the lake was at or above elevation 1744 feet over these months. The total number of days at or above the threshold is within one day across all alternatives/benchmarks.

Table 16. Kootenay Lake Average Days/Month at or above Elevation 1744 Feet

Month	LS1 (No-Action)	LV1	LS2	LV2		LS benchmark	LV benchmark
January	30	30	30	30		30	30
February	5	2	5	2		5	2
March	0	0	0	0		0	0
April	1	1	1	1		1	1
May	16	19	17	19		15	19
Total	52	52	52	52		51	52

3.4.3 Kootenay Lake Fishing (Kootenay Kampsites)

In addition to the non-detrimental recreational range evaluated in section 3.4.1, Kootenay Kampsites, a private recreation facility, indicated fishing impacts at lake levels below 1744 feet. **Table 17** shows the number of days at or above the threshold elevation of 1744 feet for each alternative/benchmark. VARQ flood control operations (LV, LV1,

and LV2) result in more days above 1744 feet than do standard flood control operations (LV, LV1, and LV2).

Table 17. Kootenay Lake Average Days/Month at or above Elevation 1744 Feet

Month	LS1 (No-Action)	LV1	LS2	LV2		LS benchmark	LV benchmark
May	16	19	17	19		15	19
June	27	27	27	27		25	27
July	18	19	17	19		17	18
August	6	7	5	7		4	4
September	16	17	16	17		18	18
Total	83	90	82	89		79	86

3.4.4 Kootenay Lake Swimming

The main recreational swimming season at Kootenay Lake is June to August. Impacts to the lake's swimming beaches can occur at high water elevations (≥ 1749 feet) that cause improved beaches to be inundated. **Table 18** shows the average number of days per month that the lake beaches were accessible (i.e., the pool was lower than elevation 1749 feet) during the swimming season.

Table 18. Kootenay Lake Average Days/Month < Elevation 1749 Feet

Month	LS1 (No-Action)	LV1	LS2	LV2		LS benchmark	LV benchmark
June	18	17	17	16		25	22
July	28	28	29	28		28	28
August	31	31	31	31		31	31
Total	77	76	76	75		84	82

3.4.5 Kootenay Lake Camping

No additional evaluation criteria for Kootenay Lake camping beyond the non-detrimental range of lake elevations presented in Section 3.4.1 were identified. No impacts were identified to Kootenay Lake campgrounds during the primary May-September recreation season.

3.4.6 Summary of Kootenay Lake Recreation Impacts

The main recreation evaluation criterion for Kootenay Lake was the number of days in the non-detrimental range of lake levels for lake recreation identified by lake stakeholders. In addition to this range, several specific threshold impact elevations were identified for specific activities and/or locations. These additional thresholds included boat moorage days at Pilot Bay Resorts, fishing days at Kootenay Kampsites, and swimming days. The total number of days for each criterion and each alternative/benchmark are summarized in **Table 19**.

Table 19. Summary of Quantified Recreation Impacts at Kootenay Lake

Recreation Evaluation Criteria	LS1 (No-Action)	LV1	LS2	LV2		LS benchmark	LV benchmark
Days in the General Recreation Non-Detrimental Range (May-Sep)	135	132	134	132		142	139
Pilot Bay Resorts Boat Moorage Days (Jan-May)	52	52	52	52		51	52
Kootenay Kampsites Fishing Days above elevation 1744 feet (May-Sep)	83	90	82	89		79	86
Swimming Days below elevation 1749 feet (Jun-Aug)	77	76	76	75		84	82

No impacts were identified to Kootenay Lake campgrounds during the primary May-September recreation season. The small changes in summer stage between standard flood control operations (LS, LS1, and LS2) and VARQ flood control operations (LV, LV1, and LV2) should not have any noticeable effect on lake aesthetics.

4.0 Area 2 – Flathead/Clark Fork/Pend Oreille River Basin Recreation Impacts

Seven subareas in Area 1 were evaluated: Hungry Horse Reservoir, the Flathead River upstream of Flathead Lake, Flathead Lake, the South Fork Flathead River and Clark Fork upstream of Lake Pend Oreille, Lake Pend Oreille, the Pend Oreille River in the U.S., and the Pend d'Oreille River in Canada including Pend d'Oreille Reservoir. As described in Section 2.0, only two alternatives (HS and HV) were evaluated in Area 2.

4.1 Hungry Horse Reservoir

Primary recreation activities at Hungry Horse Reservoir that could potentially be affected by changes in water surface levels include camping, fishing, and boating. **Table 20** presents average end-of-month water surface elevations for Hungry Horse Reservoir for all 12 months with both alternatives.

Table 20. Hungry Horse Reservoir Month-End Average Stage (feet)

Month	HS (No-Action)	HV
January	3522	3523
February	3510	3515
March	3505	3509
April	3501	3512
May	3529	3533
June	3555	3556
July	3552	3552
August	3540	3540
September	3538	3538
October	3536	3536
November	3535	3535
December	3533	3532

During the summer recreation season of May to September, VARQ flood control operations (HV) result in higher average end-of-month stage in May. There is little to no change in average end-of-month stage between VARQ flood control operations (HV) and standard flood control operations (HS) in the remaining summer season months. During the remaining lower demand months, average end-of-month stage is similar for both alternatives from October to December and higher with HV from January to April.

4.1.2 Hungry Horse Camping

Campsites at Hungry Horse Reservoir are all above full pool elevation of 3560 feet; therefore, there are no impacts expected from inundation with the modeled alternatives. During the summer recreation season, higher average pool levels in May associated with HV could provide a slight benefit from improved aesthetics. HV will result in no perceptible changes to elevations from HS during the rest of the summer.

4.1.2 Hungry Horse Fishing

Refill probabilities are slightly higher at Hungry Horse Reservoir with HV. This is expected to benefit bull trout in Hungry Horse Reservoir and anadromous fish downstream in the Columbia River. Recreational fishermen may eventually benefit from the improved fishery effect of HV at Hungry Horse and in the Columbia River system.

4.1.1 Hungry Horse Boating

The main concern for boating on Hungry Horse reservoir is access to the lake. Ten boat ramps were identified and compared with water surface elevations to determine the impact of each alternative on ramp functionality. Average end-of-month water surface elevations for HS and HV were compared to minimum usable boat ramp elevations. The end-of-month analysis found no change in the number of usable ramps at the end of each month in the summer recreation season.

Analysis of daily stage data was performed to identify the number of days that boat ramps at the reservoir were functional. **Table 21** shows the sum of the average number of days per month that each ramp was usable (boat ramp days) over the summer recreation season (May to September). The analysis shows increased usable boat ramp days in May with HV. In other summer months there is little to no change in boat ramp days between the alternatives. Reference the **Exhibits** at the end of this report for results of average end-of-month and average daily elevation analysis for each ramp.

Table 21. Hungry Horse Reservoir Average Usable Boat Ramp Days/Month

Month	HS (No-Action)	HV
May	103	145
June	257	262
July	309	309
August	293	293
September	213	209
Total	1,175	1,218

4.1.3 Summary of Hungry Horse Reservoir Recreation Impacts

Quantified recreation evaluation criteria for Hungry Horse Reservoir included boat ramp days at the lake. The results of the evaluation were:

- HS (No-Action) Total Boat Ramp Days (May-September) = 1,175
- HV Total Boat Ramp Days (May-September) = 1,218

Non-quantified potential recreation impacts included effects on camping and fishing. Slight benefits may be expected to camping at the lake as a result of improved aesthetics with the slightly higher pools associated with HV and the resultant slight increase in boat ramp functionality. The additional flows with HV are expected to benefit bull trout in Hungry Horse Reservoir and anadromous fish downstream in the Columbia River which may result in recreation benefits associated with the improved fisheries.

4.2 Flathead River

Hungry Horse Dam discharges to the South Fork Flathead River which joins the mainstem Flathead River and flows on to Flathead Lake approximately 35 miles downstream of the dam. Primary recreation activities on the Flathead River that could be affected by changes in discharge from Hungry Horse Dam include boating and fishing. **Table 22** shows the average monthly discharge from Hungry Horse Dam for both alternatives in all months.

Table 22. Hungry Horse Dam Monthly Average Discharge (cfs)

Month	HS (No-Action)	HV
January	4,789	4,068
February	5,129	3,956
March	2,732	2,862
April	5,418	3,466
May	3,667	5,659
June	2,978	4,238
July	5,146	5,246
August	5,469	5,433
September	1,828	1,829
October	1,634	1,635
November	1,655	1,654
December	1,937	2,103

During the main recreation season of May to September, flows increase with HV from May to July. HV results in a minor decrease in flow in August. Flows are basically the same with either alternative in September. In the off season months, HV flows are lower

in January, February, and April and relatively close in March, September, October, November, and December compared to HS flows.

Flow is also measured at Columbia Falls, downstream of the confluence of the north, middle, and south Forks of the Flathead River. **Table 23** shows the average monthly flow at Columbia Falls for both alternatives and all months.

Table 23. Flathead River at Columbia Falls Monthly Average Discharge (cfs)

Month	HS (No-Action)	HV
January	6,594	5,751
February	6,499	5,465
March	4,558	4,688
April	12,681	10,592
May	23,874	26,088
June	23,650	24,839
July	13,323	13,451
August	8,571	8,573
September	3,871	3,871
October	3,916	3,916
November	4,143	4,143
December	3,887	4,054

During the main recreation season of May to September, downstream flows as measured at Columbia Falls are increased in May and June with HV. There is little to no difference in flows in the remaining summer months. In the winter months, HV flows are lower in January, February, and April and relatively close in March and from September-December.

4.2.1 Flathead River Boating

There are several unimproved boat ramps along the Flathead River. These ramps are operable down to flows of 4,000 cfs. There is no change between HS and HV in the number of days with flows at or above 4,000 cfs during the summer recreation season **(Table 24)**.

Table 24: Average Days ≥ 4,000 cfs, Flathead River at Columbia Falls

Month	HS (No-Action)	HV
May	31	31
June	30	30
July	30	30
Aug	30	30
Sep	6	6
Total	127	127

Additionally, there is no increase in the occurrence of flooding on the Flathead River at Columbia Falls, MT with HV that would affect boating or the day use recreation areas. Below flood stage, flows are slightly higher for HV compared to HS. This small increase would be imperceptible to recreation users.

4.2.2 Flathead River Mainstem Fishing

The optimal discharge range for recreational fishing was identified as 4,000 to 17,000 cfs. During the summer months, HV results in slightly fewer fishing days in May, June, and July. August and September resulted in the same number of fishing days as the no action alternative. **Table 25** shows the average days per month with optimal fishing flows as modeled at Columbia Falls for the two alternatives.

Table 25. Flathead River at Columbia Falls Average Days between 4,000 & 17,000 cfs

Month	HS (No-Action)	HV
May	8	6
June	9	8
July	23	22
August	30	30
September	6	6
Total	76	72

4.2.3 Summary of Flathead River Recreation Impacts

The recreation evaluation criteria for the Flathead River included boating days and fishing days. The total number of days for each criterion and each alternative are summarized in **Table 26**.

Table 26. Summary of Quantified Recreation Impacts at the Flathead River

Recreation Evaluation Criteria	HS (No-Action)	HV
Boating Days with flows at or above 4,000 cfs at Columbia Falls Gage	127	127
Fishing Days with flows at 4,000 to 17,000 cfs at Columbia Falls Gage	76	72

The higher flows in May and June with HV are an increase of 9% and 5%, respectively from the flows with HS. This level of increase is not likely to result in perceptible changes to aesthetics in the area.

4.3 Flathead Lake

Recreation activities at Flathead Lake that could be affected by changes in lake levels include boating, fishing, swimming, and camping. **Table 27** shows the average end-of-month stage for Flathead Lake for both alternatives in all months.

Table 27. Flathead Lake Month-End Average Stage (feet)

Month	HS (No-Action)	HV
January	2887	2887
February	2885	2885
March	2884	2884
April	2887	2886
May	2890	2890
June	2893	2893
July	2893	2893
August	2893	2893
September	2892	2892
October	2891	2891
November	2890	2890
December	2888	2888

There is no difference in the average end-of-month stage at Flathead Lake with either alternative in the summer recreation season of May-September.

4.3.1 Flathead Lake Boating

The most important factor for boating on Flathead Lake is access to the lake. Full pool at Flathead Lake is at elevation 2062.5. Average end-of-month water elevations with HS and HV were compared to minimum usable boat ramp elevations. No changes in ramp

usability were identified across the alternatives during the summer months (May-September) based on average end-of-month elevations. Additional analysis of average daily stages showed a slight increase in usable boat ramp days at Flathead Lake during the summer with HV. Based on usable pool elevation for each boat ramp and the number of days it is above that elevation each month, **Table 28** shows the total number of usable boat ramp days per month. Reference the **Exhibits** at the end of this report for results of average end-of-month and average daily elevation analysis for each ramp.

Table 28. Flathead Lake Average Usable Boat Ramp Days/Month

Month	HS (No-Action)	HV
May	130	132
June	267	269
July	295	298
August	302	303
September	271	271
Total	1,265	1,273

Note: Ramp elevations were provided by Jim Vashro of Montana Fish, Wildlife and Parks (MFWP) for the MFWP ramps through personal communications in 2004. The remaining ramps in Table 9 are privately operated and elevations were obtained through personal communications with facility managers in 2004.

4.3.2 Flathead Lake Swimming

On Flathead Lake, swimming would be affected at pool elevations below 2890 feet because the beach is separated from the water. As shown in **Table 29**, there is no difference in the number of days at or above elevation 2890 feet during the swimming season (June to August).

Table 29: Average Days/Month with Beach Access on Flathead Lake

Average Days with Water Elevation ≥ 2890 ft		
Month	**HS (No-Action)**	**HV**
June	29	29
July	29	29
August	30	30
Total	88	88

4.3.3 Flathead Lake Fishing and Camping

No impacts were identified for fishing or camping facilities on Flathead Lake with implementation of VARQ flood control operations (HV).

4.3.4 Summary of Flathead Lake Recreation Impacts

Quantified recreation evaluation criteria for Flathead Lake included boating days and fishing days. The total number of days for each criterion and each alternative are summarized in **Table 30**.

Table 30. Summary of Quantified Recreation Impacts at Flathead Lake

Recreation Evaluation Criteria	HS (No-Action)	HV
Total Boat Ramp Days (May-Sep)	1,265	1,273
Swimming Days (Jun-Aug)	88	88

The higher Hungry Horse discharges in May and June under HV can be stored in Flathead Lake during the refill period. This results in Flathead Lake having a slightly better probability of filling to full pool. Flathead Lake can also stay full a little longer in the summer under HV. This provides a slight beneficial effect for lake recreation by extending the quantity and quality of recreation opportunities and is desirable for boat ramp function, shoreline activities, and aesthetic values.

4.4 Lower Flathead River and Clark Fork River

Recreational activities on the lower Flathead River between Kerr Dam and the confluence with the Clark Fork that could be affected by changes in discharge from Kerr Dam include boating and fishing. Activities on the lower Clark Fork that could be affected include boating, fishing, swimming, and camping. **Table 31** shows the average end-of-month discharge in cubic feet per second from Kerr Dam for both alternatives in all months.

Table 31. Kerr Dam Monthly Average Discharge (cfs)

Month	HS (No-Action)	HV
January	10,331	9,657
February	10,595	9,412
March	8,206	8,246
April	9,913	9,058
May	21,592	22,312
June	24,222	25,675
July	15,652	15,793
August	8,741	8,821
September	6,062	6,075
October	6,363	6,366
November	7,012	7,012
December	8,624	8,789

Flows are slightly higher with HV in May and June and approximately the same in the remainder of the summer (July-September).

No modeling of flows on the lower Clark Fork was performed downstream of the confluence with the Flathead River. Examination of USGS gage data (1990-2000) identified that flows on the lower Flathead (as measured at the Polson, MT gage) are approximately 55% of flows downstream of the confluence with the Clark Fork (as measured at the Noxon, MT gage). This suggests that relative changes in discharge at Kerr Dam would be reduced by nearly half in the lower Clark Fork reach from the Flathead River confluence to Lake Pend Oreille. This is because of the nearly doubling of flows below the Flathead confluence.

4.4.1 Lower Flathead River and Lower Clark Fork Boating

Non-motorized recreational boating is popular on the lower Flathead River below Kerr Dam. The optimal range of flows for kayaking on the Flathead River below Kerr Dam is 10,000 to 20,000 cfs. **Table 32** shows the number of days per month with optimal flows on this reach of the river for kayaking activities.

Table 32. Lower Flathead River Average Kayaking Days/Month

Average Days per Month with Flows between 10,000 and 20,000 cfs		
Month	**HS (No-Action)**	**HV**
May	13	11
June	14	13
July	17	16
August	10	10
September	1	1
Total	55	51

No impacts to boating on the lower Clark Fork were identified with implementation of VARQ flood control operations (HV).

4.4.2 Lower Flathead River and Lower Clark Fork Fishing

The optimal discharge range for recreational fishing on the Flathead River was identified as 4,000 to 17,000 cfs. **Table 33** shows the number of days per month of the fishing season with optimal flows for fishing for both alternatives.

Table 33. Lower Flathead River Average Days between 4,000 and 17,000 cfs

Month	HS (No-Action)	HV
May	13	13
June	12	11
July	20	19
August	27	28
September	26	27
Total	99	97

No impacts to fishing on the lower Clark Fork were identified with implementation of VARQ flood control operations (HV).

4.4.3 Summary of Lower Flathead River and Lower Clark Fork Recreation Impacts

Quantified recreation evaluation criteria for lower Flathead River and lower Clark Fork included kayaking days and fishing days. The total number of days for each criterion and each alternative are summarized in **Table 34**.

Table 34. Summary of Quantified Recreation Impacts at Lower Flathead River and Lower Clark Fork

Recreation Evaluation Criteria	HS (No-Action)	HV
Lower Flathead River Kayaking Days (May-Sep)	55	51
Lower Flathead River Fishing Days (May-Sep)	99	97

No impacts were identified to boating or fishing on the lower Clark Fork with VARQ flood control operations (HV). HV results in higher flows in May and June; increases of 3% and 6%, respectively from the flows with HS. This level of increase in flow is not likely to result in perceptible changes to aesthetics in the area.

4.5 Lake Pend Oreille

Recreation activities at Lake Pend Oreille that could be affected by changes in lake levels include boating, fishing, camping, and swimming. Average end-of-month water surface elevations at the lake with the two alternatives are shown in **Table 35**.

Table 35. Lake Pend Oreille Month-End Average Stage (feet)

Month	HS (No-Action)	HV
January	2054	2054
February	2054	2054
March	2054	2054
April	2055	2055
May	2059	2059
June	2062	2062
July	2062	2062
August	2062	2062
September	2061	2061
October	2057	2057
November	2054	2054
December	2054	2054

Both summer and winter lake elevations remain the same with both alternatives. No effects are expected for recreation or visual resources. Additional average daily stage analysis found that HV resulted in a slight increase of 3 boat ramp days at Lake Pend Oreille (from 1,896 to 1,899 ramp-days, a change of one tenth of one percent). Reference the **Exhibits** at the end of this report for results of average end-of-month and average daily elevation boat ramp analysis for Lake Pend Oreille.

4.5.1 Summary of Lake Pend Oreille Recreation Impacts

The recreational effects of both alternatives at Lake Pend Oreille would be similar. No impacts to recreational resources or aesthetics are expected from VARQ flood control operations (HV) at the lake.

4.6 Pend Oreille River – U.S.

Primary recreation activities on the Pend Oreille River that could be affected by changes in discharge from Albeni Falls Dam include camping, fishing, and boating. **Table 37** shows the average monthly discharge from Albeni Falls Dam for both alternatives.

Table 37. Albeni Falls Dam Monthly Average Discharge (cfs)

Month	HS (No-Action)	HV
January	17,296	16,956
February	19,448	17,948
March	19,521	19,516
April	28,016	27,513
May	52,961	52,625
June	55,277	57,402
July	29,700	29,885
August	14,526	14,602
September	13,363	13,405
October	18,380	18,364
November	19,464	19,387
December	16,393	16,477

Discharge from the dam is slightly lower in February (-8%), slightly higher in June (+4%), and approximately the same (within 2%) in all other months with VARQ flood control operations relative to standard flood control operations.

4.6.1 Summary of Pend Oreille River Recreation Impacts

Due to the relatively minor changes in discharge from Albeni Falls Dam during the summer recreation season with HV, no impacts to recreational resources and activities or aesthetics are expected on the Pend Oreille River.

4.7 Pend d'Oreille River – Canada

The primary location for recreational activities on the Pend d'Oreille River in Canada is BC Hydro's Pend d'Oreille Recreation Area. Activities at the recreation area that could be affected by changes in discharge from Albeni Falls Dam include camping, swimming, boating, and fishing. Based upon the minimal changes to discharge from Albeni Falls Dam with HV, no impacts to recreational resources or aesthetics are expected at Pend d'Oreille Reservoir.

5.0 Area 3 – Columbia River Mainstem Recreation Impacts

Evaluation of recreation impacts was performed for four subareas; the upper Columbia River from the Kootenay River confluence to its inflow point to Lake Franklin Delano Roosevelt (Lake Roosevelt), Lake Roosevelt itself, Lake Rufus Woods, and the middle and lower Columbia River (downstream of Chief Joseph Dam). The upper Columbia River reach is in Canada, the other subareas are in the U.S.

5.1 Upper Columbia River

This reach includes the Columbia River from the confluence with Kootenai River in Canada to the U.S. Border. Popular river recreation activities identified in the upper Columbia River reach include fishing, swimming, and boating. No flow data were modeled for the different combinations downstream of Libby Dam. Examination of USGS and Environment Canada gage data (1991-2000) identified that flows just downstream of Libby Dam are approximately 15% of the volume of flows downstream of the Kootenai/Columbia confluence (as measured at the Birchbank, BC gage). This suggests that changes in discharge from Libby Dam would be reduced in terms of their relative magnitude by a factor of about five times downstream of the confluence with the Columbia. Regulation of Kootenay Lake would also likely provide additional reduction of the changes. No impacts to recreational resources or aesthetics on the upper Columbia River reach are expected with any of the combinations.

5.2 Lake Roosevelt

The Lake Roosevelt reach extends from Grand Coulee Dam upriver to the Canadian border. Popular recreation activities at Lake Roosevelt that could be affected by changes in lake levels include boating, fishing, swimming, and camping. **Table 39** shows the average end-of-month stages at the lake for all combinations.

Table 39. Lake Roosevelt Month-End Average Stage (feet)

Month	LS1+HS (No-Action)	LV1+HV	LS2+HS	LV2+HV		LS+HS benchmark	LV+HV benchmark
January	1268	1268	1268	1268		1268	1268
February	1264	1264	1264	1264		1264	1263
March	1261	1260	1261	1260		1261	1259
April	1244	1242	1244	1242		1244	1242
May	1254	1253	1254	1253		1254	1253
June	1287	1287	1287	1287		1287	1287
July	1288	1288	1288	1288		1288	1288
August	1280	1280	1280	1280		1280	1280
September	1290	1290	1290	1290		1290	1290
October	1290	1290	1290	1290		1290	1290
November	1286	1286	1286	1286		1286	1286
December	1287	1287	1287	1287		1287	1287

All average end-of-month stages at Lake Roosevelt for all combinations are similar. The month of April exhibits the largest change in average end-of-month stage; -2 feet with VARQ combinations (LV+HV, LV1+HV, and LV2+HV) as compared to standard flood control combinations (LS+HS, LS1+HS, and LS2+HS). VARQ combinations also result in an average 1 foot reduction in stage at the end of May. Average end-of-month stages are basically the same for combinations in all other months.

5.2.1 Lake Roosevelt Boating

Average end-of-month water elevations with all combinations were compared to minimum boat ramp elevations. No changes in ramp usability were identified across the combinations during the summer months (May- September) based on average end-of-month elevations. Additional analysis of average daily stages showed very little change in usable boat ramp days at Lake Roosevelt during the summer. **Table 40** shows the number of usable boat ramp days per month. The ramp days with all combinations are within .5% of each other. Reference the **Exhibits** at the end of this report for results of average end-of-month and average daily elevation analysis for each ramp.

Table 40. Lake Roosevelt Average Usable Boat Ramp Days/Month

Month	LS1+HS (No-Action)	LV1+HV	LS2+HS	LV2+HV		LS+HS benchmark	LV+HV benchmark
May	349	336	349	336		349	337
June	695	694	695	694		695	694
July	744	744	744	744		744	744
August	650	650	650	650		647	647
September	720	720	720	720		720	720
Total	3,158	3,144	3,157	3,144		3,155	3,142

5.2.2 Lake Roosevelt Fishing, Swimming, and Camping

No impacts to Lake Roosevelt fishing, swimming, or camping recreation are expected with any of the combinations.

5.2.5 Summary of Lake Roosevelt Recreation Impacts

No impacts to Lake Roosevelt recreational resources or aesthetics are expected with any of the combinations.

5.3 Lake Rufus Woods

Recreation activities at Lake Rufus Woods include boating, fishing, swimming, and camping. Water surface elevations were not modeled for the combinations at Lake Rufus Woods, which is a run-of-river reservoir rather than a storage reservoir. Its relatively narrow range of pool levels is governed by power requirements; it does not operate for flood control. Average monthly discharges from Grand Coulee with each combination were modeled and are presented in **Table 42**.

Table 42. Grand Coulee Dam Monthly Average Discharge

Month	LS1+HS (No-Action)	LV1+HV	LS2+HS	LV2+HV		LS+HS benchmark	LV+HV benchmark
January	161,507	152,491	161,492	152,492		161,824	152,792
February	93,219	89,154	93,221	89,156		93,232	89,445
March	88,705	88,567	88,703	88,552		88,712	88,455
April	117,940	118,038	117,939	118,038		117,981	117,832
May	161,380	164,241	161,928	164,734		159,490	163,146
June	149,242	153,132	149,696	153,537		142,543	149,566
July	142,841	144,822	142,613	144,592		139,211	141,149
August	111,443	114,127	110,948	113,673		108,619	108,761
September	59,887	60,179	59,820	60,068		72,969	72,985
October	73,262	73,476	73,197	73,465		73,862	73,859
November	82,568	83,018	82,519	82,997		82,913	83,084
December	96,385	96,838	96,335	96,818		97,196	97,381

During the summer recreation season of May to September, VARQ flood control combinations (LV+HV, LV1+HV, and LV2+HV) result in slight increases in discharge from Grand Coulee from May – August relative to standard flood control combinations (LS+HS, LS1+HS, and LS2+HS). These relatively minor changes are not expected to affect recreational resources or aesthetics at Lake Rufus Woods.

5.4 Middle and Lower Columbia River

The lower Columbia River reach includes the river downstream of Chief Joseph Dam. No modeling of flows or water surface elevations for the combinations was performed downstream of Chief Joseph Dam. Modeled average monthly discharge from Grand Coulee Dam was presented in **Table 42**. The relative effect of changes in discharge from Grand Coulee is reduced as the volume of flows increases downstream. Examination of mean annual flows (1990-2000) at Grand Coulee, Priest Rapids, and The Dalles indicates that flows at Grand Coulee are approximately 88% of the volume at Priest Rapids and 58% of the volume at The Dalles. As was found to be the case with Lake Rufus Woods, the relatively minor changes in discharge from Grand Coulee dam during the summer recreation season with VARQ flood control operations are not expected to affect recreational resources or aesthetics on the Columbia River downstream of Chief Joseph Dam.

UPPER COLUMBIA ALTERNATIVE FLOOD CONTROL AND FISH OPERATIONS EIS

RECREATION APPENDIX IMPACT ANALYSIS EXHIBITS

List of Exhibits

Exhibit 1: Lake Koocanusa Avg. End of Month Boat Ramp In/Out Analysis
Exhibit 2: Lake Koocanusa Avg. Boat Ramp Days per Month
Exhibit 3: Hungry Horse Reservoir Avg. End of Month Boat Ramp In/Out Analysis
Exhibit 4: Hungry Horse Reservoir Avg. Boat Ramp Days per Month
Exhibit 5: Flathead Lake Avg. End of Month Boat Ramp In/Out Analysis
Exhibit 6: Flathead Lake Avg. Boat Ramp Days per Month
Exhibit 7: Lake Pend Oreille Avg. End of Month Boat Ramp In/Out Analysis
Exhibit 8: Lake Pend Oreille Avg. Boat Ramp Days per Month
Exhibit 9: Lake Roosevelt Avg. End of Month Boat Ramp In/Out Analysis
Exhibit 10: Lake Roosevelt Avg. Boat Ramp Days per Month

Exhibit 1: Lake Koocanusa Average End of Month Boat Ramp In/Out Analysis

Boat Ramp Name	End of Ramp Elevation (feet)	May						June						July						August						September					
		LS	LV	LS1	LV1	LS2	LV2	LS	LV	LS1	LV1	LS2	LV2	LS	LV	LS1	LV1	LS2	LV2	LS	LV	LS1	LV1	LS2	LV2	LS	LV	LS1	LV1	LS2	LV2
Month End Average Stage (feet)		2400	2409	2393	2406	2391	2404	2449	2449	2430	2440	2429	2438	2458	2458	2442	2447	2441	2447	2458	2458	2437	2438	2437	2438	2437	2438	2434	2435	2434	2435
US Boat Ramps																															
Tobacco River	2449	out[2]	out	out	out	out	out	in[1]	in	out	out	out	out	in	in	out	out	out	out	in	in	out	out	out	out	out	out	out	out	out	out
Gateway Boat Camp[3]	2445	out	out	out	out	out	out	in	in	out	out	out	out	in	in	out	in	out	in	in	in	out	out	out	out	out	out	out	out	out	out
Warland Flats	2444	out	out	out	out	out	out	in	in	out	out	out	out	in	in	out	in	out	in	in	in	out	out	out	out	out	out	out	out	out	out
Tobacco Plains	2435	out	out	out	out	out	out	in	in	out	in	out	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	out	in	out	in
Rexford Bench Complex	2431	out	out	out	out	out	out	in	in	out	in	out	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Koocanusa Lake Campsite and Resort	2420	out	out	out	out	out	out	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Mariner's Haven	2420	out	out	out	out	out	out	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
McGillvary	2385	out	out	out	out	out	out	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Rocky Gorge	2370	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Lake Koocanusa Resort and Marina	2334	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Peck Gulch	2310	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Souse Gulch	2310	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Barron Creek	2282	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Canadian Boat Ramps																															
Englishman Creek	2458	out	out	out	out	out	out	out	out	out	out	out	out	in	in	out	out	out	out	in	in	out	out	out	out	out	out	out	out	out	out
Newgate Sandy Shores Resort	2439	out	out	out	out	out	out	in	in	out	in	out	out	in	in	in	in	in	in	in	in	out	out	out	out	out	out	out	out	out	out
Koocanusa Marina	2430	out	out	out	out	out	out	in	in	in	in	out	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Golden Ears (Gold Creek Bay)	2427	out	out	out	out	out	out	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Kikomun Creek Provincial Park[4]	2396	in	in	out	in	out	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in

Full pool = 2459 ft.

Notes:
1-in = end of the boat ramp would be in the water so ramp would most likely be useable.
2-out = end of the boat ramp would be out of the water so ramp would probably not be useable.
3- No boat ramp, this level is the lowest operating level for the site.
4-This data from BC Hydro, Sept 2004.

Exhibit 2: Lake Koocanusa Average Boat Ramp Days per Month

Boat Ramp Name	End of Ramp Elevation (feet)	May						June						July						August						September					
		LS	LV	LS1	LV1	LS2	LV2	LS	LV	LS1	LV1	LS2	LV2	LS	LV	LS1	LV1	LS2	LV2	LS	LV	LS1	LV1	LS2	LV2	LS	LV	LS1	LV1	LS2	LV2
US Boat Ramps																															
Tobacco River	2449	0.0	0.0	0.0	0.0	0.0	0.0	6.0	6.5	1.8	2.8	1.5	2.5	28.1	28.5	7.5	14.4	5.9	13.5	31.0	31.0	2.2	4.2	1.6	3.5	14.5	14.5	0.0	0.0	0.0	0.0
Gateway Boat Camp	2445	0.0	0.0	0.0	0.0	0.0	0.0	8.3	9.2	2.4	4.5	2.3	4.3	29.9	30.0	10.6	18.1	9.4	17.1	31.0	31.0	6.8	10.2	6.0	9.5	20.4	20.4	0.0	0.0	0.0	0.0
Warland Flats	2444	0.1	0.0	0.0	0.0	0.0	0.0	9.0	9.9	2.6	5.0	2.5	4.8	30.1	30.2	11.8	20.3	10.6	18.0	31.0	31.0	8.3	12.4	7.3	11.1	21.4	21.4	0.0	0.0	0.0	0.0
Tobacco Plains	2433	1.0	0.9	0.3	0.4	0.3	0.3	15.3	17.9	6.1	11.5	5.5	10.4	31.0	31.0	21.7	28.3	20.8	27.7	31.0	31.0	27.1	30.8	26.8	30.4	30.4	30.5	0.0	28.3	24.3	28.1
Koocanusa Lake Campsite and Resort	2420	2.3	4.8	2.1	4.0	2.1	3.7	21.3	23.9	12.0	18.5	10.9	17.6	31.0	31.0	29.2	30.8	28.9	30.6	31.0	31.0	31.0	31.0	31.0	31.0	30.6	30.6	30.1	30.2	30.0	30.2
Mariner's Haven	2420	2.3	4.8	2.1	4.0	2.1	3.7	21.3	23.9	12.0	18.5	10.9	17.6	31.0	31.0	29.2	30.8	28.9	30.6	31.0	31.0	31.0	31.0	31.0	31.0	30.6	30.6	30.1	30.2	30.0	30.2
McGillvary	2385	10.9	19.4	9.9	19.3	9.5	19.3	28.9	29.2	27.6	28.9	26.5	28.8	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.6	30.6	30.6	30.6	30.6	30.6
Rocky Gorge	2370	16.4	23.1	16.0	23.1	16.0	23.1	29.6	29.7	29.4	29.6	29.1	29.5	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.6	30.6	30.6	30.6	30.6	30.6
Rexford Bench Complex	2341	24.3	27.8	24.2	27.7	24.2	27.7	30.0	30.0	30.0	30.0	30.0	30.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.6	30.6	30.6	30.6	30.6	30.6
Lake Koocanusa Resort and Marina	2334	26.1	28.7	26.1	28.7	26.1	28.7	30.0	30.0	30.0	30.0	30.0	30.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.6	30.6	30.6	30.6	30.6	30.6
Souse Gulch Dock	2310	30.0	30.3	29.8	30.3	29.8	30.3	30.0	30.0	30.0	30.0	30.0	30.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.6	30.6	30.6	30.6	30.6	30.6
Peck Gulch	2310	30.0	30.3	29.8	30.3	29.8	30.3	30.0	30.0	30.0	30.0	30.0	30.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.6	30.6	30.6	30.6	30.6	30.6
Barron Creek	2282	31.0	31.0	31.0	31.0	31.0	31.0	30.0	30.0	30.0	30.0	30.0	30.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.6	30.6	30.6	30.6	30.6	30.6
Number of Useable Days		**174.4**	**201.0**	**171.4**	**198.8**	**170.9**	**198.0**	**289.7**	**300.2**	**243.8**	**269.4**	**239.2**	**265.4**	**398.0**	**398.8**	**327.0**	**359.7**	**321.4**	**354.6**	**403.0**	**403.0**	**323.3**	**336.5**	**320.7**	**333.4**	**361.8**	**362.1**	**274.2**	**302.8**	**298.4**	**302.6**
Canadian Boat Ramps																															
Englishman Creek	2458	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.9	0.2	0.3	0.2	0.2	17.3	18.2	1.0	1.2	1.1	0.8	29.6	30.2	0.0	0.0	0.0	0.0	2.5	2.5	0.0	0.0	0.0	0.0
Newgate Sandy Shores Resort	2439	0.3	0.1	0.0	0.0	0.0	0.0	12.1	13.8	4.1	7.8	3.5	7.2	30.8	30.9	17.1	25.2	16.0	24.2	31.0	31.0	21.9	28.7	21.4	28.0	28.1	28.2	1.7	3.1	1.5	2.0
Koocanusa Marina	2430	1.2	1.5	0.7	0.9	0.5	0.6	16.9	19.4	7.1	13.6	6.6	12.0	31.0	31.0	23.9	29.1	23.0	28.6	31.0	31.0	28.3	31.0	27.7	30.9	30.5	30.6	27.2	28.9	26.6	28.9
Golden Ears (Gold Creek Bay)	2427	1.5	2.1	1.2	1.6	1.0	1.3	18.3	20.9	8.3	15.3	7.7	13.8	31.0	31.0	26.2	29.9	25.4	29.4	31.0	31.0	30.8	31.0	30.2	31.0	30.6	30.6	29.3	29.5	28.9	29.5
Kikomun Creek Provincial Park	2396	7.4	16.3	6.4	16.2	6.0	16.0	27.7	28.5	24.1	27.9	22.8	27.4	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.6	30.6	30.6	30.6	30.6	30.6
Number of Useable Days		**10.4**	**20.0**	**8.3**	**18.8**	**7.6**	**17.9**	**75.9**	**83.5**	**43.9**	**64.8**	**40.8**	**60.6**	**141.0**	**142.1**	**99.3**	**116.4**	**96.5**	**113.9**	**153.6**	**154.2**	**112.0**	**121.7**	**110.4**	**120.9**	**122.3**	**122.5**	**88.7**	**92.1**	**87.6**	**91.0**

Exhibit 3: Hungry Horse Reservoir Average End of Month Boat Ramp In/Out Analysis

Boat Ramp Name	End of Ramp Elevation	May		June		July		August		September	
		HS	HV	HS	HV	HS	HV	HS	HV	HS	HV
Month End Average Stage (feet)		3529.2	3533.1	3555.3	3555.7	3552.3	3552.3	3540.3	3540.3	3537.6	3537.6
Doris Creek	3545	out	out	in	in	in	in	out	out	out	out
Canyon Creek	3542	out	out	in	in	in	in	out	out	out	out
Murray Bay CG	3540	out	out	in	in	in	in	out	out	out	out
Lost Johnny Camp	3536	out	out	in	in	in	in	in	in	in	in
Lid Creek CG	3529	in	in	in	in	in	in	in	in	in	in
Emery Bay CG	3527	in	in	in	in	in	in	in	in	in	in
Devil's Corkscrew CG	3517	in	in	in	in	in	in	in	in	in	in
Lost Johnny Point CG	3515	in	in	in	in	in	in	in	in	in	in
Riverside	3507	in	in	in	in	in	in	in	in	in	in
Abbot Bay	3430	in	in	in	in	in	in	in	in	in	in
Full Pool = 3560 ft.											

Notes:
1-in = end of the boat ramp would be in the water so ramp would most likely be useable.
2-out = end of the boat ramp would be out of the water so ramp would probably not be useable.

Exhibit 4: Hungry Horse Reservoir Average Boat Ramp Days per Month

Boat Ramp Name	End of Ramp Elevation	May		June		July		August		September	
		HS	HV	HS	HV	HS	HV	HS	HV	HS	HV
Doris Creek	3545	0.7	3.0	18.9	19.9	30.5	30.6	18.7	18.7	0.0	0.0
Canyon Creek	3542	1.5	4.3	20.9	22.0	30.6	30.6	26.6	26.6	0.4	0.1
Murray Bay CG	3540	2.0	5.2	22.2	23.1	30.6	30.6	30.6	30.6	3.6	0.3
Lost Johnny Camp	3536	3.1	7.6	24.3	24.9	31.0	31.0	30.7	30.6	28.8	28.8
Lid Creek CG	3529	6.3	13.4	26.8	27.1	31.0	31.0	31.0	31.0	30.0	30.0
Emery Bay CG	3527	7.4	14.4	27.3	27.6	31.0	31.0	31.0	31.0	30.0	30.0
Devil's Corkscrew CG	3517	14.2	20.1	28.7	28.9	31.0	31.0	31.0	31.0	30.0	30.0
Lost Johnny Point CG	3515	15.7	21.4	28.9	29.0	31.0	31.0	31.0	31.0	30.0	30.0
Riverside	3507	20.8	24.4	29.4	29.4	31.0	31.0	31.0	31.0	30.0	30.0
Abbot Bay	3430	31.0	31.0	30.0	30.0	31.0	31.0	31.0	31.0	30.0	30.0
Number of Useable Days		**102.7**	**144.8**	**257.4**	**261.7**	**308.7**	**308.7**	**292.6**	**292.5**	**212.8**	**209.3**

Exhibit 5: Flathead Lake Average End of Month Boat Ramp In/Out Analysis

Boat Ramp Name	End of Ramp Elevation (feet)	May		June		July		August		September	
		HS	HV	HS	HV	HS	HV	HS	HV	HS	HV
Month End Average Stage (feet)		2890	2890	2893	2893	2893	2893	2893	2893	2892	2892
Ducharme	2893	out[2]	out	out	out	out	out	out	out	out	out
Arrowhead Park and Marina	2891	out	out	in[1]	in	in	in	in	in	in	in
Marina Cay Resort and Conference Center	2891	out	out	in	in	in	in	in	in	in	in
Averills Ranch	2891	out	out	in	in	in	in	in	in	in	in
Bigfork	2890	in	in	in	in	in	in	in	in	in	in
Finley Point	2890	in	in	in	in	in	in	in	in	in	in
Bayshore Resort	2887	in	in	in	in	in	in	in	in	in	in
Walstead	2885	in	in	in	in	in	in	in	in	in	in
Woods Bay	2884	in	in	in	in	in	in	in	in	in	in
Elmo	2883	in	in	in	in	in	in	in	in	in	in
Full Pool = 2893 ft.											

Notes:
1-out = end of the boat ramp would be out of the water so ramp would probably not be useable.
2-in = end of the boat ramp woulb be in the water so ramp would most likely be useable.

Exhibit 6: Flathead Lake Average Boat Ramp Days per Month

Boat Ramp Name	Ramp Elevation (feet)	May		June		July		August		September	
		HS	HV	HS	HV	HS	HV	HS	HV	HS	HV
Ducharme	2893	0.0	0.0	11.7	12.3	25.2	25.6	27.8	28.2	0.9	0.9
Arrowhead Park and Marina	2891	1.2	1.6	24.9	25.2	28.5	29.2	29.5	29.7	29.5	29.5
Marina Cay Resort and Conference Center	2891	1.2	1.6	24.9	25.2	28.5	29.2	29.5	29.7	29.5	29.5
Averills Ranch	2891	1.2	1.6	24.9	25.2	28.5	29.2	29.5	29.7	29.5	29.5
Bigfork	2890	4.1	5.2	29.5	29.7	29.6	29.8	30.3	30.3	30.0	30.0
Finley Point	2890	4.1	5.2	29.5	29.7	29.6	29.8	30.3	30.3	30.0	30.0
Bayshore Resort	2887	25.0	24.4	30.3	30.3	31.0	31.0	31.0	31.0	30.0	30.0
Walstead	2885	30.6	30.2	30.4	30.4	31.4	31.4	31.4	31.4	30.4	30.4
Woods Bay	2884	31.2	31.1	30.4	30.4	31.4	31.4	31.4	31.4	30.4	30.4
Elmo	2883	31.4	31.4	30.4	30.4	31.4	31.4	31.4	31.4	30.4	30.4
Number of Useable Days		**130.0**	**132.2**	**267.0**	**268.9**	**295.3**	**297.9**	**302.2**	**303.4**	**270.8**	**270.8**

Exhibit 7: Lake Pend d'Oreille Average End of Month Boat Ramp In/Out Analysis

Boat Ramp Name	End of Ramp Elevation (feet)	May		June		July		August		September	
		HS	HV	HS	HV	HS	HV	HS	HV	HS	HV
Month End Average Stage (feet)		2059	2059	2062	2062	2062	2062	2062	2062	2061	2061
Beyond Hope Resort	2060	out[1]	out	in[2]	in	in	in	in	in	in	in
Island View Resort	2060	out	out	in	in	in	in	in	in	in	in
Springy Point Recreation Area	2059	in	in	in	in	in	in	in	in	in	in
Samowen Park	2056	in	in	in	in	in	in	in	in	in	in
Albeni Cove Recreation Area	2055	in	in	in	in	in	in	in	in	in	in
Garfield Bay	2055	in	in	in	in	in	in	in	in	in	in
Buttonhook	2055	in	in	in	in	in	in	in	in	in	in
Farragut State Park	2055	in	in	in	in	in	in	in	in	in	in
MacDonalds Hudson Bay Resort	2054	in	in	in	in	in	in	in	in	in	in
Trestle Creek Recreation Area	2054	in	in	in	in	in	in	in	in	in	in
Idaho Country Resorts	2053	in	in	in	in	in	in	in	in	in	in
Bitter End Marina	2052	in	in	in	in	in	in	in	in	in	in
East Hope	2049	in	in	in	in	in	in	in	in	in	in
Full pool = 2063.5 ft.											

Notes:
1-out = end of the boat ramp would be out of the water so ramp would probably not be useable.
2-in = end of the boat ramp woulb be in the water so ramp would most likely be useable.

Exhibit 8: Lake Pend d'Oreille Average Boat Ramp Days per Month

Boat Ramp Name	Boat Ramp Elevation (feet)	May		June		July		August		September	
		HS	HS	HS	HS	HS	HS	HS	HS	HS	HS
Beyond Hope Resort	2060	2.9	3.1	18.9	19.5	31.4	31.4	31.4	31.4	30.4	30.4
Island View Resort	2060	2.9	3.1	18.9	19.5	31.4	31.4	31.4	31.4	30.4	30.4
Springy Point Recreation Area	2059	4.6	4.9	25.4	26.0	31.4	31.4	31.4	31.4	30.4	30.4
Samowen Park	2056	23.9	23.2	30.4	30.4	31.4	31.4	31.4	31.4	30.4	30.4
Albeni Cove Recreation Area	2055	31.4	31.4	30.4	30.4	31.4	31.4	31.4	31.4	30.4	30.4
Garfield Bay	2055	31.4	31.4	30.4	30.4	31.4	31.4	31.4	31.4	30.4	30.4
Buttonhook	2055	31.4	31.4	30.4	30.4	31.4	31.4	31.4	31.4	30.4	30.4
Farragut State Park	2055	31.4	31.4	30.4	30.4	31.4	31.4	31.4	31.4	30.4	30.4
MacDonalds Hudson Bay Resort	2054	31.4	31.4	30.4	30.4	31.4	31.4	31.4	31.4	30.4	30.4
Trestle Creek Recreation Area	2054	31.4	31.4	30.4	30.4	31.4	31.4	31.4	31.4	30.4	30.4
Idaho Country Resorts	2053	31.4	31.4	30.4	30.4	31.4	31.4	31.4	31.4	30.4	30.4
Bitter End Marina	2052	31.4	31.4	30.4	30.4	31.4	31.4	31.4	31.4	30.4	30.4
East Hope	2049	31.4	31.4	30.4	30.4	31.4	31.4	31.4	31.4	30.4	31.4
Number of Useable Days		**316.9**	**316.9**	**367.2**	**369.0**	**408.2**	**408.2**	**408.2**	**408.2**	**395.2**	**396.2**

Exhibit 9: Lake Roosevelt Average End of Month Boat Ramp In/Out Analysis

Boat Ramp Name	End of Ramp Elevation	May						June						July						August						September					
		LS+HS	LV+HV	LS1+HS	LV1+HV	LS2+HS	LV2+HV	LS+HS	LV+HV	LS1+HS	LV1+HV	LS2+HS	LV2+HV	LS+HS	LV+HV	LS1+HS	LV1+HV	LS2+HS	LV2+HV	LS+HS	LV+HV	LS1+HS	LV1+HV	LS2+HS	LV2+HV	LS+HS	LV+HV	LS1+HS	LV1+HV	LS2+HS	LV2+HV
		1254	1253	1254	1253	1254	1253	1287	1287	1287	1287	1287	1287	1288	1288	1288	1288	1288	1288	1280	1280	1280	1280	1280	1280	1290	1290	1290	1290	1290	1290
Jones Bay	1282	out	out	out	out	out	out	in	in	in	in	in	in	in	in	in	in	in	in	out	out	out	out	out	out	in	in	in	in	in	in
Hawk Creek	1281	out	out	out	out	out	out	in	in	in	in	in	in	in	in	in	in	in	in	out	out	out	out	out	out	in	in	in	in	in	in
Marcus Island	1281	out	out	out	out	out	out	in	in	in	in	in	in	in	in	in	in	in	in	out	out	out	out	out	out	in	in	in	in	in	in
Evans	1280	out	out	out	out	out	out	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
North Gorge	1280	out	out	out	out	out	out	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Napoleon Bridge	1280	out	out	out	out	out	out	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Snag Cove Camp	1277	out	out	out	out	out	out	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
China Bend	1277	out	out	out	out	out	out	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Crescent Bay	1265	out	out	out	out	out	out	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Daisy	1265	out	out	out	out	out	out	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
French Rocks	1265	out	out	out	out	out	out	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Two Rivers (marina)	1260	out	out	out	out	out	out	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Hansen Harbor	1253	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Bradbury Beach	1251	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Barnaby Island	1251	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Gifford	1249	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Fort Spokane	1247	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Lincoln Mill	1245	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Porcupine Bay	1243	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Kettle Falls (marina)	1234	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Hunters Camp	1230	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Keller Ferry (marina)	1229	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Seven Bays (marina)	1227	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in
Spring Canyon (marina)	1222	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in

Full Pool = 1290 ft.

Notes:
1-out = end of the boat ramp would be out of the water so ramp would probably not be useable.
2-in = end of the boat ramp would be in the water so ramp would most likely be useable.

Exhibit 10: Lake Roosevelt Average Boat Ramp Days per Month

Boat Ramp Name	End of Ramp Elevation (feet)	May						June						July						August						September					
		LS+HS	LV+HV	LS1+HS	LV1+HV	LS2+HS	LV2+HV	LS+HS	LV+HV	LS1+HS	LV1+HV	LS2+HS	LV2+HV	LS+HS	LV+HV	LS1+HS	LV1+HV	LS2+HS	LV2+HV	LS+HS	LV+HV	LS1+HS	LV1+HV	LS2+HS	LV2+HV	LS+HS	LV+HV	LS1+HS	LV1+HV	LS2+HS	LV2+HV
Jones Bay	1282	4	4	4	4	4	4	26.5	26.0	26.5	26.0	26.5	26.0	31.0	31.0	31.0	31.0	31.0	31.0	5	5	6	6	6	5	30.0	30.0	30.0	30.0	30.0	30.0
Hawk Creek	1281	4	4	4	4	4	4	26.5	26.5	26.5	26.5	26.5	26.5	31.0	31.0	31.0	31.0	31.0	31.0	5	5	6	6	6	6	30.0	30.0	30.0	30.0	30.0	30.0
Marcus Island	1281	4	4	4	4	4	4	26.5	26.5	26.5	26.5	26.5	26.5	31.0	31.0	31.0	31.0	31.0	31.0	5	5	6	6	6	6	30.0	30.0	30.0	30.0	30.0	30.0
Evans	1280	7	6	7	6	7	6	27.7	27.7	27.7	27.7	27.7	27.7	31.0	31.0	31.0	31.0	31.0	31.0	25	25	25	25	25	25	30.0	30.0	30.0	30.0	30.0	30.0
North Gorge	1280	7	6	7	6	7	6	27.7	27.7	27.7	27.7	27.7	27.7	31.0	31.0	31.0	31.0	31.0	31.0	24.7	24.7	24.7	24.7	24.7	24.7	30.0	30.0	30.0	30.0	30.0	30.0
Napoleon Bridge	1280	7	6	7	6	7	6	27.7	27.7	27.7	27.7	27.7	27.7	31.0	31.0	31.0	31.0	31.0	31.0	24.7	24.7	24.7	24.7	24.7	24.7	30.0	30.0	30.0	30.0	30.0	30.0
Snag Cove Camp	1277	8	8	8	8	8	8	27.7	27.7	27.7	27.7	27.7	27.7	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.0	30.0	30.0	30.0	30.0	30.0
China Bend	1277	8	8	8	8	8	8	27.7	27.7	27.7	27.7	27.7	27.7	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.0	30.0	30.0	30.0	30.0	30.0
Crescent Bay	1265	11	11	11	11	11	11	28.8	28.8	28.8	28.8	28.8	28.8	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.0	30.0	30.0	30.0	30.0	30.0
Daisy	1265	11	11	11	11	11	11	28.8	28.8	28.8	28.8	28.8	28.8	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.0	30.0	30.0	30.0	30.0	30.0
French Rocks	1265	11	11	11	11	11	11	28.8	28.8	28.8	28.8	28.8	28.8	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.0	30.0	30.0	30.0	30.0	30.0
Two Rivers (marina)	1260	14	12	14	12	14	12	30.0	30.0	30.0	30.0	30.0	30.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.0	30.0	30.0	30.0	30.0	30.0
Hansen Harbor	1253	16	16	16	15	16	15	30.0	30.0	30.0	30.0	30.0	30.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.0	30.0	30.0	30.0	30.0	30.0
Bradbury Beach	1251	16	16	16	16	16	16	30.0	30.0	30.0	30.0	30.0	30.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.0	30.0	30.0	30.0	30.0	30.0
Barnaby Island	1251	16	16	16	16	16	16	30.0	30.0	30.0	30.0	30.0	30.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.0	30.0	30.0	30.0	30.0	30.0
Gifford	1249	17	17	17	17	17	17	30.0	30.0	30.0	30.0	30.0	30.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.0	30.0	30.0	30.0	30.0	30.0
Fort Spokane	1247	18	17	18	17	18	17	30.0	30.0	30.0	30.0	30.0	30.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.0	30.0	30.0	30.0	30.0	30.0
Lincoln Mill	1245	18	18	18	18	18	18	30.0	30.0	30.0	30.0	30.0	30.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.0	30.0	30.0	30.0	30.0	30.0
Porcupine Bay	1243	18	18	18	18	18	18	30.0	30.0	30.0	30.0	30.0	30.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.0	30.0	30.0	30.0	30.0	30.0
Kettle Falls (marina)	1234	25	24	25	24	25	24	30.0	30.0	30.0	30.0	30.0	30.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.0	30.0	30.0	30.0	30.0	30.0
Hunters Camp	1230	25	25	25	25	25	25	30.0	30.0	30.0	30.0	30.0	30.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.0	30.0	30.0	30.0	30.0	30.0
Keller Ferry (marina)	1229	27	27	27	27	27	27	30.0	30.0	30.0	30.0	30.0	30.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.0	30.0	30.0	30.0	30.0	30.0
Seven Bays	1227	27	27	27	27	27	27	30.0	30.0	30.0	30.0	30.0	30.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.0	30.0	30.0	30.0	30.0	30.0
Spring Canyon (marina)	1222	27	27	27	27	27	27	30.0	30.0	30.0	30.0	30.0	30.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	30.0	30.0	30.0	30.0	30.0	30.0
Number of useable days		**349**	**337**	**349**	**336**	**349**	**336**	**695**	**694**	**695**	**694**	**695**	**694**	**744**	**744**	**744**	**744**	**744**	**744**	**647**	**647**	**650**	**650**	**650**	**650**	**720**	**720**	**720**	**720**	**720**	**720**

APPENDIX F

Detailed Socioeconomic Assessment

UPPER COLUMBIA ALTERNATIVE FLOOD CONTROL AND FISH OPERATIONS EIS

SOCIOECONOMIC AFFECTED ENVIRONMENT

Appendix F: Part 1 of 2

prepared for:

U.S. Army Corps of Engineers
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and

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May 2005

UPPER COLUMBIA ALTERNATIVE FLOOD CONTROL AND FISH OPERATIONS EIS

SOCIOECONOMIC AFFECTED ENVIRONMENT

TABLE OF CONTENTS

Page F-

Appendix F: Part 1 of 2 i
1.0 Introduction 1
2.0 Area 1 – Kootenai River Basin 2
2.1 Area 1 Demographics 3
2.2 Area 1 Employment and Income 6
2.3 Area 1 Flood Control 8
2.4 Area 1 Navigation 9
2.5 Area 1 Agriculture and Irrigation 9
2.6 Area 1 Municipal and Industrial Water Supply 10
2.7 Area 1 Tribal Socioeconomics 11
3.0 Area 2 – Flathead, Clark Fork, Pend Oreille River Basins 12
3.1 Area 2 Demographics 13
3.2 Area 2 Employment and Income 16
3.3 Area 2 Flood Control 19
3.4 Area 2 Navigation 20
3.5 Area 2 Agriculture and Irrigation 20
3.6 Area 2 Municipal and Industrial Water Supply 21
3.7 Area 2 Tribal Socioeconomics 22
4.0 Area 3 – Mainstem Columbia River 24
4.1 Area 3 Demographics 24
4.2 Area 3 Employment and Income 28
4.3 Area 3 Flood Control 31
4.4 Area 3 Navigation 32
4.5 Area 3 Agriculture and Irrigation 33
4.6 Area 3 Municipal and Industrial Water Supply 35
4.7 Area 3 Tribal Socioeconomics 36
REFERENCES 38

TABLES

Page F-

Table 1: Dams and Reservoirs in Area 1 3
Table 2: Selected Demographic and Socioeconomic Information for Area 1 5
Table 3: Percent of Income of Various British Columbia Industries in Area 1.....6
Table 4: Percent Employment by Industry in the U.S. Portion of Area 1 8
Table 5: Agricultural and Irrigation Summary Statistics for the U.S. Portion of Area 1 ..10
Table 6: Selected Statistics for M&I Water Supply for the U.S. Portion of Area 1 11
Table 7: Dams and Reservoirs in Area 2 12
Table 8: Selected Demographic and Socioeconomic Information for Area 2 15
Table 9: Percent Employment by Industry for the U.S. Portion of Area 2.....18
Table 10: Agricultural and Irrigation Summary Statistics for the U.S. Portion of Area 2 21
Table 11: Selected Statistics for M&I Water Supply for Area 2 22
Table 12: Dams and Reservoirs in Area 3 25
Table 13: Selected Demographic and Socioeconomic Information for Area 3 28
Table 14: Percent of Employment by Industry for the U.S. Portion of Area 3 31
Table 15: Agricultural and Irrigation Summary Statistics for Area 3 35
Table 16: Selected Statistics for M&I Water Supply for the U.S. Portion of Area 3 36

UPPER COLUMBIA ALTERNATIVE FLOOD CONTROL AND FISH OPERATIONS EIS

SOCIOECONOMIC AFFECTED ENVIRONMENT

1.0 Introduction

The Columbia River and its tributaries form the dominant water system in the Pacific Northwest Region. The mainstem of the Columbia rises in Columbia Lake on the west slope of the Rocky Mountain Range in Canada. After flowing a circuitous path for about 1200 miles, 415 miles of which are in Canada, it joins the Pacific Ocean near Astoria, Oregon. The river drains an area of approximately 219,000 square miles in the States of Washington, Oregon, Idaho, Montana, Wyoming, Nevada, and Utah. An additional 39,500 square mile portion of the basin, or about 15%, is within Canada. The major tributaries to the Columbia are the Kootenai and Flathead/Pend Oreille rivers, which drain southeastern British Columbia (BC), western Montana, and northern Idaho, the Snake River which drains western Wyoming, most of Idaho, eastern Oregon and southeastern Washington, and the Willamette River of western Oregon. (U.S.G.S, 9/02)

The Columbia River basin has been important to the peoples of the region for thousands of years, fostering the socioeconomic development of the region. First, the salmon runs, floodplains and wildlife sustained numerous Native American groups, and then as European settlers moved west the river became an important navigation corridor from the inland to the coast. The subsequent development of irrigation, hydropower and flood control facilities significantly facilitated the economic growth of the region.

The Columbia River system remains a very important component of the socioeconomic and natural environment through which it flows. The river system provides both direct and indirect economic benefits to the region. Socioeconomic categories evaluated in this EIS include:

- River-related recreation and associated employment and income
- Hydropower
- Flood control
- Navigation
- Agriculture and irrigation
- Municipal and industrial water supply
- Tribal socioeconomics

The affected environment and impact analysis for recreation are addressed in the **Recreation Sections** of the EIS. The affected environment and impact analysis for hydropower are addressed in the **Hydropower Sections** of the EIS. In this section, socioeconomic conditions in the Columbia basin for the remaining river uses listed above are discussed for three regional areas:

- Area 1 - Kootenai River Basin from Lake Koocanusa in Montana (MT) and British Columbia (BC) through Idaho (ID) to the Columbia River in BC
- Area 2 - Flathead/Clark Fork/Pend Oreille Basin from Hungry Horse Reservoir in MT to the Columbia River in Washington (WA)
- Area 3 - Columbia River mainstem from the mouth of the Kootenai River in BC downstream to the Pacific Ocean in Oregon (OR) and WA

All financial figures presented in this section are in Canadian dollars for Canadian locations and U.S dollars for U.S. locations.

2.0 Area 1 – Kootenai River Basin

Area 1 is dominated by federal and provincial forested and mountainous reserves including Kootenai National Forest (US), Panhandle National Forest (US), Flathead National Forest (US), Kootenay National Park (Canada), Purcell Wilderness (Canada), and many other smaller parks and private and public forest lands. Historically, miners settled this sub-basin followed by timber workers and the supporting communities that grew up around these natural resource industries. As the natural resource base has declined, other industries have become more important, particularly tourism.

Selected data on demographics, employment, and income for Area 1 are presented in the following paragraphs. **Table 1** summarizes the dams and reservoirs in Area 1.

Table 1: Dams and Reservoirs in Area 1

DAM	LAKE/ RESERVOIR	RIVER	LOCATION	YEAR COMPLETED	AUTHORIZED PURPOSE	CAPACITY	OPERATOR
Duncan	Duncan Reservoir	Duncan River	Howser, BC	1967	Flood Control	1,400,000 Acre-feet	BC Hydro
Libby	Lake Koocanusa	Kootenai	Libby, MT	1973	Flood Control	4,979,500 Acre-feet	U.S. Army Corps of Engineers
					Hydropower	525 MW	
Corra Linn	Kootenay Lake	Kootenay	Nelson, BC	1931	Hydropower	42 MW	BC Hydro
Upper Bonnington	n/a run of river	Kootenay	Nelson, BC	1907	Hydropower	63 MW	BC Hydro
Lower Bonnington	n/a run of river	Kootenay	Nelson, BC	1897	Hydropower	47 MW	BC Hydro
South Slocan	n/a run of river	Kootenay	Nelson, BC	1928	Hydropower	47 MW	BC Hydro
Kootenay Canal Generating Station	n/a run of river (side canal)	Kootenay	Nelson, BC	1976	Hydropower	529 MW	BC Hydro
Brilliant	n/a run of river	Kootenay	Castlegar, BC	1944	Hydropower	130 MW	Columbia Power

Sources: BC Hydro 2002; Hirst 1991

2.1 Area 1 Demographics

Area 1 includes portions of the East and Central Kootenay Regional Districts, BC; Lincoln County, MT; and Boundary County, ID. Cities and towns located adjacent to the Kootenai and Columbia Rivers are Cranbrook, Kimberley, Creston, Nelson, and Castlegar, BC; Eureka, Libby, and Troy, MT; and Bonners Ferry, ID. The following paragraphs provide an overview of selected Area 1 demographics in British Columbia, Montana and Idaho. **Table 2** presents a summary of this information for Area 1.

British Columbia. Approximately half of the population of the *East Kootenay Regional District* (RD) lives in the Cranbrook and Kimberley area, upstream of Lake Koocanusa. The East Kootenay RD is generally sparsely populated. The District's population in 2003 was 59,334. Annual population data shows that the population has been slowly increasing since 1999, with increases from 0.13 to 0.65 percent per year (an average annual growth rate from 1999-2003 of 0.44%). Growth is primarily attributable to births, and retirement and recreation population in-migration. (BC Ministry of Management Services 2004)

If the population of the East Kootenay RD increases at the same average annual rate as from 1999-2003, the population would be approximately 65,410 in 2025. The overall

projected population growth of British Columbia in whole to the year 2025 is estimated to be a 27% increase, an average annual increase of 1.09%. (BC Ministry of Management Services 2004). If the population of the District were to increase at the average annual rate projected for BC, the District's population would be approximately 75,280 in 2025.

The East Kootenay RD has an overall minority population of 7%, predominantly First Nation (Native American) peoples including those living in the Tobacco Plains and Kootenay Reserves. (BC Ministry of Management Services 2004)

Creston, Nelson and Castlegar are the major towns in the *Central Kootenay Regional District* and comprise approximately 40% of the overall district population. The Central Kootenay RD is also sparsely populated with a population in 2003 of 59,388. The population in this RD has been slowly declining since 1999 with decreases from 0.0 to 0.5 percent (annual average rate of -0.226%). If the population of the Central Kootenay RD continues to decline at the same average annual rate as from 1999-2003, the population would be approximately 56,500 in 2025. If the population of the District were to increase at the average annual rate projected for BC, the District's population would be approximately 75,350 in 2025.

The Central Kootenay RD has an overall minority population of 5%, again predominantly First Nation peoples. The Lower Kootenay (Yaqan Nukiy) Band main reserve is located near Creston. (BC Ministry of Management Services 2004)

Montana. *Lincoln County, Montana* is sparsely populated with a population of 18,835 in 2003. The largest towns in the county are Libby, Troy, and Eureka, all adjacent to the Kootenai River or its tributaries. The population of these towns, however, only accounts for about 25% of the county's population. The rest of the population is widely dispersed in rural areas and smaller towns. The population in Lincoln County increased by approximately 9% from 1990 to 2000 and has been estimated to be essentially steady since 2000 (0% annual average; US Census Bureau 2003 Population Estimates). This is below the average population increase for the nation since the 1990 census (13.2% increase). The State of Montana is projected to increase by approximately 11% from 2005 to 2025 (0.6% annual average; 1995 to 2025 Population Projections, U.S. Census Bureau). If the population of Lincoln County were to maintain as it has since the 2000 census, the population in 2025 would remain at approximately 18,835. If the population of Lincoln County were to increase at the Montana annual average projections, the population would be approximately 21,355 in 2025. Lincoln County has a small minority population (3.9%), predominantly Native American and Hispanic. (US Census Bureau 2004)

Idaho. *Boundary County, Idaho* is very sparsely populated with a population of 10,173 in 2003. The towns of Bonners Ferry and Moyie Springs, both on the Kootenai River, constitute approximately 33% of the county's population. The population of Boundary County increased approximately 15.6% from 1990 to 2000, and has increased slightly (~2.5 %) since 2000 (0.8% annual average; US Census Bureau 2003 Population Estimates). The population increased slightly faster than the national average from 1990

to 2000. The State of Idaho is projected to increase by approximately 17.5% from 2005 to 2025 (0.9% annual average; 1995 to 2025 Population Projections, U.S. Census Bureau). If the population of Boundary County were to increase as it has since the 2000 census, the population would be approximately 12,175 in 2025. If the population of Boundary County were to increase at the Idaho annual average projections, the population would be approximately 12,390 in 2025. Boundary County has a small minority population of ~4%, comprising predominantly individuals of Hispanic or Native American descent. (US Census Bureau 2004) The Kootenai Reservation is located along the Kootenai River in Boundary County.

Table 2: Selected Demographic and Socioeconomic Information for Area 1

	POPULATION ESTIMATE[1]	MEDIAN PER CAPITA INCOME[2]	% OF STATE/ PROVINCE INCOME[2]	% BELOW POVERTY LINE[2]	% MINORITY POPULATION [2]
STATES/PROVINCES IN AREA 1					
British Columbia	4,146,580	$22,095	not applicable	no data	26.0%
Montana	917,621	$17,151	not applicable	14.6%	9.4%
Idaho	1,366,332	$17,841	not applicable	11.8%	4.8%
CITIES/COUNTIES/REGIONAL DISTRICTS IN AREA 1					
East Kootenay Regional District	59,334	$21,732	98.4%	no data	7.0%
Cranbrook	24,275	$28,975	131.1%	no data	8.0%
Kimberley	6,484	$29,679	134.3%	no data	4.0%
Central Kootenay Regional District	59,388	$19,008	86.0%	no data	5.0%
Creston	4,795	$23,935	108.3%	no data	4.0%
Nelson	9,298	$25,041	113.3%	no data	5.0%
Castlegar	7,002	$31,601	143.0%	no data	5.0%
Lincoln County, Montana	18,835	$13,923	81.2%	19.2%	3.9%
Eureka	1,009	$12,619	73.6%	22.9%	3.2%
Libby	2,606	$13,090	76.3%	16.3%	4.5%
Troy	963	$10,620	61.9%	27.5%	4.2%
Boundary County, Idaho	10,173	$14,636	82.0%	15.7%	4.8%
Bonners Ferry	2,647	$13,343	74.8%	20.0%	4.3%

Notes:
[1]U.S. State and county population estimates are for 2003 from U.S. Census Annual Population Estimates, Release Date: April 9, 2004.
U.S. city/town population estimates are for 2003 from U.S. Census Annual Population Estimates FRO Incorporated Places, Release Date: June 24, 2004.
Canadian Province, Regional District, and city/town population data are for 2003 from BC Stats Community Facts, release date October 06, 2004.
[2]Canadian income and minority population data are for 2000 from the 2001 Census
U.S. data on income, poverty, and minority population are for 1999 from the 2000 Census.

2.2 Area 1 Employment and Income

Area 1 is a forested mountainous region with a historically strong natural resources industry including timber and mining. Tourism and recreation have become important components of the regional economy and government employment is also important. Agriculture is less important in this area relative to per capita employment. The population base is small and does not support a large number of manufacturing industries, but a few are important and are described below. Area 1 employment and income data are presented below for British Columbia, Montana and Idaho.

British Columbia. The major industries in the Central and East Kootenay Regional Districts, BC include forestry, mining, tourism, technology and electronics, construction, agriculture, and retail and commercial businesses. Federal, provincial, and local governments (including school districts) are the dominant employers. Forestry is an important employer in the Castlegar region, as well as Selkirk College and other educational facilities. Other major employers in Cranbrook and Kimberley include Tembec Industries, Ltd (forestry) and Cominco (mining, fertilizer). Nelson is the provincial administrative center for the Central Kootenay Regional District.

Lake Koocanusa and Kootenay Lake in British Columbia are tourist attractions for fishing, hunting, camping, and boating. Small towns and resorts are located along Lake Koocanusa catering to fishers and campers. The agriculture, hydropower, and tourism industries are most closely related to the river and reservoir system.

Sources of community income by percent of total income in the Kootenay Region, BC are shown in **Table 3**. As shown in Table 3, transfer payments such as retirement benefits and other social services rank as the second most important source of income, following public sector income. This reflects the overall attractiveness of the Kootenay Region, BC as a retirement area. Other major sources of income to the population in various communities in the region are forestry, mining and tourism, in that order. (BC Ministry of Management Services 2004)

Table 3: Percent of Income of Various British Columbia Industries in Area 1

	CRANBROOK-KIMBERLEY REGION	CASTLEGAR REGION	NELSON REGION	CRESTON REGION
FORESTRY	14	25	13	10
MINING	9	6	2	2
FISHING	0	0	0	0
AGRICULTURE	1	0	1	7
TOURISM	8	3	7	5
HIGH TECH	0	1	2	0
PUBLIC SECTOR	25	23	30	23
CONST	6	9	8	5
OTHER	5	3	2	2
TRANSFER PAYMENTS	18	18	19	29

Source: BC Ministry of Management Services 2004

Montana. The federal government owns approximately 72% of the area of Lincoln County, Montana. Lake Koocanusa, Kootenai National Forest and wilderness areas within Lincoln County are tourist destinations for fishing, boating, camping, hiking, and hunting. The major industries in the county include government (Federal, state, and local), retail trade, forestry, manufacturing, construction, and health care/social assistance. Major employers in Libby include Plum Creek Lumber Company, hospitals and health care facilities, First National Bank, and city, county and federal government.

The per capita money income in Lincoln County was reported as $13,923 in the 2000 Census; for comparison, this was approximately 81% of the Montana average. Approximately 19.2% of the population of the county lived below poverty level in 1999; for comparison, this was higher than the state average of 14.6% in that year. Historically, forestry and mining were major employers in the area, but have declined over many years and now provide a relatively smaller number of jobs (~8% of county employment--US Census Bureau 2004 and Bureau of Economic Analysis 2004). The percent of employment by industry in Lincoln County is summarized in **Table 4**.

Idaho. *Boundary County, Idaho* is dominated by 61% federally owned lands, including the Panhandle National Forest. The Kootenai River and Panhandle National Forest are tourist destinations for fishing, camping, hiking, and hunting. The major industries in the county include agriculture, forestry, health care, transportation, and government.

The per capita income in Boundary County was reported as $14,636 in the 2000 Census, approximately 82% of the state average. Approximately 15.7% of the population lived below poverty level in 1999, for comparison, this rate was higher than the state average of 11.8% in that year. Historically, transportation and supply to the mining and timber industries were large employers. Mining and timber were also major employers. Currently, timber and agriculture are still dominant industries, including Crown Pacific and Louisiana-Pacific, but CEDU Education Service (Rocky Mountain Academy) is the largest employer in the county. The Kootenai Tribe operates the Kootenai River Inn and Casino, which is also a relatively large employer. The Boundary Community Hospital, school district, and local and federal government are also major employers (US Census Bureau 2004 and Bureau of Economic Analysis 2004). Boundary County's employment by industry is summarized in **Table 4**.

Table 4: Percent Employment by Industry in the U.S. Portion of Area 1

	LINCOLN COUNTY, MT	BOUNDARY COUNTY, ID	AREA 1 AVERAGE (U.S.)
AGRICULTURE	6.8	14.2	10.5
FORESTRY AND FISHING	7.4	6.6	7.0
MINING	0.5	0.2	0.4
CONSTRUCTION	7.3	7.4	7.4
MANUFACTURING	9.5	9.7	9.6
RETAIL TRADE	11.7	10.1	10.9
TRANSPORTATION/WAREHOUSING	3.0	3.2	3.1
INFORMATION	1.4	0.8	1.1
FINANCE/INSURANCE	2.2	1.1	1.7
REAL ESTATE	4.5	2.7	3.6
PROFESSIONAL/TECHNICAL	3.4	3.8	3.6
EDUCATION	0.4	1.4	0.9
HEALTH CARE/SOCIAL ASSISTANCE	9.9	11.7	10.8
RECREATION/ENTERTAINMENT	2.0	0.9	1.5
ACCOMODATION/RESTAURANT	6.7	3.3	5.0
OTHER SERVICES	6.9	1.7	4.3
GOVERNMENT	16.5	21.3	18.9

SOURCE: Employment data is for 2002 as presented in Table CA25N – Total full-time and part-time employment by industry, Bureau of Economic Analysis, Regional Economic Information System, Table CA25 (NAICS), May 2004.

2.3 Area 1 Flood Control

In the U.S. portion of Area 1, economic losses from flooding have historically occurred along the Kootenai River, between Bonners Ferry, Idaho and Kootenay Lake, in Canada. This area is downstream of Libby Dam and is referred to informally as Kootenai Flats. Historically, high water from rain on snow events and snowmelt runoff would cover portions of the floodplain every year and less frequent events would flood the entire valley of more than 60,000 acres. Levees were constructed to protect about 35,000 acres of croplands in the United States and about 17,000 acres of agricultural land in Canada. Construction of Libby Dam provided further flood control in the area by providing flood control storage. (BPA *et al.* 1995, SOR EIS Main Report)

Bonners Ferry and Kootenai Flats floodplain land use and infrastructure with flood protection includes:

- 35,000 acres of agricultural croplands in U.S.
- 17,000 acres of agricultural croplands in Canada
- 190 acres of commercial and residential development in Bonners Ferry, ID
- Other transportation and public infrastructure

The zero-damage stage for the Bonners Ferry and Kootenai Flats floodplain has been identified at 1764 ft-msl.

In Canada, flooding from Kootenay Lake is a concern. The 1972 Columbia River Treaty Flood Control Operating Plan (FCOP) states that "damage commences at Nelson when Kootenay Lake reaches elevation 1755 feet and the major damage stage is elevation 1759 feet" (Corps 1972). Since 1972, encroachment around Kootenay Lake has occurred, and studies are being planned for identification of development and damages below elevation 1755 feet. A 2004 study involving interviews with Kootenay Lake stakeholders identified water levels as detrimental when above elevation 1750 feet. (BC Hydro *et al.* 2004)

2.4 Area 1 Navigation

The Canadian Ministry of Highways operates the Kootenay Lake Ferry. The 35 minute ferry crossing runs across Kootenay Lake, 20 miles east of Nelson on Highway 3A, between Balfour and Kootenay Bay. Year-round daily service is offered for car, truck and foot passengers.

Recreational Boating is discussed in the **Recreation Affected Environment Section** and the **Recreation Impact Sections** of this EIS.

2.5 Area 1 Agriculture and Irrigation

East and Central Kootenay Regional Districts, Canada: The East Kootenay RD is primarily a ranching area, although farming is also carried out. Total farm sales receipts from the East Kootenay RD in 2001 were approximately $15 million. Hay, much of which is irrigated, is the largest crop and is produced for cattle use. Alfalfa, oats, and barley are other crops produced in the area. Approximately 221,000 square ft of greenhousing is also present in the RD.

The Central Kootenay RD has a large area of prime farmland around Creston. Field vegetables and tree fruits grown here on irrigated fields include potatoes, peas, beans, apples, and berries. The dairy industry is important in this area. Total farm sales receipts in the Central Kootenay RD were approximately $26,000,000 Canadian in 2000 (U.S. equivalent equals $34,068,000, BC Ministry of Management Services 2004).

Lincoln County, Montana: Approximately 54,000 acres are farmed in Lincoln County, with about 4,700 acres irrigated (~9%). Major agricultural products include livestock and poultry such as beef cows, milk cows, hogs and pigs, sheep and lambs, and chickens. Hay and pastureland is the other dominant crop, with small amounts of oats and barley grown for grain. A total of 15 acres is in vegetable or fruit production in the county. The market value of the County's agricultural products sold in 2002 was $2,516,000. Net cash income is the cash earnings realized within a calendar year from the sales of farm production and the conversion of assets, both inventories (in years in which reduced) and capital consumption, into cash. Net cash farm income is a solvency measure representing the funds that are available to farm operators to meet family living expenses and make debt payments. The county's 2002 net cash farm income totaled -$478,000, an average of -$1,589 per farm. (USDA - NASS, Table 1, County Summary Highlights, 2002) A

summary of Lincoln County agricultural and irrigation information is presented in **Table 5**.

Boundary County, Idaho: Approximately 76,000 acres are farmed in Boundary County with about 2,750 acres irrigated (<4%). Major agricultural products primarily include wheat and both beef and milk cows. Hay and alfalfa are also dominant crops with oats and barley for both grain and forage. Specialty crops include hops and tree fruits (apples). The market value of the County's agricultural products sold in 2002 was $2,822,000. The county's 2002 net cash farm income totaled $6,545,000, an average of $15,115 per farm. (USDA - NASS, Table 1, County Summary Highlights, 2002) A summary of Boundary County agricultural and irrigation information is presented in **Table 5**. Approximately 2,200 acres are farmed by the Kootenai Tribe and include grain and hay crops.

Table 5: Agricultural and Irrigation Summary Statistics for the U.S. Portion of Area 1

COUNTY, STATE	LAND IN FARMS	TOTAL CROPLAND	HARVESTED CROPLAND	IRRIGATED ACRES	IRRIGATED ACRES AS % OF HARVESTED CROPLAND	COUNTY'S NET CASH FARM INCOME
Boundary, ID	76,506	47,706	40,440	2,750	7%	$6,545,000
Lincoln, MT	54,236	18,696	9,188	4,762	52%	-$478,000

Source: USDA - NASS 2002

2.6 Area 1 Municipal and Industrial Water Supply

The Kootenai River and the reservoirs are used to provide municipal and industrial (M&I) water supply for several communities and private landowners in Area 1. **Table 6** is a summary of municipal, domestic and industrial water withdrawals in the U.S. Portion of Area 1 in 2000 (USGS 2000).

Table 6: Selected Statistics for M&I Water Supply for the U.S. Portion of Area 1

	LINCOLN COUNTY, MONTANA	BOUNDARY COUNTY, IDAHO
TOTAL POPULATION (x1,000)	18.84	9.87
TOTAL POPULATION SERVED BY PUBLIC SUPPLY (x1,000)	7.19	6.81
TOTAL PUBLIC SUPPLY FRESH SURFACE WATER WITHDRAWALS (million gal/d)	0.46	1.00
TOTAL DOMESTIC SELF-SUPPLY FRESH SURFACE WATER WITHDRAWALS (million gal/d)	0.04	0.00
TOTAL INDUSTRIAL SELF-SUPPLY FRESH SURFACE WATER WITHDRAWALS (million gal/d)	13.77	0.20

Source: http://water.usgs.gov/watuse/

2.7 Area 1 Tribal Socioeconomics

The recognized Native American Tribes and Bands located in the Kootenai sub-basin include the Kootenay and Tobacco Plains bands in British Columbia, and the Kootenai Tribe of Idaho in northern Idaho. The reserves and reservations are all located along the Kootenai River. The Tobacco Plains Reserve is located near Grasmere and encompasses approximately 10,800 acres. The reserve is located in the rolling hills and flat areas in the Kootenay River valley and the primary industries are forestry and agriculture. Commercial development includes a restaurant, gas station and duty-free shop (Tobacco Plains Website 2004).

The Lower Kootenay Indian Band reserve is located near Creston and is approximately 6000 acres. Agriculture is the primary economic activity including fruit, corn, wheat and barley. Other development includes recreational guiding and outfitting and tribal operations such as the elementary school and other administration. The Lower Kootenay Indian Band also holds an annual Pow Wow which is a tourist attraction (Lower Kootenay Indian Band Website 2004).

The Kootenai Tribe reservation is located north of Bonner's Ferry along the Kootenai River. The Kootenai River Inn and Casino is the major employer. The tribal business/administration operations and the fish hatchery also employ many tribal members. Approximately 2200 acres are farmed for hay, grains, and livestock; none of the agricultural lands are irrigated. Currently, their agricultural lands are subject to spring flooding and poor drainage. (P. Perry, Kootenai Tribe, pers. comm. 10/2004).

3.0 Area 2 – Flathead, Clark Fork, Pend Oreille River Basins

Area 2 is dominated by federal reserves, tribal lands and parks including the Flathead National Forest, Kootenai National Forest, Idaho Panhandle National Forest, Kaniksu National Forest, Colville National Forest, Lolo National Forest and Flathead Indian Reservation.

The Flathead Valley was developed and settled during and following the construction of the Great Northern Railroad. Major industries in this sub-basin were historically natural resource based including timber, mining, and agriculture. In more recent times, other industries such as tourism are becoming more important.

Table 7 provides a summary of dams and reservoirs in Area 2.

Table 7: Dams and Reservoirs in Area 2

DAM	LAKE/ RESERVOIR	RIVER	LOCATION	YEAR COMPLETED	AUTHORIZED PURPOSE	CAPACITY	OPERATOR
Hungry Horse	Hungry Horse Reservoir	S. Fork Flathead	Hungry Horse, MT	1953	Flood Control	2,982,000 ac-ft	U.S. Bureau of Reclamation
					Hydropower	428 MW	
					Irrigation		
Kerr Dam	Flathead Lake	Flathead	Polson, MT	1938	Hydropower	168 MW	PPL Montana
					Irrigation		
Thompson Falls	Thompson Falls Reservoir	Clark Fork	Thompson Falls, MT	1915	Hydropower	197 MW	PPL Montana
Noxon Rapids Dam	Noxon Reservoir	Clark Fork	Noxon, MT	1959	Hydropower	466 MW	Avista Corp.
Cabinet Gorge Dam	Cabinet Gorge Reservoir	Clark Fork	Cabinet, ID	1952	Hydropower	231 MW	Avista Corp.
						42 MW	
						1,155,200 ac-ft	
Albeni Falls Dam	Lake Pend Oreille	Pend Oreille	2.5 miles east of Newport, WA	1955	Hydropower	42.6 MW	U.S. Army Corps of Engineers
					Flood Control	1,155,200 ac-ft	
					Navigation		
Box Canyon Dam	Box Canyon Reservoir	Pend Oreille	Ione, WA	1956	Hydropower	60 MW	Pend Oreille Public Utility District PUD
Boundary Dam	Boundary Dam Reservoir	Pend Oreille	Metaline, WA	1967	Hydropower	1050 MW	Seattle City Light
Seven Mile	Pend Oreille Reservoir	Pend d'Oreille	Near Trail, BC	1979	Hydropower	608 MW	BC Hydro
Waneta	Waneta Reservoir	Pend d'Oreille	Near Trail, BC	1954	Hydropower	375 MW	Cominco, Columbia Power

3.1 Area 2 Demographics

Area 2 includes portions of the Central Kootenay Regional Districts, BC; Flathead, Lake, and Sanders Counties in MT; and Bonner County, ID; and Pend Oreille County, Washington. Cities and towns located along the rivers include Hungry Horse, Columbia Falls, Polson, Thompson Falls, Kalispell and Noxon, MT; Clark Fork, Sandpoint, and Priest River, ID; and Newport, Ione and Metaline Falls, WA. The following paragraphs provide an overview of selected Area 2 demographic data organized by British Columbia, Montana, Idaho, and Washington. **Table 8** presents a summary of selected demographic and socioeconomic information for Area 2.

British Columbia. A short reach of the Pend d'Oreille River flows through the *Central Kootenay RD*, but no large towns or cities are located along this stretch of river in Canada.

Montana. The several forks of the Flathead River flow primarily out of national park or wilderness areas and join near Hungry Horse and Columbia Falls, MT in Flathead County.

Flathead County had a population of 79,485 in 2003. The major population center and county seat is Kalispell. Other larger towns include Whitefish and Columbia Falls. The greater Kalispell area comprises approximately 43% of the county's population. The population of Flathead County increased 23% from 1990 to 2000, nearly double the average rate for the nation. Average annual population increases since 2000 have been approximately 2% (2003 Population Estimates, U.S. Census Bureau). If Flathead County were to increase in population at a similar rate as it has since 2000, the population in 2025 would be approximately 121,715. If the population in Flathead County were to increase at the Montana annual average (.6%), the population in 2025 would be approximately 88,335. Flathead County is likely to continue to increase in population faster than the State of Montana as a whole. Flathead County has a small minority population of 3.7%, predominantly individuals of Native American and Hispanic descent.

The Flathead River flows through Flathead Lake and Lake County, MT.

Lake County had a population of 27,195 in 2003. The largest city in Lake County is Polson, the county seat, which comprises approximately 15% of the county's population. Polson is located within the Flathead Indian Reservation. The population of Lake County increased substantially (38%) from 1990 to 2000. Since 2000, annual average growth has been approximately 0.7%. If Lake County were to increase in population at a similar rate as it has since 2000, the population in 2025 would be approximately 31,510. If the population in Lake County were to increase at the Montana annual average, the population in 2025 would be approximately 30,780. Lake County has a substantial minority population of 28.6%, predominantly Native American. Downstream of Flathead Lake, The Flathead River forms the boundary between Lake and Sanders Counties, MT before it joins the Clark Fork River and flows northwest through sparsely populated Sanders County, MT.

Sanders County had a population of 10,455 in 2003. The largest town is Thompson Falls, but generally the population is highly dispersed in several small towns located along the Clark Fork River and other rural areas, including the Flathead Indian Reservation. The population of Sanders County increased 20% from 1990 to 2000, and has averaged approximately 0.6% annual growth since 2000 (2003 Population Estimates, U.S. Census Bureau). If Sanders County were to increase in population at a similar rate as it has since 2000, the population in 2025 would be approximately 12,035. If the population in Sanders County were to increase at the Montana annual average, the population in 2025 would be approximately 11,900. Sanders County has a minority population of 8.1%, predominantly Native American and Hispanic. (All information from US Census Bureau 2000 Census and 2003 Population Estimates)

Idaho. The Clark Fork River ends when it enters Pend Oreille Lake and continues as the Pend Oreille River as it flows through Bonner County, ID.

Bonner County had a population of 39,160 in 2003. The largest town is the county seat, Sandpoint, which comprises approximately 18.6% of the county's population. Other towns along the river include Clark Fork and Priest River. The population of Bonner County increased by approximately 29% from 1990 to 2000, and has continued increasing by an average annual rate of approximately 1.9% since 2000 (2003 Population Estimates, U.S. Census Bureau). If Bonner County were to increase in population at a similar rate as it has since 2000, the population in 2025 would be approximately 59,120. If the population in Bonner County were to increase at the Idaho annual average, the population in 2025 would be approximately 47,695. Bonner County has a small minority population of 3.4%, predominantly Hispanic and Native American. (All information from US Census Bureau 2000 Census and 2003 Population Estimates)

Washington. The Pend Oreille River flows north through Pend Oreille County, WA to the Canadian border.

Pend Oreille County is sparsely populated and had a population of 12,254 in 2003. The largest town along the river is Newport, with approximately 16% of the county's population. The remainder of the population is dispersed among several other small towns and rural areas along the river and south. The population of Pend Oreille County increased by 24% from 1990 to 2000 and has continued increasing by an annual average of 1.4% since 2000. The State of Washington population is projected to increase by nearly 25% from 2005 to 2025 (annual average of 1.2%; Population Projections 1995 to 2025, U.S. Census Bureau). If Pend Oreille County were to increase in population at a similar rate as it has since 2000, the population in 2025 would be approximately 16,725. If the population in Pend Oreille County were to increase at the Washington annual average, the population in 2025 would be approximately 15,930. Pend Oreille County has a small minority population of 6.5%, predominantly Hispanic, Native American and Asian. The Kalispel Indian Reservation is located north of Newport. (All information from US Census Bureau 2000 Census and 2003 Population Estimates)

Table 8: Selected Demographic and Socioeconomic Information for Area 2

	POPULATION ESTIMATE[1]	MEDIAN PER CAPITA INCOME[2]	% OF STATE/ PROVINCE INCOME[2]	% BELOW POVERTY LINE[2]	% MINORITY POPULATION[2]
STATES/PROVINCES IN AREA 2					
British Columbia	4,146,580	$22,095	not applicable		26.0%
Montana	917,621	$17,151	not applicable	14.6%	9.4%
Idaho	1,366,332	$17,841	not applicable	11.8%	4.8%
Washington	6,131,445	$22,973	not applicable	10.6%	18.2%
CITIES/COUNTIES/REGIONAL DISTRICTS IN AREA 2					
Central Kootenay Regional District	59,388	$19,008	86.0%	no data	5.0%
Flathead County, Montana	79,485	$18,112	105.6%	13.0%	3.7%
Kalispell	16,391	$16,224	94.6%	15.9%	4.2%
Hungry Horse	934	$10,530	61.4%	29.7%	5.1%
Columbia Falls	3,963	$14,355	83.7%	17.1%	3.7%
Evergreen	6,215	$14,277	83.2%	14.2%	5.2%
Lake County, Montana	27,197	$15,173	88.5%	18.7%	28.6%
Polson	4,497	$13,777	80.3%	19.8%	21.8%
Sanders County, Montana	10,455	$14,593	85.1%	17.2%	8.1%
Plains	1,169	$13,010	75.9%	20.3%	4.1%
Thompson Falls	1,323	$13,245	77.2%	16.1%	3.3%
Noxon	230	$14,350	83.7%	14.7%	2.6%
Bonner County, Idaho	39,162	$17,263	100.7%	12.4%	3.4%
Clark Fork	566	$13,979	81.5%	20.8%	6.0%
Sandpoint	7,378	$20,643	120.4%	18.0%	3.8%
Priest River	1,863	$14,125	82.4%	18.9%	5.3%
Pend Oreille County, Washington	12,254	$15,731	68.5%	18.1%	6.5%
Newport	2,105	$13,900	60.5%	23.6%	5.4%
Ione	487	$12,093	52.6%	16.4%	7.3%
Metaline Falls	226	$16,390	71.3%	33.2%	5.1%

Notes:
[1]U.S. State and county population estimates are for 2003 from U.S. Census Annual Population Estimates, Release Date: April 9, 2004.
U.S. city/town population estimates are for 2003 from U.S. Census Annual Population Estimates FRO Incorporated Places, Release Date: June 24, 2004.
Canadian Province, Regional District, and city/town population data are for 2003 from BC Stats Community Facts, release date October 06, 2004.
[2]Canadian income and minority population data are for 2000 from the 2001 Census
U.S. data on income, poverty, and minority population are for 1999 from the 2000 Census.

3.2 Area 2 Employment and Income

Area 2 is primarily a forested mountainous region, but there are large open valleys in some areas (Montana) suitable for extensive agriculture. Forestry has historically been and continues to be a major part of the economy; but tourism, government and health care are now very important industries with higher employment than natural resource extraction industries. Area 2 employment and income data are discussed below for British Columbia, Montana, Idaho, and Washington. A summary of employment data by industry is provided in **Table 9**.

British Columbia. This sparsely populated reach of the Pend Oreille River is dominated by hilly and mountainous forestlands. The major industries are timber and ranching (BC Ministry of Management Services 2004).

Montana. *Flathead County, Montana* primarily consists of federally owned lands, particularly the Flathead National Forest, which includes the Great Bear and Bob Marshall Wilderness areas, and it is the western gateway into Glacier National Park. These are tourist destinations for camping, hiking, fishing, boating and hunting. Hungry Horse Reservoir and Flathead Lake are also tourist destinations for fish and boating in Area 2. Whitefish is well known as a ski destination. Education, health care and social services, retail, construction, manufacturing, and tourism are the major industries in the region (Kalispell Chamber of Commerce web site 2004). High-tech industry is becoming important in the area.

Some of the major employers in Kalispell include American Timber and Plum Creek Timber Companies, Big Mountain Ski Resort, Semitool, Burlington Northern, Wal-Mart, Columbia Falls Aluminum, hospitals and retirement/nursing homes, Flathead Valley Community College and school districts, and federal, state, and local government. Agriculture is also an important industry with products such as cattle, wheat, barley, hay, and fruit crops.

The 2000 census reported that the average per capita money income in Flathead County was $18,112, which was 105% of the state average. Approximately 13.0% of the population lived below poverty level in 1999, for comparison, this rate was less than the state average of 14.6% in that year. (US Census Bureau 2004)

Lake County, Montana comprises the Flathead Indian Reservation and Flathead Lake. There are also numerous wildlife refuges and state parks. These are all tourist destinations for activities such as fishing, camping, boating, and wildlife watching. However, government and agriculture are the larger industries in Lake County. Major employers in the area include Salish Kootenai College, and various health care and nursing facilities. The tourism industry is dispersed around Flathead Lake and near other destinations and supports numerous accommodation, restaurant, golf courses, marinas, and outfitters.

The 2000 census reported the County's average per capita money income at $15,173, approximately 88% of the state average. Approximately 18.7% of the population lived below poverty level in 1999, for comparison, this rate was above the state average of 14.6% in that year. (US Census Bureau 2004)

Sanders County, Montana is primarily comprises the Flathead Indian Reservation, Lolo National Forest, and Thompson River State Forest. There is a moderate amount of tourism for camping, hiking, fishing, and boating. The major industries are agriculture, retail, and government. Thompson Falls is the county seat and headquarters for all county government.

The 2000 census reported that the County's average per capita money income at $14,593, approximately 85% of the state average. Approximately 17.2% of the population lived below poverty level in 1999, for comparison, this rate was above the state average of 14.6%. (US Census Bureau 2004)

Idaho. *Bonner County, Idaho* has less federally owned land than other portions of the sub-region, although Panhandle National Forest comprises a large portion of the county. Tourism is a major component of the economy between Schweitzer Mountain Resort ski area and Pend Oreille Lake. Major employers include Coldwater Creek (catalog), Stimson Lumber, J.D. Lumber, and Riley Creek Lumber, Litehouse (food product manufacturing), Schweitzer Mountain Resort, government, and various health care and nursing facilities. Agriculture is also an important part of the economy.

The 2000 census reported that County's average per capita money income to be $17,263, 97% of the state average. Approximately 15.5% of the population lived below poverty level in 1999, for comparison, this rate was slightly higher than the state average of 11.8 that year. (US Census Bureau 2004)

Washington. *Pend Oreille County, Washington* is predominantly comprised of the Colville and Kaniksu National Forests. Due to its remote location it is not a major tourist destination, although some hunting and fishing take place. Agriculture, manufacturing, and government are the dominant industries, including agricultural products such as hay, beef and poultry.

The 2000 census reported that the County's average per capita income at $15,731, approximately 68% of the state average. Approximately 18.1% of the population lived below poverty level in 1999, for comparison, this rate was higher than the state average of 10.6%. (US Census Bureau 2004)

Table 9: Percent Employment by Industry for the U.S. Portion of Area 2

	FLATHEAD COUNTY, MT	LAKE COUNTY, MT	SANDERS COUNTY, MT	BONNER COUNTY, IDAHO	PEND OREILLE COUNTY, WA	AVERAGE AREA 2 (U.S.)
AGRICULTURE	4.2	17.9	18.1	5.6	15.2	12.2
FORESTRY AND FISHING	1.8	1.7	5.2	3.8	D	3.1
MINING	0.6	0.4	1.1	0.6	D	0.7
CONSTRUCTION	9.4	7.5	7.1	10.0	5.2	7.8
MANUFACTURING	6.5	6.8	7.1	8.8	12.1	8.3
RETAIL TRADE	14.0	11.4	9.2	15.6	8.2	11.7
TRANSPORTATION/WAREHOUSING	2.4	D	3.2	2.0	3.6	2.8
INFORMATION	1.4	1.2	0.9	1.2	1.3	1.2
FINANCE/INSURANCE	3.9	2.8	2.1	3.0	2.4	2.8
REAL ESTATE	5.5	3.5	4.8	6.0	2.0	4.4
PROFESSIONAL/TECHNICAL	6.4	3.6	3.0	5.1	2.3	4.1
EDUCATION	0.9	0.5	D	1.2	D	0.9
HEALTH CARE/SOCIAL ASSISTANCE	9.4	10.3	D	6.0	D	8.6
RECREATION/ENTERTAINMENT	3.4	1.9	1.4	4.0	D	2.7
ACCOMODATION/RESTAURANT	9.2	6.5	6.3	6.7	D	7.2
OTHER SERVICES	11.6	4.4	16.4	8.8	17.2	11.7
GOVERNMENT	9.3	19.6	14.0	11.8	30.0	16.9

NOTES:
(D) Not shown to avoid disclosure of confidential information, but the estimates for this item are included as "Other Services".
SOURCE: Employment data is for 2002 as presented in Table CA25N – Total full-time and part-time employment by industry, Bureau of Economic Analysis, Regional Economic Information System, Table CA25 (NAICS), May 2004.

3.3 Area 2 Flood Control

In Area 2, economic losses from flooding have historically occurred along the Flathead River, Flathead Lake, Clark Fork River, Pend Oreille River, and Pend Oreille Lake. Flood regulation in Area 2 is provided by Hungry Horse Dam on the South Fork, Flathead River; Kerr Dam on the Flathead River; and Albeni Falls Dam on the Pend Oreille River. Economic effects associated with flooding in Area 2 are described below for the following sub areas:

- Columbia Falls to Flathead Lake (Flathead River)
- Flathead Lake (Flathead River)
- Pend Oreille Lake (Pend Oreille River)
- Albeni Falls, ID to Cusick, WA (Pend Oreille River)

Columbia Falls to Flathead Lake (Flathead River): The Flathead River upstream drainage from Flathead Lake comprises of agricultural property upstream near Columbia Falls and becomes more commercial and residential downstream through Kalispell to Flathead Lake. The floodway is broad, extending one to three miles in width. Flood regulation occurs at Hungry Horse Dam and typically the controlled flood event duration is short, on the order of days. Additional flood control works have been constructed along the river including levees, channel realignments, and bank protection and erosion control measures. Flood stage discharge at Columbia Falls is identified as 51, 500 cfs. Minor localized flooding can occur at discharges above 44,500 (BPA 1995f).

Flathead Lake: Historic data indicate that there are no significant flood losses for Flathead Lake and that flooding has not been a problem since the construction of Kerr Dam in 1938. Kerr Dam is primarily operated to prevent flooding in upstream areas caused by the lake backwater effect. The zero-damage stage for Flathead Lake has been identified as 2893 ft-msl (coincident with river flow above 51,500 c.f.s. (BPA 1995).

Pend Oreille Lake (Pend Oreille River): The normal operating range of Albeni Falls Dam, which controls the level of Lake Pend Oreille, is 2,051.0 to 2,062.5 ft-msl. Albeni Falls Dam operates to control flooding along the river and lakeshore upstream of the dam. The 2,062.5 ft-msl elevation represents the zero-damage stage (BPA 1995f).

Albeni Falls Dam to Cusick, WA (Pend Oreille River): In the Albeni Falls Dam to Cusick reach, flood losses occur on agricultural and the Kalispel Reservation lands. Historical flood control levees are no longer maintained since the construction of Albeni Falls Dam (BPA, 1995f, B-14).

This reach can be impacted by two types of flooding: 1) agricultural flooding in March and April as a result of early spring runoff from Calispell and Trimble Creeks and 2) flooding in June due to high flows in the Pend Oreille River from high elevation snowmelt.

Farmers near Cusick may have problems draining their fields in late March and April when Calispell and Trimble Creeks are running high and flows in excess of 43,000 cfs are passed through Lake Pend Oreille. Pend Oreille PUD operates Box Canyon Dam and pumping facilities at the mouth of the creeks to minimize backwater effects on agricultural lands.

Flooding below Albeni Falls Dam in June is due to spring snowmelt, and is a relatively common occurrence happening historically about one year in four. The National Weather Service issues flood warnings when the releases from Albeni Falls Dam are expected to exceed 100,000 cfs.

3.4 Area 2 Navigation

There is currently no commercial navigation at Albeni Falls Dam. For a short time, the dam's unique log chute feature was used to transport logs from the dam to the Diamond Match Company downstream during the 1950s. The chute was used about four years until hauling logs by trucks became more cost effective. The log chute hasn't been used since, and the old pilings are gone. Upstream of the dam, there is recreational boating, which is addressed in the **Recreation Affected Environment Section** of the EIS.

3.5 Area 2 Agriculture and Irrigation

In *British Columbia*, there is limited agriculture in Area 2 because fertile flat land is scarce along the Pend Oreille River. There is some cattle ranching on the uplands and hay/pasture production (BC Ministry of Management Services 2004).

Flathead County, Montana is an agricultural area, primarily in the Flathead Valley. Approximately 235,000 acres were farmed in the county in 2002, including approximately 32,000 irrigated acres (~14%). The market value of the County's agricultural products sold in 2002 was $30,513,000. The county's 2002 net cash farm income totaled $4,106,000, an average of $3,827 per farm. (USDA - NASS, Table 1, County Summary Highlights, 2002) The major agricultural products included livestock (primarily cattle, calves, and beef cows), wheat, barley, hay/grass, and approximately 150 acres of vegetables and fruits. (USDA – NASS 2002)

Lake County, Montana is also an agricultural area, primarily south of Flathead Lake. Approximately 601,500 acres were farmed in the county in 2002, including some 89,000 irrigated acres (~15%). The market value of the County's agricultural products sold in 2002 was $39,360,000. The county's 2002 net cash farm income totaled $6,056,000, an average of $5,089 per farm. (USDA - NASS, Table 1, County Summary Highlights, 2002) Major crops included livestock, primarily cattle and beef cows; wheat, oats, barley, potatoes, hay/pasture, and cherries. (USDA – NASS 2002)

Sanders County, Montana has ranch land along the Flathead and Clark Fork Rivers and uplands. Approximately 346,000 acres were farmed in 2002, including approximately 17,000 irrigated acres (<5%). The market value of the County's agricultural products sold in 2002 was $14,079,000. The county's 2002 net cash farm income totaled $1,420,000, an average of $3,047 per farm. (USDA - NASS, Table 1, County Summary Highlights, 2002) Major crops included livestock, primarily cattle and beef cows; oats and hay/pasture. Approximately 35 acres were in vegetable and fruit production. (USDA – NASS 2002)

Bonner County, Idaho has a moderate agricultural industry. Approximately 91,000 acres were farmed in 2002, including approximately 1,800 irrigated acres (<2%). The market value of the County's agricultural products sold in 2002 was $7,150,000. The county's 2002 net cash farm income totaled -$1,458,000, an average of -$1,962 per farm. (USDA - NASS, Table 1, County Summary Highlights, 2002) The major agricultural products included livestock, primarily cattle and beef cows; oats and hay/pasture. Approximately 110 acres were in vegetable and fruit production. (USDA – NASS 2002)

Pend Oreille County, Washington has a moderate agricultural industry. Approximately 61,000 acres were farmed in 2002; including approximately 1,400 acres irrigated (2%). The market value of the County's agricultural products sold in 2002 was $3,366,000. The county's 2002 net cash farm income totaled $1,038,000, an average of $3,949 per farm. (USDA - NASS, Table 1, County Summary Highlights, 2002) The major agricultural products included livestock, primarily cattle and beef cows; oats and hay/pasture. (USDA – NASS 2002)

Table 10: Agricultural and Irrigation Summary Statistics for the U.S. Portion of Area 2

COUNTY, STATE	LAND IN FARMS	TOTAL CROPLAND	HARVESTED CROPLAND	IRRIGATED ACRES	IRRIGATED ACRES AS % OF HARVESTED CROPLAND	COUNTY'S NET CASH FARM INCOME
Bonner, ID	90,585	33,430	18,052	1,844	10%	-$1,458,000
Flathead, MT	234,861	107,636	81,462	32,346	40%	$4,106,000
Lake, MT	601,544	135,199	78,680	88,871	113%	$6,056,000
Pend Oreille, WA	61,239	24,473	15,363	1,427	9%	$1,038,000
Sanders, MT	345,775	52,539	31,942	17,173	54%	$1,420,000

Source: USDA – NASS 2002

3.6 Area 2 Municipal and Industrial Water Supply

The rivers and reservoirs in Area 2 are used to provide municipal and industrial (M&I) water supply for several communities and private landowners. **Table 11** is a summary of municipal, domestic and industrial water withdrawals in Area 2 (USGS 2000).

Table 11: Selected Statistics for M&I Water Supply for Area 2

	FLATHEAD COUNTY, MONTANA	LAKE COUNTY, MONTANA	SANDERS COUNTY, MONTANA	BONNER COUNTY, IDAHO	PEND OREILLE COUNTY, WASHINGTON
TOTAL POPULATION (x1,000)	74.47	26.51	10.23	36.84	11.73
TOTAL POPULATION SERVED BY PUBLIC SUPPLY (x1,000)	52.74	15.05	5.42	16.94	5.39
TOTAL PUBLIC SUPPLY FRESH SURFACE WATER WITHDRAWALS (million gal/d)	2.11	0.89	0.14	3.38	0.13
TOTAL DOMESTIC SELF-SUPPLY FRESH SURFACE WATER WITHDRAWALS (million gal/d)	0.79	0.09	0.03	0.00	0.00
TOTAL INDUSTRIAL SELF-SUPPLY FRESH SURFACE WATER WITHDRAWALS (million gal/d)	0.07	0.00	0.00	0.81	0.92

Source: http://water.usgs.gov/watuse/

3.7 Area 2 Tribal Socioeconomics

The recognized Native American Tribes located in the Flathead-Clark Fork-Pend Oreille sub-basin include the Confederated Salish and Kootenai Tribes of the Flathead Reservation, Coeur d'Alene Tribe, and Kalispel Tribe. The Flathead and Kalispel Reservations are located along the river whereas the Coeur D'Alene Reservation is located on Coeur D'Alene Lake.

The Flathead Indian Reservation (CSKT) is located on the southern half of Flathead Lake and along the Flathead River from Polson to Paradise. Primary tribal associated business enterprises include many small businesses in the agriculture, construction, home improvement, retail, timber, professional/consulting, and recreation industries. The tribes also operate Salish Kootenai College. Water related businesses and facilities include the Kwataqnuk Best Western Hotel, S&K marina, a campground with temporary boat moorage, 3 lake boat ramps, and water intakes, as well the hydroelectric power generation at Hungry Horse Dam. The tribe also has facilities on the Lower Flathead River (below Flathead Lake) including 4 boat ramps and numerous undeveloped access locations for fishing, camping, and subsistence use. (Les Bigcrane, pers. comm. 2004; Confederated Salish and Kootenai Tribes Website 2004) Businesses and facilities that could be affected by changed flows and elevations include Flathead Lake marinas, boat

ramps, and water intakes, as well the hydroelectric power generation at Hungry Horse Dam.

The Coeur d'Alene Indian Reservation is located south of Lake Coeur d'Alene, however, the tribe has usual and accustomed hunting, fishing, and gathering rights up to the north bank of the Pend Oreille River. There are also numerous archaeological and cultural resource sites associated with the tribe along the Pend Oreille River and Lake Pend Oreille. The tribe has no economic development adjacent to the Pend Oreille River or Lake, but continues to use many sites for fishing, hunting, or gathering of fruits and other plant materials. The Coeur d'Alene is primarily concerned about any impacts on cultural resource sites as a result of variable river and lake elevations. (Q. Matheson, Coeur d'Alene Tribe, pers. comm. 11/04)

The Kalispel Indian Reservation is located along both banks of the Pend Oreille River near Cusick, Washington. Tribal business enterprises include the Northern Quest Casino, Kalispel Case Line (manufacturing), Kalispel Agricultural Enterprise, Kalispel Day Care, and the Camas Institute. The tribe operates one boat ramp on the river. Future business development includes a marina, improved or additional boat ramp, and a commerce park. (Kalispel Tribe Website 2004)

4.0 Area 3 – Mainstem Columbia River

Historically, the mainstem Columbia River was a major navigation and immigration corridor on the Oregon Trail. Farmers and other immigrants taking advantage of first the Donation Land Act and then the Homestead Act to acquire free or very inexpensive land settled the Oregon Territory region. The subsequent dams provided a significant boost to development in the region by providing irrigation water and low-cost electricity for industry and residents. Today, the area remains a major farming region, although the larger metropolitan areas have far more diversified and economically important economies.

The following socioeconomic discussion of the mainstem Columbia River focuses primarily on the reach from the mouth of the Kootenay River to Chief Joseph Dam. The reason for this focus is that any planned variation in discharge volume and timing from Libby and Hungry Horse Dams will be largely reregulated at Grand Coulee Dam, thus minimizing any effects downstream from that point. Socioeconomic characteristics downstream of Chief Joseph Dam are addressed at a more general level where appropriate. **Table 12** presents a summary of dams and reservoirs in Area 3.

4.1 Area 3 Demographics

Area 3 includes portions of the Kootenay-Boundary Regional District, BC; Stevens, Ferry, Lincoln, Douglas, Grant, Okanogan, Chelan, Kittitas, Yakima, Benton, Walla Walla, Franklin, Klickitat, Skamania, Clark, Cowlitz, Wahkiakum, and Pacific Counties in WA; and Umatilla, Morrow, Gilliam, Sherman, Wasco, Hood River, Multnomah, Columbia, and Clatsop Counties in OR.

Cities and towns along the mainstem Columbia River within BC in Area 3 include Castlegar, Trail, and Montrose. Cities and towns along the mainstem Columbia River within WA include Northport, Kettle Falls, Grand Coulee, Bridgeport, Brewster, Pateros, Chelan, Wenatchee, Richland, Kennewick, Pasco, Vancouver, Kalama, and Kelso/Longview. Cities and towns along the mainstem Columbia River within OR include Umatilla, Boardman, Arlington, The Dalles, Hood River, Cascade Locks, Stevenson, the greater Portland metropolitan area, Cathlamet, Astoria, and Warrenton.

The following paragraphs provide an overview of selected Area 3 demographic data for British Columbia and the six Washington counties along the river downstream through the vicinity of Chief Joseph Dam (the primary affected reach of Area 3). These counties include Stevens, Ferry, Lincoln, Douglas, Grant, and Okanogan. **Table 13** presents a summary of selected demographic and socioeconomic statistics for these Area 3 jurisdictions.

Table 12: Dams and Reservoirs in Area 3

DAM	LAKE/ RESERVOIR	RIVER	LOCATION	YEAR COMPLETED	AUTHORIZED PURPOSE	CAPACITY	OPERATOR
Mica	Kinbasket Reservoir	Columbia	Sprague Bay, BC	1973	Flood Control	12,000,000 ac-ft	BC Hydro
					Hydropower	1,805 MW	
Revelstoke	Revelstoke Reservoir	Columbia	Revelstoke, BC	1984	Flood Control		BC Hydro
					Hydropower*	1,980 MW	
Hugh Keenlyside Dam	Arrow Lake	Columbia	Castlegar, BC	1968	Flood Control		BC Hydro
					Hydropower*	185 MW	
Grand Coulee	Lake Roosevelt	Columbia	Coulee City, WA	1942	Flood Control	125,000,000 ac-ft	U.S. Bureau of Reclamation
					Irrigation	Irrigates approx. 550,000 acres	
					Hydropower	6,809 MW	
					Navigation		
Chief Joseph	Rufus Woods Lake	Columbia	Bridgeport, WA	1961	Hydropower	2,069 MW	U.S. Army Corps of Engineers
Wells	Lake Pateros	Columbia	Pateros, WA	1967	Hydropower	840 MW	Douglas Cty PUD
Rocky Reach	Lake Entiat	Columbia	Wenatchee, WA	1961	Hydropower	1,280 MW	Chelan Cty PUD
Rock Island	Rock Island Reservoir	Columbia	Wenatchee, WA	1932	Hydropower	660 MW	Chelan Cty PUD
Wanapum	Wanapum Lake	Columbia	Vantage, WA	1963	Hydropower	1,038 MW	Grant Cty PUD
Priest Rapids	Priest Rapids Lake	Columbia	Priest Rapids, WA	1961	Hydropower	955 MW	Grant Cty PUD
McNary	Lake Wallula	Columbia	Umatilla, OR	1957	Hydropower	980 MW	U.S. Army Corps of Engineers
					Navigation		
John Day	Lake Umatilla	Columbia	Rufus, OR	1971	Flood Control	534,000 ac-ft	U.S. Army Corps of Engineers
					Hydropower	2,160 MW	
					Navigation		
The Dalles	Lake Celilo	Columbia	The Dalles, OR	1960	Hydropower	1,780 MW	U.S. Army Corps of Engineers
					Navigation		
Bonneville	Lake Bonneville	Columbia	Stevenson, WA	1938	Hydropower	1,050 MW	U.S. Army Corps of Engineers
					Navigation		

British Columbia. The mainstem Columbia River from Castlegar to the border primarily flows through the Kootenay Boundary RD.

The Kootenay Boundary RD is sparsely populated with a population of 33,227 in 2003. The population has been slowly declining since 1999, with an average annual decline of -0.376% over the period of 1999-2003. The larger towns along the river in Areas 3 include Trail and Montrose, with populations of 7,905 and 1,114, respectively. Nearby Castlegar, on the Kootenay River, is described in the Section on Area 1. If the population of the Kootenay Boundary RD declines similar to the past four year annual average the population would be approximately 30,582 in 2025. If the population increases at the British Columbia annual average projections, the population would be approximately 42,159 in 2025. The Kootenay Boundary RD has a very small minority population of 3%. (BC Ministry of Management Services 2004)

Washington. The mainstem Columbia River flows through or adjacent to 18 counties in Washington. The Primary Affected Reach includes those 6 counties upstream of Grand Coulee Dam and between Grand Coulee Dam and Chief Joseph Dam as presented in **Table 13**.

Stevens County, WA is sparsely populated with a population of 40,776 in 2003. Northport and Kettle Falls are the two larger towns located along the river, but only comprise 4.6% of the county's population. The rest of the population is dispersed in many small towns and rural areas. The Spokane Indian Reservation occupies a large portion of the county. The population of Stevens County increased by 23% from 1990 to 2000, and has been increasing by an average annual growth of 0.44% since 2000. If Stevens County were to increase in population at a similar rate as it has since 2000, the population in 2025 would be approximately 44,905. If the population in Stevens County were to increase at the Washington annual average, the population in 2025 would be approximately 53,010. Stevens County has a minority population of 10%, predominantly Native American and Hispanic. (US Census Bureau 2004)

Ferry County, WA has no major towns along the river and is primarily comprised of Federal and Tribal lands of the Colville Indian Reservation. The county is sparsely populated with a population of 7,260 in 2000. The population, which is primarily dispersed in the Kettle River Valley, increased by 13% from 1990 to 2000. Since the 2000 census, population has shown an average annual increase of approximately 0.57%. If Ferry County were to increase in population at a similar rate as it has since 2000, the population in 2025 would be approximately 8,400. If the population in Ferry County were to increase at the Washington annual average, the population in 2025 would be approximately 9,645. The minority population of Ferry County is 25%, predominantly Native American and Hispanic.

Lincoln County, WA is primarily in private ownership, mostly dryland wheat farms and ranches. Lincoln County is sparsely populated with no major cities; the population was

10,201 in 2003. The population increased by 15% from 1990 to 2000 and has been increasing by an average annual increase of 0.06% since 2000. If Lincoln County were to increase in population at a similar rate as it has since 2000, the population in 2025 would be approximately 10,335. If the population in Lincoln County were to increase at the Washington annual average, the population in 2025 would be approximately 13,260. The minority population is approximately 4%, predominantly individuals of Native American and Hispanic descent. (US Census Bureau 2004)

Grant County, WA includes the Grand Coulee Dam and associated towns. The population of Grant County was 78,691 in 2003. The population increased by 27% from 1990 to 2000 and has been increasing by an average annual increase of 1.6% since 2000. If Grant County were to increase in population at a similar rate as it has since 2000, the population in 2025 would be approximately 111,750. If the population in Grant County were to increase at the Washington annual average, the population in 2025 would be approximately 102,305. The minority population of Grant County is 23.5%, predominantly Hispanic. (US Census Bureau 2004)

Douglas County, WA includes the town of Bridgeport along the river. The population of Douglas County was 33,753 in 2003. The population increased by 20% from 1990 to 2000 and has been increasing by an average annual rate of 1.1% since 2000. If Douglas County were to increase in population at a similar rate as it has since 2000, the population in 2025 would be approximately 42,865. If the population in Douglas County were to increase at the Washington annual average, the population in 2025 would be approximately 43,880. The minority population of Douglas County is approximately 15%, predominantly Hispanic. (US Census Bureau 2004)

Okanogan County, WA includes the town of Brewster along the Columbia River, and the majority of the county's population is located in the Okanogan valley. The population of Okanogan County was 39,134 in 2003. The population increased by 16% from 1990 to 2000, and has experienced a slight average annual decline of 0.4% since 2000. If Okanogan County were to decline in population at a similar rate as it has since 2000, the population in 2025 would be approximately 36,105. If the population in Okanogan County were to increase at the Washington annual average, the population in 2025 would be approximately 50,875. The minority population of Okanogan County is approximately 25%, predominantly Native American and Hispanic. (US Census Bureau 2004)

Table 13: Selected Demographic and Socioeconomic Information for Area 3

	POPULATION ESTIMATE[1]	MEDIAN PER CAPITA INCOME[2]	% OF STATE/ PROVINCE INCOME[2]	% BELOW POVERTY LINE[2]	% MINORITY POPULATION[2]
STATES/PROVINCES IN AREA 2					
British Columbia	4,146,580	$22,095	not applicable		26.0%
Washington	6,131,445	$22,973	not applicable	10.6%	18.2%
Oregon	3,559,596	$20,940	not applicable	11.6%	13.4%
AFFECTED CITIES/COUNTIES/REGIONAL DISTRICTS IN AREA 3					
Kootenay-Boundary Regional District	33,227	$19,668	89.0%	no data	3.0%
Trail	8,167	$20,003	90.5%	no data	9.0%
Montrose	1,098	$23,714	107.3%	no data	3.0%
Stevens County, Washington	40,776	$15,895	69.2%	15.9%	10.0%
Northport	332	$11,679	50.8%	27.7%	5.1%
Kettle Falls	1,545	$13,614	59.3%	21.1%	8.7%
Ferry County, Washington	7,417	$15,019	65.4%	19.0%	24.6%
Lincoln County, Washington	10,201	$17,888	77.9%	12.6%	4.4%
Douglas County, Washington	33,753	$17,148	74.6%	14.4%	15.3%
Bridgeport	2,051	$10,302	44.8%	33.2%	39.2%
Grant County, Washington	78,691	$15,037	65.5%	17.4%	23.5%
Grand Coulee/Electric City	1,877	$16,513	71.9%	15.8%	14.5%
Okanogan County, Washington	39,134	$14,900	64.9%	21.3%	24.7%
Brewster	2,154	$9,555	41.6%	31.7%	45.1%

Notes:
[1]U.S. State and county population estimates are for 2003 from U.S. Census Annual Population Estimates, Release Date: April 9, 2004.
U.S. city/town population estimates are for 2003 from U.S. Census Annual Population Estimates FRO Incorporated Places, Release Date: June 24, 2004.
Canadian Province, Regional District, and city/town population data are for 2003 from BC Stats Community Facts, release date October 06, 2004.
[2]Canadian income and minority population data are for 2000 from the 2001 Census
U.S. data on income, poverty, and minority population are for 1999 from the 2000 Census.

4.2 Area 3 Employment and Income

Area 3 is highly diverse, encompassing the interior Columbia Basin in southern British Columbia, central Washington and Oregon down to the Pacific Ocean. The economy of this area cannot be easily summarized because it is so varied. Upstream of Chief Joseph Dam, agriculture is the major industry. Additional major industries include

manufacturing, forestry, government, tourism, and retail trade. Downstream of Chief Joseph Dam agriculture is still an important industry, as are manufacturing, government, tourism, retail trade, transportation/ navigation, and commercial and sport fishing. **Table 14** provides a summary of employment by industry within Area 3.

British Columbia. The *Kootenay-Boundary RD* was historically the most important copper mining region in the entire British Commonwealth, with three major smelters. Today, Teck Cominco Limited is still a major zinc producer along with other metals and products. A major smelter and metallurgical complex is located in Trail, BC. However, mining is now much less important to the region, and forestry is the dominant industry in the district. Tourism and agriculture, and other manufacturing are also major industries.

Pope and Talbot Limited (timber) is the region's largest employer. Other major employers include Canpar Industries (particleboard door cores), Roxul West Inc. (wool insulation), Telus Technologies, Firebird Technologies, Inc. (semiconductors), and BOC Gases Ltd. Healthcare is also a major employer at various facilities.

Agricultural crops include tree nurseries, flower and fruit nurseries, and vegetable and fruit crops. Tourism has less importance in this region than in either the East or Central Kootenays, but skiing and mountain biking are carried out. Fishing and boating along the Columbia River also occurs. The average per capita income is $19,688, approximately 89% of the provincial average. (BC Ministry of Management Services 2004, Boundary Country 2004)

Washington. *Stevens County* is mainly composed of the Spokane Indian Reservation, Lake Roosevelt National Recreation Area, and the Colville National Forest. Agriculture and government employment are the primary industries, and mining, forestry, and tourism are also important. Major private employers in the county include Boise Cascade, Stimson Lumber, Vaagen Brothers Lumber, Aladdin Hearth Products (wood and pellet stoves) and Wal-Mart. The Colville National Forest, Stevens County, and school districts are also major employers. Agricultural products include grains and hay, and livestock. Only a small number of acres are in orchard fruit crops. Agriculture is primarily located in the Colville Valley.

The 2000 census reported the County's per capita money income at $15,895, approximately 69% of the state average. Approximately 15.9% of the population lived below poverty level in 1999, higher than the state average of 10.6%. (US Census Bureau 2004)

Ferry County is predominantly occupied by the Colville National Forest and the Colville Indian Reservation. Major industries include agriculture, government, and timber. Tourism on Lake Roosevelt and camping, hiking, and fishing in the national forest are also important to the economy of the county. Agricultural products include hay and livestock.

The 2000 census reported the County's per capita money income at $15,019, approximately 65% of the state average. Approximately 19.0% of the individuals in the county lived below poverty level in 1999, almost double the state average of 10.6%. (US Census Bureau 2004)

Lincoln County is dominated by dryland wheat farming and ranching, and is the second largest wheat-producing county in the nation. Other major employers include government, and retail trade. There is limited tourism in the county, primarily camping and boating along Lake Roosevelt.

The 2000 census reported the County's per capita money income at $17,888, approximately 78% of the state average. Approximately 12.6% of the individuals lived below poverty level in 1999, slightly higher than the state average of 10.6 in that year. (US Census Bureau 2004)

Grant County consists primarily of private agricultural lands, predominantly irrigated by the Columbia Basin irrigation project from Grand Coulee Dam and Banks Lake. Leading agricultural products include wheat, corn, hay, dry beans, peas, onions and sweet corn. Fruit orchards are also numerous. Tourism is also an important industry in the county with many wildlife refuges and a multitude of camping, fishing and hunting areas both along the Columbia River and in the numerous pothole lakes and canals. Major employers include J.R. Simplot (food processing), Grant County, school districts, Inflation Systems (airbag manufacturing), and Wal-Mart.

The per capita income in 2000 was $15,037, approximately 65% of the state average. Approximately 17.4% of the individuals in the county lived below poverty level in 1999, which is higher than the state average of 10.6% that year. (Bureau of Economic Analysis 2004 and US Census Bureau 2004)

Douglas County is also dominated by privately owned agricultural lands. Farming is primarily dryland farming such as wheat and hay, although there is irrigated agriculture along the Columbia River, including orchard fruit crops, particularly peaches and apricots. Major employers in the county include Douglas County, school districts, Fred Meyer, Costco, Cashmere Valley Bank and Douglas County PUD #1.

The 2000 census reported the County's average per capita money income at $17,148, approximately 75% of the state average. Approximately 14.4% of the individuals in the county lived below poverty level in 1999, higher than the state average of 10.6% that year. (US Census Bureau 2004)

Okanogan County is the largest county in Washington by area and is very diverse, with major federal land holdings in the Okanogan National Forest and the Pasayten and Lake Chelan-Sawtooth Wilderness Areas. The Colville Indian Reservation also occupies a large part of the county, and there are large areas owned by the Washington Department of Natural Resources. Okanogan County is known as a major orchard fruit growing region, particularly apples and pears, mainly grown along the Okanogan and Columbia

Rivers. The county also has ranching and hay production in dryland and upland areas. Tourism is a major feature in the county including camping, hiking, fishing and hunting.

The 2000 census reported the County's average per capita money income at $14,900, approximately 65% of the state average. Approximately 21% of the individuals in the county lived below poverty level in 1999, more than double the state average of 10.6% that year. (US Census Bureau 2004)

Table 14: Percent of Employment by Industry for the U.S. Portion of Area 3

	STEVENS COUNTY, WA	FERRY COUNTY, WA	LINCOLN COUNTY, WA	GRANT COUNTY, WA	DOUGLAS COUNTY, WA	OKANOGAN COUNTY, WA	AVERAGE AREA 3 (U.S.)
AGRICULTURE	17.4	16.3	34.0	22.4	31.7	26.6	24.7
FORESTRY AND FISHING	5.2	D	2.5	D	6.3	7.9	5.5
MINING	0.5	D	0.2	D	0.1	0.3	0.3
CONSTRUCTION	5.4	D	3.8	3.6	5.4	4.5	4.5
MANUFACTURING	11.5	D	2.3	11.5	2.1	1.3	5.7
RETAIL TRADE	10.5	10.0	9.5	9.8	10.8	9.8	10.1
TRANSPORTATION/WAREHOUSING	2.6	D	D	2.6	3.4	1.3	2.5
INFORMATION	1.1	0.6	0.5	0.7	0.5	0.7	0.7
FINANCE/INSURANCE	2.0	1.2	4.3	1.7	1.7	1.8	2.1
REAL ESTATE	3.6	4.0	3.2	2.5	1.7	3.4	3.1
PROFESSIONAL/TECHNICAL	2.7	D	3.6	D	2.3	2.6	2.8
EDUCATION	0.7	D	L	0.6	0.9	0.5	0.7
HEALTH CARE/SOCIAL ASSISTANCE	10.4	3.6	D	7.2	4.9	6.5	6.5
RECREATION/ENTERTAINMENT	1.4	D	1.5	1.3	2.8	1.4	1.7
ACCOMODATION/RESTAURANT	4.4	D	3.3	4.6	6.4	5.8	4.9
OTHER SERVICES	1.2	31.4	3.7	13.8	1.3	1.0	8.7
GOVERNMENT	19.5	33.0	27.5	17.9	17.8	24.4	23.4

NOTES:
(D) Not shown to avoid disclosure of confidential information, but the estimates for this item are included in the totals.
(L) Less than 10 jobs, but the estimates for this item are included in the totals.
SOURCE: Employment data is for 2002 as presented in Table CA25N – Total full-time and part-time employment by industry, Bureau of Economic Analysis, Regional Economic Information System, Table CA25 (NAICS,), May 2004.

4.3 Area 3 Flood Control

The major cities along the Columbia River in study Area 3 are Wenatchee, the Tri-cities (Richland, Pasco and Kennewick) and the Portland/Vancouver area. These areas are

protected by flood control operations of the dams and reservoirs in the Upper Columbia River system, the Snake River system and John Day Dam on the Lower Columbia as well as local flood control works and infrastructure. For example, the Tri-cities are protected by 17 miles of levees that prevent flooding from the backwater, storage pool behind McNary Dam. In addition, the Portland/Vancouver area is protected from flooding by dams and reservoirs in the Willamette River system and local levees.

The primary flood loss subarea identified for Area 3 is the Lower Columbia River area, which has a variety of floodplain types and land uses. The entire Lower Columbia is tidally influenced to Bonneville Dam at river mile 146. In the reach between Bonneville Dam and Washougal, the river is confined between steep, forested hills. It provides little floodplain, which is occupied by a few small communities, homes and farms. The landscape, floodplain and land use change through the Washougal and the Portland/Vancouver areas. As the floodplain widens, approaching the Willamette valley and confluence with the Willamette River, larger agricultural areas are found in the floodplain in the upstream portion of this segment and then a distinct transition into commercial/industrial and residential property in Portland and Vancouver. Downstream from the cities, the Columbia turns north towards Longview and travels through broad lowlands occupied by mostly rural and agricultural areas and industrial areas near Longview, WA. Downstream from Longview the Columbia progresses through the final 40 river miles through a broad, flat-bottomed valley, bordered by a steep and rocky headland on the north and a low peninsula on the south.

Flooding along the reach typically occurs from spring snowmelt runoff originating from the Snake and Upper Columbia Rivers, and rainfall or rainfall on snowmelt runoff originating from the Willamette River. Downstream from Westport, flooding concerns are related to the tidal influence on the reach. The system of reservoirs on the Upper Columbia and Snake Rivers provides spring flood control, and reservoirs in the Willamette River System provide wintertime rainfall and rain-on-snow runoff flood control protection. Major levee systems protect the urban and agricultural areas in the Lower Columbia reach (BPA 1995f).

4.4 Area 3 Navigation

For the purpose of this report, navigation is described for two subareas: Lake Roosevelt and lower Columbia River. For this analysis, the lower Columbia River subarea comprises the reach of the Columbia River downstream of the Snake River confluence and includes McNary, John Day, The Dalles, and Bonneville Locks and Dams.

Lake Roosevelt: The majority of navigation in the Lake Roosevelt subarea is recreational in nature. The affected environment and impact analysis associated with recreational boating is addressed in **Recreation Affected Environment Section** and the **Recreation Impact Sections** of this EIS. Commercial navigation is limited to the Keller Ferry on Lake Roosevelt, upstream from Grand Coulee Dam. Keller Ferry operations are under the jurisdiction of the Washington State Department of Transportation. The Keller Ferry

crosses the Columbia River at its confluence with the Sanpoil River from Ferry County and the Colville Indian Reservation on the north bank to Lincoln County on the south. The Columbia River is 1 1/4 miles wide at this point. Approximately 60,000 vehicles travel on the Keller Ferry each year. Walk-on passengers are few as the ferry route is a link in a rural highway, State Route 21. The nearest communities are Wilbur, 14 miles to the south, and Republic, 53 miles north. The free ferry operates seven days a week, 18 hours a day, from 6:00 a.m. until midnight. An additional small car ferry, the Gifford/Inchelium Ferry run by the Confederated Tribes of Colville Indian Reservation, runs every fifteen minutes in the daytime across the river.

Lower Columbia River: Commercial navigation occurs within the lower Columbia Reach of Area 3. Navigation projects in this subarea are classified into two types of projects; deep and shallow draft projects.
Deep draft navigation occurs in the lower portions of the river from the mouth upstream to Vancouver where a shipping channel 55 feet deep and 600 feet wide is maintained. Deep draft harbors along the Lower Columbia are at Astoria, Longview, Kalama, Woodland, Henrici Bar, Willow Bar, Kelley Point and Hayden Island. Deep draft harbors are also located on the Willamette River in Portland. The deep draft channel is used extensively by ocean going vessels transporting products to and from national and international markets. Waterborne commerce for deep draft projects is primarily composed of wheat, grain, corn, automobiles, containerized products, logs, petroleum, chemicals and other miscellaneous goods.

Major countries involved in import and exports area are Japan, Korea, Taiwan, Mexico, Canada and Pacific Rim nations. In 2002, more than 30 million tons of cargo valued at $14 billion was imported and exported from Columbia River Ports (CRCC 2003).

Shallow draft navigation using tugs, barges and log rafts occurs upstream from Vancouver through Bonneville, and continues upstream of McNary Dam to connect with the mainstem Snake River. Access to the inland areas is made possible through a series of locks on the dams. Products shipped on the shallow draft channel comprise mainly wheat, grain, wood products, petroleum, chemicals and other agricultural products. In 2001, 12 million tons of products were shipped along the Columbia shallow draft navigation channel. Shallow draft navigation projects upstream from Vancouver account for $2.2 billion in commerce annually in 1997 dollars (CSSR 2003).

4.5 Area 3 Agriculture and Irrigation

In Area 3, agriculture and irrigation was evaluated along the Columbia River through southern British Columbia and the six Washington counties along the mainstem Columbia River to Chief Joseph Dam. In this discussion, Franklin County is also included because it is a major user of irrigation water from the Columbia Basin irrigation project at Grand Coulee Dam and Lake Roosevelt/Banks Lake. **Table 15** provides a summary of agriculture and irrigation data for this portion of Area 3 in WA.

British Columbia: Along the mainstem Columbia River in British Columbia, there is limited farmland. The primary agricultural industry is cattle ranching. Some minor dairy and tree fruits are also present. The acreage of farmland has increased in the Kootenay Boundary RD from 1995 to 2000 to a total of about 141,000 acres, but the majority of the farmland is located west of the Columbia River valley in the Kettle River valley (BC Ministry of Management Services 2004 and Boundary Country 2004).

Stevens County, Washington has approximately 528,000 acres in farmland, with approximately 12,000 acres irrigated (2%). The major agricultural products include cattle and beef cows, with moderate numbers of other livestock such as hogs/pigs, sheep and chickens. Other major crops include wheat, oats, barley, hay/pasture, and about 250 acres in vegetable and fruit production. The market value of the County's agricultural products sold in 2002 was $28,245,000. The county's 2002 net cash farm income totaled $7,441,000, an average of $5,882 per farm. (USDA - NASS, Table 1, County Summary Highlights, 2002)

Ferry County, Washington has approximately 800,000 acres in farmland. Irrigated farmland however is limited, with approximately 4,000 acres irrigated (<1%). The major agricultural products are livestock, primarily beef cattle and hogs/pigs. There are limited other crops, primarily hay/pasture. The market value of the County's agricultural products sold in 2002 was $4,346,000. The county's 2002 net cash farm income totaled -$756,000, an average of -$3,734 per farm. (USDA - NASS, Table 1, County Summary Highlights, 2002)

Lincoln County, Washington is a major agricultural area with approximately 1,200,000 acres of farmland; approximately 53,000 acres irrigated (4%). The major agricultural crop is dryland wheat (2nd highest producing county in the nation); cattle and beef cows, barley, potatoes, and hay/pasture are also important crops. Approximately 100 acres are in orchard production. The market value of the County's agricultural products sold in 2002 was $93,555,000. The county's 2002 net cash farm income totaled $31,037,000, an average of $41,660 per farm. (USDA - NASS, Table 1, County Summary Highlights, 2002)

Douglas County, Washington has approximately 879,000 acres of farmland, with approximately 24,000 acres irrigated (3%). The major agricultural products are livestock (primarily cattle), wheat, oats, barley, and hay/pasture. Approximately 17,000 acres are in orchard production. The major fruit crops are apricots, peaches, and apples. The market value of the County's agricultural products sold in 2002 was $124,348,000. The county's 2002 net cash farm income totaled $29,345,000, an average of $30,922 per farm. (USDA - NASS, Table 1, County Summary Highlights, 2002)

Grant County, Washington is another major agricultural area with approximately 1,070,000 acres of farmland, including approximately 485,000 acres irrigated (45%). This county is a major beneficiary of the Columbia Basin irrigation project (along with Franklin County). The major agricultural products are livestock (over 150,000 cattle inventory); as well as hogs/pigs, wheat, oats, barley, beans, potatoes, hay/pasture, corn,

peppermint, spearmint, onions, sweet corn, apples, cherries, grapes, and pears. The market value of the County's agricultural products sold in 2002 was $881,756,000. The county's 2002 net cash farm income totaled $178,799,000, an average of $99,101 per farm. (USDA - NASS, Table 1, County Summary Highlights, 2002)

Okanogan County, Washington has the second largest amount of farmland in the state (second to Whitman County) with approximately 1,240,000 acres and approximately 48,000 acres irrigated (4%). The major agricultural products are livestock (primarily cattle and beef cows and sheep), wheat, oats, barley, hay/pasture, and fruit crops (primarily apples and pears). The market value of the County's agricultural products sold in 2002 was $137,418,000. The county's 2002 net cash farm income totaled $33,467,000, an average of $22,507 per farm. (USDA - NASS, Table 1, County Summary Highlights, 2002)

Franklin County. Franklin County has approximately 665,000 acres of farmland with approximately 241,000 acres irrigated (36%). The major agricultural products are livestock, primarily cattle; corn, wheat, beans, potatoes, hay/pasture, asparagus, carrots, onions, sweet corn, and tree fruits such as apples, grapes, and cherries. The market value of the County's agricultural products sold in 2002 was $350,483,000. The county's 2002 net cash farm income totaled $88,144,000, an average of $92,979 per farm. (USDA - NASS, Table 1, County Summary Highlights, 2002)

Table 15: Agricultural and Irrigation Summary Statistics for Area 3

COUNTY, STATE	LAND IN FARMS	TOTAL CROPLAND	HARVESTED CROPLAND	IRRIGATED ACRES	IRRIGATED ACRES AS % OF HARVESTED CROPLAND	COUNTY'S NET CASH FARM INCOME
Stevens, WA	528,402	116,370	72,272	11,553	16%	$7,441,000
Douglas, WA	878,867	550,085	213,942	24,049	11%	$29,345,000
Ferry, WA	799,435	23,644	11,705	4,184	36%	-$765,000
Franklin, WA	664,875	475,804	288,963	241,063	83%	$88,144,000
Grant, WA	1,074,074	804,793	599,943	485,459	81%	$178,799,000
Lincoln, WA	1,233,377	854,791	510,356	52,991	10%	$31,037,000
Okanogan, WA	1,241,316	139,753	71,149	48,416	68%	$33,467,000

Source: USDA, NASS 2002

4.6 Area 3 Municipal and Industrial Water Supply

The Columbia River and its reservoirs in Area 3 are used to provide municipal and industrial (M&I) water supply for several communities and private landowners. M&I

water use is a relatively small portion (~8%) of water withdrawn from the river. Approximately 90 percent of water withdrawn from the entire Columbia River system in the U.S. is for irrigation purposes. Water supply for domestic use accounts for 4 percent; commercial use accounts for about 2 percent; and industrial use accounts for about 2 percent. The remaining 2 percent are shared between livestock, mining and thermoelectric. Water is pumped from Lake Roosevelt to Banks Lake to provide storage for irrigation. **Table 16** is a summary of municipal, domestic and industrial water withdrawals in Area 3 (USGS 2000).

Table 16: Selected Statistics for M&I Water Supply for the U.S. Portion of Area 3

	STEVENS COUNTY, WASHINGTON	FERRY COUNTY, WASHINGTON	LINCOLN COUNTY, WASHINGTON	DOUGLAS COUNTY, WASHINGTON	GRANT COUNTY, WASHINGTON	OKANOGAN COUNTY, WASHINGTON
TOTAL POPULATION (x1,000)	40.07	7.26	10.18	32.60	74.70	39.56
TOTAL POPULATION SERVED BY PUBLIC SUPPLY (x1,000)	23.40	2.88	0.00	28.84	49.56	21.06
TOTAL PUBLIC SUPPLY FRESH SURFACE WATER WITHDRAWALS (million gal/d)	0.00	0.03	0.00	0.00	0.57	0.63
TOTAL DOMESTIC SELF-SUPPLY FRESH SURFACE WATER WITHDRAWALS (million gal/d)	0.00	0.02	0.00	0.00	0.00	0.00
TOTAL INDUSTRIAL SELF-SUPPLY FRESH SURFACE WATER WITHDRAWALS (million gal/d)	0.12	0.00	0.00	0.00	0.00	0.00

4.7 Area 3 Tribal Socioeconomics

The recognized Native American Tribes located along the mainstem Columbia River, or with mainstem Columbia River interests, include the Confederated Tribes of the Colville Reservation, Spokane, Yakama, Umatilla, and Confederated Tribes of the Warm Springs Reservation. Only the Colville and Spokane Tribes will be discussed in detail in this EIS.

The Colville Indian Reservation is located along the west bank of the Columbia River and Lake Roosevelt from a few miles south of Kettle Falls, Washington to the Okanogan River confluence. Major tribal business enterprises and employers include the timber and construction industries and social and tribal services (K. Desautel, Colville Tribes, pers. comm. 11/04). The tribe operates a small fish hatchery near Bridgeport. The tribe also

operates a number of boat ramps, a campground, and two marinas under contract with the National Park Service. They operate the Inchelium ferry year-round. A total of 16 boat docks/ramps on Lake Roosevelt are on tribal lands. Five water intakes are located on Lake Roosevelt and 17 intakes are located on Lake Rufus Woods downstream of Grand Coulee Dam. Most of the boat docks are not usable during low lake elevations currently. (Fulcrum Environmental Consulting, Inc. 2004) The tribe would be concerned about potential effects on the ferry operation, boat ramps and marinas, water intakes, and fish populations.

The Spokane Indian Reservation is located on the east bank of Lake Roosevelt and the north bank of the Spokane River. A boat ramp, marina, and 11 campgrounds on Lake Roosevelt are located on tribal lands adjacent to Lake Roosevelt; the remainder of the shoreline is fairly undeveloped, although there are a number of undeveloped fishing access locations.

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UPPER COLUMBIA ALTERNATIVE FLOOD CONTROL AND FISH OPERATIONS EIS

SOCIOECONOMIC IMPACT ANALYSIS

Appendix F: Part 2 of 2

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UPPER COLUMBIA ALTERNATIVE FLOOD CONTROL AND FISH OPERATIONS EIS

SOCIOECONOMIC IMPACT ANALYSIS

TABLE OF CONTENTS

Page F-

1.0 Introduction....45
2.0 Socioeconomic Impact Analysis Methodology....47
2.1 Flood Control Methodology....47
2.2 Navigation Methodology....48
2.3 Agriculture and Irrigation Methodology....48
2.4 Municipal and Industrial Water Supply Methodology....50
2.5 Employment and Income Methodology....50
2.6 Tribal Socioeconomics Methodology....51
3.0 Area 1 – Kootenai River Basin....52
3.1 Area 1 Flood Control....52
3.2 Area 1 Navigation....55
3.3 Area 1 Agriculture and Irrigation....56
3.4 Area 1 Municipal and Industrial Water Supply-....58
3.5 Area 1 Employment and Income....60
3.6 Area 1 Tribal Socioeconomics....63
4.0 Area 2 – Flathead, Clark Fork, Pend Oreille River Basin....65
4.1 Area 2 Flood Control....65
4.2 Area 2 Agriculture and Irrigation....72
4.3 Area 2 Municipal and Industrial Water Supply....75
4.4 Area 2 Employment and Income....78
4.5 Area 2 Tribal Socioeconomics....80
5.0 Area 3 – Mainstem Columbia River....82
5.1 Area 3 Flood Control....82
5.2 Area 3 Navigation....83
5.3 Area 3 Agriculture and Irrigation....83
5.4 Area 3 Municipal and Industrial Water Supply....84
5.5 Area 3 Employment and Income....84
5.6 Area 3 Tribal Socioeconomics....84

LIST OF TABLES

Page F-

Table 1. Flood Impacts Evaluation Areas....48
Table 2. Irrigation Water Use by Month....49
Table 3. M&I Water Use by Month....50
Table 4: Stage vs. Flood Damage - Libby Dam to Kootenay Lake....53
Table 5: Expected Annual Damages - Libby Dam to Kootenay Lake....54
Table 6. Average Days per Month with Kootenay Lake Elevation at or below 1752 Feet55
Table 7. Summary of Agricultural Pumping Power Requirements, Area 1 - Kootenai River in MT....56
Table 8. Summary of Agricultural Pumping Power Requirements Hours, Area 1 - Kootenai River in ID....57
Table 9. Impacts of High Groundwater Levels, Kootenai River Floodplain....58
Table 10. Summary of M&I Pumping Power Requirements, Area 1 - Kootenai River in MT....59
Table 11. Summary of M&I Pumping Power Requirements, Area 1 - Kootenai River in ID....60
Table 12. Simulated Hydropower Generation with Each Combination....63
Table 13: Discharge vs. Flood Damage - Columbia Falls to Flathead Lake....66
Table 14: Expected Annual Damages - Columbia Falls to Flathead Lake....67
Table 15: Flathead Lake Flood Control Operations....67
Table 16: Stage vs. Flood Damage - Flathead Lake....68
Table 17: Expected Annual Damages - Flathead Lake....68
Table 18: Stage vs. Flood Damage - Pend Oreille Lake....69
Table 19: Expected Annual Damages - Pend Oreille Lake....70
Table 20: Albeni Falls Dam Peak Discharges....70
Table 21: Discharge vs. Flood Damage - Albeni Falls to Box Canyon Dam....71
Table 22: Expected Annual Damages - Albeni Falls to Box Canyon Dam....72
Table 23. Summary of Agricultural Pumping Power Requirements, Area 2 – Flathead River at Columbia Falls....72
Table 24. Summary of Agricultural Pumping Power Requirements, Area 2 – Flathead Lake....73
Table 25. Summary of Agricultural Pumping Power Requirements, Area 2 – Lower Flathead River, Polson MT....74
Table 26. Summary of Agricultural Pumping Power Requirements, Area 2 – Pend Oreille River, Albeni Falls ID to U.S-Canada Border....74
Table 27. Summary of M&I Pumping Power Requirements, Area 2 – Flathead River at Columbia Falls....75
Table 28. Summary of M&I Pumping Power Requirements, Area 2 – Flathead Lake....76
Table 29. Summary of M&I Pumping Power Requirements, Area 2 – Lower Flathead River, Polson MT....77
Table 30. Summary of M&I Pumping Power Requirements, Area 2 – Pend Oreille River, Albeni Falls ID to U.S-Canada Border....78

UPPER COLUMBIA ALTERNATIVE FLOOD CONTROL AND FISH OPERATIONS EIS

SOCIOECONOMIC IMPACT ANALYSIS

1.0 Introduction

The Socioeconomic Affected Environment report describes the potentially affected environment associated with Upper Columbia River Alternative Flood Control and Fish Operations. The affected environment report identified the following categories of potential socioeconomic impacts associated with changes in operations at Libby and Hungry Horse Dams:

- Flood Control
- Navigation
- Agriculture and Irrigation
- Municipal and Industrial Water Supply
- Hydropower
- Employment and Income, and
- Tribal Socioeconomics

Potential socioeconomic impacts in these categories were examined for each of the following three study areas.

- Area 1 - Kootenai River Basin from Lake Koocanusa in Montana (MT) and British Columbia (BC) through Idaho (ID) to the Columbia River in BC
- Area 2 - Flathead/Clark Fork/Pend Oreille Basin from Hungry Horse Reservoir in MT to the Columbia River in Washington (WA)
- Area 3 - Columbia River mainstem from the mouth of the Kootenai River in BC downstream to the Pacific Ocean in Oregon (OR) and WA

Two operations without fish flows, referred to as “benchmarks”[1], were evaluated:

- Standard Flood Control Operations *without* Fish Flows (LS)
- VARQ Flood Control Operations *without* Fish Flows (LV)

The two benchmark operations were evaluated to facilitate assessment of the potential recreational impacts of fish flows that have been implemented in response to the 2000 U.S Fish and Wildlife Service and National Marine Fisheries Service Biological Opinion.

[1] A "benchmark” does not meet the purpose and need of the action and provides a basis for comparison of the impacts of the effects of the fish flows at Libby.

In addition to the two benchmarks, four other operational alternatives were evaluated in Area 1 that include fish flows.

- Standard Flood Control Operations *with* Fish Flows up to Powerhouse Capacity at Libby Dam (LS1)
- VARQ Flood Control Operations *with* Fish Flows up to Powerhouse Capacity at Libby Dam (LV1)
- Standard Flood Control Operations *with* Fish Flows up to 10,000 cfs above Powerhouse Capacity at Libby Dam (LS2)
- VARQ Flood Control Operations *with* Fish Flows up to 10,000 cfs above Powerhouse Capacity at Libby Dam (LV2)

In Area 2, two operational alternatives were evaluated.

- Standard Flood Control Operations (HS)
- VARQ Flood Control Operations (HV)

To evaluate the effects that the Area 1 and Area 2 operational alternatives have in Area 3, the following combinations were addressed:

- HS + LS1 (no-action)
- HV + LV1
- HS + LS2
- HV + LV2
- HS + LS (benchmark combination)
- HV + LV (benchmark combination)

2.0 Socioeconomic Impact Analysis Methodology

Methodologies for evaluating direct socioeconomic impacts and their indirect impacts on regional employment and income are described below. Cost and benefit data are based upon October 2004 prices and conditions.

2.1 Flood Control Methodology

When flood waters exceed river banks and flow onto developed properties, losses may occur. The extent of flood impact is a function of the depth and duration of the floodwaters. Assessing expected flood losses involves three relationships; the stage-damage relationship, discharge-stage relationship, and discharge-frequency relationship.

- The stage-damage function defines the amount of losses that is expected to occur at different depths of flooding for defined flood impact areas.
- The discharge-stage function (sometimes called the rating curve) specifies the river stage associated with measured flow volumes at specified control points. For flood loss assessment associated with flow volume, the rating curve is integrated with the stage-damage curve to yield a discharge-damage curve.
- The discharge-frequency function defines the probability of exceeding a given discharge in any year. The discharge-frequency curve is integrated with the discharge-damage curve to yield the frequency-damage curve.

Expected annual flood damages are equal to the area under a frequency damage curve. Expected annual damages were estimated for flood-prone river reaches in Areas 1 and 2 with each alternative or benchmark using the Corps' Hydrologic Engineering Center program, Expected Annual Damages (EAD). Categories of impacts evaluated include residential, commercial, industrial, agricultural, public, and transportation-related losses; and emergency aid costs. Flood loss study reaches evaluated for flooding impacts are presented in **Table 1**.

Table 1. Flood Impacts Evaluation Areas

Study Area	Flood Loss Study Reach	Control Point
Area 1	Kootenai River (Bonners Ferry to Canadian Border)	Kootenai River Stage at Bonners Ferry, ID
Area 1	Kootenay Lake Shoreline	Stage at Kootenay Lake
Area 2	Flathead River from Columbia Falls, MT to Flathead Lake	Flathead River Flow at Columbia Falls, MT
Area 2	Flathead Lake Shoreline	Stage at Flathead Lake
Area 2	Lake Pend Oreille Shoreline	Stage at Lake Pend Oreille
Area 2	Pend Oreille River from Albeni Falls Dam to the Columbia River	Pend Oreille River Flow at Newport, WA
Area 3	Lower Columbia River	Columbia River Flow at The Dalles, OR

2.2 Navigation Methodology

Commercial navigation in the affected area is limited to ferry transportation in Areas 1 and 3. The operating range of each ferry loading ramp was identified and compared to water surface elevations with each alternative/alternative combination or benchmark/benchmark combination to identify impacts to ferry operations.

2.3 Agriculture and Irrigation Methodology

Changing reservoir and river stages may impact agricultural production in the study area. The primary categories of potential impact to agricultural production are changes in the energy required to pump water and resultant changes in irrigation pumping costs and changes in expected crop losses resulting from high groundwater levels. Any losses resulting from overbank flooding of crops are accounted for in the flood control analysis. Different methodologies were applied for evaluating each type of agricultural impact.

2.3.1 Irrigation Pumping Costs

Water rights data were collected, from MT, ID and WA state water rights databases[2], and evaluated for each county along the river to estimate the quantity of water pumped for irrigation. These irrigation volumes were distributed over the growing season of May to September. For the analysis, pumping volumes were divided with 20% assumed to occur prior to July 1 and 80% after July 1. The 20% was divided evenly across May and June and the 80% was divided evenly across July- September[3]. The distribution is shown in **Table 2**. Average monthly stages with each alternative/benchmark were used to estimate the relative number of kilowatt-hours required for pumping with each alternative/benchmark.

Table 2. Irrigation Water Use by Month

Month	% Use
May	10 %
June	10 %
July	20 %
August	20 %
September	20 %
TOTAL:	100%

Note: Because stage data was not modeled for Kootenai River at Bonners Ferry, ID gage in September, for that reach, irrigation use was assumed to be 30% in July and 30% in August.
Source: Orvis Irrigation, 2005 – Personal communication with Karl Orvis of Kalispell MT, regarding typical irrigation seasonal distribution in Upper Columbia Basin.

A typical pumping configuration for the Upper Columbia River was developed and applied for the analysis. For reaches with modeled stage data, the modeled stages were used. For river reaches without modeled stage data, stage discharge curves were used to

[2] The following is a summary of the surface water rights data sources:
-State of Montana Rivers: Two internet reference sources were utilized to determine the amount of agricultural and M&I water diversions within the state.
1)Digital Atlas of Montana - Surface water, points of diversion database query
This system provided all surface water diversions with each respective basin (http://maps2.nris.state.mt.us/mapper/index.html).
2) Montana Department of Natural Resources and Conservation Water Right Query
This system provided a summary of water rights and diversion method. The study focused on water rights with diversion methods stated as surface water and pumping (http://nris.state.mt.us/apps/dnrc2002/waterrightmain.asp).
-State of Idaho Rivers: The resource for State of Idaho water rights information is the State of Idaho, GIS Web Server named IDWR Water Right and Adjudication Search (http://www.idwr.idaho.gov/apps/ExtSearch/SearchWRAJ.asp).
-State of Washington: The resource for the State of Washington water rights information is a recent watershed level 1 planning report for WRIA 62 (Entrix, 2001 – Level 1 Assessment, WRIA 62, Pend Oreille Watershed Planning Unit.).

[3] Bonners Ferry stage data during the irrigation season were only available for May through August. For this reach the 80% of irrigation occurring after July 1 was spread evenly over the months of July and August for analysis.

relate flow rates to river stage. A standard power pumping formula was used to calculate power requirements for each alternative/benchmark.

2.3.2 Agricultural Impacts from High Groundwater Levels

Potential agricultural losses could result from higher stages in the Kootenai Flats reach of Area 1. Crop loss functions were developed that associate losses to river flows and/or stages in the area using a groundwater model developed for the region. Losses from high groundwater levels were evaluated for the four alternatives and two benchmarks in a separate report.

2.4 Municipal and Industrial Water Supply Methodology

Change in the energy required to pump water and the resultant change in pumping cost is the primary category of potential impact to Municipal and Industrial (M&I) Water Supply in the study area. The same methodology as described above for irrigation pumping power requirements was applied to collect data on M&I water rights and volumes; and to evaluate potential impacts to M&I pumping power requirements. For the analysis, monthly M&I water use was distributed as identified in **Table 3**.

Table 3. M&I Water Use by Month

Month	% Use
January	7.00%
February	7.00%
March	8.00%
April	8.25%
May	9.00%
June	9.25%
July	9.50%
August	9.50%
September	9.00%
October	8.50%
November	8.00%
December	7.00%
TOTAL	100.00%

Source: AQUARIOUS: A Modeling System For River Basin Allocation; U.S. Forest Service 2000; Chapter3; Municipal and Industrial Water Use.

2.5 Employment and Income Methodology

A qualitative evaluation of potential effects to local and regional economies was performed for each study area. The evaluation addresses potential localized impacts of changes in direct socioeconomic and recreation outputs.

2.6 Tribal Socioeconomics Methodology

Tribal socioeconomic characteristics are identified for each study area in the Recreation Affected Environment Report. Potential impacts to Tribal Socioeconomics in these study areas are addressed in this report. Categories of potential impact that were evaluated include flood control, navigation, irrigation, M&I water supply, and employment and income. Methodologies applied for evaluation of impacts in each of these categories are the same as described in the preceding paragraphs of this section.

3.0 Area 1 – Kootenai River Basin

3.1 Area 1 Flood Control

Impacts on existing flood control levels in Area 1 were identified as a concern on the Kootenai River from Bonners Ferry to (and including) Kootenay Lake. An assessment of overbank flooding impacts that would be associated with the different flood control and fish operation alternatives/benchmarks is documented below. Potential agricultural impacts associated with high groundwater levels are presented in **Section 3.3.2**.

3.1.1 Kootenai River Flood Control

The primary area of potential flood losses along the Kootenai River between Libby Dam and Kootenay Lake occurs in the reach known as Kootenai Flats, extending from Bonners Ferry, ID, to Kootenay Lake in Canada. In addition to Libby Dam, flood protection is provided in the United States portion of the floodplain by approximately 95 miles of levees that protect about 35,000 acres of agricultural lands used to grow wheat, barley, oats, canola, and hops. With a few exceptions (levees protecting hops) these levees have not been well maintained since Libby Dam began flood control operations. Levees also protect about 17,000 acres in Canada, between the international boundary and Kootenay Lake. Cropping patterns are similar to those in the United States. About 190 acres within the town of Bonners Ferry are also in the Kootenai River floodplain and are protected by well-maintained levees. In 1987 (the most recent floodplain survey data available) this area contained 106 homes, 66 commercial establishments and 12 public facilities.

Flood History: Before the Kootenai Flats area was partially protected by man made levees, yearly high water would flood portions of the floodplain and more infrequent events would flood the entire valley, in excess of 60,000 acres. Floods in the Kootenai Basin generally occurred during the snowmelt season often augmented by intense rainfall. Floods are of long duration and are notable for great volume rather than extreme stage crest. Because of the backwater effect of Kootenay Lake, maximum discharge of the river at Bonners Ferry usually occurs prior to the maximum river elevation. As Kootenay Lake rises, the gradient of the river becomes less, the velocity decreases and a higher stage for a given discharge occurs. The 1948 flood in the Kootenai Valley exceeded the 1894 flood, the largest known in the Columbia River Basin as a whole, in stage, although not in discharge. Estimates of flood losses caused by the 1948 flood totaled $5,792,000 ($107,036,000 in October 2004 prices and conditions). Prior to the completion of Libby Dam (operational for flood control in 1972), the town of Bonners Ferry experienced a 50-year event in 1894, a 40-year event in 1916, a 25-year event in 1948, and a 10-year event in 1956. During the course of interviews with merchants in Bonners Ferry, many revealed that they had been forced to move inventory and supplies four to six times between 1948 and 1972.

Stage – Damage Analysis: Data on damageable property, including residential, commercial/ industrial, public, agricultural, and emergency aid were obtained from a detailed economic study conducted for the *Columbia River System Operation Review – Environmental Impact Statement,* published in November 1995. For this analysis, loss figures were updated (from July 1992 Prices & 1995 Conditions) to October 2004 Prices and Conditions using the *Engineering News Record* building and construction cost indices, the CPI for West Urban areas, and an assumed rate of growth (0.5%/yr). Loss, by stage, for all categories of impact, is summarized on **Table 4**. The zero dollar damage point for this reach is 1764.0 feet.

Table 4: Stage vs. Flood Damage - Libby Dam to Kootenay Lake

Stage*	Residential	Commercial/ Industrial	Public	Agriculture	Emergency Aid	Other	Total Losses
1764	0	0	0	0	0	0	0
1768	28.2	382.3	191.2	438.8	232.4	95.6	1,368.5
1770	58.6	829.8	417.1	947.1	504.0	206.4	2,963.0
1772	99.9	1,405.4	699.5	1,605.3	853.7	351.9	5,015.7
1776	356.2	4,976.5	2,489.4	5,691.2	3,023.7	1,244.7	17,781.7
1777	510.5	7,148.8	3,575.5	8,169.7	4,340.1	1,787.7	25,532.3
1778	866.7	12,127.5	6,064.8	13,858.7	7,363.8	3,032.4	43,313.9
1780	2,033.2	28,471.2	14,234.5	32,535.4	17,284.3	7,116.2	101,674.8
1781	2,189.6	30,639.1	15,318.5	35,016.1	18,602.9	7,659.2	109,425.4
1782	2,278.7	31,916.4	15,957.1	36,475.8	19,378.3	7,978.5	113,984.8

*Note: *Elevation in feet, MSL Datum. Data presented in October 2004 Prices & Conditions - $1,000*

Expected Annual Damages: Stage – frequency relationships developed at the Bonners Ferry gage for the four alternatives and two benchmarks were used to derive expected annual damages for this flood impact reach. Details of these derivations can be found in the **Hydrology and Flood Control Section** of the EIS. Expected annual damages were derived using Corps of Engineers Hydrologic Engineering Center computer program *Expected Annual Flood Damage Computation.* This program integrates exceedance frequency with associated losses to determine expected annual damages for a given frequency interval. **Table 5** presents a summary of expected annual damages by impact category for the alternatives and benchmarks. As shown on **Table 5**, all operations except the LV benchmark would have identical expected annual damages of $21,780. Benchmark LV would increase total expected annual damages by $1,170, or 5 percent relative to benchmark LS.

Table 5: Expected Annual Damages - Libby Dam to Kootenay Lake

Alternative	Residential	Commercial/ Industrial	Public	Agriculture	Emergency Aid	Other	Total Damages
LS1	0.44	6.10	3.05	6.97	3.7	1.52	21.78
LV1	0.44	6.10	3.05	6.97	3.7	1.52	21.78
LS2	0.44	6.10	3.05	6.97	3.7	1.52	21.78
LV2	0.44	6.10	3.05	6.97	3.7	1.52	21.78
Benchmark							
LS	0.44	6.10	3.05	6.97	3.7	1.52	21.78
LV	0.46	6.43	3.22	7.34	3.9	1.60	22.95

Note: Data presented in October 2004 Prices & Conditions - $1,000

3.1.2 Kootenay Lake Flood Control

The 1972 Columbia River Treaty Flood Control Operating Plan (FCOP) states that "damage commences at Nelson when Kootenay Lake reaches elevation 1755 feet and major damage stage is elevation 1759 feet" (Corps 1972). Since 1972, development around Kootenay Lake has occurred, and it is probable that damage now commences below elevation 1755 feet. The Canadian entity is endeavoring to create an updated stage-damage relationship at Kootenay Lake.

From a flood control perspective, the impacts of VARQ flood control operations and fish flows on the level of Kootenay Lake are of greatest importance in May, June, and July. Elevation-frequency analysis during this period shows that for high percent-chance-exceedance (low runoff) events, the Kootenay Lake levels associated with VARQ flood control operations would be consistently higher than those under standard flood control operations. This effect diminishes toward the low percent-chance-exceedance (higher runoff) events, and the effects of the different flood control operations would be basically the same at or above elevation 1754 feet. In all simulations, the maximum stage at Kootenay Lake would remain below elevation 1755 feet, regardless of the flood control alternative/benchmark modeled.

Results were similar for alternatives (with fish flows) relative to the benchmark operations without fish flows. Overall, the alternatives all would lead to higher spring and summer time elevations at Kootenay Lake than the benchmarks (without fish flows) for the high percent-chance-exceedance events. The alternatives where fish flows are provided at powerhouse capacity +10,000 cfs would result in a higher Kootenay Lake stage than the alternatives where fish flows are limited to powerhouse capacity. In all of the fish flow simulations, the maximum stage at Kootenay Lake would remain below elevation 1755 feet.

In 2004, BC Hydro, the Columbia Basin Trust, Environment Canada, the Lower Kootenay Band, and the Ministry of Water Land and Air Protection collaborated to produce the report: A Stakeholders Summary of Preferred and Potential Negative

Reservoir Levels and River Stages on the Kootenay River System in Canada, Interest Group Response Summary to proposed VARQ Alternative Flood Control Operation. The report documents detrimental Kootenay Lake elevations relative to regional residential and commercial values, including the flooding of residential and commercial waterfront properties. The highest non-detrimental lake elevation identified in the report was elevation 1752 feet. Daily lake elevations were modeled with each alternative/benchmark over a 52-year period and reviewed to identify the average number of days per month that the lake level was at or below elevation 1752 feet. The results are shown in **Table 6**. Results show that the average number of days per year that the lake is below 1752 is the same for LS1 and LV1 (363 days) and one day less with LS2 or LV2 (362 days). The greatest numbers of days below 1752 were with the benchmark operations (365 days with LS and 364 days with LV). The greatest change in the number of days between any two alternatives/benchmarks is less than 1%.

Table 6. Average Days per Month with Kootenay Lake Elevation at or below 1752 Feet

Month	LS1 (No-Action)	LV1	LS2	LV2		LS benchmark	LV benchmark
January	31	31	31	31		31	31
February	28	28	28	28		28	28
March	31	31	31	31		31	31
April	30	30	30	30		30	30
May	31	31	31	31		31	31
June	28	28	27	27		30	29
July	31	31	31	31		31	31
August	31	31	31	31		31	31
September	30	30	30	30		30	30
October	31	31	31	31		31	31
November	30	30	30	30		30	30
December	31	31	31	31		31	31
Total:	363	363	362	362		365	364

3.2 Area 1 Navigation

Impacts on commercial navigation in Area 1 were identified as a concern on Kootenay Lake, where the Canadian Ministry of Highways operates the Kootenay Lake Ferry. The ferry is operational down to lake levels of 1739 feet. No alternatives/benchmarks would result in water surface elevations outside the ferry's operational range.

3.3 Area 1 Agriculture and Irrigation

The primary categories of potential impacts to Area 1 agriculture from changes in operations at Libby Dam are changes in agricultural pumping power requirements and changes in expected losses to agricultural production from seepage.

3.3.1 Irrigation Pumping Impacts

To evaluate the impacts to irrigation pumping from the Kootenai River, water rights data from MT and ID were reviewed to estimate pumped volumes for agricultural irrigation. Pumping power requirements were estimated based upon the average monthly stage for each alternative/benchmark as measured at the Libby, MT gage[4] for MT use and the Bonners Ferry, ID gage for ID use. In general, higher river stages tend to reduce power requirements for irrigation pumping.[5]

Montana Irrigation from Kootenai River: Based on review of state water rights data, annual Kootenai River withdrawals for agricultural irrigation in MT were estimated at 817 acre-feet. For the analysis, the total annual volume was distributed across the irrigation season (May-September) per the monthly distribution shown in **Table 2**. **Table 7** presents the estimates of pumping kilowatt-hours associated with each alternative/benchmark. Compared to no-action (LS1), the greatest change in the agricultural pumping power requirements with any other alternative/benchmark is less than one half of one percent.

Table 7. Summary of Agricultural Pumping Power Requirements, Area 1 - Kootenai River in MT

Location	Month	Pumping Power Requirements (kW-hr)						
		LS1 (No-Action)	LV1	LS2	LV2		LS benchmark	LV benchmark
Libby	May	16,100	16,000	16,100	16,000		16,300	16,100
	June	15,900	15,900	15,900	15,900		16,200	16,000
	July	42,700	42,500	42,700	42,500		42,600	42,600
	Aug	42,700	42,600	42,700	42,600		43,100	43,100
	Sep	43,200	43,200	43,200	43,200		42,000	42,100
Total		160,600	160,200	160,600	160,200		160,200	159,900

[4] The flow at this location was assumed to be equal to the simulated outflow from Libby Dam for each alternative.
[5] Methodology described in Section 2.3.1.

Idaho Irrigation from Kootenai River: Based on review of state water rights data, annual withdrawals for agricultural irrigation in ID were estimated at 2334 acre-feet. For the analysis, the total annual volume was distributed across the months of May to August (the months with modeled stage data for each alternative/benchmark) per the distribution identified in **Table 2**. **Table 8** presents the estimates of pumping kilowatt-hours associated with each alternative/benchmark. Compared to no-action (LS1), the greatest change in the agricultural pumping power requirements with any other alternative/benchmark is less than one percent.

Table 8. Summary of Agricultural Pumping Power Requirements Hours, Area 1 - Kootenai River in ID

Location	Month	Pumping Power Requirements (kW-hr)						
		LS1 (No-Action)	LV1	LS2	LV2		LS benchmark	LV benchmark
Bonners Ferry	May	44,700	44,200	44,600	44,100		44,900	44,100
	June	43,900	43,900	43,900	43,900		44,800	44,200
	July	182,200	180,900	182,500	181,200		181,100	180,700
	Aug	184,800	183,500	185,100	183,800		186,300	186,300
Total		455,600	452,500	456,100	453,000		457,100	455,300

3.3.2 Agricultural Impacts from High Groundwater Levels

Agricultural impacts were evaluated associated with crop losses from high groundwater levels in Kootenai Flats in a separate section of this EIS (see Appendix G). For this analysis, the Corps worked with local officials, USFWS, tribal staff, and property owners under facilitation of the Kootenai Valley Resources Initiative (KVRI) to reach a consensus on two years representing conditions of interest to the valley stakeholders and relevant to the seepage issue.

Water year 1964 was selected to represent a typical year, which was defined as a year with a May 1st Libby seasonal water supply forecast between 6.0 and 6.7 million acre-feet[6], with a relatively small May 1st forecast error, and hydrograph timing and volume similar to the 50% exceedance summary hydrograph. 1964 had a seasonal runoff of 6.9 million acre-feet (111% of average, with a May 1st forecast of 6.7 million acre-feet).

Water year 1961 was selected to represent "a more significant year," which was defined as a high-water year that is a cause of concern for the community. The high-water year was chosen solely by the stakeholder group from the period of record as the one year they wanted modeled to capture the upper bounds of seepage impacts. 1961 had a seasonal

[6] The average April-August water supply for Libby is 6.25 million acre-feet (MAF). Actual runoff in 1964 was 6.9 MAF, or 111% of average.

runoff of 7.9 million acre-feet (126% of average) and a May 1st forecast of 7.5 million acre-feet. Forecasts for 1961 in January, February, March, and April were all lower than the May 1st forecast. The greatest difference in river flows and resulting groundwater levels between VARQ and Standard FC would be expected in years such as 1961 with increasing water supply forecasts through the winter.

Analysis of groundwater pumping costs for each of these years was performed for each alternative/benchmark. The analysis was based upon crop budget research and a groundwater model developed for the study. Losses were evaluated for hops, winter wheat, spring wheat, barley, canola, and alfalfa. Aggregated results of the analysis for these crops are presented in **Table 9**.

Results show that for the typical year (1964), crop losses associated with high groundwater would be expected to increase by 0.8% with LV1, 2.8% with LS2, and 3.4% with LV2, when compared to no-action (LS1). The two benchmark operations show a decrease in losses when compared to no-action; a decrease of 31.5% with LS and a decrease of 14.9% with LV. For the more significant year (1961), results showed that losses would be expected to increase by 9.8% with LV1 and LV2, and decrease by 2.2% with LS2, when compared to no-action (LS1). The benchmark operations showed a decrease of 11.7% with LS and an increase of 9.0% with LV when compared to no-action.

Table 9. Impacts of High Groundwater Levels, Kootenai River Floodplain

Year	LS1	LV1	LS2	LV2		LS benchmark	LV benchmark
1964 (a typical year)	$3,811,000	$3,843,000	$3,916,000	$3,940,000		$2,609,000	$3,244,000
1961 (a more signifi-cant year)	$5,336,000	$5,860,000	$5,221,000	$5,860,000		$4,714,000	$5,817,000

3.4 Area 1 Municipal and Industrial Water Supply-

The primary category of potential impact to M&I water supplies resulting from changes in operations at Libby Dam is associated with changes in the energy required to pump water. MT and ID water rights data were reviewed to estimate pumped volumes for M&I water supply from the Kootenai River. Pumping power requirements were estimated based upon the average monthly stage for each alternative/benchmark as measured at Libby, MT for MT use and Bonners Ferry, ID for ID use.[7]

Montana M&I Water Supply from Kootenai River: Based on review of state water rights data, annual Kootenai River withdrawals for M&I water supply in MT were estimated at 5,263 acre-feet. For the analysis, the total annual volume was distributed

[7] Methodology described in Section 2.4.

across all months as presented in **Table 3**. **Table 10** presents the estimates of pumping kilowatt-hours associated with each alternative/benchmark. Compared to no-action (LS1), the greatest change in M&I pumping power requirements with any other alternative/benchmark is less than three tenths of one percent.

Table 10. Summary of M&I Pumping Power Requirements, Area 1 - Kootenai River in MT

Location	Month	Pumping Power Requirements (kW-hr)						
		LS1 (No-Action)	LV1	LS2	LV2		LS benchmark	LV benchmark
Libby	Jan	71,300	72,500	71,300	72,500		71,300	72,500
	Feb	72,200	73,000	72,200	73,000		72,200	73,000
	March	83,600	83,900	83,600	83,900		83,600	83,900
	Apr	86,600	86,600	86,600	86,600		86,600	86,600
	May	93,600	92,900	93,400	92,700		94,400	93,300
	June	94,600	94,700	94,600	94,700		96,300	95,600
	July	97,900	97,500	98,000	97,600		97,800	97,800
	Aug	98,000	97,700	98,100	97,800		98,900	99,000
	Sep	93,900	94,000	93,900	94,000		91,300	91,500
	Oct	89,000	89,100	89,000	89,100		88,900	89,100
	Nov	83,900	84,000	83,900	84,000		83,800	84,000
	Dec	71,800	71,900	71,800	71,900		71,600	71,800
	Total	1,036,400	1,037,800	1,036,400	1,037,800		1,036,700	1,038,100

Idaho M&I Water Supply from Kootenai River: Based on review of state water rights data, annual Kootenai River withdrawals for M&I water supply in ID were estimated at 1452 acre-feet. For the analysis, the total annual volume was distributed evenly across the months with modeled stages at Bonners Ferry (April-August). **Table 11** presents the estimates of pumping kilowatt-hours associated with each alternative/benchmark. Compared to no-action (LS1), the greatest change in M&I pumping power requirements with any other alternative/benchmark is less than 1 percent.

Table 11. Summary of M&I Pumping Power Requirements, Area 1 - Kootenai River in ID

Location	Month	Pumping Power Requirements (kW-hr)						
		LS1 (No-Action)	LV1	LS2	LV2		LS benchmark	LV benchmark
Bonners Ferry	Apr	69,500	68,700	69,300	68,500		69,800	68,600
	May	68,200	68,200	68,200	68,200		69,700	68,700
	June	70,800	70,300	70,900	70,400		70,400	70,300
	July	71,900	71,400	72,000	71,400		72,400	72,400
	Aug	69,500	68,700	69,300	68,500		69,800	68,600
Total		280,400	278,600	280,400	278,500		282,300	280,000

3.5 Area 1 Employment and Income

3.5.1 Employment and Income Effects of Flood Control Impacts

No employment and income effects are expected from flood control impacts of different alternatives/benchmarks in Area 1. All alternatives being considered for implementation were estimated to provide the same level of flood protection as measured by expected annual damages. Although no stage damage data was available to estimate expected annual flood damages at Kootenay Lake, analysis of days with the lake at documented flooding stages showed no substantial differences across the alternatives/benchmarks.

3.5.2 Employment and Income Effects of Navigation

No employment and income effects are expected from navigation impacts of different alternatives/benchmarks in Area 1. No navigation impacts were identified for any alternatives/benchmarks evaluated.

3.5.2 Employment and Income Effects of Agriculture and Irrigation Impacts

No employment and income effects are expected in Area 1 from changes in agricultural irrigation costs associated with different alternatives/benchmarks. All alternatives being considered for implementation were estimated to result in similar pumping costs (changes in cost from no-action to each alternative were 1% or less).

Employment and income effects for Area 1 farmers are expected as a result of changes in expected crop losses from high groundwater, as identified in **Section 3.3.2**. **Table 9**

shows the losses with each alternative/benchmark. These crop losses would be income losses for Area 1 farmers.

3.5.3 Employment and Income Effects of Municipal and Industrial Water Supply Impacts

No employment and income effects are expected in Area 1 from changes in M&I water pumping costs associated with different alternatives/benchmarks. All alternatives being considered for implementation were estimated to result in similar M&I pumping costs (changes in cost from no-action to each alternative were 1% or less).

3.5.4 Employment and Income Effects of Recreation Impacts

The Corps completed a Visitor Spending Profile Survey based on 12 Corps lakes in 1990.[8] This study showed that, on average, boating visitors spend $58 per person-day within 30 miles of the recreation site ($84 in October 2004 prices). Non-boating recreation visitors were found to spend an average of $55 per person-day within 30 miles of the recreation site ($79 in October 2004 prices). This spending supports local economies, including hotels and motels, paid camping areas, grocery stores, restaurants, auto and RV services, boating supplies and services, fishing and hunting guides and supplies, and entertainment services. Operational changes that affect recreation opportunities and visitation can have employment and income effects on regional communities.

Lake Koocanusa: The most recent (1999) Corps data on spending associated with visitation for Libby Dam/Lake Koocanusa shows that in 1999 the project was responsible for $4.23 million in annual sales ($4.8 million on October 2004 prices) within 30 miles of the project; translating to income of $2.23 million ($2.53 million in October 2004 prices) and 109 jobs (citation). There is potential for positive employment and income benefits at Lake Koocanusa with implementation of LV1 or LV2. These alternatives would result in an increase in usable boat ramp days, swimming days, and days with optimal lake elevations for lake area campsites.

In the U.S. portion of the lake, usable boat ramp days would increase by approximately 9% with LV1 or LV2 as compared to no-action (LS1). Usable days at the lake's swimming beaches would increase by 40% with LV1 and 32% with LV2 relative to no-action. Similarly, days with lake elevations that would be best for camping increase by 44% with LV1 and by 36% with LV2. In the Canadian portion of the lake, LV1 and LV2

[8] The Corps of Engineers 12 Lakes Visitor Spending Profile Survey was performed in 1990. Durable goods and visitor spending profiles information was gathered in personal interviews on site. Trip expenses for the entire trip were reported in mailback spending diaries, returned at the end of the trip. Source: Propst, D.B., D.J. Stynes, and R.S. Jackson. 1992. A Summary of spending profiles for recreation visitors to Corps of Engineers Projects. Technical Report R-92-1. Vicksburg, MS: Department of the Army, Waterways Experiment Station.

result in an 18% and 15% increase in usable boat ramp days, respectively when compared to no-action. Average swimming days would increase by 76% with LV1 and 55% with LV2. It is expected that increases of this magnitude in recreational opportunity would translate to increased visitation and local spending.

Kootenai River: Recreation analysis of the Kootenai River between Libby Dam and Kootenay Lake found that shore fishing days would be reduced with implementation of LV1 (-35%) and LV2 (-30%) relative to no-action (LS1) due to increased days exceeding the upper range of optimal shore fishing flows identified as 10,000 cfs. There is a slight improvement in shore fishing days relative to no-action with LS2 (+4%). Negative employment effects of the reduced shore fishing days would likely be offset by an increase in days with flows permitting boat fishing on the river. LV1 and LV2 would result in increases of 15% and 19% in boating days, respectively. The average spending associated with boat fishing ($82 per party day) is greater than that for shore fishing ($61 per party-day).[9]

Kootenay Lake: Recreation analysis for Kootenay Lake found a slight decrease (-2%) in the number of days in the identified optimal recreational range between elevations 1740 and 1754 feet with LV1 and LV2. The 2% decrease corresponds to an average reduction of 3 days in that range over the period of May to September.

Localized concern was voiced for impacts to off season moorage at Pilot Bay Resorts and fishing impacts at Kootenay Kampsites. No impacts were identified with any of the alternatives/benchmarks for Pilot Bay Resorts. It was indicated that fishing at Kootenay Kampsites requires a lake elevation of 1744 feet or higher. LV1 and LV2 would result in an increase of days with lake elevations above this level (+8% and +7% respectively over the period of May through September). Function of swim beaches at the lake requires lake elevations below 1749 feet. The recreation analysis showed a slight decrease in days under this elevation with LV1, LS2, and LV2 (-1%, -1%, and -3%, respectively).

It is not expected that these slight changes in usable recreation days at Kootenay Lake would result in significant effects to regional employment and income.

3.5.5 Employment and Income Effects of Hydropower Impacts

The hydroelectric dams in the Columbia River Basin provide the foundation of the northwest United States' power supply. The **Hydropower Section** of this EIS documents the evaluation of impacts to the Columbia River Basin hydropower system associated with the proposed alternative/benchmark combinations. The documentation in this Section applies to all socioeconomic study areas in this report.

[9] Recreation visitors spending profiles were calculated from data on Corps Lakes from the Corps 1989/1990 National Visitor Survey. Table 4A: Trip Spending by Fishing Segments (boat-angler vs. other angler, $ per party-day).

Table 12 shows simulated average annual hydropower generation with each alternative/benchmark combination for three groupings of hydropower projects. The three groupings listed are the Columbia River basin hydropower system (System), the Federal hydropower projects downstream of Libby and Hungry Horse Dams (Federal), and non-Federal hydropower projects downstream of Libby and Hungry Horse Dams (Non-Federal). Some combinations result in a loss of generating capacity for the system. The loss in generated electricity will need to be replaced by other higher cost resources which may lead to rate increases for consumers. This in turn may increase the electric bills of residential and commercial consumers of electricity. Conversely, some combinations result in increased generating capacity and could result in lower electric rates.

Table 12. Simulated Hydropower Generation with Each Combination

Hydropower Generation (GWh)							
	LS1+HS	LV1+HV	LS2+HS	LV2+HV		LS+HS benchmark	LV+HV benchmark
System	131,442	131,370	131,724	131,611		131,463	131,384
Federal	67,043	67,072	67,233	67,235		67,060	67,085
Non-Federal	32,082	31,934	32,084	31,948		32,072	31,936

When compared to no-action (LS1+HS), Columbia River System hydropower generation would be expected to decrease by approximately 72 GWh with LV1+HV (-0.05%), and increase by 282 GWh (+0.21%) and 169 GWh (+0.13%) with LS2+HS and LV2+HV, respectively. The change in expected system generation from no-action to either benchmark combination was less than 0.1%. With the exception of LS2+HS, all alternative/benchmark combinations showed a decrease in generation at non-federal projects downstream of Libby and Hungry Horse Dams of 0.5% or less, when compared to no-action. Alternative combinations LS2+HS showed a very slight increase in generation of 0.01%.

3.6 Area 1 Tribal Socioeconomics

The socioeconomic affected environment report identified existing agricultural problems associated with agricultural lands on the Kootenai Tribe Reservation, north of Bonners Ferry, ID. These problems relate to spring flooding and poor drainage. As identified in **Section 3.1.1**, the Area 1 flood control analysis did not identify any increase in expected annual flood damages with any alternative/benchmark when compared to the no action (LS1) with the exception of benchmark operation LV. This benchmark operation is not being considered for implementation.

As identified in **Section 3.3.2**, a separate study identifies and quantifies the effects of high groundwater levels on agriculture in the Kootenai River Valley with the different alternatives/benchmarks at Libby Dam. Results of this study are reported in Appendix G.

The study evaluates agricultural impacts of high groundwater throughout the Kootenai Valley for each alternative and benchmark operation.

As identified in **Section 3.5.4**, no employment and income effects were identified along the Kootenai River. It is expected that employment and income effects associated with reductions in optimal days for shore fishing would be offset by increased days suitable for boat fishing. Additionally, no employment and income effects are expected in the Kootenay Lake study reach in the vicinity of the Lower Kootenay Indian Band reserve and the Tobacco Plains reserve.

4.0 Area 2 – Flathead, Clark Fork, Pend Oreille River Basin

4.1 Area 2 Flood Control

In addition to providing approximately 5% of the total flood storage in the Columbia River Basin for system flood control, Hungry Horse Dam provides local flood control benefits along the Flathead River from Columbia Falls to Flathead Lake and downstream to Lake Pend Oreille and Albeni Falls Dam. Changes in the timing and volume of discharge from Hungry Horse Dam have potential implications on expected annual flood damages in Area 2. Flood impact evaluation areas in Area 2 include the Flathead River from Columbia Falls to Flathead Lake, the Flathead Lake Shoreline, Lake Pend Oreille, and the Pend Oreille River from Albeni Falls Dam to the Columbia River. Flood impact assessments were performed for each evaluation area and for each of the two alternatives applicable to Area 2 (HS and HV).

4.1.1 Flathead River (Columbia Falls, MT to Flathead Lake)

The primary area of potential flood losses along the upper Flathead River downstream of Hungry Horse Dam occurs in the reach between Columbia Falls, MT and Flathead Lake. Residential and commercial losses are concentrated in an area adjacent to the city of Kalispell, MT, and agricultural losses are predominately upstream and downstream of this area. In recent years, residential development has been displacing agriculture in the floodplain upstream of Kalispell. The slope of the Flathead River from its source to Columbia Falls is very steep. In the flood impact reach between Columbia Falls and Flathead Lake, the slope varies from 5 to 7 feet per mile. The river flows through meandering channels in a floodplain varying from 1 to about 3 miles wide. Flood durations are relatively short because of regulation of the South Fork of the Flathead River by Hungry Horse Dam. During the extremely rare flood of June 1964, the river had a maximum rate of rise of about 1 foot per hour at the Columbia Falls gage, and remained out of banks between two and three days. Water velocities during major floods range up to six feet per second in the channel, and are generally less than three feet per second overbank.

Flood loss prevention measures within this flood impact reach include several miles of levees along both banks of the river, channel improvements and realignments, bank protection and erosion control devices. The South Fork of the Flathead River, a major tributary of the river upstream of Columbia Falls, is regulated by Hungry Horse Dam, a Federal (Bureau of Reclamation) multi-purpose project completed in 1951. The regulation of the South Fork during large floods reduces the extent and duration of flooding in this reach, as well as in Flathead Lake and the lower Flathead valley.

Flood History: The Flathead River floods the lower portions of this flood impact reach about once in every four years. Normally flooding is caused by runoff from snowmelt. Floods from snowmelt are the basis for the Standard Project Flood (SPF) determination. Normally, a SPF is an extremely rare occurrence, and on most rivers is usually larger than floods that have occurred. On the Flathead River however, the June 1964 flood was approximately 70 percent greater in magnitude than the calculated SPF. The June 1964 flood was also caused by rainfall rather than snowmelt, and was an extremely rare event. Nevertheless, a recurrence of this flood event in October 2004 prices and conditions would result in $40.4 million in losses. Major floods in 1932 (89,800 c.f.s.), 1933 (91,200 c.f.s.), and 1948 (102,000 c.f.s.) also caused extensive losses. Actual discharges of floods and losses caused by floods prior to October 1951 would now be reduced somewhat by available storage at Hungry Horse Reservoir.

Discharge – Damage Analysis: Data on damageable property, including residential, commercial, agricultural, and other (emergency aid and public) were obtained from a detailed economic study conducted for the *Columbia River System Operation Review – Environmental Impact Statement*, published in November 1995. For this analysis, loss figures were updated (from July 1992 Prices & 1995 Conditions) to October 2004 Prices and Conditions using the *Engineering News Record* building and construction cost indices, the CPI for West Urban areas, and an assumed rate of growth (0.5%/yr). Losses by discharge, for all categories of impact, are summarized in **Table 13**. The zero dollar damage point for this reach (assumed to be the design levee height in areas with levees) is 52,000 c.f.s.

Table 13: Discharge vs. Flood Damage - Columbia Falls to Flathead Lake

Discharge (cfs)	Residential	Commercial	Agricultural	Other	Total Damages
52,000	0	0	0	0	0
79,000	3,630	1,162	2,178	871	7,841
100,000	9,438	3,485	5,808	2,178	20,909
130,000	14,084	5,082	8,567	3,194	30,927
176,000	18,295	6,824	11,180	4,065	40,364

Note: Data presented in October 2004 Prices & Conditions - $1,000

Expected Annual Damages: The point of zero damage for this reach was determined from historical flood records and available information on stream bank capacity. Expected annual damages were derived from discharge-damage data calculated for three hypothetical floods and the 1964 flood event. Discharge-frequency relationships developed for the Columbia Falls gage for the no action - base case condition (HS), and one alternative (HV) were used in this analysis. Details of these derivations can be found in the **Hydrology and Flood Control Section** of the EIS. Expected annual damages were derived using Corps of Engineers Hydrologic Engineering Center computer program *Expected Annual Flood Damage Computation.* This program integrates exceedance frequency with associated losses to determine expected annual damages for a given frequency interval. **Table 14** presents a summary of expected annual damages by

impact category for both alternatives. As would be expected, since the discharge-frequency curves of both alternatives merge at a point just below the zero damage discharge of 52,000 c.f.s., there is no difference in total expected annual damages between the two alternatives.

Table 14: Expected Annual Damages - Columbia Falls to Flathead Lake

Alternative	Residential	Commercial	Agricultural	Other	Total Damages
HS	233.41	78.02	140.89	55.13	507.45
HV	233.41	78.02	140.89	55.13	507.45

Note: Data presented in October 2004 Prices & Conditions - $1,000

4.1.2 Flathead Lake Shoreline

Kerr Dam located near Polson, MT, controls Flathead Lake. Kerr Dam is operated by PPL-Montana for power, flood control, and recreation. While Kerr Dam regulates the level of Flathead Lake and thus prevents flooding to lake front property, the dam is primarily operated to prevent flooding upstream of the lake which is caused by backwater effects of high lake levels and high Flathead River flows. Specifically, flooding in the Kalispell area begins if the lake level reaches elevation 2893 feet coincident with the river flow being above 52,000 c.f.s. The zero damage lake stage for lake front flooding is also 2893 feet. The Corps and PPL-Montana jointly manage the springtime refill of Flathead Lake for flood control. If no flood potential exists in the river basin above the lake, the agreed upon target flood control rule curve for Flathead Lake is presented in **Table 15.**

Table 15: Flathead Lake Flood Control Operations

Date	Lake Stage (ft)
15 April	2883.0
30 May	2890.0
15 June	2893.0

Flood History: No information has been found regarding historic flooding of Flathead Lake, but it is believed that lake front flooding has not been a significant problem since construction of Kerr Dam in 1938.

Stage – Damage Analysis: Data on damageable property including residential, commercial, agricultural, and public were obtained from windshield surveys and analysis conducted in 1993 for the *Columbia River System Operation Review – Environmental Impact Statement*, published in November 1995. For this current analysis, loss figures were updated (from July 1992 Prices & 1995 Conditions) to October 2004 Prices and Conditions using the *Engineering News Record* building and construction cost indices, the CPI for West Urban areas, and an assumed rate of growth of 0.5 percent per year.

Erosion losses of waterfront land and dock impacts represent the majority of losses. Erosion losses are included in the Residential and Public categories, and dock impacts are included in the Residential category. The lake front floodplain has changed significantly over the years from a primarily rural agricultural area to a developing residential area of primary or recreational second homes. Residential development has accelerated over the last 5 years. Losses by lake stage, for all categories of impacts, are summarized in **Table 16**. The zero dollar damage point for this reach is 2893 feet.

Table 16: Stage vs. Flood Damage - Flathead Lake

Stage*	Residential	Commercial	Agricultural	Public	Total Damages
2893	0	0	0	0	0
2895	2,904	116	58	755	3,833
2897	5,764	290	145	1,510	7,709
2899	8,697	581	290	2,294	11,862
2900	10,599	726	363	3,049	14,737

*Note: *Elevation in feet, MSL Datum. Data presented in October 2004 Prices & Conditions - $1,000*

Expected Annual Damages: Expected annual damages were derived for stage-damage data calculated for four hypothetical floods. Stage-frequency relationships, developed for the Polson gage for two alternatives (HS, and HV) were used in this analysis. Details of these derivations can be found in the **Hydrology and Flood Control Section** of the EIS. Expected annual damages were derived using Corps of Engineers Hydrologic Engineering Center computer program *Expected Annual Flood Damage Computation.* This program integrates exceedance frequency with associated losses to determine expected annual damages for a given frequency interval. **Table 17** presents a summary of expected annual damages by impact category for both alternatives. As shown in the table, implementing HV would increase total expected annual damages about $15,000, or 4 percent over the no action alternative (HS).

Table 17: Expected Annual Damages - Flathead Lake

Alternative	Residential	Commercial	Agricultural	Public	Total Damages
HS	250.92	15.92	7.96	70.96	345.76
HV	262.44	16.38	8.19	73.95	360.96

Note: Data presented in October 2004 Prices & Conditions - $1,000

4.1.3 Lake Pend Oreille

Pend Oreille Lake is controlled by Albeni Falls Dam, which was constructed by the Corps starting in 1951. It was authorized for the regulation of Lake Pend Oreille and for the associated purposes of flood control, navigation, conservation, recreation, and power generation as part of the comprehensive plan of improvement for the Columbia River system. The flood control benefits of the project are realized from lowering of maximum

stages on Lake Pend Oreille and managing downstream discharges. The project was operational for flood control in 1952. The reservoir is formed by artificial control of Lake Pend Oreille between elevations 2062.5 and 2051.0 feet. The area of the lake at elevation 2062.5 feet is 94,600 acres with 226 miles of shoreline.

Flood History: The lowlands along Lake Pend Oreille and portions of the cities of Sandpoint and Priest River have been flooded in 1894, 1913, 1927, 1928, 1933, 1948, 1956, 1969, and 1974. The major cause of this flooding is snowmelt. The flood of record occurred in 1894, and resulted in a maximum lake stage of 2075.9 feet (which equates to 2069.3 feet with the present upstream storage regulation). Losses from that event were estimated at $50.5 million (October 2004 prices and level of development). Losses from previous flooding have included residential and commercial development in urban areas, and grain crops, pasture land and roads in rural areas around the lake.

Stage – Damage Analysis: Data on damageable property including residential, commercial, agricultural, and public properties were obtained from windshield field surveys and aerial photography analysis conducted in 1992 for the *Columbia River System Operation Review – Environmental Impact Statement*, published in November 1995. For this current analysis, loss figures were updated (from July 1992 Prices & 1995 Conditions) to October 2004 Prices and Conditions using the *Engineering News Record* building and construction cost indices, the CPI for West Urban areas, and an assumed rate of growth of 0.5 percent per year.

The lake front floodplain has changed significantly over the years from a primarily rural agricultural area to a developed area of commercial activity and primary or recreational second homes. Sandpoint and surrounding areas have experienced extraordinary residential development (single and multi-family) since the mid 1990's. Losses by lake stage, for all categories of damage, are summarized on **Table 18**. The zero dollar damage point for this reach is 2062.5 feet.

Table 18: Stage vs. Flood Damage - Pend Oreille Lake

Stage	Residential	Commercial	Agricultural	Public	Total Damages
2062.5	0	0	0	0	0
2065.0	15	10	3	9	37
2067.0	38	25	9	22	94
2069.0	84	51	20	49	204
2071.0	164	100	38	97	399

*Note: *Elevation in feet, MSL Datum. Data presented in October 2004 Prices & Conditions - $1,000*

Expected Annual Damages: Expected annual damages were derived for stage-damage data calculated for four hypothetical floods. Stage-frequency relationships, developed for the Hope gage for two alternatives (HS and HV) were used in this analysis. Details of these derivations can be found in the **Hydrology and Flood Control Section** of the EIS. Expected annual damages were derived using Corps of Engineers Hydrologic

Engineering Center computer program *Expected Annual Flood Damage Computation.* This program integrates exceedance frequency with associated losses to determine expected annual damages for a given frequency interval. **Table 19** presents a summary of expected annual damages by impact category for both alternatives. As shown in the table, total expected annual damages would be essentially the same for the two alternatives analyzed.

Table 19: Expected Annual Damages - Pend Oreille Lake

Alternative	Residential	Commercial	Agricultural	Public	Total Damages
HS	5.18	3.27	1.16	3.07	12.68
HV	5.17	3.26	1.16	3.06	12.65

Note: Data presented in October 2004 Prices & Conditions - $1,000

4.1.4 Pend Oreille (Albeni Falls Dam to Columbia River)

The area subject to flooding along the Pend Oreille River downstream of Albeni Falls Dam is located in the reach known as Calispell Flats, in the vicinity of Cusick, WA. In addition to the community of Cusick (2000 population 212, and 106 housing units), areas subject to flooding under natural conditions include about 15,000 acres of agricultural land on the west bank of the river and about 2,000 acres of the Kalispel Indian Reservation, located across the river from Cusick, on the east bank of the river. Prior to the completion of Albeni Falls Dam and other upstream storage, low levels of flood protection were provided to Cusick and the agricultural land on the west bank by locally constructed levees, which are no longer maintained.

Flood History: Historically, before the area was partially protected by local levees, portions of the Calispell Flats area were inundated by yearly high water. The flood of record occurred in 1894 and had an estimated peak discharge of 195,000 cubic feet per second at the Albeni Falls Dam site. Other major floods occurred in 1913, 1927, 1928, 1933, and 1948. Losses from previous flooding have been primarily agricultural and residential, but have also included some commercial and public property. **Table 20** presents peak discharges (at Albeni Falls Dam) for selected historical floods.

Table 20: Albeni Falls Dam Peak Discharges

Date	Lake Stage (ft)
1894	195,000
1913	139,000
1927	133,000
1928	137,000
1933	137,000
1948	171,000

Discharge – Damage Analysis: Data on damageable property including residential, commercial/ industrial, agricultural, and public were obtained from windshield field surveys and aerial photography analysis conducted in 1992 for the *Columbia River System Operation Review – Environmental Impact Statement*, published in November 1995. For this current analysis, loss figures were updated (from July 1992 Prices & 1995 Conditions) to October 2004 Prices and Conditions using the *Engineering News Record* building and construction cost indices, the CPI for West Urban areas, and an assumed rate of growth of 0.5 percent per year. Damageable property in the flood plain is believed to have changed little (except cropping patterns) since the 1992 survey was conducted. The little residential development that is believed to have occurred in the flood plain likely has been flood proofed to above the 100-year flood level due to strict local and WA State flood plain ordinances and enforcement.

Losses, by discharge, for all categories of impacts is summarized on **Table 21**. The zero dollar damage point for this reach is 85,000 c.f.s. which causes nuisance flooding in areas without levees. Substantial losses begin to occur at flows of about 120,000 c.f.s. which approximates the design levee height in the areas protected by levees.

Table 21: Discharge vs. Flood Damage - Albeni Falls to Box Canyon Dam

Discharge (cfs)	Residential	Commercial/Industrial	Agricultural	Public	Total Damages
85,000	0	0	0	0	0
120,000	436	145	1,307	290	2,178
140,000	1,307	290	3,920	581	6,098
160,000	4,211	1,016	13,358	2,178	20,763
180,000	6,098	1,597	19,021	3,049	29,765
200,000	8,131	2,033	25,700	4,065	39,929

Note: Data presented in October 2004 Prices & Conditions - $1,000

Expected Annual Damages: Expected annual damages were derived for discharge-damage data calculated for five hypothetical floods. Discharge-frequency relationships, developed for the Newport gage for two alternatives (HS and HV) were used in this analysis. Details of these derivations can be found in the **Hydrology and Flood Control Section** of the EIS. Expected annual damages were derived using Corps of Engineers Hydrologic Engineering Center computer program *Expected Annual Flood Damage Computation.* This program integrates exceedance frequency with associated losses to determine expected annual damages for a given frequency interval.

Table 22 presents a summary of expected annual damages by impact category for both alternatives. As shown in the table, implementing HV would increase total expected annual damages about $83,860, or 12 percent, over the no action alternative (HS).

Table 22: Expected Annual Damages - Albeni Falls to Box Canyon Dam

Alternative	Residential	Commercial/Industrial	Agricultural	Public	Total Damages
HS	140.05	39.50	423.81	76.18	679.54
HV	157.25	44.32	477.66	84.17	763.40

Note: Data presented in October 2004 Prices & Conditions - $1,000

4.2 Area 2 Agriculture and Irrigation

The primary categories of potential impacts to Area 2 agriculture from changes in operations at Hungry Horse Dam are changes in the energy required to pump water and resultant changes in agricultural pumping costs. The potential for impacts to Area 2 irrigators were evaluated along the Flathead River, Flathead Lake, lower Flathead River, and Pend Oreille River downstream of Albeni Falls Dam.[10]

4.2.1 Flathead River Agriculture and Irrigation

To evaluate the impacts to the power required for irrigation pumping from the Flathead River, water rights data from MT were reviewed to estimate pumped volumes for agricultural irrigation. Power requirements were estimated based upon the average monthly stage for each alternative as measured at the Columbia Falls, MT gage.

Based on review of state water rights data, annual Flathead River withdrawals for agricultural irrigation were estimated at 18,315 acre-feet. For the analysis, the total annual volume was distributed across the months of May-September as identified in **Table 2**. **Table 23** presents the estimates of pumping kilowatt-hours associated with each alternative. Compared to no-action (HS), the change in agricultural pumping power requirements with HV is less than two tenths of one percent.

Table 23. Summary of Agricultural Pumping Power Requirements, Area 2 – Flathead River at Columbia Falls

Location	Month	Pumping Power Requirement (kW-hr)	
		HS (No-Action)	HV
Flathead River, Columbia Falls	May	351,100	350,100
	June	351,300	350,700
	July	952,400	952,100
	Aug	961,500	961,500
	Sep	973,400	973,400
Average Annual Power Requirement:		3,589,700	3,587,800

[10] Methodology described in Section 2.3.1.

4.2.2 Flathead Lake Agriculture and Irrigation

To evaluate the impacts to irrigation pumping from Flathead Lake, water rights data from MT were reviewed to estimate pumped volumes for agricultural irrigation. Pumping power requirements were estimated based upon the average monthly stage for each alternative.

Based on review of state water rights data, annual Flathead River withdrawals for agricultural irrigation were estimated at 1,598 acre-feet. For the analysis, the total annual volume was distributed across the months of May-September as identified in **Table 2**. **Table 24** presents the estimates of pumping kilowatt-hours associated with each alternative. Compared to no-action (HS), the change in agricultural pumping power requirements with HV is less than one tenth of one percent.

Table 24. Summary of Agricultural Pumping Power Requirements, Area 2 – Flathead Lake

Location	Month	Pumping Power Requirement (kW-hr)	
		HS (No-Action)	HV
Flathead Lake	May	30,600	30,500
	June	30,100	30,100
	July	80,200	80,200
	Aug	80,100	80,100
	Sep	80,600	80,600
Average Annual Power Requirement:		301,600	301,500

4.2.3 Lower Flathead River and Lower Clark Fork Agriculture and Irrigation

To evaluate the impacts to irrigation pumping from the lower Flathead and lower Clark Forks, water rights data from MT were reviewed to estimate pumped volumes for agricultural irrigation. Pumping power requirements were estimated based upon the average monthly stage for each alternative as measured at the Flathead River; Polson, MT gage.

Based on review of state water rights data, annual lower Flathead and lower Clark Fork withdrawals for agricultural irrigation were estimated at 4,148 acre-feet. For the analysis, the total annual volume was distributed across the months of May-September as identified in **Table 2**. **Table 25** presents the estimates of pumping kilowatt-hours associated with each alternative. Compared to no-action (HS), the change in agricultural pumping power requirements with HV is less than two tenths of one percent.

Table 25. Summary of Agricultural Pumping Power Requirements, Area 2 – Lower Flathead River, Polson MT

Location	Month	Pumping Power Requirement (kW-hr)	
		HS (No-Action)	HV
Lower Flathead, Polson MT	May	80,900	80,800
	June	80,600	80,400
	July	218,100	218,000
	Aug	216,100	216,000
	Sep	220,700	220,700
Average Annual Power Requirement:		816,400	815,900

4.2.5 Pend Oreille River Agriculture and Irrigation

To evaluate the impacts to irrigation pumping from the Pend Oreille River, water rights data from ID and WA were reviewed to estimate pumped volumes for agricultural irrigation. Pumping power requirements were estimated based upon the average monthly stage for each alternative as measured at the Cusick, WA gage.

Based on the review of water rights data, annual Pend Oreille River withdrawals for agricultural irrigation were estimated at 2,139 acre-feet. For the analysis, the total annual volume was distributed across the months of May-September as identified in **Table 2**. **Table 26** presents the estimates of pumping kilowatt-hours associated with each alternative. Compared to no-action (HS), the change in agricultural pumping power requirements with HV is less than one tenth of one percent.

Table 26. Summary of Agricultural Pumping Power Requirements, Area 2 – Pend Oreille River, Albeni Falls ID to U.S-Canada Border

Location	Month	Pumping Power Requirement (kW-hr)	
		HS (No-Action)	HV
Pend Oreille River, Newport WA	May	40,400	40,400
	June	40,300	40,200
	July	111,300	111,300
	Aug	113,600	113,600
	Sep	113,800	113,800
Average Annual Power Requirement:		419,400	419,300

4.3 Area 2 Municipal and Industrial Water Supply

The primary category of potential impact to M&I water supplies resulting from changes in operations at Hungry Horse Dam is associated with changes in the energy required to pump water and the resultant change in the cost of pumping. MT and WA water rights data were reviewed to estimate pumped volumes for M&I water supply from the Flathead, Clark Fork, and Pend Oreille Rivers. Pumping costs were estimated based upon the average monthly stage for each alternative as measured at Columbia Falls, Flathead Lake, and Polson gages in MT; and Cusick gage in WA.[11]

4.3.2 Flathead River Municipal and Industrial Water Supply

Based on review of state water rights data, annual Flathead River withdrawals for M&I water supply in MT were estimated at 5,136 acre-feet. For the analysis, the total annual volume was distributed across all months as identified in **Table 3**. **Table 27** presents the estimates of pumping kilowatt-hours associated with each alternative. Compared to no-action (HS), the change in M&I pumping power requirements with HV is less than one tenth of one percent.

Table 27. Summary of M&I Pumping Power Requirements, Area 2 – Flathead River at Columbia Falls

Location	Month	Pumping Power Requirement (kW-hr)	
		HS (No-Action)	HV
Flathead River, Columbia Falls	Jan	71,100	71,300
	Feb	71,100	71,300
	March	81,700	81,700
	Apr	82,700	83,100
	May	88,600	88,300
	June	91,100	91,000
	July	95,100	95,100
	Aug	96,100	96,100
	Sep	92,100	92,100
	Oct	87,000	87,000
	Nov	81,800	81,800
	Dec	71,600	71,600
Average Annual Power Requirement:		1,010,000	1,010,400

[11] Methodology described in Section 2.4

4.3.3 Flathead Lake Municipal and Industrial Water Supply

Based on review of state water rights data, annual Flathead Lake withdrawals for M&I water supply in MT were estimated at 1,101 acre-feet. For the analysis, the total annual volume was distributed across all months as identified in **Table 3**. **Table 28** presents the estimates of pumping kilowatt-hours associated with each alternative. No change in M&I pumping requirements was identified between no-action (HS) and HV.

Table 28. Summary of M&I Pumping Power Requirements, Area 2 – Flathead Lake

Location	Month	Pumping Power Requirement (kW-hr)	
		HS (No-Action)	HV
Flathead Lake	Jan	15,100	15,100
	Feb	15,300	15,300
	March	17,600	17,600
	Apr	17,800	17,900
	May	19,000	18,900
	June	19,200	19,200
	July	19,700	19,700
	Aug	19,700	19,700
	Sep	18,700	18,700
	Oct	17,800	17,800
	Nov	16,900	16,900
	Dec	15,000	15,000
Average Annual Power Requirement:		211,800	211,800

4.3.4 Lower Flathead River / Lower Clark Fork Municipal and Industrial Water Supply

Based on review of state water rights data, annual lower Flathead River and lower Clark Fork withdrawals for M&I water supply were estimated at 3,856 acre-feet. For the analysis, the total annual volume was distributed across all months as identified in **Table 3**. **Table 29** presents the estimates of pumping kilowatt-hours associated with each alternative. Compared to no-action (HS), the change in M&I pumping power requirements with HV is less than one half of one percent.

Table 29. Summary of M&I Pumping Power Requirements, Area 2 – Lower Flathead River, Polson MT

Location	Month	Pumping Power Requirement (kW-hr)	
		HS (No-Action)	HV
Lower Flathead, Polson MT	Jan	53,800	52,400
	Feb	53,800	52,500
	March	60,500	60,500
	Apr	61,600	62,000
	May	67,700	67,600
	June	69,300	69,100
	July	72,200	72,200
	Aug	71,600	71,500
	Sep	69,200	69,200
	Oct	65,200	65,200
	Nov	61,100	61,100
	Dec	52,800	52,700
Average Annual Power Requirement:		758,800	756,000

4.3.5 Pend Oreille River Municipal and Industrial Water Supply

Based on review of water rights data, annual pumped withdrawals from the Pend Oreille River (between Albeni Falls Dam in ID to the U.S/Canadian Border in WA) for M&I water supply were estimated at 1,656 acre-feet. For the analysis, the total annual volume was distributed across all months as identified in **Table 3**. **Table 30** presents the estimates of pumping kilowatt-hours associated with each alternative. No change in M&I pumping requirements was identified between no-action (HS) and HV.

Table 30. Summary of M&I Pumping Power Requirements, Area 2 – Pend Oreille River, Albeni Falls ID to U.S-Canada Border

Location	Month	Pumping Power Requirement (kW-hr)	
		HS (No-Action)	HV
Pend Oreille, Newport WA	Jan	23,000	23,000
	Feb	22,900	23,000
	March	26,200	26,200
	Apr	26,700	26,700
	May	28,200	28,200
	June	28,900	28,800
	July	30,700	30,700
	Aug	31,300	31,300
	Sep	29,700	29,700
	Oct	27,900	27,900
	Nov	26,200	26,200
	Dec	23,000	23,000
Average Annual Power Requirement:		324,700	324,700

4.4 Area 2 Employment and Income

4.4.1 Employment and Income Effects of Flood Control Impacts

Columbia Falls to Flathead Lake: No employment and income effects would be expected from flood control impacts of different alternatives in the Columbia Falls to Flathead Lake reach of Area 2. HS (no-action) and HV were estimated to provide the same level of flood protection as measured by expected annual damages.

Flathead Lake: Slight negative employment and income effects could be expected from flood control impacts of different alternatives in the Flathead Lake portion of Area 2. HV would result in a 4.2% increase in expected annual damages over HS (no-action). Employment and income effects could be witnessed by the commercial and agricultural sectors in this reach that show increases in expected annual damages (**Table 17**).

Lake Pend Oreille: No employment and income effects would be expected from flood control impacts of different alternatives in the Lake Pend Oreille area of Area 2. HS (no-action) and HV were estimated to provide approximately the same level of flood protection as measured by expected annual damages.

Pend Oreille River: Slight negative employment and income effects could be expected from flood control impacts of different alternatives in the Pend Oreille River reach of Area 2. HV would result in an 12% increase in expected annual damages over HS (no-action) in this reach. Employment and income effects could be witnessed by the

commercial/industrial and agricultural sectors in this reach that show increases in expected annual damages (**Table 22**).

4.4.2 Employment and Income Effects of Agriculture and Irrigation Impacts

No employment and income effects would be expected in Area 2 from changes in agricultural irrigation pumping costs associated with different alternatives . All alternatives being considered for implementation were estimated to result in similar pumping costs. Changes in cost from HS (no-action) and HV would be less than 1% in all reaches evaluated except for the lower Flathead River as evaluated at the Polson, MT gage, where the change would be 1.6%.

4.4.3 Employment and Income Effects of Municipal and Industrial Water Supply Impacts

No employment and income effects would be expected in Area 2 from changes in M&I water supply pumping costs associated with alternative alternatives. All alternatives being considered for implementation were estimated to result in similar pumping costs. Changes in cost from HS (no-action) and HV would be less than 1% in all reaches evaluated.

4.4.4 Employment and Income Effects of Recreation Impacts

Operational changes that affect recreation opportunities and visitation can have employment and income effects on regional communities. **Section 3.5.4** described how spending associated with recreational visitation supports local economies, including hotels and motels, paid camping areas, grocery stores, restaurants, auto and RV services, boating supplies and services, fishing and hunting guides and supplies, and entertainment services. Effects of identified recreation impacts on regional employment and income are described below for applicable Area 2 study reaches.

Hungry Horse Reservoir: Recreational analysis of Hungry Horse Reservoir identified a slight increase in usable boat ramp days at the lake (+4%, or 43 additional usable ramp days) under HV. The increased recreational opportunity could result in increased boating visitation and associated regional spending.

Flathead River: The optimal range of Flathead River flows for fishing were identified as between 4,000 and 17,000 cfs. HV would result in an average of 4 less days in this range per summer (May to September), a 5% decrease. This slight decrease would not be expected to have a significant effect on regional income and employment in Area 2.

Flathead Lake: Recreational analysis of Flathead Lake identified a very slight (less than 1%) increase in usable boat ramp days at Flathead Lake. This slight increase in recreational opportunity at the lake would not be expected to have a significant impact on regional income and employment.

Lower Flathead River: Recreational analysis for the lower Flathead River and lower Clark Fork identified a decrease in average kayaking days per month at Buffalo Rapids with HV. The decrease would be four days over the summer months of May to September (-7%). The analysis also showed a very slight decrease (-2%) in days within the identified optimal flow range for fishing of 4,000-17,000 cfs. It is not expected that these minor changes in recreational opportunity would have a substantive impact on regional income and employment in Area 2.

Lake Pend Oreille: Recreational analysis of Lake Pend Oreille identified no recreational impacts that would be expected to result in changes to regional income and employment.

4.4.5 Employment and Income Effects of Hydropower Impacts

The potential for employment and income effects of hydropower impacts are discussed in **Section 3.5.5** of this report.

4.5 Area 2 Tribal Socioeconomics

Native American Tribes with socioeconomic interests/development adjacent to affected rivers and reservoirs within Area 2 are the Confederated Salish and Kootenai Tribes of the Flathead Reservations (CSKT) and the Kalispel Tribe of the Kalispel Indian Reservation.

The CSKT are located on the southern half of Flathead Lake and along the Flathead River from Poulson, MT to Paradise, MT. CSKT businesses and facilities that could be affected by changed flows and water surface elevations include marinas, boat ramps, water intakes, and hydroelectric power generation at Kerr Dam. The **Recreation Impact Section** of the EIS shows slight increases in function of boating facilities with HV as compared to HS (no-action). **Sections 4.2.2 and 4.3.3** of this report identified a slight decrease in expected power requirements for agricultural and M&I water pumping from the Lake with HV as compared to HS. No employment and income effects are expected associated with these slight changes. A portion of Kerr Dam hydroelectric power generation revenue goes to the CSKT. Impacts to hydroelectric power generation at Kerr Dam is documented in the **Hydropower Section** of the EIS and in Appendix J. **Section 4.1.2** documents findings of flood control studies that show an approximate 4% increase in expected annual damages along the Flathead Lake shoreline.

The Kalispel Indian Reservation is located along both banks of the Pend Oreille River near Cusick, WA. The tribe operates a boat ramp on the river and is interested in future

development including a marina and additional boat ramp. No impacts to use of boat ramps were identified in the reach. Additionally, no alternatives would be expected to preclude the identified future development of a marina or additional boat ramp. Flood control analysis in the vicinity of the Kalispel Indian Reservation is documented in **Section 4.1.4** of this report. **Table 20** presents a summary of expected annual damages by impact category for both alternatives. As shown in the table, implementing HV would increase total expected annual damages about $83,860, or 12 percent, over HS. As identified in **Section 4.4.1** of this report, slight negative employment and income effects could be expected from the flood control impacts with HV in this Pend Oreille River reach of Area 2. Employment and income effects could include lost income due to increased agricultural flooding.

5.0 Area 3 – Mainstem Columbia River

5.1 Area 3 Flood Control

The Columbia River Treaty Flood Control Plan (FCOP) provides the basis for the current Columbia River system flood control operation. The Columbia River at The Dalles, in OR, is used as the main system control point in the FCOP. The exceedance flow at The Dalles for initiation of minimal flood impacts is 450,000 cfs. The exceedance flow for major flood impact is 750,000 cfs. Changes in flow at The Dalles with the different alternative/benchmark combinations were evaluated. Expected annual damages were not calculated in Area 3 based upon findings of the hydrologic and hydraulic (H&H) studies that indicated no significant flood control impacts in Area 3 from the alternative combinations evaluated. The H&H analysis is documented in the **Hydrology and Flood Control Section** of the EIS. Conclusions of the H&H studies included the following: [12]

- The LV+HV benchmark operation at Libby and Hungry Horse Projects would cause a small change in flow at The Dalles during the winter drawdown and spring runoff season. During the spring runoff, LV+HV would add less than 10,000 cfs, on average, to the flow at The Dalles for duration of flow between one and 120 days with LS+HS. Libby would provide about 60 percent of the extra flow while Hungry Horse would provide 40 percent.
- The chance of a flood level flow of 450,000 cfs at The Dalles, OR (exceedance flow for minimal flood impacts) would increase from 40 percent for LS+HS to 43 percent for LV+HV. The frequency curves converge in the neighborhood of one-percent exceedance.
- Peak 1-day discharges at The Dalles would increase for nine of the ten study years evaluated, and decrease for the remaining year with LV1+HV compared to LS1+HS. The average absolute difference would be about 1.6 percent. Peak 1-day discharges at The Dalles would increase for all ten years with LV2+HV compared to LS2+HV. The average absolute difference would be about 1.4 percent.
- There would be minimal difference at The Dalles with LV1+HV when compared to LS1+HS, and also with LV2+HV when compared to LS2+HV. For the 0.5%-chance-exceedance event, however, LV1+HV and LV2+HV would increase the discharge at The Dalles by 21,000 cfs.

In addition to the analysis of flows at The Dalles, an analysis of changes in frequency of flood stages for the Vancouver, WA/Portland, OR area was performed. Results include:

[12] Since flood control operations superseded fish flow operations if they were in conflict, the frequencies of exceeding the flood flow threshold at The Dalles for Standard FC Alternative Combinations LS1+HS and LS2+HS, would be no greater than those described for Benchmark Combination LS+HS, and those for VARQ FC Alternative Combinations LV1+HV and LV2+HV would be no greater than those for Benchmark Combination LV+HV.

- The impact to flooding in the Portland/Vancouver harbor from LV+HV would average about 0.2 ft in peak stage for the 1929-1989 hydro-regulations modeled. The chance that a stage of 16 ft (flood stage) would be equaled or exceeded in a given year increases from 44 percent with LS+HS to 46 percent with LV+HV. The modeled frequency curves converge as exceedance levels approach five percent.
- Peak 1-day elevations at Vancouver would increase for nine of ten study years, and decrease for the remaining year, with LV1+HV compared to LS1+HS. The average absolute difference for all values would be about 0.3 ft.

5.2 Area 3 Navigation

There are two ferries on Lake Roosevelt, the Keller Ferry and the Inchelium Ferry which operate throughout the year. The Washington Department of Transportation (WDOT) operates the Keller Ferry, and the Confederated Tribes of the Colville Indian Reservation operates the Inchelium Ferry. The lowest operating levels for the ferries are 1208 feet and 1225 feet, respectively. No impact was observed when the modeled alternative/benchmark combinations were compared to the operating range of the ferries. Impacts to navigation on the lower Columbia River are not expected.

5.3 Area 3 Agriculture and Irrigation

The predominate source of water for irrigation uses in the potentially affected portion of Area 3 is provided by the Columbia Basin Project, operated by the Bureau of Reclamation. The Columbia Basin Project is a multipurpose development utilizing a portion of the resources of the Columbia River in the central part of the State of WA. The key structure, Grand Coulee Dam, is on the main stem of the Columbia River about 90 miles west of Spokane, WA. The extensive irrigation works extend southward on the Columbia Plateau 125 miles to the vicinity of Pasco, WA, where the Snake and Columbia Rivers join.

The widely distributed irrigation works that extend southward from the Grand Coulee Pump- Generating Plant begin with the 16-mile feeder canal which carries water to Banks Lake, the equalizing reservoir. This 27-mile-long reservoir occupies the floor of the upper Grand Coulee between North Dam near the town of Coulee Dam, WA, and Dry Falls Dam near Coulee City. The project irrigation facilities were planned to deliver a full water supply to about 1.1 million acres of land previously used only for dry farming or grazing. About 671,000 acres are currently irrigated and further development is not anticipated. Power production facilities at Grand Coulee Dam are among the largest in the world; the total name plate generating capacity is rated at 6,809 megawatts.

Because of the linkage of Columbia Basin Project irrigation to the power costs associated with pumping from Lake Roosevelt, the impact analysis for Area 3 irrigation is provided in the **Hydropower Section** of the EIS.

5.4 Area 3 Municipal and Industrial Water Supply

No impacts were identified for M&I pumping costs in Area 3.

5.5 Area 3 Employment and Income

The potential for employment and income effects of hydropower impacts are discussed in **Section 3.5.5** of this report. No additional impacts were identified from the implementation of the different alternative/benchmark combinations in Area 3 that would be expected to affect regional employment and/or income.

5.6 Area 3 Tribal Socioeconomics

The socioeconomic affected environmental report focused the identification of Area 3 Tribal socioeconomic resources to those of the Confederated Tribes of the Coleville Reservation and the Spokane Indian Reservation.

The Coleville Indian Reservation is located along the west bank of the Columbia River and Lake Roosevelt. The Tribe owns and operates or leases a number of boat ramps and docks, a campground, two marinas, the Inchelium Ferry, and a number of water intakes. No impacts to the operation of these facilities or to employment and income in this reach was identified with any combinations as compared to HS + LS1 (no-action).

The Spokane Indian Reservation is located on the east bank of Lake Roosevelt and the north bank of the Spokane River. A boat ramp, marina, and 11 campgrounds on Lake Roosevelt are located on tribal lands adjacent to Lake Roosevelt; the remainder of the shoreline is fairly undeveloped, although there are a number of undeveloped fishing access locations. No impacts to the operation of these facilities or to employment and income in this reach was identified with any combinations as compared to HS + LS1 (no-action).

APPENDIX G

Kootenai River Valley Agricultural Seepage Study Summary Report

Kootenai River Valley Agricultural Seepage Study Summary Report

Boundary County, Idaho

September 2005

US Army Corps of Engineers ®
Seattle District

TABLE OF CONTENTS

Page G-

EXECUTIVE SUMMARY **1**

1.0 STUDY PURPOSE **1**

2.0 BACKGROUND **3**

2.1 PRE-DAM CONDITIONS 3
2.2 POST-DAM CONDITIONS 3

3.0 STUDY SUMMARY **7**

3.1 CHARACTERISTICS OF THE KOOTENAI VALLEY AGRICULTURE 7
3.1.1 Information/Data Flow *7*
3.1.2 Methods *7*
3.1.3 Crops *7*
3.1.4 Agricultural Practices *8*
3.1.5 Observations and Implications of High Groundwater *9*
3.2 AGRONOMY 11
3.2.1 Information/Data Flow *11*
3.2.2 Methods *11*
3.2.3 Results *11*
3.3 GROUNDWATER MODEL 12
3.3.1 Information/Data Flow *12*
3.3.2 Methods *12*
3.3.3 Results and Limitations *16*
3.4 ECONOMIC ANALYSIS 18
3.4.1 Information/Data Flow *18*
3.4.2 Methods *18*
3.4.3 Results *19*
Calibration and Validation of Methods – 1997 and 2003 19
Simulation of the Effects of Different Dam Operational Scenarios on Agricultural Losses – 1961 and 1964 21

4.0 DISCUSSION & RECOMMENDATIONS **24**

5.0 REFERENCES **25**

FIGURES

Page G-

Figure 1. Map of Agricultural Areas in the Kootenai Valley 6
Figure 2. Effects of Interpolation of Tributary Stages 17

TABLES

Page G-

Table 1: Average Acres by Crop in Kootenai River Valley, 1998 to 2003. 8
Table 2. Drainage Districts with Concentrations of Delineated Seepage Areas 10
Table 3. Libby Dam Operational Scenarios Simulated By the Groundwater Model 15
Table 4. Sorting Protocol for Nodes That Could Fall into More Than One Category 18
Table 5: Aggregate Crop Loss Impacts for All Crop Stages, DTGW-Duration Categories based on actual river, tributary, and precipitation in 1997 and 2003. 20

Table 6: Aggregate Acreage Affected by High Groundwater for Simulated Operational Scenarios of Libby Dam, 1961 and 1964.....22
Table 7: Aggregate Crop Loss Impacts for All Crop Stages, DTGW-Duration Categories and Dam Operational Scenarios, 1961 and 1964.....22

EXECUTIVE SUMMARY

The effects of six different Libby Dam operational scenarios on agricultural production and economic losses attributed to seepage[1] in the Kootenai Valley were estimated using a combination of field observations and data, computer modeling tools, and economic statistics. The methods used provide a regional evaluation of potential changes in groundwater conditions, crop yield, and production value for two years: a typical year as represented by simulation of the six operational scenarios for hydrologic conditions in 1964, and a more significant year as represented by simulation of the six operational scenarios for hydrologic conditions in 1961.

Estimates of dollar losses (in 2003 dollars) for different dam operations appear to include baseline losses on the order of $2,000,000. In all cases, impacts to hops produce the largest losses for a single crop. Annual crop losses are dominated by spring wheat, winter wheat, and barley.

In a typical year such as 1964, agricultural impacts for any given fish flow operation would be similar, regardless of the flood control operation of Libby Dam. In these years, total impacts due to high groundwater are estimated to be about 50% higher with fish flows than without. Estimated economic losses due to high groundwater in a typical year such as represented by 1964 range from $2,609,000 to $3,940,000, which include some level of baseline losses.

In a more significant year like 1961, where runoff forecasts through the winter are lower than actual runoff and runoff is substantially higher than average, growers would tend to experience relatively high agricultural impacts under any of the scenarios, and VARQ flood control operations are estimated to generate higher impacts than compared to Standard flood control operations. Fish flows are expected to add to impacts in more significant years, but additional losses are estimated at about 10% of total impacts, much less than the relative contribution of fish flows in more typical years. As happened in the VARQ flood control simulations for 1961, more significant years may result in fish flows not adding any additional losses since flood control operations may supersede fish flow considerations. Estimated economic losses due to high groundwater in a significant year such as represented by 1961 range from $4,714,000 to $5,860,000, which include some level of baseline losses.

1.0 STUDY PURPOSE

The purpose of the study is to identify and quantify the effects of high groundwater levels on agricultural in the Kootenai River Valley given different flow regimes generated by

[1] The term “seepage” refers to the physical transference of water; the high groundwater condition that results from this transference is sometimes referred to as “waterlogging.”

different flood control and fish operations at Libby Dam, which regulates Kootenai River flows. This project is a requirement of the 2000 US Fish and Wildlife Service Biological Opinion (reasonable and prudent alternative components 8.1.d and 8.3.c). The study results will inform the Upper Columbia Alternative Flood Control and Fish Operations Environmental Impact Statement (UCEIS) scheduled for release for public comment in mid-2005.

Agricultural interests and officials in Boundary County, Idaho have identified agricultural impacts resulting from seasonally high groundwater levels in agricultural areas along the Kootenai River. Affected parties have asserted that spring flow augmentation for endangered Kootenai River white sturgeon is responsible for keeping river levels high for periods long enough to produce areas of saturated soils in fields, thus affecting crop production and associated farming activities.

Concerns about the impact of high groundwater levels on agriculture in the Kootenai Valley date back to before Libby Dam and played prominently in “reclamation” activities in the early 1900s (Tolman 1923). A detailed 1987 Corps study on damageable property between Libby Dam and Kootenay Lake (Seattle District Records c/o Don Bisbee) describes agricultural damages that occurred during major flooding events prior to Libby Dam, as well as potential impacts on agriculture from seepage during the flood season. To date, construction of Libby Dam has largely eliminated major flooding, but high groundwater levels and the consequential impacts on crops continue to be an issue for local growers.

Spring flow augmentation for sturgeon commenced at Libby Dam in 1992 and heightened concerns by local agricultural interests about impacts of high groundwater levels. The 1995 Columbia River System Operation Review (SOR) Environmental Impact Statement (EIS) documented the effects of various alternative operations of federal dams in the Columbia River basin (including Libby), but did not address the potential impacts of high groundwater levels on Kootenai valley agriculture because the issue was not identified in scoping or public comments.

Since the 1995 SOR EIS, the Seattle District has attempted to better quantify the potential relationship between dam operations, high groundwater levels, and agricultural impacts in the Kootenai valley. Previous studies that address this phenomenon include Harp and Darden (2001) and HDR Engineering, Inc. (2001), and Corps (1998). Based on observations of recent conditions and impacts, these studies identified the issue of high groundwater-induced impacts on agricultural production and produced rough estimates of dollar losses due to lost or reduced agricultural production. Unlike the study at hand, these studies did not allow prediction of potential agricultural and economic impacts resulting from potential future conditions and various different Libby Dam operational scenarios.

2.0 BACKGROUND

2.1 Pre-Dam Conditions

Prior to construction of Libby Dam, spring runoff in the Kootenai River at Bonners Ferry, Idaho peaked during May and June. Average annual peak flow was about 75,000 cubic feet per second (75 kcfs). The peak runoff period tended to be concentrated over several weeks, followed by rapidly decreasing flows to base flows of generally less than 10 kcfs by mid-August.

According to Perkins Geosciences (2004):

> *Significant agricultural activity in the Kootenai valley started in the 1880s when W.A. Baillie-Grohman began to drain wetlands for farming in Canada. Construction of dikes and draining of wetlands to allow farming continued throughout the early portion of the 20th century.*
>
> *By 1931, nine drainage/diking districts had already constructed levees, drainage ditches and pumping stations "for the reclamation and protection of about 22,000 acres of land" in the Kootenai Flats area in Idaho (House Document No. 157, 1931; cited in Pick 1991). This is confirmed by aerial photographs from 1932, which show levees along most but not all banks of the river below Deep Creek. The portion of the river between Deep Creek and Bonners Ferry appears to have been completely leveed by 1932. Setback levees above Bonners Ferry in the braided portion of the river were also constructed by 1932. This portion of the river was also constrained by construction of the railroad embankment around the turn of the century. Approximately 7 more diking districts were formed later, resulting in some level of protection by levees of 94 percent of the land in Kootenai Flats by the end of the 1940s (Pick 1991).*

Historically, the primary crops were grains, cover crops (hay, alfalfa, clover), and other annually planted species. Groundwater conditions under pre-dam conditions are unknown. Construction of drainage canals and pumping systems helped control groundwater and drain land for agricultural use. High groundwater levels likely occurred during the spring runoff, with groundwater dropping as the river and tributary flows rapidly decreased through the summer. To a certain extent, high groundwater levels may have played a role in determining the types of crops grown in the valley, particularly in low-lying areas where seasonally high water tables were likely.

2.2 Post-Dam Conditions

Between dam construction and when Libby Dam began to augment spring flows for sturgeon, agricultural impacts due to high groundwater were minimal (HDR 2003). Since the early 1990's, Libby Dam has provided higher flows in the spring and summer that are intended to benefit threatened and endangered species and growers have indicated that

the duration and magnitude of these fish flows adversely affects farm operations in a number of ways, including loss of crops and/or reduction in crop yield. Reaction to these impacts by the growers have been somewhat varied but have not resulted in significant changes in the types or acreages of crops being grown in the Valley.

According to Farm Service figures, since 1998 an average of approximately 30,000 acres has been involved with farm operations (including Conservation Reserve Program or CRP lands; HDR 2003). Areas of agricultural production are shown on Figure 1. The following annually harvested crops are grown in the valley :

Alfalfa	Barley	Bluegrass	Brome	Canola	Mustard
Oats	Peas	Soybeans	Timothy	Wheat	

In addition, Elk Mountain Farms grows hops on two separate farms. Backwoods Farm grows approximately 1200 acres of hops on the west side of the valley in Drainage District 16 and the Tavern Farm grows another 550 acres near the Canadian border in Drainage District 8. Elk Mountain Farms, a subsidiary of the Anheuser-Busch Company, was established in the mid-1980s.

Threatened and endangered fish populations in the Kootenai River and the Columbia River basins (Kootenai River white sturgeon and bull trout, and several Columbia River salmon and steelhead stocks) benefit from certain high flow periods, which historically were provided by natural runoff patterns driven by snowmelt and rainfall. Since the early 1990's, the Corps has operated Libby Dam to augment flows under a variety of operational actions in an effort to provide flow at sufficient levels and durations to benefit the threatened and endangered fish in the Kootenai River and Columbia River basins. Fish flow operations increase dam discharges during the spring and summer, which result in relatively higher river flows and stages during the prime agricultural season. These higher river flows and stages have the potential to alter groundwater levels by direct influence on the water table and indirect influences on drainage of valley bottom areas via tributaries and constructed drainage features (i.e. drainage ditches, pump facilities). Local farmers and various Corps studies have reported adverse impacts from high groundwater levels in the period since the start of fish flow operations. 1996 and 1997, two wet years with high snowmelt runoff through the spring and summer, resulted in notable adverse agricultural impacts in the Kootenai Valley in Idaho. This study estimates the economic impacts of high groundwater levels on agricultural related to several different Libby Dam operations.

Through the provisions of Section 7 of the Endangered Species Act, the structure of the various fish flows has been formalized since the early 1990s. In their 2000 Biological Opinion for operation of the Federal Columbia River Power System (FCRPS), including Libby Dam, the U.S. Fish and Wildlife Service (USFWS) recommended actions that would modify dam operations and river flows for the conservation and recovery of threatened Columbia Basin bull trout and endangered Kootenai River white sturgeon. The 2004 Updated Proposed Action that supports the 2004 NOAA Fisheries FCRPS Biological Opinion also details a variety of operational actions that would modify river flows for conservation and recovery of threatened and endangered Columbia Basin

salmon and steelhead. Implementation of alternative flood control and fish flow operations at Libby Dam is a key component of both the 2000 USFWS FCRPS Biological Opinion and the 2004 Updated Proposed Action. As an action agency responsible for Libby Dam operations, the Corps is investigating the potential effects of various combinations of flood control and fish flow operations.

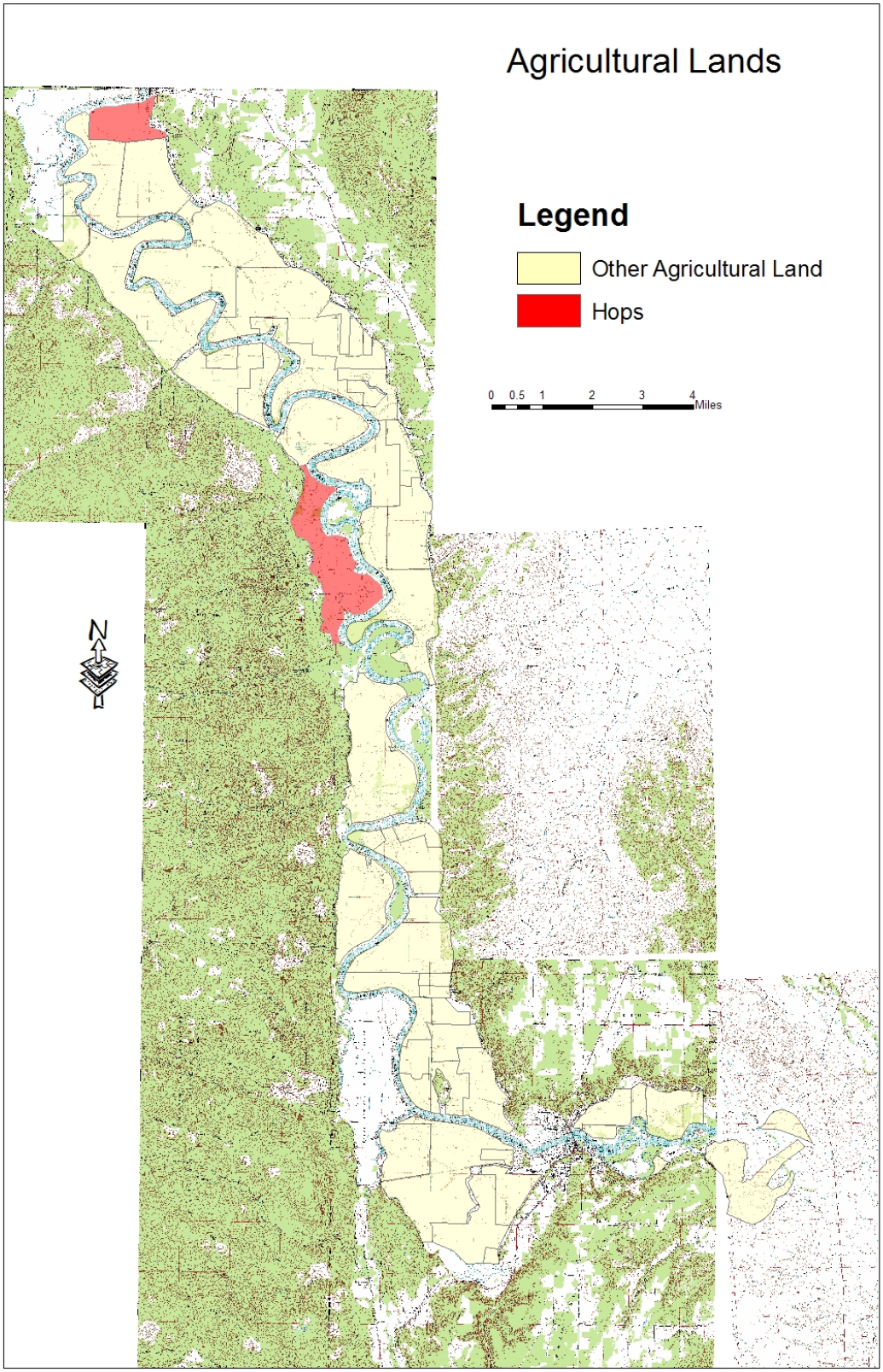
As recommended in the Biological Opinions (BiOps), variable discharge flood control (or VARQ FC, with Q representing engineering shorthand for discharge) is proposed to replace Standard FC at Libby Dam. Compared to Standard FC, VARQ FC procedures require less system flood control space be made available at Libby Dam prior to spring runoff in many years. In years where the April-August seasonal water supply forecast is between about 80 and 120 percent[2] of average at Libby Dam, the reservoir elevation typically would be higher for VARQ FC during the draw-down period from January through April. During reservoir refill, dam outflows under VARQ FC vary based on the water supply forecast (hence, the name variable discharge or VARQ). Because some water that would be stored during the refill period under Standard FC is instead passed through the dam, the amount of storage space needed for flood control can be reduced without compromising system flood control. In years where the seasonal water supply forecast is high (above about 120 percent of the average volume at Libby Dam), storage space for flood control and outflows during refill would be the same for either VARQ FC or Standard FC.

Although VARQ FC does not specifically include flow augmentation for fish, implementation of VARQ FC at Libby Dam enables the Corps to more reliably supply spring and summer flows for fish while simultaneously better ensuring higher reservoir elevations in the summer. These summer flows for fish include flow augmentation for sturgeon, bull trout, and anadromous salmon and steelhead. The volume of water available for sturgeon flows is based on the seasonal water supply forecast with less water dedicated to sturgeon in drier years. The sturgeon flows typically occur in May and June and involve high dam discharges designed to cue sturgeon spawning, egg incubation, hatching, and survival of larvae and juveniles. Bull trout minimum flows, also based on the seasonal water supply forecast, are specified for June through August and represent the lowest allowable dam discharges during this period. Salmon flow augmentation typically occurs during July and August and involves dam discharges necessary to draft Lake Koocanusa to elevation 2439 feet by August 31.

Currently, Libby Dam operates using VARQ FC on an interim basis and provides sturgeon, bull trout, and salmon flows. Sturgeon flows are currently limited to the Libby Dam powerhouse capacity (about 25 kcfs) plus an additional 1 kcfs of spillway flows (the maximum that can be spilled without exceeding the Montana State standard of 110% total dissolved gas saturation). The UCEIS will evaluate six operational scenarios, including the current operation, to inform a decision on implementation of flood control and fish flow operations on a long-term basis.

[2] For forecasts greater than 120 percent of average. Libby Dam typically does not achieve the draft required by either VARQ FC or Standard FC. This is because Libby Dam outflows must be reduced to comply with the International Joint Commission (IJC) Order of 1938 concerning Kootenay Lake levels.

Figure 1. Map of Agricultural Areas in the Kootenai Valley



3.0 STUDY SUMMARY

3.1 Characteristics of the Kootenai Valley Agriculture

3.1.1 Information/Data Flow

Under contract with the Seattle District Corps, HDR Engineering, Inc. prepared a detailed report describing characteristics of Kootenai Valley agriculture and agricultural practices. This report serves as a foundation of our evaluation of the impacts of high groundwater on agricultural economics in the valley (HDR 2003). The report describes the locations and estimated sizes of observed seepage areas, the location and alignment of ditches and pumping facilities, and the characterization of soil types which supported the development, calibration, and validation of the groundwater model. Information on crop distribution and location, grower characteristics, and agricultural practices (crop rotation, pumping, chemical application) supported the economic analysis.

The following summarizes key findings of the report on characteristics of Kootenai Valley agriculture.

3.1.2 Methods

Information on agriculture in the Kootenai Valley was collected from field interviews with growers, previous reports, aerial photographs, and information that could be obtained from agencies such as the Natural Resources Conservation Service (NRCS) and the U.S. Geological Survey. Mapping was accomplished during grower interviews and recorded using handheld Geographic Positioning System units and range finders. Tasks accomplished included identification of the types and acreages of crops in the valley, identification of agricultural practices relevant to high groundwater or soil moisture conditions, assessment of historical crop impacts due to high groundwater levels or soil moisture conditions, and mapping of areas of observed crop impacts from high groundwater levels.

3.1.3 Crops

Growers indicated that temperature is a limiting factor for types of crops that can be grown in the valley. Based on crop type, the interaction of precipitation, drainage, and groundwater levels plays a major role in determining eventual crop yield – the degree and timing of ground moisture conditions can make the difference between a high crop yield and a low crop yield.

With the exception of hops, crops are rotated from season to season and from year to year. Crop rotation planning is generally centered on the primary cash crop of winter wheat. Growers factor the profitability of rotation crops into their planting between

winter wheat crops. Table 1 summarizes the average annual acreage of crops in the valley. On average, wheat, barley, alfalfa, canola, and grass/hay make up nearly 90% of the crops grown in the valley.

Table 1: Average Acres by Crop in Kootenai River Valley, 1998 to 2003.

Crop	Average Acres	% of Total Acres
Winter Wheat	9,385	31.2%
Spring Wheat	8,010	26.6%
Barley	3,910	13.0%
Other[1]	3,123	10.4%
Hops	1,711	5.7%
Canola	1,611	5.4%
Alfalfa	1,491	5.0%
Timothy	839	2.8%
Total Acres	**30,080**	**100.0%**

Source: Natural Resource Conservation Service, Bonners Ferry, ID

[1] 'Other' category includes acres of all crops not presented in the table [See HDR, Inc. (2003)].

3.1.4 Agricultural Practices

In the valley, drainage districts were formed in the early 20th century to maintain the levees, drainage ditches and pump stations. Most of the districts have concentrated on intercepting groundwater using either permanent or temporary ditches in the fields, then running the water in open ditches to a pump plant to be pumped to the river. These systems appear to have been set up to primarily address the local flowage from the surrounding mountains or precipitation. The growers have noted that with higher sustained flows in the river, high river stages become a key contributor to waterlogging. A number of drainage systems in the valley cannot adequately function during periods of peak runoff, high river stages, or both.

In several of the drainage districts, the restoration of wildlife habitat on some parcels has included removal of the drainage ditches that intercepted the smaller tributaries. At these locations, shallow water ponds have formed along the edge of the valley that appear to remain year round. In one such case, the grower estimated that each year the ground adjacent to the pond that is too wet to farm increases in extent by approximately 100 feet laterally. It is not clear if the water surface of the pond is increasing in size each year or if the increase results from the subsurface effects from the pond. Nor is it clear what the potential interaction is between the shallow pond and river stages.

The effects of waterlogging include crop losses resulting from ponded water, reduced yields caused by high soil moisture content, high soil moisture content that prevents farm equipment from traveling over the ground, increased costs associated with working around affected areas, and loss of investment when areas are affected after the application of fertilizers and pesticides. Areas that cannot be sprayed because equipment cannot be driven across waterlogged areas can harbor disease and insects. These areas can re-infect the remainder of the crop and cause increased costs if the grower is forced to re-apply chemicals to the remainder of the field. Also, farmers can be forced to operate with a

buffer zone around the areas of waterlogging to avoid becoming "stuck" in the mud. This can result in the loss of portions of the crop outside the waterlogged area.

Many areas that have had problems with waterlogging are being planted with crops that are more tolerant of higher soil moisture contents, but even in these areas there can be evidence of crop loss due to elevated ground water levels.[3] However, most growers are reluctant to pursue alternative crops that would be more tolerant of high moisture conditions. Reasons range from the cost of purchasing new equipment that would be required for a crop that is significantly different from what they are growing now, to memories of past efforts that have failed.[4] Growers are not necessarily opposed to using alternative crops that would be more tolerant of higher moisture contents, but likely require clear evidence that the crop will be profitable before they would be willing to switch from more traditional crops or types.

The tenacity and optimism of the growers plays a role in how growers farm likely waterlogged areas. There are areas in the valley where the growers have identified a high potential for impacts from waterlogging to the crop at that location, but the surrounding field exhibits either no such problem or a limited impact from high soil moisture. In some cases, the growers have elected to plant these areas despite the probability of either reduced yields, loss of crop, or increased operating costs. Reasons given for planting these areas vary from determining that diverting equipment around the area would cost more in increased fuel costs than the potential loss of crop, to a belief that the conditions in some years will be sufficient to get a harvestable crop from the area.

3.1.5 Observations and Implications of High Groundwater

High groundwater levels and precipitation can impact crops in two general ways. In some instances, high ground water levels can increase soil moisture content significantly in an area so that infiltration of rainfall is severely restricted. Alternatively, areas may remain wet for longer periods of time after a rainfall event when ground water levels are high. High ground water levels can reduce the soil infiltration capacity enough that even small amounts of rainfall will result in standing water that will drown out crops.

Average elevations within agricultural areas range from approximately 1,750 feet (Drainage District 8 near the Canadian border) to 1,765 feet (Drainage District 2 near Shorty's Island and 3 upstream of Bonners Ferry). The growers indicated that even if the river stage reached an elevation of 1,764 feet at Bonners Ferry, they would see minimal impacts from waterlogging if the river remained at that level for a week or less and then dropped to a stage at or below 1758 feet at Bonners Ferry. However, growers start to see some impacts from waterlogging if the stage at Bonners Ferry exceeds 1758 feet for two weeks; if the duration lasts three weeks or more, the impacts are significantly greater.

[3] A number of growers grow a grass crop in certain areas not suitable for other crops due to impacts from waterlogging, areas where surface runoff tends to collect, or some combination of these factors.

[4] Attempts have been made to grow rice in the valley, but the crop was lost to birds, leaving a negative experience that is easily recalled by the growers.

Mapping of seepage areas during recent years identified over 150 distinct locations covering 1,990 acres throughout the valley (see Plates 12-16 from HDR (2003) in Appendix A). Areas with concentrations of delineated seepage areas are noted in Table 2 (arranged from upstream to downstream areas).

Table 2. Drainage Districts with Concentrations of Delineated Seepage Areas

Drainage District	Location	Affected Grower(s)	Crops Currently Grown
2	North side of the river just upstream of Bonners Ferry	Michalk (Fry Creek Farms)	Wheat, barley, alfalfa hay, timothy hay, soy beans
1	South side of the river between Bonners Ferry and Deep Creek	Figgins, Peterson, Copeland	Wheat, timothy hay, barley
11	East side of the river between the Kootenai Tribe of Idaho reservation and Shorty's Island	Hubbard, Iverson	Wheat, barley, alfalfa hay, timothy hay and seed, canola, potatoes, bluegrass
3	West side of the river adjacent to Shorty's Island	Day Farms	Wheat, barley
16	West side of the river straddling Farnham Creek	Elk Mtn. Farms (Backwoods Farm)	Hops
9	West side of the river at the Copeland bridge	Amoth	Wheat
13	West side of the river south of Parker Creek	Olmsted	Wheat, timothy hay, canola, oats/peas mix
8	East side of the river near the Canadian border	Day Farms, Jantz	Wheat, barley, canola, clover

In general, observations of crop impacts and mapped seepage areas are limited to areas with visible characteristics such as wet ground, stunted growth and/or plant discoloration. Areas with more subtle reductions in crop yield are likely more extensive than the seepage areas identified based on field observations by growers. Also, a number of locations where the ground appears to have relatively low moisture content can exhibit evidence of crop loss.

In general terms, the southern part of the valley appears to have more gravels and sands, resulting in a much quicker response of ground water level to changes in river stage than is experienced in the northern portions of the valley where the soils are typically silts and clays. The growers noted that there is a complex network of subsurface drainages formed by gravels and sands that were deposited by either tributary drainages of the Kootenai River or by the Kootenai River over geologic time; it is their opinion that these subsurface features appear to have significant influence over where and how quickly waterlogged areas respond to a change in the river stage.

3.2 Agronomy

3.2.1 Information/Data Flow

Under subcontract with HDR, Glen Murray, an agronomist, prepared a report that details how water table depth, duration of waterlogging, precipitation events, crop species, crop growth stage, and crop nutrition have affected crop production worldwide (Murray 2003). Results were then applied to crops grown and conditions in the Kootenai River valley to develop relationships between depth-to-groundwater at specific durations and crop yield reduction, by plant growth stage.

Agronomic information on crops grown in Kootenai valley supports the processing of groundwater model output by providing thresholds for when certain groundwater levels at specified durations reduce crop yield. Using these relationships, the model output was sorted to identify how much of the valley (on a proportional basis) might experience adverse effects from seepage. The sorted output then provided a primary input to the economic analysis. The economic analysis relied heavily on the yield reduction functions to quantify the potential economic impact due to different groundwater conditions.

3.2.2 Methods

Information from Boundary County producers and other local and regional experts, together with published literature, were the key ingredients used to determine how high groundwater levels affect yields of the crops grown in the valley.

3.2.3 Results

Water table depths less than 2 feet will likely cause 10% to 100% yield reduction to most crops in most years. As duration and frequency of such waterlogging increases and water table depth becomes shallower, crop losses increase. The stage of plant growth affects its tolerance to waterlogging. For the major crops grown in the Kootenai valley, tolerance to waterlogging, from most to least tolerant, is generally:

1. Grass Hay
2. Alfalfa Hay
3. Timothy
4. Winter Wheat
5. Spring Canola
6. Spring Wheat
7. Spring Barley
8. Hops

For several crops, reductions in crop yield are dependent on the stage of crop development when waterlogging occurs (Murray 2003). For example, spring wheat is very vulnerable to short duration, very shallow groundwater levels during its germination period (defined as April 15 through May 1). During germination, groundwater that is shallower than 1 foot depth for 1 week or more will cause complete loss of the crop. During stem extension after germination (defined as May 1 through June 30), spring wheat is more tolerant of waterlogging and can tolerate groundwater at the surface for:

- One week with a yield reduction of 40%,
- Two weeks with a yield reduction of 50%, and

- Four weeks with a yield reduction of 70%.

Basically, areas that stay wet for longer lead to larger crop losses (i.e. yield reduction increases as the duration of waterlogging increases).

Additionally, for any given duration, crop losses aren't as severe in areas where groundwater is deeper and farther away from the surface root zone (i.e. as the depth-to-groundwater increases, the yield reduction for a given duration generally decreases). For example, hops would have 25% less yield when groundwater remains at one foot depth for two weeks, but would have only 15% less yield when groundwater is at a depth of two feet for two weeks. Murray (2003) details the relationships between the crop-specific development periods, depth-to-groundwater/duration combinations, and yield reduction.

3.3 Groundwater Model

3.3.1 Information/Data Flow

The Corps assembled a computer model to simulate daily groundwater elevations throughout the Kootenai Valley in Idaho under six different dam operational scenarios. The groundwater model output provides the depth-to-groundwater at more than 80,000 locations spread throughout the valley. This raw output was processed to sort out which nodes would have shallow groundwater for long enough to reduce yields of crops grown in the valley (see Section 3.4.2, and Harp and Darden 2005).

The processed groundwater model output provided the inputs for the economic analysis (Harp and Darden 2005). Although outside of the scope of this study, other uses of the groundwater model could include evaluation of options to avoid or minimize seepage (i.e. dam operations, drainage improvements) or impacts from seepage (i.e. avoidance of potentially wet areas given a particular dam operation and drainage system).

3.3.2 Methods

Computer Model Code: The groundwater modeling computer code FEMWATER (Linn et al, 1997) was used for the groundwater model of the Kootenai Valley. Pennsylvania State University and the U. S. Army Engineer Waterways Experiment Station (WES) developed FEMWATER under a cooperative research agreement between the U. S. Environmental Protection Agency (EPA) and the U. S. Department of Defense (DOD).

Model Structure: The area subject to the model included the valley bottom and terraces from 3 miles north of the Canadian border to about 5 miles upstream of Bonners Ferry,

and into the Deep Creek Valley for about 8 miles south of the Kootenai River.[5] Observations and data used as fixed inputs for the model included soil and bedrock characteristics and ground elevations. Inputs for the model that varied over time included precipitation, and stage (water surface elevation) at selected points along the Kootenai River and tributaries. The model simulated daily groundwater elevations at discrete locations (nodes) distributed approximately every 600 feet across the modeled area.

Calibration: Model calibration involved running the model using:

- Observed conditions in 2002-2003 with observed groundwater levels provided by the U.S. Geological Survey in wells installed in the floodplain (Campbell 2003) as the calibration target.
- Observed conditions in 1996-1997 with reported soil waterlogging locations from HDR (2003) as the calibration target. This water year was used as a validation tool for the project

After calibrating to 2002-2003 to provide the best fit to observed conditions, the validation of 1996-1997 conditions predicted waterlogging in the vicinity of about 80 percent of surveyed waterlogging locations. The model was unable to predict waterlogging at about 20 percent of the surveyed locations, even when the model was adjusted to encourage high groundwater levels at these locations. These results indicate that the waterlogging in these areas is caused by factors other than groundwater flow (i.e. infiltration of surface water from runoff or precipitation) or that the model resolution is too coarse to simulating localized subsurface features. The model also showed some waterlogging in areas which were not reported by HDR (2003). Total waterlogged acreage throughout the valley bottom appeared similar to the total area of surveyed waterlogged areas reported by HDR (2003).

Predictive Simulations: The seepage study required evaluation of the effects on agricultural production from a range of different dam operations, some of which have no historical precedent. The groundwater model provided a method to simulate how the various dam operations might affect the Kootenai River, Kootenay Lake, and groundwater levels throughout the valley.

Under facilitation of the Kootenai Valley Resources Initiative (KVRI), the Corps worked with local officials, USFWS, tribal staff, and property owners to select two water years[6] representing conditions of interest to the valley stakeholders and relevant to the seepage issue. In selecting two representative years, the Corps recognized that the stakeholder groups strongly preferred that more than two years be modeled if the project schedule and budget allowed.

[5] The geographic area covered by the model is larger than the valley bottom agricultural areas that were of primary interest. This design allows the economic analysis to avoid use of model output that could be unduly influenced by assumptions of boundary conditions near the margins of the modeled area.

[6] The water year runs from October through September. Thus, water year 1961 begins October 1, 1960 and ends September 30, 1961.

Water year 1964 was selected to represent a typical year, which was defined as a year with a May 1st Libby seasonal water supply forecast between 6.0 and 6.7 million acre-feet[7], with a relatively small May 1st forecast error, and hydrograph timing and volume similar to the 50% exceedance summary hydrograph. 1964 had a seasonal runoff of 6.9 million acre-feet (111% of average, with a May 1st forecast of 6.7 million acre-feet).

Water year 1961 was selected to represent "a more significant year," which was defined as a high-water year that is a cause of concern for the community. The high-water year was chosen solely by the stakeholder group from the period of record as the one year they wanted modeled to capture the upper bounds of seepage impacts. 1961 had a seasonal runoff of 7.9 million acre-feet (126% of average) and a May 1st forecast of 7.5 million acre-feet. Forecasts for 1961 in January, February, March, and April were all lower than the May 1st forecast. The greatest difference in river flows and resulting groundwater levels between VARQ and Standard FC would be expected in years such as 1961 with increasing water supply forecasts through the winter.

The predictive simulations consisted of groundwater model runs for each of the six operational scenarios which were completed for each of the two selected years (1964 as typical, and 1961 as significant), for a total of 12 model runs and output data sets. The predictive groundwater model simulations used Kootenai River and Kootenay Lake stages generated by simulation of the six Libby Dam operational scenarios (see Corps 2004 for complete details of this hydro-regulation modeling) as the primary input that varied between model runs. The hydro-regulation modeling operated Libby Dam to avoid exceeding a river stage of 1764 feet at Bonners Ferry whenever possible.[8] For each separate year, the same tributary stages and precipitation were used for all model runs. The six Libby Dam operational scenarios are described in Table 3.

More details on the construction of the groundwater model is provided in the report titled *Kootenai Flats Seepage Analysis – Groundwater Modeling Report* (Corps 2005)

[7] The average April-August water supply for Libby is 6.25 million acre-feet (MAF).

[8] Actual river stages in 1997 and 2003 never exceeded 1764 feet at Bonners Ferry. Simulated river stages for the 6 different Libby Dam operations for 1961 and 1964 also never exceeded 1764 feet at Bonners Ferry.

Table 3. Libby Dam Operational Scenarios Simulated By the Groundwater Model

Operational Scenario	Description of Dam Operations
LS - (Scenario 1) Standard Flood Control (FC) without Fish Flows	The flood control procedure currently authorized for long-term use is referred to as Standard FC. Standard FC was the method used at Libby Dam prior to and through calendar year 2002. To determine the required flood control operation at Libby, the Standard FC storage reservation diagram (SRD) is used in combination with Libby's seasonal water supply forecasts to determine how much space needs to be made available by 15 March for flood control. As the season progresses and the forecasts change, so do the storage requirements. During refill, the assumed outflow from Libby is 4,000 cubic feet per second (cfs). There is no flow augmentation for fish in this scenario.
LV – (Scenario 2) Variable Discharge (VARQ) FC without Fish Flows	VARQ FC is the flood control method being used on an interim basis at Libby Dam, and recommended for long-term implementation in both the 2000 USFWS FCRPS Biological Opinion (USFWS, 2000) and the 2000 NMFS FCRPS Biological Opinion (NMFS, 2000). This interim operation began in January 2003. Similar to Standard FC, VARQ FC also requires a SRD in conjunction with the water supply forecast to determine the flood control space needed. As the season progresses and the forecasts change, so do the storage requirements. However, as compared with the Standard FC SRD, the VARQ SRD requires less flood control space in years with slightly-below- to slightly-above-average water supply forecasts. During refill, the outflow from Libby varies (hence the name variable discharge or "VARQ," with Q representing engineering shorthand for discharge), and is almost always greater than 4,000 cfs. There is no flow augmentation for fish in this scenario.
LS1 – (Scenario 3) Standard FC with fish flows at powerhouse capacity *(operation prior to 2003)*	In addition to following the Standard FC rules (described for LS – Scenario 1), fish flows were modeled as follows: First, provide a tiered volume of water during the spring freshet for sturgeon spawning and recruitment, using only the maximum powerhouse capacity (about 25,000 cfs). Next, make sure Libby outflow is greater than or equal to the minimum bull trout flow during July and August. Finally, draft the pool to elevation 2,439 feet (20 feet from full) for salmon flow augmentation during July and August. An effort was also made to minimize the impact of a "double peak" – that is, ramping down between sturgeon flows and salmon flows was avoided if for only short periods.
LV1 – (Scenario 4) VARQ FC with fish flows at powerhouse capacity *(operation since 2003)*	Identical to LS1 – Scenario 3, except the VARQ flood control procedure (described for LV – Scenario 2) is followed instead of the Standard FC procedure.
LS2 – (Scenario 5) Standard FC with fish flows at powerhouse plus 10,000 cfs additional flow capacity	Identical to LS1 – Scenario 3, except that now sturgeon flows are provided using the powerhouse capacity plus 10,000 cfs additional capacity, for a total of about 35,000 cfs.
LV2 – (Scenario 6) VARQ FC with fish flows at powerhouse plus 10,000 cfs additional flow capacity	Identical to LV1 – Scenario 4, except that now sturgeon flows are provided using the powerhouse capacity plus 10,000 cfs additional capacity (about 35,000 cfs total).

3.3.3 Results and Limitations

In general, the following observations can be made from the predictive simulations and the calibration runs:

- Modeled water level elevations drop steeply from near 2200 ft at the base of the mountain slopes to below 1800 ft at the edge of the floodplain.
- Water levels tend to be relatively flat below the flood plain, due to the combined effects of the Kootenai River and the agricultural drainage systems.
- Predicted water levels patterns near the Kootenai River closely resemble the stage hydrographs input for the river.
- Predicted water levels at locations distant from the river are higher compared to levels near the river, with broader seasonal peaks compared to locations near the river.
- Predicted water levels at some locations near the valley margins appear not to be affected by the Kootenai River, and instead appear likely due to other causes than groundwater flows (i.e. ponding, precipitation, surface runoff, tributary stages).
- Drains have a strong influence on water levels at some locations, and create depressions in the groundwater surface. In the absence of agricultural drains, acreage of waterlogged areas would be substantially larger than currently observed.
- Groundwater levels for the 1961 simulations during the spring-summer runoff period are clearly higher than the levels for the corresponding 1964 simulations. This is expected since 1961 was selected to represent a relatively wetter year. Precipitation during both water years, with 31.7 inches in 1961 and 28.6 inches in 1964, was above the average precipitation of 22.1 inches/year.
- In 1961 (a wetter year), all the VARQ FC scenarios (LV, LV1, and LV2) result in higher groundwater levels for longer duration than any of the Standard FC scenarios (LS, LS1, and LS2). In part, this results from almost identical river stages under all the VARQ FC scenarios because flood control operations drive dam operations under VARQ FC in the 1961 simulations (i.e. the timing and magnitude of river flows, or hydrograph, is essentially the same for all VARQ FC scenarios).
- In 1964 (a more typical year), fish flows appear to influence groundwater to a greater degree than flood control operation. Groundwater levels are lowest for scenarios without fish flows, midrange for fish flows to powerhouse capacity (LS1 and LV2), and highest for fish flows to 10,000 cfs above powerhouse capacity (LS2 and LV2). LV results in clearly higher groundwater levels for longer duration than those under LS, but groundwater levels and durations for a given fish flow operation are similar between the two flood control operations.

The groundwater model is a useful tool for the purposes of the seepage study, but is subject to some limitations:

- Primarily because of scale and the approximately 600-foot spacing between nodes, the model allows general assessment of groundwater impacts due to river stages across the valley, but should not be used as a predictor of exact groundwater levels at precise locations.
- Simulated flooding or waterlogging near some tributaries is likely an artifact of linear interpolation between a limited number of locations with known stages that were available as inputs to the model (see Figure 2). Filtering of model output helped diminish the effect of flooding or waterlogging that is the sole result of this interpolation artifact.

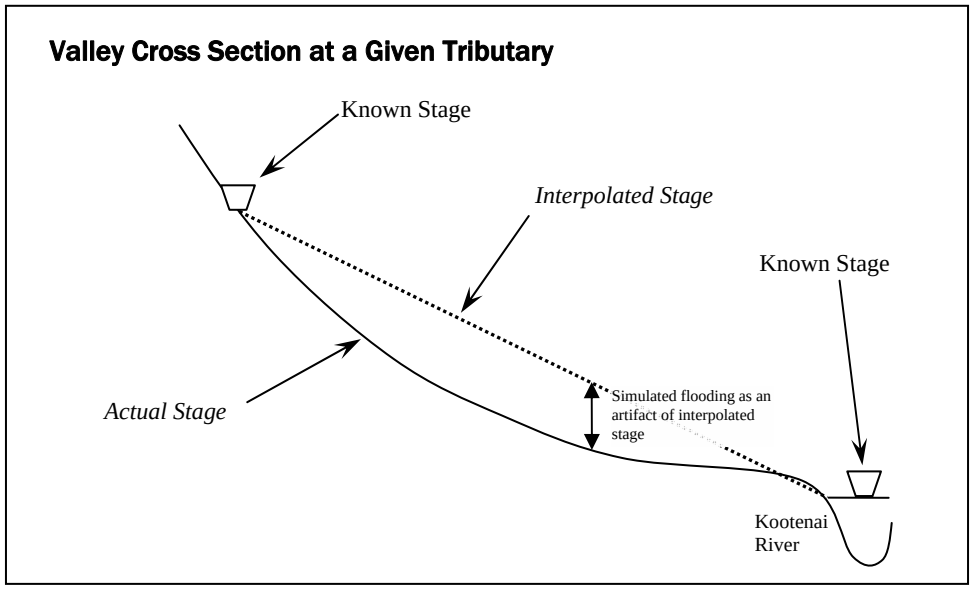


Figure 2. Effects of Interpolation of Tributary Stages

- The model simulates groundwater flow only, and cannot predict flooding or waterlogging caused by precipitation, snowmelt, or surface runoff. However, comparisons of model predictions with observed waterlogged areas can provide a way to estimate where groundwater levels may not be the primary cause of waterlogging.
- The predictive capability of the model is somewhat less at the valley margins than in the center portion of the valley.
- The model predictions of depth-to-groundwater are based partly on ground-surface elevations, so a high precision topographic survey of the valley could help improve the accuracy of the model results.

The full implications of the groundwater model output are summarized the discussion of the economic analysis in Section 3.4.3 below.

3.4 Economic Analysis

3.4.1 Information/Data Flow

The economic analysis produces the final product of the study: the economic impacts of agricultural seepage under the various dam operational scenarios. The integration of the agronomy, groundwater model output, and economic parameters come together to produce estimates of the economic impacts, in dollar values, that allow direct comparison of the different dam operational scenarios. These results are discussed in detail in Harp (2005) and will be summarized in the Upper Columbia Alternative Flood Control and Fish Operations Environmental Impact Statement (abbreviated as UCEIS) in accordance with the National Environmental Policy Act.

3.4.2 Methods

As discussed in Section 3.3, the groundwater model simulates the depth of groundwater at specified locations or nodes distributed across the valley, thus generating a daily record of groundwater depth at each node. When combined with all other nodes in the valley, the groundwater simulation provides a representation of water table fluctuations throughout the valley.

To sort the output, the daily groundwater levels at each node were evaluated to determine if the groundwater remained shallow for long enough to fall within one of the crop yield reduction categories as defined by the agronomic report (see Section 3.2). For example, hops suffer a 90% yield reduction if groundwater is 1-foot below land surface for 28 continuous days. The sorting of the model output counted the number of nodes within the hops producing portion of the valley that met the criteria of 1 foot depth-to-groundwater for at least 28 days. The sorting process classified all nodes in the valley for each category of crop based on crop period (based on time of year), and depth-to-groundwater/duration category.

To avoid “double counting” nodes that could qualify for more than one depth-to-groundwater/duration category, the sorting process was designed to assign a given node to the category with the highest yield reduction category (Table 4).

Table 4. Sorting Protocol for Nodes That Could Fall into More Than One Category

Over a 28 day period, a specific node may have groundwater within 1 foot of the surface for the first 14 days, then groundwater within 2 feet of the surface for the next 14 days. With this pattern, the node could fall into at least 2 different yield reduction categories (for hops in this case):

Depth-to-Groundwater (DTGW)	Duration	Yield Reduction
≤1 foot	14 days	25%
≤2 feet	28 days	60%

For the processed data, the node would be categorized in the highest yield reduction category, with 60% yield reduction, of DTGW of ≤2 feet for 28 days.

Complete details on the sorting protocol are found in Harp and Darden (2005).

Processing of the groundwater model output provided an estimate of the percent (%) of total acreage in the valley with a specific depth-to-groundwater, measured in feet, for a certain period of the year for a defined duration in days. This percent is used to allocate the total acreage of each crop affected at each river stage DTGW-duration category based on the average acres per crop grown in the valley (see Table 1; for example, if 10% of the nodes met depth-to-groundwater/duration criteria to affect yield of hops, the total affected acreage would be 1,711 acres of hops multiplied by 10% to get 171 acres of affected hops).

While this method simplifies calculations, it cannot account for yield losses in the previous crop stages on overall yields in subsequent crop stages (i.e. the winter wheat yield in a specific field could be reduced by high groundwater during March 1 to April 30 - early stem extension, but that yield loss would not be captured as the starting condition for any yield loss during May 1 to August 5 - mid-stem extension). An area with high groundwater during an early period is likely to have high groundwater in following periods. This leads to affected acres being counted more than once. Thus, the estimates used throughout this analysis are the maximum acres the model estimates could be affected.

The processed groundwater model results were combined with the set of yield reductions due to waterlogging for each crop (see Section 3.2 and Murray 2003) and average yield per acre for each crop. This provided a conversion from affected acreage to lost production for each DTGW-duration category by crop development phase.

The lost production figures were then combined with price and cost information to generate an estimate of the monetary value attributed to crop harm that might occur due to groundwater seepage. The aggregate losses to agricultural production in the valley under different conditions are totaled by adding the estimated losses for each crop.

Harp and Darden (2005) detail allocation of costs and lost revenues that were used to generate losses due to high groundwater.

3.4.3 Results

Calibration and Validation of Methods – 1997 and 2003

Based on observed river conditions input into the groundwater model, estimated affected acreage and the associated economic impacts were calculated for the 2003, the calibration year for the groundwater model, and 1997, the validation year for the groundwater model (Table 5). These estimates provide a baseline for the simulations of the six different dam operational scenarios that were completed for 1961 and 1964.

Table 5: Aggregate Crop Loss Impacts for All Crop Stages, DTGW-Duration Categories based on actual river, tributary, and precipitation in 1997 and 2003.

	1997		2003	
Crop	**Affected Acres**	**Loss**	**Affected Acres**	**Loss**
Hops	890	($3,098,418)	342	($1,250,021)
Spring Wheat	4,180	($1,117,040)	2,135	($344,167)
Winter Wheat	4,803	($846,015)	1,778	($362,824)
Barley	2,344	($813,709)	868	($269,730)
Canola	966	($200,601)	358	($66,785)
Alfalfa	946	($125,663)	472	($54,118)
Totals	**14,129 acres**	**($6,201,447)**	**5,953 acres**	**($2,347,645)**

For each crop, 1997, a wet year[9] with a water supply that was 124% of the average for Libby, resulted in more acreage affected by high groundwater levels, higher yield loss, and higher economic impact than occurred in 2003, a dry year.[10] The largest yield losses are associated with longer durations with shallow depth-to-groundwater, conditions which were more frequent in 1997. In both years, hops are estimated to sustain the biggest losses, followed by winter and spring wheat.

Focusing on 1997, the overall estimate of affected acreage is 14,129 acres. This exceeds the estimate of 1,990 acres in HDR (2003) and the 8,000 acres used in previous evaluations of seepage (Harp and Darden 2001; McGrane 1999), but is relatively close to the 13,300 acres estimated in Corps of Engineers (1971). The estimated economic impact in 1997 is also larger than previous estimates: Harp and Darden (2001) estimated losses from seepage at $1.6 million; McGrane (1999) cites local estimates for 1997 seepage losses at $1.44 million.

The higher estimates using the model output may be due to the fact that the groundwater model is capturing all seepage during the growing season. The estimates in Harp and Darden (2001) and McGrane (1999) relied on visual evaluation of crop harm at the peak of seepage and captured only those yield reductions that appeared visually obvious in a crop stand, such as stunted growth or discoloration. Areas that may suffer yield reduction without obvious visual indications are not included in these earlier estimates (HDR 2003). The model captures additional seepage that occurs before and after peak seepage that leads to visual identifiers of stressed crops.

Historically, the most likely time for river stages to be high and remain so for significant periods of time is May and June. For example, in 1997 river elevations began to rise above 1755 feet elevation at Bonners Ferry in early May, stayed above 1760 feet for most of June, and remained above 1755 feet until early July (Corps, 2005). Under the 2003 scenario, the Bonners Ferry gauge rose above 1755 feet at the very end of May and fell below that mark by mid-June (Corps, 2005). In both years, 28-day durations during this period produce significant losses for hops and grains and to a lesser extent for canola and alfalfa. In general, for both years, the time of high water combined with greater

[9] Actual April-August runoff for Libby was 124% of average.
[10] Actual April-August runoff for Libby was 81% of average.

susceptibility of crops to harm at certain stages of their development produces a predictable pattern of losses when comparing months: May and June are generally going to be the months in which harm is most likely to occur and therefore aggregate losses will be highest. And, in years like 1997, high river stages persisting into July can result in continued additional crop losses extending into the early summer.

Unlike 1997, no anecdotal data is available for 2003 to indicate if the $2.3 million in model-simulated losses actually occurred, especially since 2003 was considered a drought year. A possible interpretation is that 2003 represents a baseline case measuring historically forgone yields due to seepage in the valley that is not due directly to dam operations (i.e. it's the cost of farming in the valley). Additionally, the sorting and analysis protocol used to combine the groundwater model output and the yield reduction figures by crop stage tends to provide conservatively high estimates of the aggregate effect from high groundwater. This is an artifact of the inability to account for cumulative yield losses in areas where high groundwater persists throughout the growing season (see Section 3.4.2). It is likely that the loss estimates for 2003 reflect a combination of over-counting of affected acres in the model and baseline seepage effects.

Simulation of the Effects of Different Dam Operational Scenarios on Agricultural Losses – 1961 and 1964

Based on simulated river stages during 1964, the year selected to represent a typical year, and 1961, the year selected to represent a more significant year for agricultural losses, estimated economic impacts were calculated for the six different dam operational scenarios (see Table 3) being evaluated in the UCEIS (results are summarized in Table 6 and Table 7). Harp and Darden (2005) present the detailed breakdown of affected acres, yield loss, and economic impacts for each crop used to calculate the total aggregate losses.

Table 6: Aggregate Acreage Affected by High Groundwater for Simulated Operational Scenarios of Libby Dam, 1961 and 1964.

		Affected Acres					
Crop	**Year**	**LS**	**LV**	**LS1**	**LV1**	**LS2**	**LV2**
Hops	1961	616	781	690	787	713	787
	1964	302	376	479	485	496	496
Winter Wheat	1961	2,732	3,121	2,940	3,116	3,030	3,116
	1964	1,780	1,957	2,258	2,220	2,342	2,273
Spring Wheat	1961	2,775	3,232	2,961	3,235	3,068	3,235
	1964	1,873	2,123	2,457	2,448	2,544	2,524
Barley	1961	1,354	1,578	1,446	1,579	1,498	1,579
	1964	914	1,037	1,199	1,195	1,242	1,232
Canola	1961	558	650	596	651	617	651
	1964	377	427	494	492	512	508
Alfalfa	1961	593	763	662	773	680	774
	1964	409	464	514	513	516	528
Aggregate Impacts	1961	8,628	10,125	9,295	10,141	9,606	10,141
	1964	5,655	6,384	7,401	7,352	7,653	7,561

Table 7: Aggregate Crop Loss Impacts for All Crop Stages, DTGW-Duration Categories and Dam Operational Scenarios, 1961 and 1964.

		Impact ($)					
Crop	**Year**	**LS**	**LV**	**LS1**	**LV1**	**LS2**	**LV2**
Hops	1961	($2,997,748)	($3,779,747)	($3,502,589)	($3,816,797)	($3,361,387)	($3,816,797)
	1964	($1,523,538)	($1,905,256)	($2,301,418)	($2,327,272)	($2,368,432)	($2,390,710)
Winter Wheat	1961	($521,192)	($627,081)	($557,736)	($629,777)	($565,902)	($629,934)
	1964	($285,381)	($407,297)	($451,084)	($453,075)	($461,636)	($462,066)
Spring Wheat	1961	($615,384)	($724,542)	($656,186)	($726,336)	($664,652)	($726,336)
	1964	($411,237)	($479,141)	($544,364)	($546,539)	($559,144)	($559,375)
Barley	1961	($441,253)	($518,850)	($470,349)	($520,116)	($476,400)	($520,116)
	1964	($294,941)	($343,413)	($390,245)	($391,660)	($400,822)	($400,846)
Canola	1961	($108,142)	($127,399)	($115,330)	($127,717)	($116,820)	($127,717)
	1964	($72,259)	($84,216)	($95,671)	($96,069)	($98,270)	($98,327)
Alfalfa	1961	($30,578)	($39,018)	($34,232)	($39,408)	($35,354)	($39,422)
	1964	($21,254)	($24,536)	($28,091)	($28,150)	($28,140)	($28,998)
Aggregate Impacts	1961	**($4,714,295)**	**($5,816,637)**	**($5,336,422)**	**($5,860,151)**	**($5,220,515)**	**($5,860,322)**
	1964	**($2,608,610)**	**($3,243,859)**	**($3,810,872)**	**($3,842,765)**	**($3,916,444)**	**($3,940,323)**

In both 2003 and the LS simulation for 1964, the river did not exceed a stage of 1758 at Bonners Ferry, which represents the anecdotal threshold for the commencement of seepage impacts. For all other model runs and years, the river stages during spring runoff exceed 1758 feet at Bonners Ferry, and only one (LV in 1964) has a peak stage that does not exceed 1760 feet at Bonners Ferry. In addition to the similar hydrograph pattern, the loss estimates in both 2003 and the LS simulation for 1964 are between $2 and $3 million. Hence, given the low river stages achieved for 2003 and LS in 1964, together with the similar loss estimates in these two scenarios, it appears that all loss estimates likely include a baseline loss of approximately $2,000,000. Note that precise quantification of the baseline loss figures would require analysis of additional years paired with ground-truthing the modeled loss estimates with actual losses. However, realizing that there is some baseline loss captured in the model, the analysis of the impacts of agricultural seepage focuses on the relative differences between the different operations.

In 1964 (a typical year), the results indicate that the largest impacts to crops are the result of providing fish flows, with relatively smaller differences attributed to the flood control operations or the variations between the two simulated fish flow operations. For example, the differences in impacts between all fish flow scenarios when compared to their respective without-fish-flow operation (i.e. LS1 and LS2 compared to LS; LV1 and LV2 compared to LV) are estimated at $1,200,000 to $1,300,000. But the differences in impacts between LS1 and LV1 are estimated at only $31,000, and at only $24,000 between LS2 and LV2. The increase in maximum sturgeon flow from powerhouse capacity (LS1, LV1) to 10,000 cfs above powerhouse capacity (LS2, LV2) is estimated to increase impacts by about $100,000, regardless of flood control operation. The difference between the most impact (LV2) and the least impact (LS) is estimated at $1,332,000 (or about 50% of the estimated impacts of LS). In summary, in a typical year like 1964, growers would experience similar impacts for a given fish flow operation, regardless of the flood control operation of Libby Dam.

Unlike a typical year such as 1964, the results indicate that the fish flows and flood control operation factor more equally into increasing losses in a significant year like 1961. Instead, the flood control operation drives river stages and resultant differences in groundwater levels. For example, the differences in impacts between LS1 and LV1 are estimated at $524,000, and at $640,000 for LS2 and LV2. The Standard FC scenarios (LS, LS1, LS2) show some of the same patterns as 1964, with the addition of fish flows contributing an estimated $500,000 to $600,000 increase in losses for LS1 and LS2, respectively, when compared to LS. Note, however, that the estimated increase in 1961 losses due to adding fish flows to Standard flood control are about 50% less than the estimated increase in 1964 losses due to fish flows. For all VARQ FC scenarios, flood control drove the 1964 dam operations, so fish flows do not play a large role in crop impacts. For example, the estimated impacts for all of the VARQ FC scenarios (LV, LV1, LV2) are within $43,000 of each other. The difference between the most impact (LV1 or LV2) and the least impact (LS) is estimated at $1,146,000 (or about 25% of the estimated impacts of LS).

In summary, in a more significant year like 1961 where runoff forecasts through the winter are lower than actual runoff and runoff is substantially higher than average, growers would tend to experience relatively high agricultural impact under any of the scenarios, with relatively higher impacts under operations which include VARQ FC operations. As for the VARQ flood control simulations for 1961, more significant years may result in fish flows not adding any additional losses since flood control operations may supersede fish flow considerations.

4.0 DISCUSSION & RECOMMENDATIONS

In a typical year like 1964, growers would experience similar impacts for a given fish flow operation, regardless of the flood control operation of Libby Dam. In these years, total impacts due to high groundwater are estimated to be about 50% higher with fish flows than without. In a more significant year like 1961, where runoff forecasts through the winter are lower than actual runoff and runoff is substantially higher than average, growers would tend to experience relatively high agricultural impact under any of the scenarios, and VARQ FC operations are estimated to generate higher impacts than Standard FC operations. Fish flows are expected to add to impacts in more significant years, but additional losses are estimated at about 10% of total impacts, much less than the relative contribution of fish flows in more typical years. As happened in the VARQ FC simulations for 1961, more significant years may result in fish flows not adding any additional losses since flood control operations would tend to supersede fish flow considerations.

Additional analysis would be necessary to evaluate how the geographic extent of shallow groundwater relates to agricultural impacts. To complete this analysis a typical distribution of crops grown over the valley could be overlaid on the groundwater model output, which is geographically referenced. This would allow more precise identification of seepage impact areas that may extend beyond those areas delineated by HDR (2003) based on visible indications of crop stress. Portions of the valley with specific problems could be targeted by stakeholders in the valley for remedial actions to address high groundwater levels and agricultural impacts. For example, drainage systems could be improved, crops or strains tolerant to shallow groundwater could be planted, or the area could be removed from production under a variety of habitat restoration programs (i.e. the Conservation Reserve Program or Wetlands Reserve Program through the U.S. Department of Agriculture; the Private Lands Restoration Program through the U.S. Department of Interior).

To be effective and sustainable, any strategy aimed at avoiding or minimizing the potential agricultural losses due to high groundwater levels must acknowledge and account for the important role of agriculture in the local economy. Site specific remedies will depend on the characteristics of the groundwater fluctuations, river conditions that are likely to occur over the foreseeable future, agricultural commodity market status, farm profitability, and limits of funding and authorization for pursuing remedial strategies.

The Corps would need specific authorization and funding from Congress in order to pursue and implement remedies for groundwater seepage in the Kootenai Valley. Until that happens, other local, state, federal, and non-governmental stakeholders may be better able to address the issues identified in this study report.

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Appendix A

Maps of Seepage Areas in the Kootenai Valley as Identified by Growers

(from HDR, 2003)

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Back of 11x17 color map, plate 15

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Back of 11x17 color map, plate 16

APPENDIX H

Hydrologic Analysis of Upper Columbia Alternative Operations, including VARQ Flood Control Plan, at Hungry Horse Dam, Montana

Hydrologic Analysis of Upper Columbia Alternative Operations, including the VARQ Flood Control Plan at Hungry Horse Dam, Montana

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Errata Sheet—
Upper Columbia Alternative Flood Control (VARQ) and Fish Operations EIS –
Hydrologic Analysis of Upper Columbia Alternative Operations, including the VARQ Flood Control Plan at Hungry Horse Dam, Montana

Nomenclature Corrections

The following should be used when reading the subject report. Alternatives are the convention for the sections of the EIS addressing the Pend Oreille River Basin.

Standard FC: corresponds to **Alternative HS** in the EIS

VARQ FC: corresponds to **Alternative HV** in the EIS

Table of Contents

Page H-

1.0 Overview 1
2.0 Hydrologic Analysis 1
2.1 Period of Record 1
2.2 Simulated Water Supply Forecasts 2
2.3 Modeling Methodology 2
2.3.1 Flood Control Drafts 3
2.3.2 Power Drafts 4
2.3.3 Minimum Releases 4
2.3.4 Refill 5
2.3.5 Local Flood Control 5
2.3.6 Flow Augmentation 6
2.3.7 Ramping Rates 6
2.4 Modeled Results 6
2.4.1 Effects at Hungry Horse Dam 6
2.4.1.1 Generation Limitations and Total Dissolved Gas 15
2.4.2 Local Flood Effects at Columbia Falls, Montana 18
2.4.3 Effects at Kerr Dam and Flathead Lake 20
2.4.4 Effects at Albeni Falls Dam and Pend Oreille Lake 26
2.4.4.1 Winter Target Elevation (2055.0 feet) 26
2.4.4.2 Winter Target Elevation (2051.0 feet) 32
3.0 Summary 37

List of Figures

Page H-

Figure 1. Vicinity Map including hungry Horse, Kerr, Albeni Falls, and Grand Coulee Dams 1
Figure 2. The Standard Flood Control Storage Reservation Diagram for Hungry Horse Dam 3
Figure 3. The VARQ Storage Reservation Diagram for Hungry Horse Dam 3
Figure 4. Simulated May 1 Hungry Horse Reservoir Elevations 7
Figure 5. Simulated Hungry Horse Reservoir Refill Percentages 7
Figure 6. Frequency Curves for Hungry Horse Reservoir, 1 Day Maximum Elevation 8
Figure 7. Average Monthly Hungry Horse Dam Discharges 9
Figure 8. Simulated Hungry Horse Discharge Duration Curves for April 10
Figure 9. Simulated Hungry Horse Discharge Duration Curves for May 11
Figure 10. Simulated Hungry Horse Discharge Duration Curves for June 11
Figure 11. Simulated Hungry Horse Discharge Duration Curves for July-August 13
Figure 12. Simulated Hungry Horse Winter Operations (Standard FC, 1996) 14
Figure 13. Simulated Hungry Horse Winter Operations (VARQ, 1996) 15
Figure 14. Hungry Horse Spill for Various Generation Restriction Scenarios 17

Figure 15. Hungry Horse Spill Duration Analysis (April-July) 18
Figure 16. Peak 1-Day Flow Frequency Curves for the Flathead River at Columbia Falls, Montana 20
Figure 17. Simulated Flathead Lake Refill Percentages.....22
Figure 18. Elevation Duration Analysis at Flathead Lake (June 15 – August 31) 23
Figure 19. Simulated Kerr Dam Average Monthly Discharges.....24
Figure 20. Peak 1-Day Flow Frequency Curves for the Flathead River below Kerr Dam 25
Figure 21. Elevation Duration Analysis at Pend Oreille Lake for July – August (winter target el. 2055 ft.).....27
Figure 22. Elevation Duration Analysis at Pend Oreille Lake for November 20 – March 31 (winter target el. 2055 ft.) 27
Figure 23. Simulated Albeni Falls Dam Average Monthly Discharges (winter target el. 2055 ft.).....28
Figure 24. Simulated Albeni Falls Discharge Duration Curves for March-April (winter target el. 2055 ft.).....29
Figure 25. Simulated Albeni Falls Discharge Duration Curves for May – June (winter target el. 2055 ft.).....30
Figure 26. Peak 1-Day Flow Frequency Curves for the Pend Oreille River below Albeni Falls Dam (winter target el. 2055 ft.).....31
Figure 27. Elevation Duration Analysis at Pend Oreille Lake for July – August (winter target el. 2051 ft.).....32
Figure 28. Elevation Duration Analysis at Pend Oreille Lake for November 20 – March 31 (winter target el. 2051 ft.) 32
Figure 29. Simulated Albeni Falls Dam Average Monthly Discharges (winter target el. 2051 ft.).....33
Figure 30. Simulated Albeni Falls Discharge Duration Curves for March-April (both winter target elevations of 2051.0 ft. and 2055.0 ft. are shown) 34
Figure 31. Simulated Albeni Falls Discharge Duration Curves for May – June (winter target el. 2051 ft.).....35
Figure 32. Peak 1-Day Flow Frequency Curves for the Pend Oreille River below Albeni Falls Dam (winter target el. 2051 ft.).....36

1.0 Overview

The VARQ flood control plan was first developed by the US Army Corps of Engineers (Corps) in the late 1980s. The current VARQ flood control plan has had some changes and refinements from the original plan but the basic logic is still the same: More water is held in storage at Hungry Horse Reservoir during the winter months in those years when local downstream flooding is not anticipated. This results in higher reservoir elevations and discharges during the spring refill period with associated benefits to resident and anadromous fish. The VARQ flood control plan was identified in both the US Fish and Wildlife Service's (USFW Biological Opinion) and National Marine Fisheries Service's (NMFS Biological Opinion) December 2000 Biological Opinions[1,2] as an action that should be taken for the benefit of bull trout in Hungry Horse Reservoir and anadromous fish downstream in the Columbia River.

2.0 Hydrologic Analysis

The hydrologic analysis compares the VARQ and standard flood control procedures (Standard FC) for Hungry Horse Reservoir, and describes the associated hydrologic effects downstream. Impacts to reservoir elevations, reservoir discharges, spill, and local flood control from Hungry Horse Reservoir downstream to Albeni Falls Dam were analyzed. Figure 1 shows a vicinity map of the affected area. This analysis simulates Hungry Horse operations under the two different flood control procedures using the hydrology during the period 1929-2002. RiverWare™, a general river basin modeling software tool, developed by CADSWES University of Colorado, Boulder, Colorado, was used to model the two different flood control procedures. The model operates at a daily timestep using limited foresight as to reflect the uncertainty associated with "real-time" operations. The model operates in a continuous mode, utilizing reservoir carry-over effects from the previous year rather than reinitializing every year. This method was used for every reservoir represented in the model (Hungry Horse, Flathead Lake, Pend Oreille Lake).

2.1 Period of Record

A 74 year record (1929-2002) was used in this study. Many significant floods (1954, 1964, 1974, and 1975) and drought years (1941, 1977, and 2001) have occurred during this period. This wide range of water supply conditions works well when comparing the two different flood control procedures and how they affect local flood control, spill potential, and refill.

[1] US Fish and Wildlife Service – Regions 1 and 6, "Biological Opinion – Effects to Listed Species from Operations of the Federal Columbia River Power System", December 20, 2000, p.84.
[2] National Marine Fisheries Service – Northwest Region, "Endangered Species Act – Section 7 Consultation, Biological Opinion - Reinitiation of Consultation on Operation of the Federal Columbia River Power System Including the Juvenile Fish Transportation Program, and 19 Bureau of Reclamation Projects in the Columbia Basin" December 21, 2000, pp. 9-63,9-64.

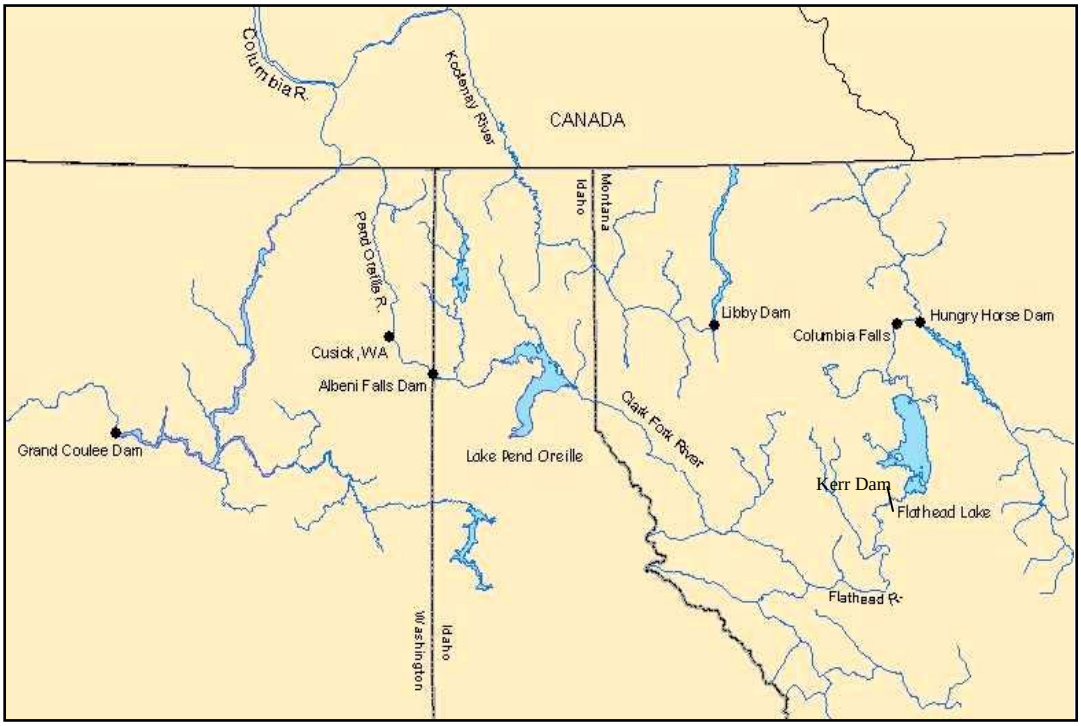

Figure 1: Vicinity Map including Hungry Horse, Kerr, Albeni Falls, and Grand Coulee Dams.

2.2 Simulated Water Supply Forecasts

Hydrologic studies and modeling efforts often require a complete set of historic forecasts in order to more accurately analyze a proposed change in operating procedures. The results of using inflow forecasts, rather than observed historic runoff, adds uncertainty about future conditions and more closely mimics real-time operations. Therefore water supply forecasts along with actual observed runoff were used in the model simulations. The U.S. Bureau of Reclamation (Reclamation) has developed a data set of monthly forecasts (January through June) for May-September inflow volume for the 1929 to 2002 period[3]. This dataset utilizes the current Reclamation forecast equation for the period 1944-2002, a modified Reclamation equation for 1932-1943, and borrows Kuehl-Moffitt forecasts for 1929-1931.

2.3 Modeling Methodology

Modeled Hungry Horse operations were dictated by a set of guidelines which set the appropriate release from the dam. These guidelines included flood control, variable draft limits for power (VDL curves), minimum flows at Hungry Horse and Columbia Falls, refill procedures, local flood control, flow augmentation, and ramping rates.

[3] "DEVELOPMENT OF MONTHLY INFLOW FORECASTS FOR HUNGRY HORSE RESERVOIR FOR THE PERIOD 1929-2002", Draft, prepared by Ted Day of the Bureau of Reclamation, PN Region, Boise, ID, March 2003

2.3.1 Flood Control Drafts

Flood control elevations were calculated using the monthly inflow (May-September) forecasts and the respective storage reservation diagrams (Figures 2 and 3). Flood control storage reservation diagrams are graphs used to determine the amount of flood control space necessary to capture anticipated spring runoff.

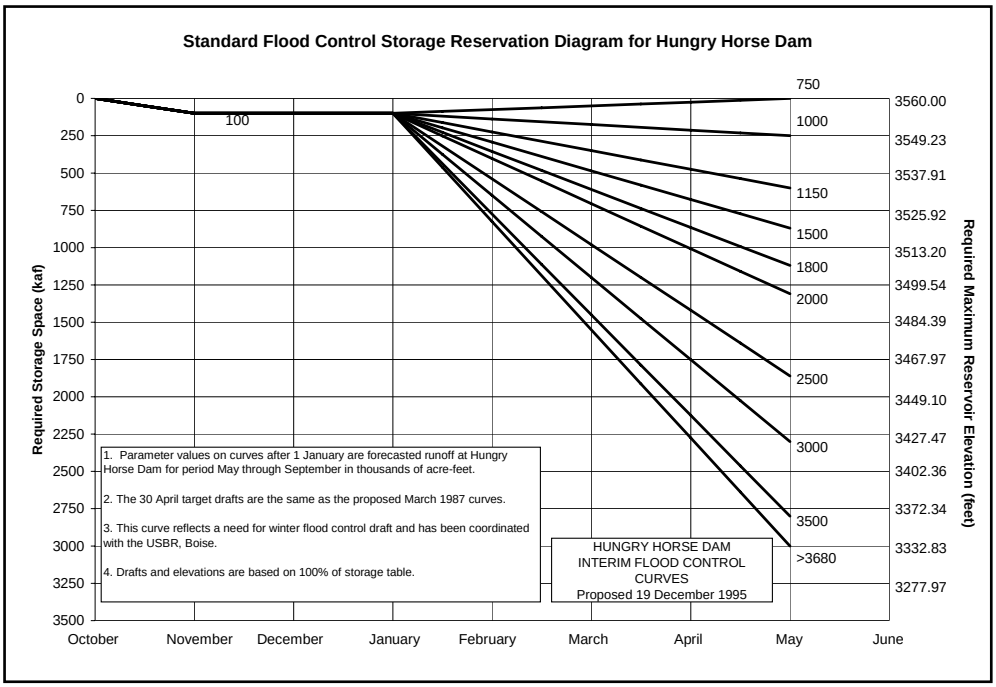

Figure 2: The Standard Flood Control Storage Reservation Diagram for Hungry Horse Dam

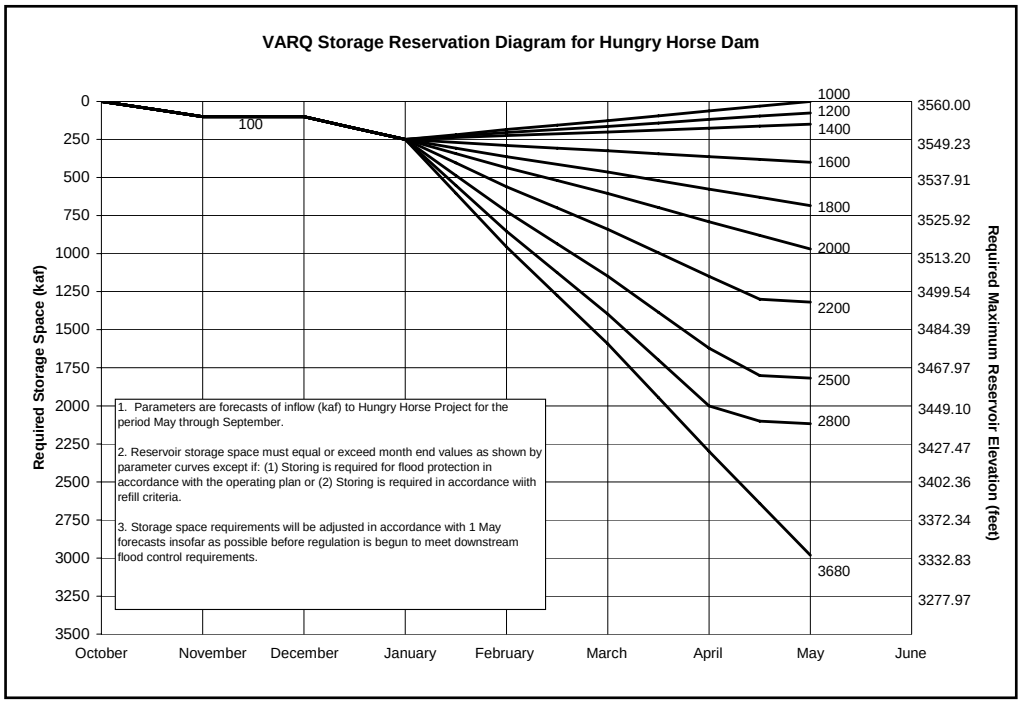

Figure 3: The VARQ Storage Reservation Diagram for Hungry Horse Dam

On January 1 of every year, the flood control space requirement is slightly greater with VARQ at 250,000 acre-ft as compared to 100,000 acre-ft for Standard FC. In 1997 Reclamation requested the Corps to increase the winter space requirement at Hungry Horse from 100,000 acre-ft to 250,000 acre-ft as an addition to the VARQ rule curves. The 250,000 acre-ft space requirement would not only provide more protection against winter rain events but it would also provide a smoother transition from minimum flows to winter flood control releases in wetter years. During most years, Hungry Horse is already drafted below the 250,000 acre-ft requirement by January 1. The 20 foot draft for anadromous fish in the summer along with the minimum flow requirement at Columbia falls usually result in Hungry Horse Reservoir having more space than 250,000 acre-ft on January 1. During the winter drawdown period (January through April), in years when flooding is not anticipated, the VARQ flood control plan allows Hungry Horse Reservoir to be more full than Standard FC. In years with high runoff conditions, VARQ will require drafting Hungry Horse to the same elevation by the end of April as was required by Standard FC. Because the reservoir is generally fuller during the winter with VARQ flood control, there is less space to fill which results in higher reservoir releases during the spring refill period and better assurance of refill. The calculated flood control elevations acted as an upper limit in which to operate the reservoir.

In order to accurately simulate real time operations, flood control releases were limited to maximum turbine discharge (around 12,000 cfs) plus 2000 cfs during the month of April. The assumption was that spill of less than 15% of the total discharge (around 2000 cfs at full power plant capacity) would not violate the Montana state water quality standard of 110% for total dissolved gases. As a result the May 1 reservoir elevations are above the flood control rule curves in some years.

2.3.2 Power Drafts

Variable draft limit (VDL) elevations were also calculated using the forecasts and flood control elevations. The VDL curves act as a lower operating limit; these curves allow reservoir drafts for power while still maintaining a 75% probability of reaching April 10 flood control elevations. These power drafts in the winter actually alleviated some of the large April flood control drafts in high volume runoff years by pre-drafting the reservoir. VDL curves are in effect from January 1 until April 10. After April 10, VDL curves are the same as the flood control rule curves.

2.3.3 Minimum Releases

Minimum releases set at Hungry Horse were determined by either the flow requirement below Hungry Horse or the flow requirement at Columbia Falls depending on whichever one was greater. The minimum flows were calculated using the Hungry Horse inflow forecast and guidelines as set forth in the USFW Biological Opinion. The minimum flows at Hungry Horse and Columbia Falls are updated every month between January and March, after the final inflow volume forecast for the month is issued. The March final forecast sets the minimum flows for the rest of the calendar year. Table 1 shows how these minimum flows are calculated.

Table 1: Minimum Flows at Hungry Horse and Columbia Falls

April – August inflow forecast (kaf)	Hungry Horse min flow (cfs)	Columbia Falls min flow (cfs)
< 1190	400	3200
1790 > forecast > 1190	Interpolate between 400 and 900	Interpolate between 3200 and 3500
> 1790	900	3500

2.3.4 Refill

Refill at Hungry Horse was initiated approximately ten days prior to when streamflow forecasts of unregulated flow were projected to exceed the Initial Control Flow (ICF) at The Dalles, Oregon. For Standard FC, Hungry Horse discharges (May-June) were calculated using forecasted inflow volumes, targeting refill by the end of June, and using a constant release. For VARQ flood control, Hungry Horse discharges (May-June) were calculated using the VARQ operating procedure[4]. This procedure follows a series of rules to set the VARQ outflow at Hungry Horse. These Rules, with the exception of Rule 6, were followed in every year of the VARQ simulation. Rule 6. Inflows Less Than VARQ Outflows states "At the initiation of refill, if inflows are less than the VARQ outflow, pass inflow until inflows rise to the VARQ level. Thereafter, if inflows drop below the VARQ outflow, pass inflow until they rise again to the VARQ level." For the VARQ simulations it was decided to continue to draft Hungry Horse Reservoir by using the calculated VARQ outflow and not hold the reservoir steady by passing inflow. Filling transition curves were used to adjust and set Hungry Horse discharges for final refill. Identical filling transition curves were used for both Standard FC and VARQ. The filling transition curves used reservoir elevations and forecasted (4 days) average daily inflow to set the outflow.

2.3.5 Local Flood Control

Discharges at Hungry Horse were limited to maintain the stage at Columbia Falls below 13 feet (~44,500 cfs). Flood stage at Columbia Falls is at 14 feet (~51,500 cfs), but there is some minor localized flooding above 13 feet. Hungry Horse releases were decreased to 300 cfs when required for local flood control. The absolute minimum flow for Hungry Horse is 145 cfs. However, to maintain power system reliability, Reclamation attempts to keep two units running at speed no-load (~300 cfs). When the elevation at Hungry Horse Reservoir reached 3555 feet, the local flood control requirement at Hungry Horse (i.e. discharges at 300 cfs) was relaxed in order to prevent the reservoir from filling too early. However, Hungry Horse Reservoir was allowed to fill to 3561 feet (1 foot of surcharge) whenever practical to limit flooding at Columbia Falls. Hungry Horse filled above elevation 3560 feet 3 out of 74 years for the VARQ simulation and 2 out of 74 years for the Standard FC simulation.

[4] U.S. Army Corps of Engineers, Northwestern Division, North Pacific Region, Portland, Oregon, "VARQ Operating Procedures for Hungry Horse Dam", February 2001. Appendix A

2.3.6 Flow Augmentation

Modeled flow augmentation from Hungry Horse Reservoir was in accordance with the NMFS Biological Opinion Action 19, which states: " The Action Agencies shall limit the reservoir draft to elevation 3,540 feet by August 31 for salmon flow augmentation". Reservoir elevation 3,540 feet was targeted on August 31 of every year in the simulation model runs.

2.3.7 Ramping Rates

Changes in Hungry Horse discharges were limited by ramping rates as set forth in the USFW Biological Opinion. These ramping rates are based on flows in the Flathead River at Columbia Falls. Table 2 shows the ramp-up and ramp-down rates for Hungry Horse discharges.

Table 2: Daily ramp-up and ramp-down rates for Hungry Horse Dam

Flow Range (cfs, measured at Columbia Falls)	Ramp Up Rate, Daily Max (cfs)	Ramp Down Rate, Daily Max (cfs)
3,500 - 6000	1,800	600
> 6,000 - 8,000	1,800	1,000
> 8,000 - 10,000	3,600	2,000
> 10,000 - 12,000	No Limit	2,000
> 12,000	No Limit	5,000

2.4 Modeled Results

The output from the Standard FC and VARQ model simulations was analyzed to determine any effects on flows and reservoir elevations from Hungry Horse Reservoir downstream to the Pend Oreille River below Albeni Falls Dam.

2.4.1 Effects at Hungry Horse Dam

The VARQ and Standard FC model simulations reflect operations that are driven by spring flood control operations, year-round minimum flow targets, summer flow augmentation releases, and winter flood control and power drafts. Hungry Horse pool elevations and discharges are frequently different between the two flood control procedures, especially in the winter and spring when flood control drafts have the greatest influence on operations. In most years of the simulations and particularly in years with an inflow forecast (May-Sep) of less than 2.4 million acre-feet (maf), reservoir elevations were higher on May 1 under VARQ Flood Control then with Standard FC. This is in large part due to the deeper flood control draft requirements of Standard FC for these years. For years with an inflow forecast (May-Sep) greater than 2.4 maf, flood control requirements for May 1 are similar for both Standard FC and VARQ. Figure 4 compares the May 1 reservoir elevation for Standard FC and VARQ as related to the seasonal volume forecast.

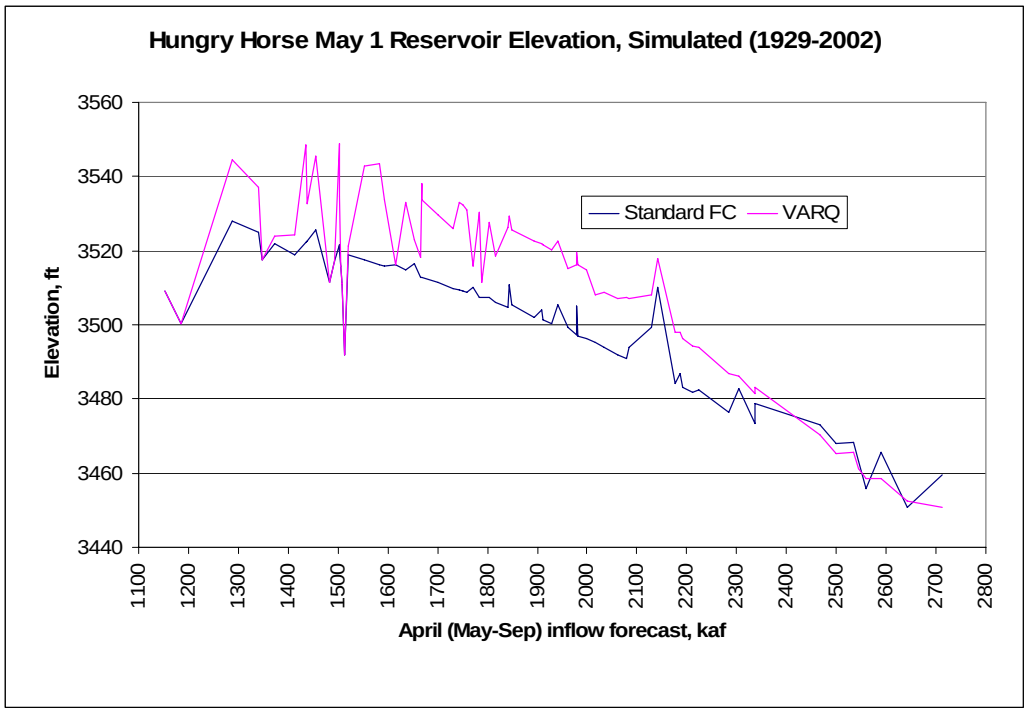

Figure 4: Simulated May 1 Hungry Horse Reservoir Elevations.

The higher May 1 reservoir elevations resulted in slightly better refill probabilities for VARQ. Figure 5 shows the percentage of years that Hungry Horse refilled to within a specified distance from full for both Standard FC and VARQ. The reservoir refilled to within 1 foot from full in 64.9% of all years for VARQ and 62.2% of all years for Standard FC.

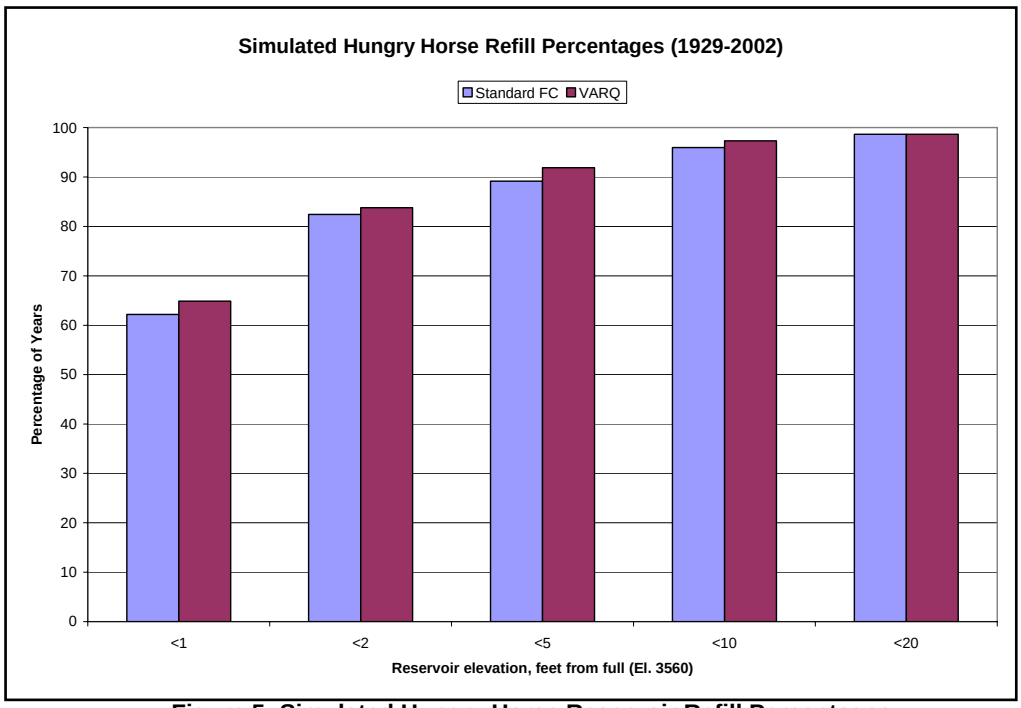

Figure 5: Simulated Hungry Horse Reservoir Refill Percentages.

Figure 6 compares the peak daily elevation reached during the summer refill period (June/July) for both Standard FC and VARQ. Figure 6 reaffirms the slightly higher probability of refill for VARQ.

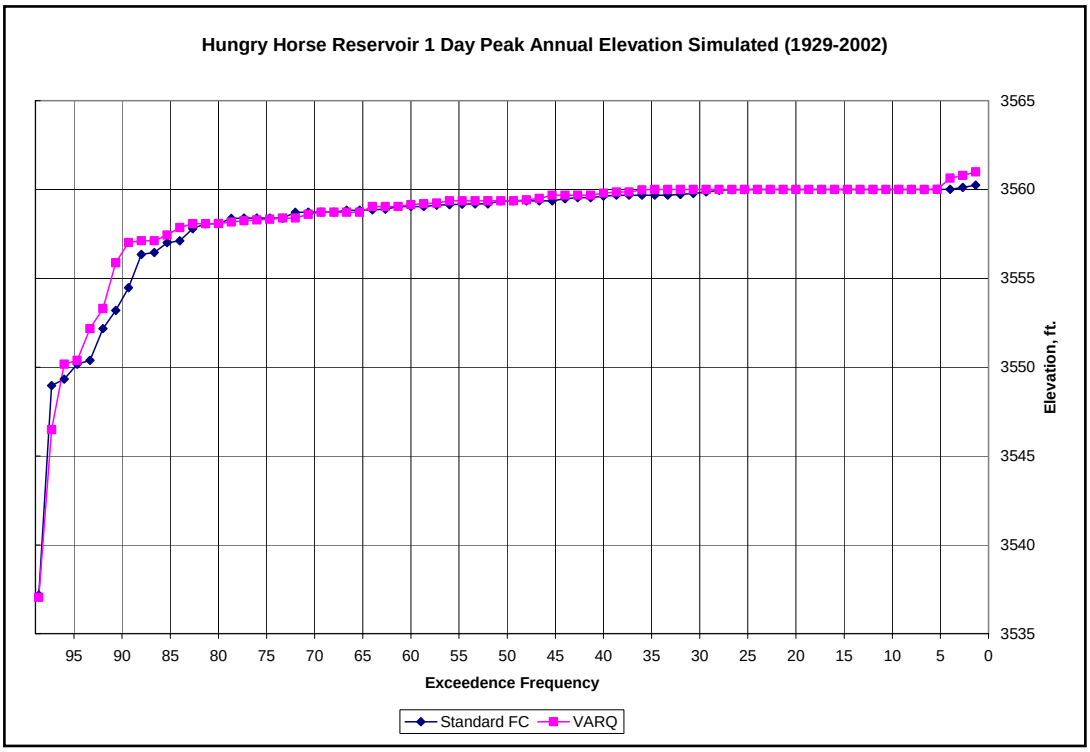

Figure 6: Frequency Curves for Hungry Horse Reservoir, 1 Day Maximum Elevation.

The generally higher May 1 elevations for VARQ also resulted in higher discharges from Hungry Horse in May and June than with Standard FC. Conversely, the deeper drafts that are required for Standard FC in April result in higher discharges for that month than under Standard FC. Larger space requirements, during the winter (January, February), also resulted in higher discharges for Standard FC during those months. Figure 7 compares average monthly discharges for Standard FC and VARQ.

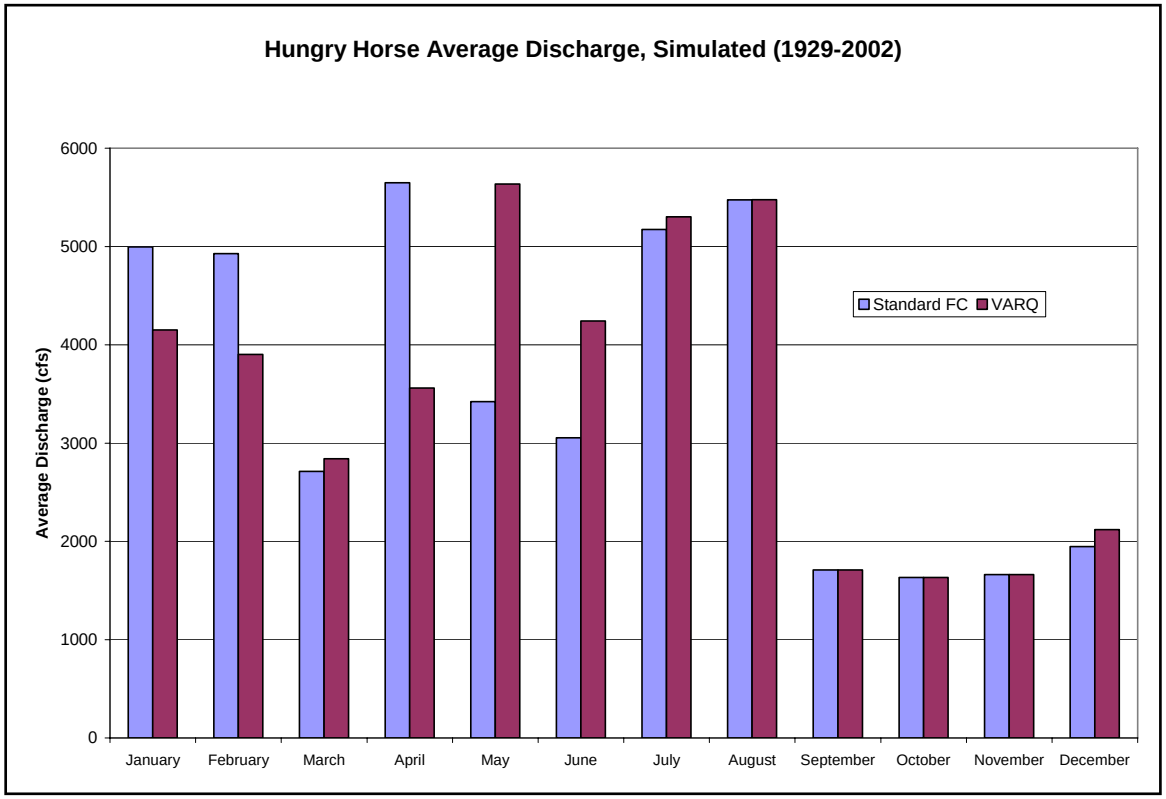

Figure 7: Average Monthly Hungry Horse Dam Discharges.

Figure 7 shows that average discharges are slightly higher for VARQ in December. Increased discharges occurred in years with high fall inflows when Hungry Horse was making releases in December for flood control. Hungry Horse releases in these years were higher under VARQ than Standard FC because of the larger end-of-December space requirement for VARQ (250 kaf vs.100 kaf). In most years, discharges during December reflect the minimum flow requirement for Columbia Falls, which is identical for both VARQ and Standard FC. Table 3 shows the years with increased December discharges for VARQ and the volume difference between VARQ and Standard FC.

Table 3: Years with Increased Hungry Horse Discharges in December for VARQ.

Years	Hungry Horse Discharge Volume Difference between VARQ and Standard FC, December (acre-feet)
1933	145,000
1959	145,000
1968	81,000
1985	122,000
1989	145,000
1995	145,000

In some cases, a change in the volume forecast combined with significant snowmelt runoff required discharges to be at power plant capacity or higher for most of April. Flood control releases were limited to maximum turbine discharge (around 12,000 cfs)

plus 2000 cfs whenever possible. Figure 8 shows the duration curves for Hungry Horse discharges for April. April discharges are much higher under Standard FC. The higher discharges of VARQ are evident in the flow duration curves for May and June as shown in Figures 9 and 10.

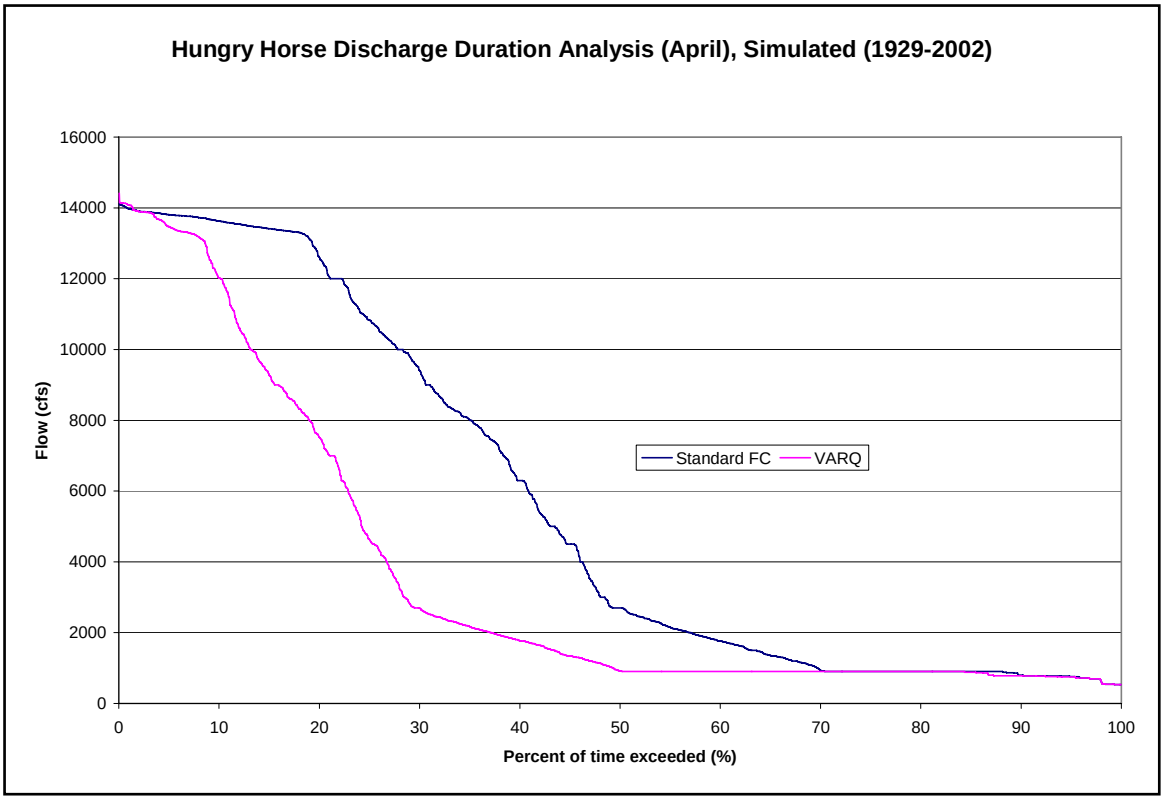

Figure 8: Simulated Hungry Horse Discharge Duration Curves for April.

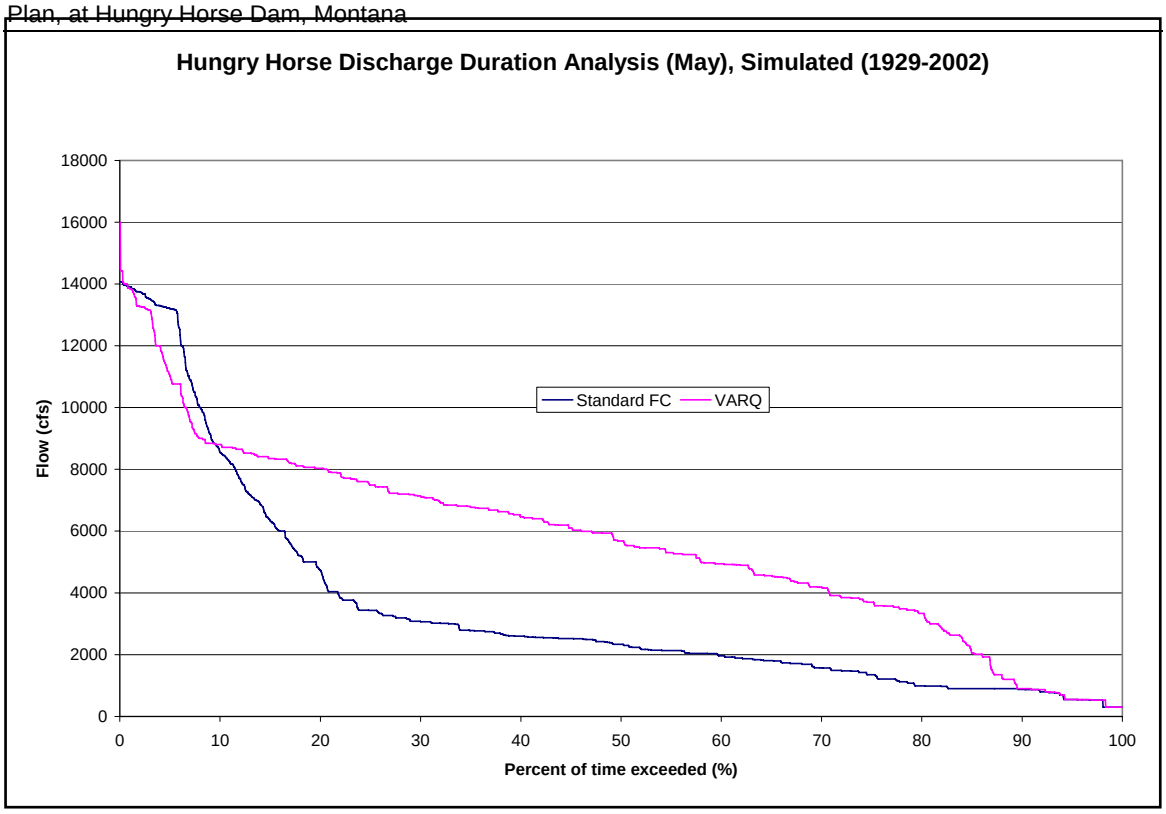

Figure 9: Simulated Hungry Horse Discharge Duration Curves for May.

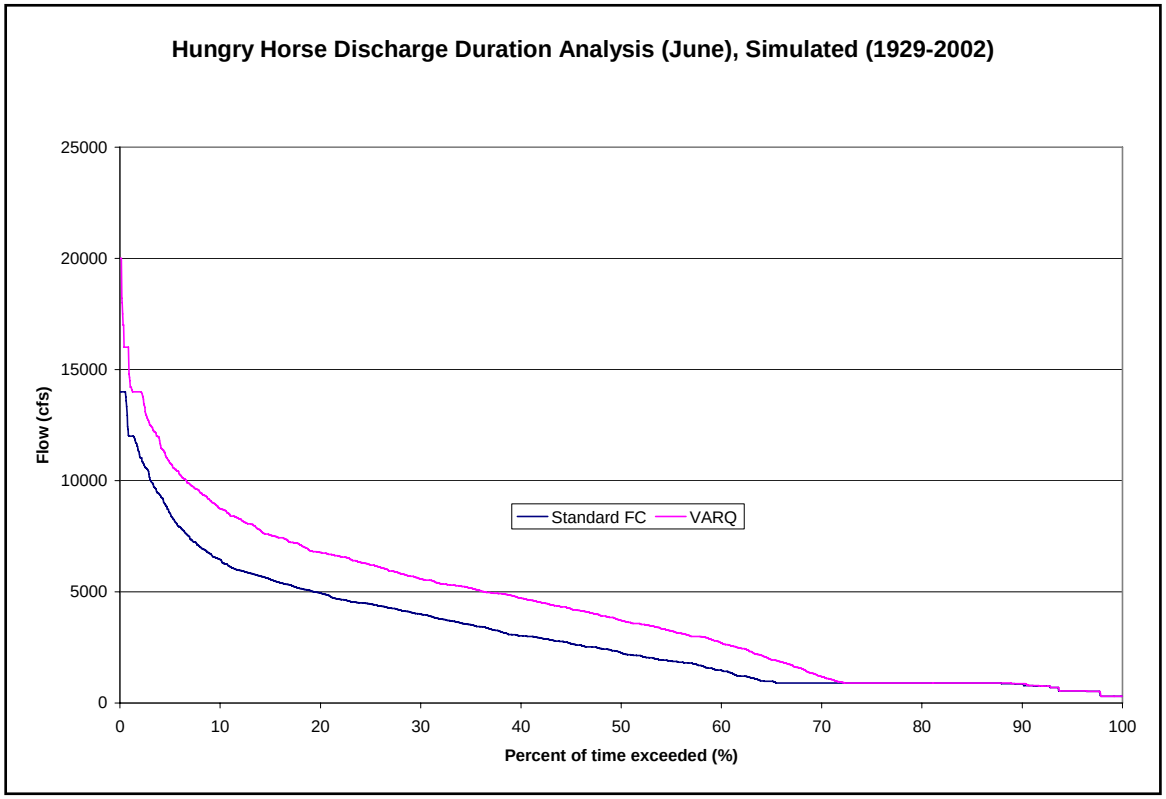

Figure 10: Simulated Hungry Horse Discharge Duration Curves for June.

Simulated Hungry Horse discharges in April were guided by the assumption that spill of less than 15% of the total discharge (around 2000 cfs at full power plant capacity) would not violate the Montana state water quality standard of 110% for total dissolved gases. Spill above 15% of the total discharge was not allowed in April. Limiting discharges to power plant capacity plus 2000 cfs in April caused May 1 reservoir elevations to exceed May 1 flood control requirements in some years (Table 4). Simulated May 1 elevations were above May 1 flood control elevations in 27 of 74 years for Standard FC and 16 of 74 years for VARQ. Years where simulated May 1 elevations are above flood control requirements are shown as positive values. Drier years, which resulted in reservoir elevations being below the VARQ flood control requirement, are shown as negative values.

Table 4: Differences between Hungry Horse May 1 flood control elevations and May 1 simulated elevations due to limiting releases to power plant capacity plus 2000 cfs in April.

Year	Amount that simulated May 1 reservoir elevation is higher than May 1 flood control requirement (ft)	
	Standard FC	VARQ
1930	+3	-16
1933	+3	+1
1934	+23	+16
1936	+2	-15
1939	+6	+3
1943	+12	+5
1946	+3	0
1947	+6	+2
1949	+1	-3
1950	+6	+1
1951	+2	+1
1952	+8	+3
1955	+1	-7
1956	+8	+1
1957	+1	-1
1959	+12	+2
1965	+10	+3
1971	+8	+2
1974	+11	+5
1980	+1	-25
1981	+2	+1
1987	+4	-5
1989	+6	+4
1990	+3	0
1991	+1	0
1997	+14	+4
2000	+1	0
Number of Years above Flood Control	**27**	**16**

For the purpose of this study, the term “spill” is designated for any release that is not used for generation. At Hungry Horse, spill can be discharged via the spillway, outlet works, or the turbines under speed no-load conditions. For example, if the maximum generation

capacity was 12,000 cfs and the total release was 15,000, then 3,000 cfs would be spill. Because it generates very high dissolved gas levels, spillway use is avoided whenever possible. Up to 13,680 cfs can be spilled through the outlet works at elevation 3560.0 ft. before it becomes necessary to use the spillway. Use of the spillway was not necessary under the Standard FC or VARQ simulations (1929-2002). For comparison purposes, only the days that spill exceeded 15% of the total release were considered. Past experience and observations show that spill that is under 15% of the total release ensures that the Montana State standard of 110% total dissolved gas saturation is not exceeded and recognizes that minor spills can occur without significant impacts. Spill that exceeded 15% of the total release did not occur under Standard FC and occurred for only 20 days in the 74 years examined under VARQ. The spill that occurred under VARQ was during the month May (1 day on May 31) in 1948 and during June in 1933, 1948, and 1961. These spill calculations were based on the assumption that all four generating units were available and that there were no power generation restrictions.

Hungry Horse discharges during the summer (July and August) are controlled primarily by flow augmentation for ESA listed mainstem Columbia River salmon. Inflows and the maximum volume of water available in the reservoir above elevation 3540 feet is used to compute July and August releases. Figure 11 is a duration analysis for Hungry Horse discharges (July-August). Note the similarities between Standard FC and VARQ; this is due to the comparable refill elevations between the simulations.

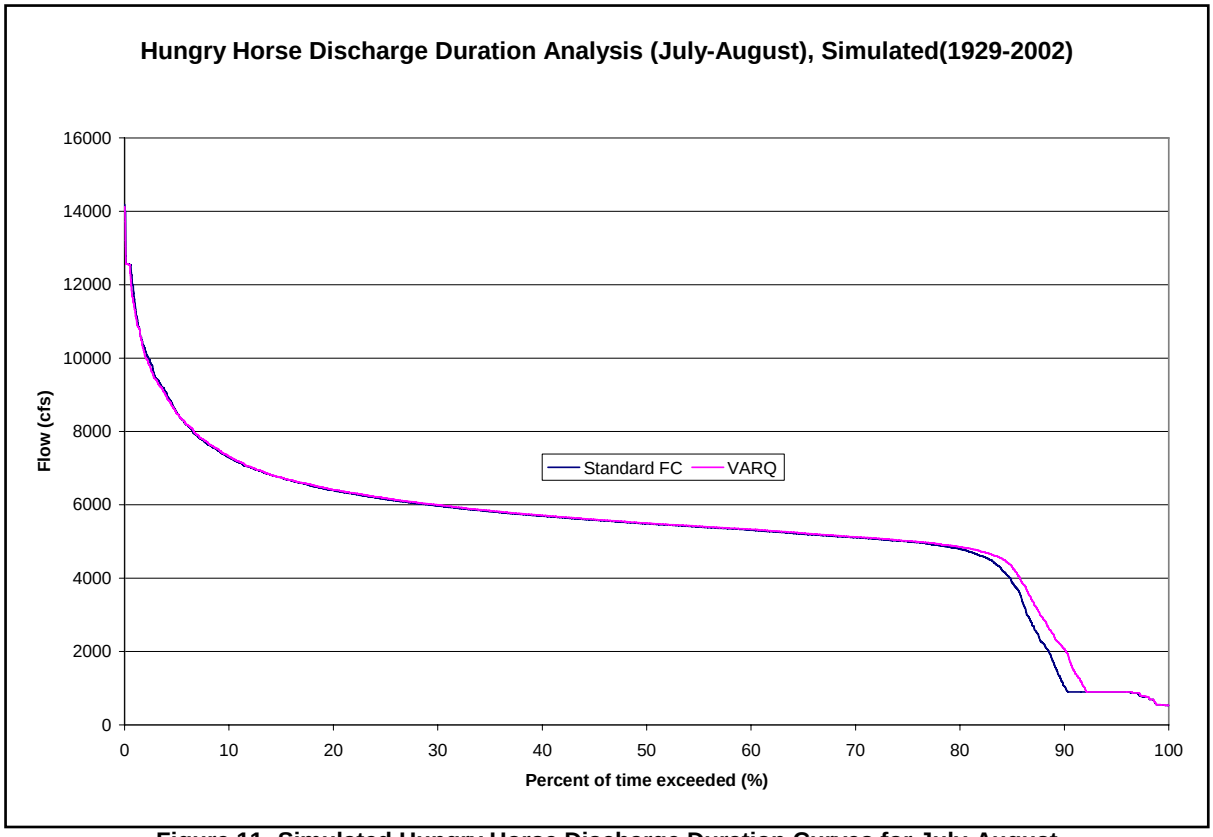

Figure 11: Simulated Hungry Horse Discharge Duration Curves for July-August

Hungry Horse discharges during the fall are generally controlled by minimum flow targets which are identical for both flood control procedures. An exception is in those rare years of high fall inflows when releases need to be made in December for flood control. Releases for power can occur in the winter (January-March) and are controlled by the VDL curves. These curves allow reservoir drafts for power while still maintaining a 75% probability of reaching April 10 flood control elevations. Figures 12 and 13 show examples of power releases which occurred in 1996 in the Standard FC and VARQ simulations. Note that even though power releases draft the reservoir below the rule curve, the reservoir is at its flood control elevation by April 10.

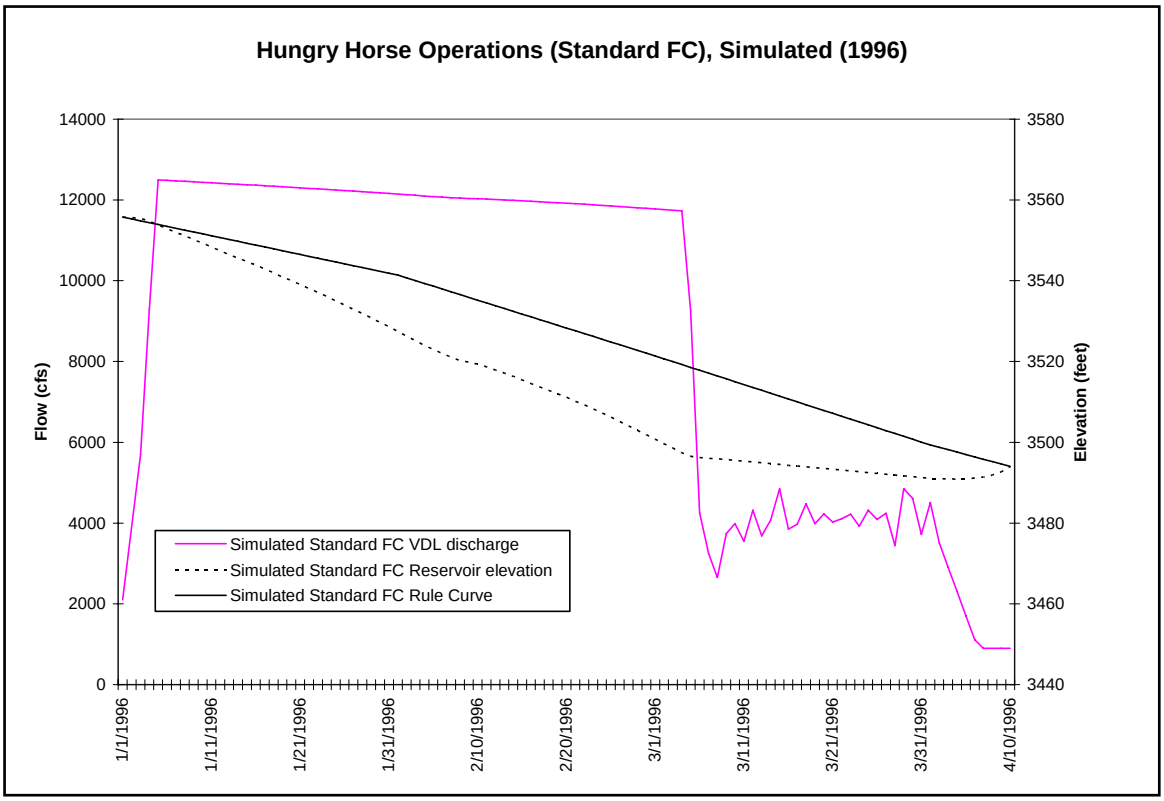

Figure 12: Simulated Hungry Horse Winter Operations (Standard FC, 1996)

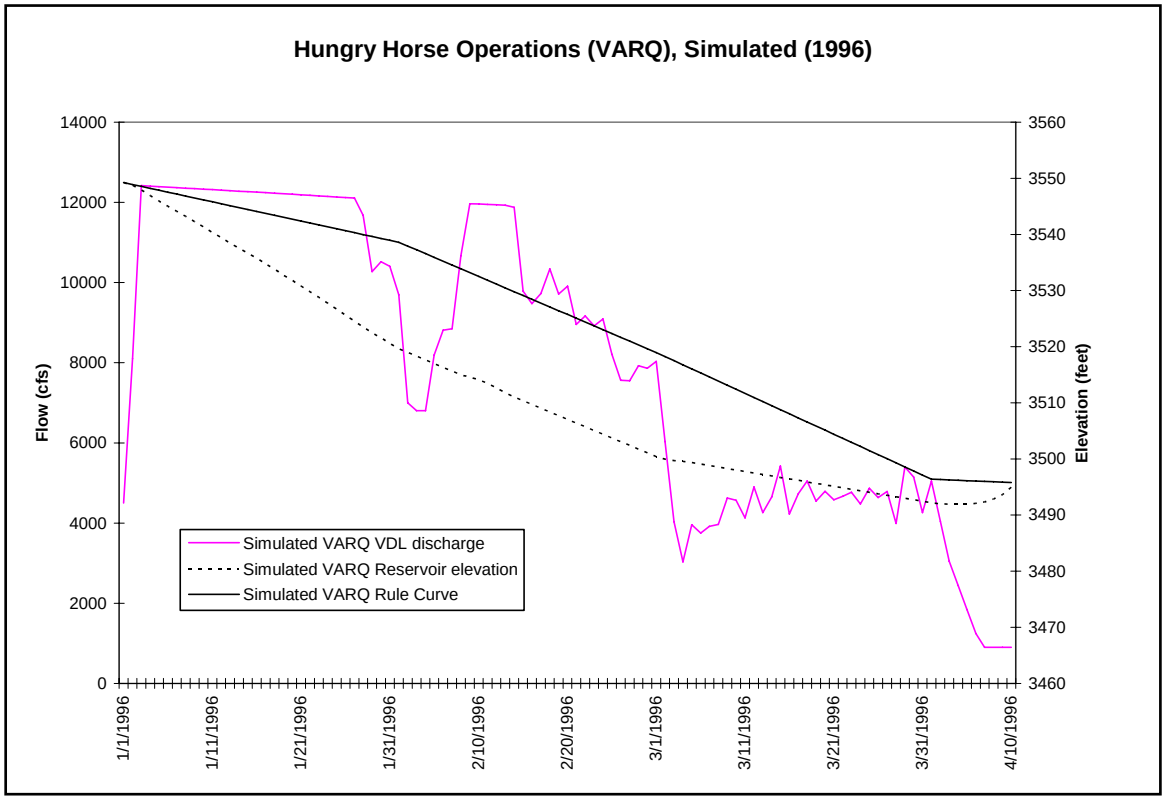

Figure 13: Simulated Hungry Horse Winter Operations (VARQ, 1996)

2.4.1.1 Generation Limitations and Total Dissolved Gas

In recent years, there has been a transmission restriction in Western Montana which has limited combined generation at Libby and Hungry Horse Dams to 900 MW. Current generation capacity is 600 MW for Libby and 428 MW for Hungry Horse for a total of 1028 MW. This transmission restriction is due in large part to the shut down of the aluminum plant at Columbia Falls, Montana (CFAC). At full operation, CFAC load is around 375 MW which is the majority of potential Hungry Horse generation. Without CFAC's load, the majority of Hungry Horse generation needs to be transmitted out of the Flathead Valley. By the summer of 2005, the limit will be raised from 900 MW to at least 944 MW due to transmission system reinforcements (Grand Coulee-Bell Project completed). Even with this increase in transmission capacity, there will still be limitations which will prevent Libby and Hungry Horse from generating at full capacity at the same time. The end result being that there could be increased releases spilled past the power plant in order to meet necessary flood control and VARQ specified releases.

Another possible generation limitation at Hungry Horse is not having four units available for generation. There are times during the year when only three units are available for generation at Hungry Horse. The fourth unit may be down for scheduled maintenance or for repair. Whatever the reason, not having four units available for generation limits total generation to a maximum of around 321 MW which may have implications on spill if required releases are above turbine capacity. It should be noted that any scheduled

maintenance tries to take into account any immediate or near future needs for the fourth unit in order to avoid spilling past the power plant.

In order to quantify the impact of these generation restrictions, two different scenarios were analyzed. In both scenarios, Hungry Horse discharges in the VARQ and Standard FC simulations were analyzed to see how much additional spill past the power plant would be required in order not to violate the generation restrictions. The scenarios examined the impact of the 944 MW Libby/Hungry Horse combined generation limitation with either four or three units available at Hungry Horse. For these scenarios, Libby elevations and discharges were obtained from the EIS modeling performed by the Corps[5]. Analysis of transmission limitations was done over the period of record of 1948-1999 because that is the time period for which the Corps simulated Libby operations. Libby generation and resultant Hungry Horse maximum generation were derived from this data.

Both scenarios were compared to the VARQ and Standard FC base case simulations (no generation restrictions). Since Hungry Horse discharges were not altered for the generation restriction scenarios, the only impact to be analyzed was spill. Figure 14 shows the total number of days that 15% spill was exceeded in a 52-year record (1948-1999) for all of the scenarios. The analysis shows only minor effects for the base case and 944 MW limit/4 unit scenarios. The largest impacts are for the three unit scenarios with spill exceeding 15% of the total release for 450 days in 34 years for VARQ and 670 days in 43 years for Standard FC. Again, the 3-unit scenario assumes only unscheduled outages. It should also be noted that in Figure 14, for the VARQ base simulation, spill occurred for 13 days in 2years. This statistic is for the period of record 1948-1999. For the period of record 1929-2002, spill occurred for 20 days in 3 years.

[5] U.S. Army Corps of Engineers, Seattle District, "Hydrologic Analysis of Upper Columbia Alternative Operations: Local Effects of Alternatives Flood Control and Fish Operations at Libby Dam, " June 2004.

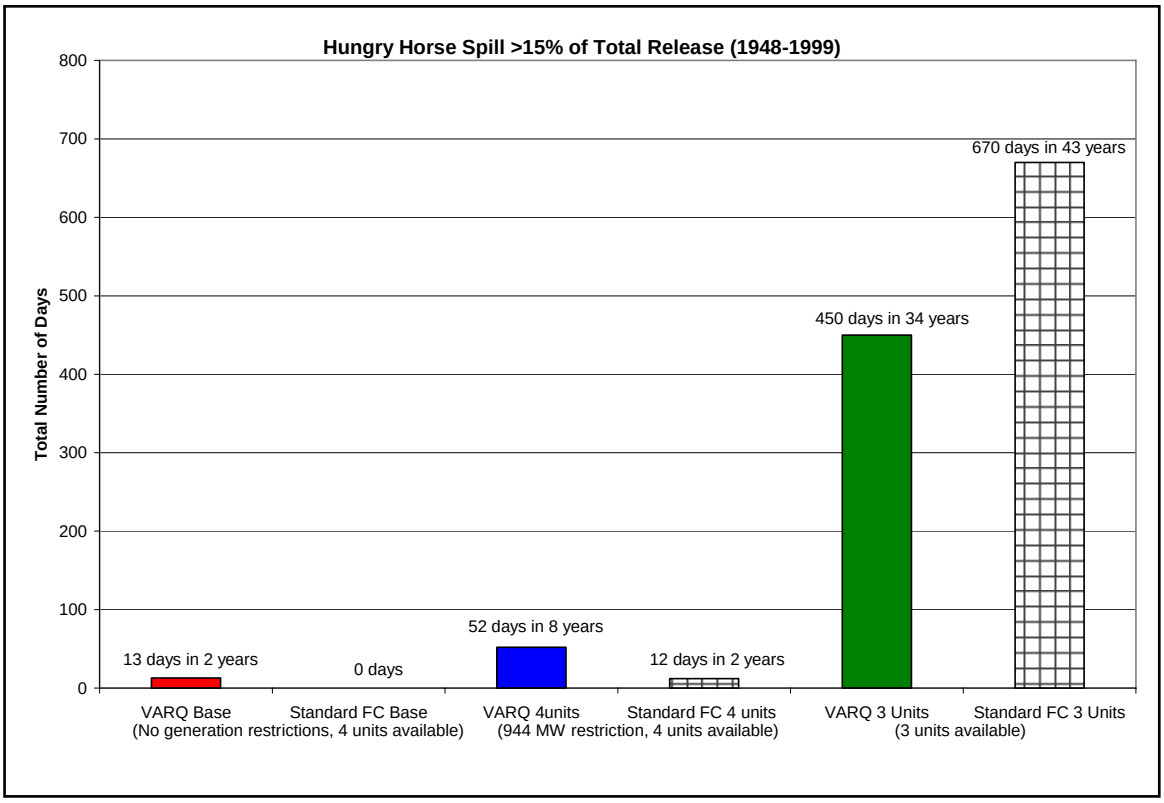

Figure 14: Hungry Horse spill for various generation restriction scenarios.

Figure 15 is a duration analysis for Hungry Horse spill (April-July) for all of the generation restriction scenarios. Once again the largest spill impacts are for the three unit scenarios, with spill exceeding 15% of the total discharge about 7 percent of the time for VARQ and 11 percent of the time for Standard FC. Also shown in Figure 15 is inset A which is a chart showing a relationship between % spill vs. % total dissolved gas saturation. Under some circumstances, high levels of total dissolved gas saturation may be harmful or lethal to fish and other aquatic organisms. This correlation used % spill and % total dissolved gas saturation that was observed in the South Fork of the Flathead River on nine different days in the winter-spring of 1996 and 1997 and in the summer of 2002. Future observations will provide more data to refine this correlation. Note that this correlation shows that spill could be as much as 20% before exceeding 110% total dissolved gases. In practice, Reclamation tries to limit Hungry Horse spill to 15% to ensure that total dissolved gas saturation is below the state of Montana's dissolved gas standard. Inset A shows that spill of 15% corresponds to around 108% total dissolved gas saturation.

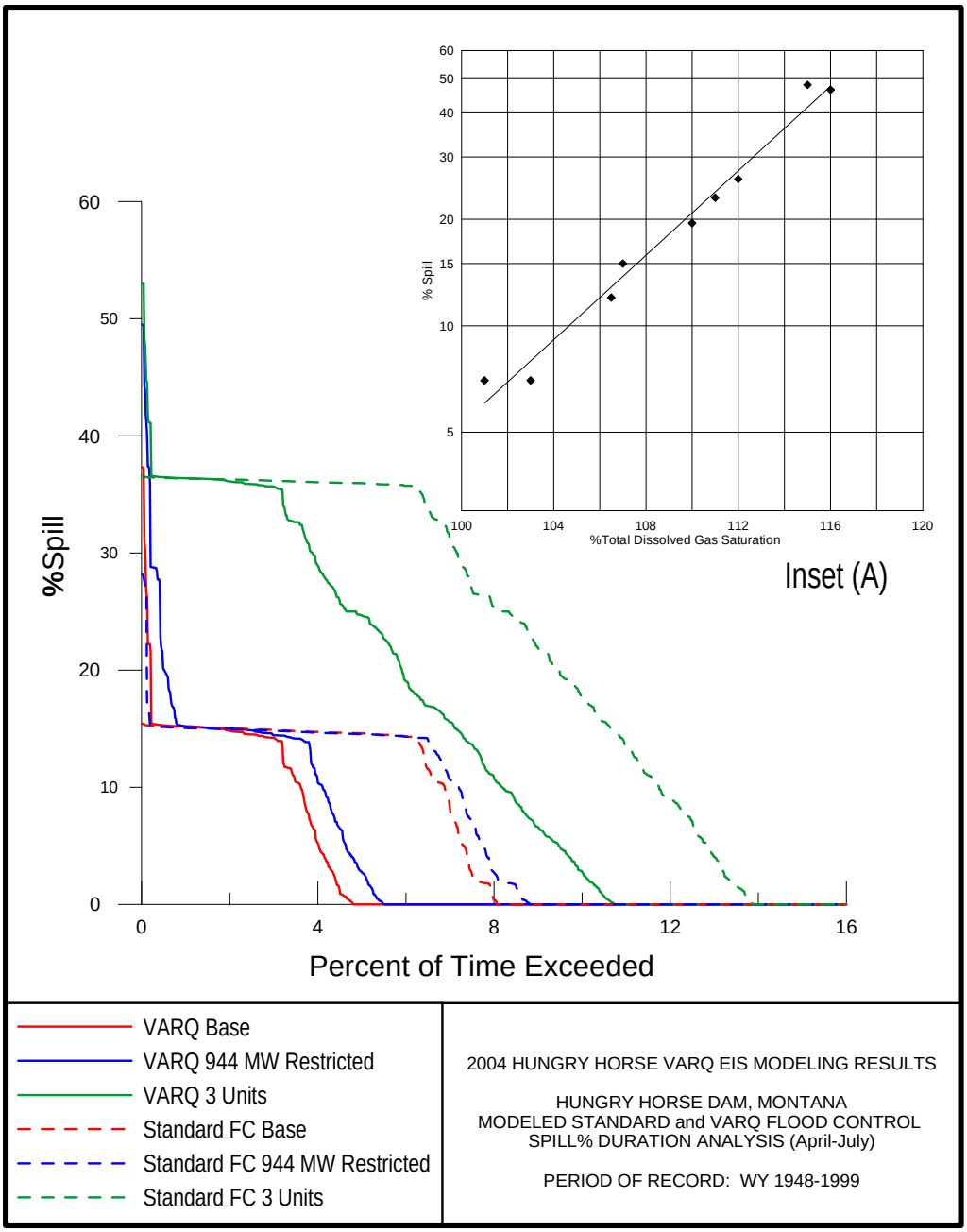

Figure 15: Hungry Horse spill duration analysis (April-July).

2.4.2 Local Flood Effects at Columbia Falls, Montana

Hungry Horse Dam is operated under Section 7 of the Flood Control Act of 1944 by the Bureau of Reclamation for flood control, in coordination with the U.S. Army Corps of Engineers. The reservoir provides flood regulation which locally benefits the flood plain from Columbia Falls to Flathead Lake and downstream to Lake Pend Oreille and Albeni Falls Dam. In addition to local flood control, Hungry Horse Reservoir provides approximately 5% of the total flood storage in the Columbia River basin for system flood control.

Columbia Falls, Montana is downstream of the confluence of the North, South, and Middle Forks of the Flathead River. Only Hungry Horse Dam on the South Fork provides flood protection. Flood stage at Columbia Falls is at 14 feet (~51,500 cfs), but there is some minor localized flooding above 13 feet (~44,500 cfs). For the Standard FC and VARQ simulations, Hungry Horse releases were decreased to 300 cfs whenever the stage at Columbia Falls exceeded 13 feet. Historically, Columbia Falls will exceed flood stage about one year in five with Hungry Horse at minimum flow. The peak 1-day flow frequency analysis for the Flathead River at Columbia Falls for the Standard FC and VARQ simulations is shown in Figure 16. A summary of the frequency analysis is shown in Table 5. Note that there is no difference in the probability of exceeding flood stage between the simulations. The stage at Columbia Falls exceeded 14 feet for a total of 35 days in 14 years for both VARQ and Standard FC. Below flood stage, flows are slightly higher for VARQ. The flow frequency analysis covers the simulation period of record (1929-2002) excluding 1964. 1964 is considered an extreme outlier event which has been assigned an exceedance probability of 0.05% based on an analysis discussed in a Memorandum for Record[6] written by the Corps in 1979. The plotting position for the 1964 flood (0.05%) is included as a separate point in the plot. There is no difference between the simulations for this event since Hungry Horse Reservoir contained the South Fork's flows and was releasing only 300 cfs for both VARQ and Standard FC at the time of the flood.

Table 5: Peak 1-day flow frequency analysis for the Flathead River at Columbia Falls[7].

Exceedance Frequency (%)[a]	Flow (cfs)		Stage (ft)		Flow Difference (cfs)	Stage Difference (ft)
	Standard FC	VARQ	Standard FC	VARQ		
1	71,800	71,800	16.5	16.5	0	0.0
2	68,600	68,600	16.1	16.1	0	0.0
5	61,800	61,800	15.3	15.3	0	0.0
10	56,900	56,900	14.7	14.7	0	0.0
18	**51,500**	**51,500**	**14.0**	**14.0**	**0**	**0.0**
20	48,800	50,200	13.6	13.8	1,400	0.2
30	44,600	44,800	13.0	13.0	200	0.0
40	44,600	44,600	13.0	13.0	0	0.0
50	43,600	44,600	12.8	13.0	1,000	0.1
70	38,500	42,100	12.1	12.6	3,600	0.6
90	28,000	29,700	10.2	10.6	1,700	0.3
99	16,600	16,600	7.8	7.8	0	0.0

[a] Probability of exceeding a given flow or stage in any given year

[6] Memorandum for Record, U.S. Army Corps of Engineers, Chief, Hydrology & Hydraulics Branch, Seattle District, Seattle, Washington, "Flood-Frequency Determination for the Flathead River at Columbia Falls, Montana – Joint Memo for Agreement Between U.S. Geological Survey and U.S. Army Corps of Engineers", September 1979.

[7] Flows based on U.S. Geological Survey rating table as of August, 2002.

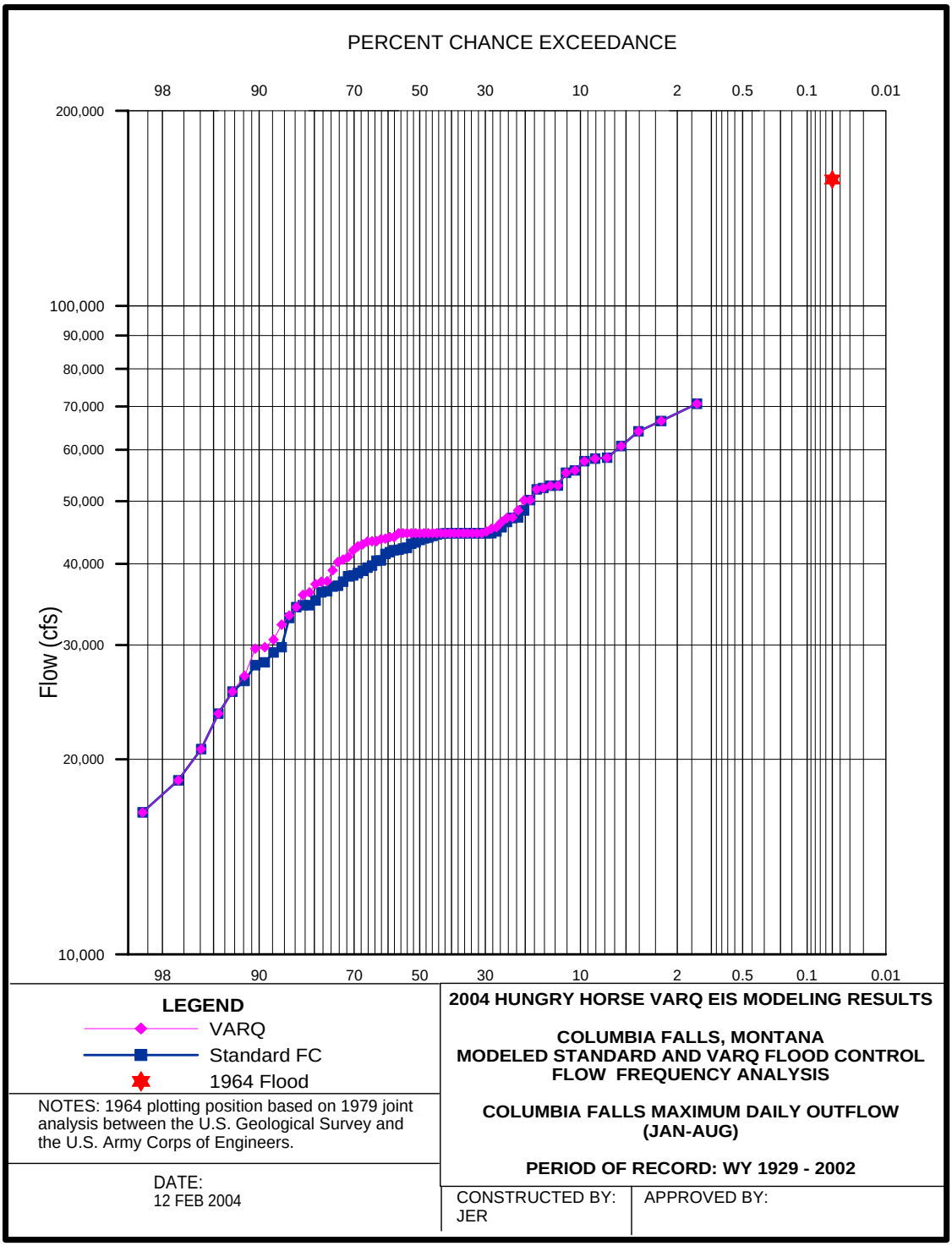

Figure 16: **Peak 1-day flow frequency curves for the Flathead River at Columbia Falls.**

2.4.3 Effects at Kerr Dam and Flathead Lake

The differences in Hungry Horse discharges between Standard FC and VARQ have subsequent effects in the operation of Kerr Dam on Flathead Lake. For the purpose of

modeling these effects at Kerr Dam, the following guidelines and assumptions were followed in the simulations:

1) Flood control requirements were followed in accordance with a 1962 Memorandum of Understanding (MOU) between the Kerr Dam licensee and Corps. The required April 15 flood control elevation of 2883.0 feet was modified, if applicable, during drought years to allow for a higher April 15 flood control elevation. This would help Flathead Lake fill in dry years and still maintain minimum flow requirements below Kerr Dam without jeopardizing flood control. Kerr Dam is currently operating under an "Interim Drought Management Plan" during drought years which includes this type of operation.

2) Minimum flows below Kerr Dam are in accordance with Article 56 of its Federal Energy Regulatory Commission (FERC) license. Table 6 shows the minimum flow requirements below Kerr Dam.

Table 6: Minimum flow requirements below Kerr Dam

Dates	Minimum Flow (cfs)	Ramped to	Daily Ramp Increment (cfs/day)
August 1 to April 15	3,200		
April 16 to April 30	3,200	5,000	120
May 1 to May 15	5,000	12,700	513
May 16 to June 30	12,700		
July 1 to July 15	12,700	6,400	-420
July 16 to July 31	6,400	3,200	-200

3) Maximum discharges are limited by the natural lake and channel configurations.

4) Discharge ramping rates were adhered to.

Differences in Standard FC and VARQ affect the timing and magnitude of Hungry Horse discharges which in turn affect operations at Kerr Dam and Flathead Lake. As mentioned in the Hungry Horse effects section, Hungry Horse discharges are generally lower in April and higher in May and June for VARQ. Since Flathead Lake is usually drafting during the first half of April to its flood control elevation of 2883.0 feet, flows from Hungry Horse are being passed through Flathead Lake. Conversely, the higher Hungry Horse discharges in May and June under VARQ can be stored in Flathead Lake during the refill period. The end result is Flathead Lake has a slightly better probability of filling to elevation 2893.0 feet while still meeting minimum flow requirements below Kerr Dam. Figure 17 shows the probability that Flathead Lake will fill to a certain elevation for both Standard FC and VARQ.

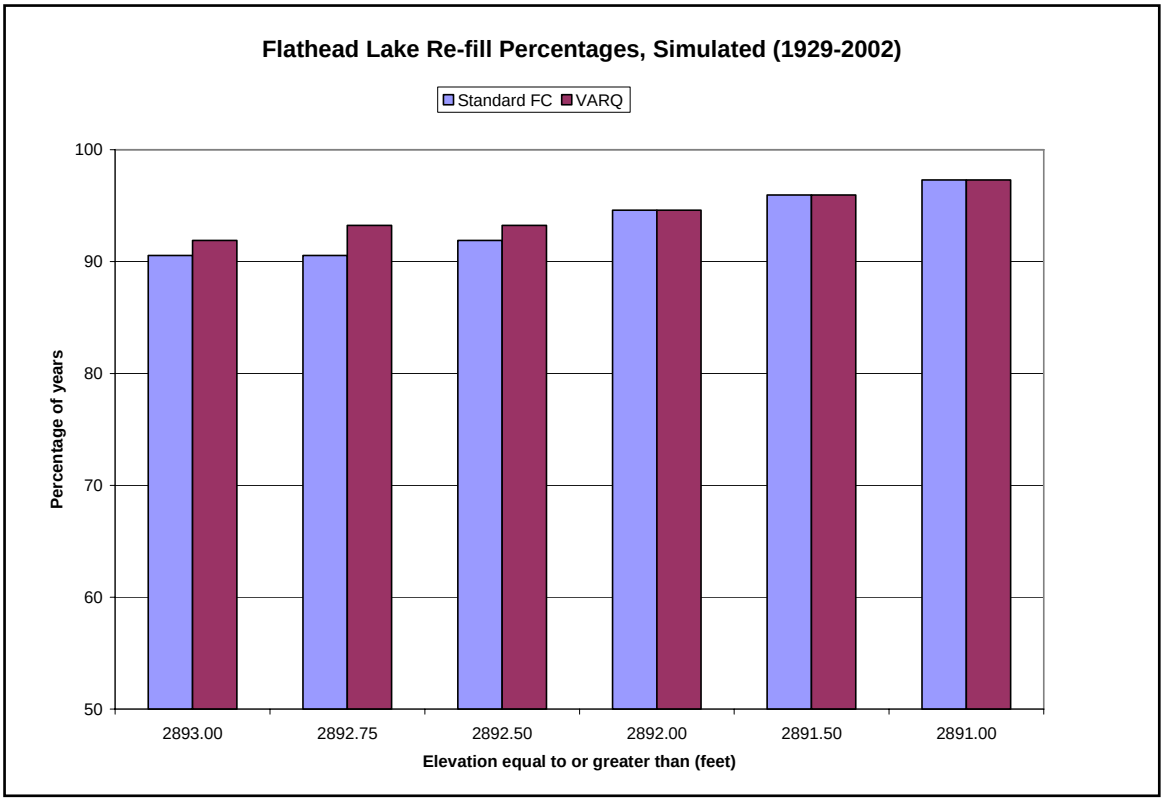

Figure 17: Flathead Lake Refill Percentages.

It is desirable to maintain Flathead Lake full (El. 2893.0) throughout the summer for recreational purposes without jeopardizing the minimum flow requirement. Figure 18 shows the duration curves for Flathead Lake elevation from June 15 – August 31 for Standard FC and VARQ. Flathead Lake has a slightly better probability of being near full under VARQ.

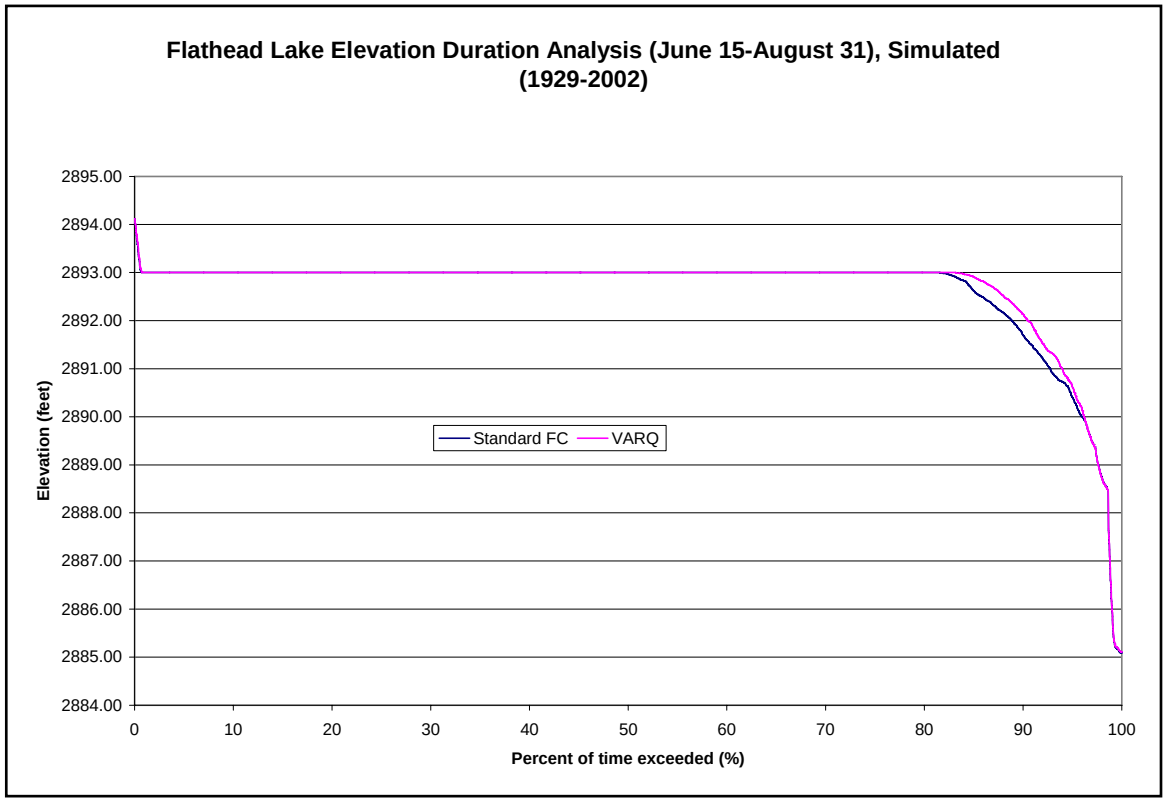

Figure 18: Elevation Duration Analysis at Flathead Lake (June 15 – August 31).

There are minor discharge differences between VARQ and Standard FC at Kerr Dam. The higher Hungry Horse releases in May and June and the lower releases in April for VARQ create a similar effect on the discharges at Kerr Dam. Figure 19 shows average monthly discharges from Kerr Dam. Flows are slightly higher in May and June and lower in January, February, and April under VARQ.

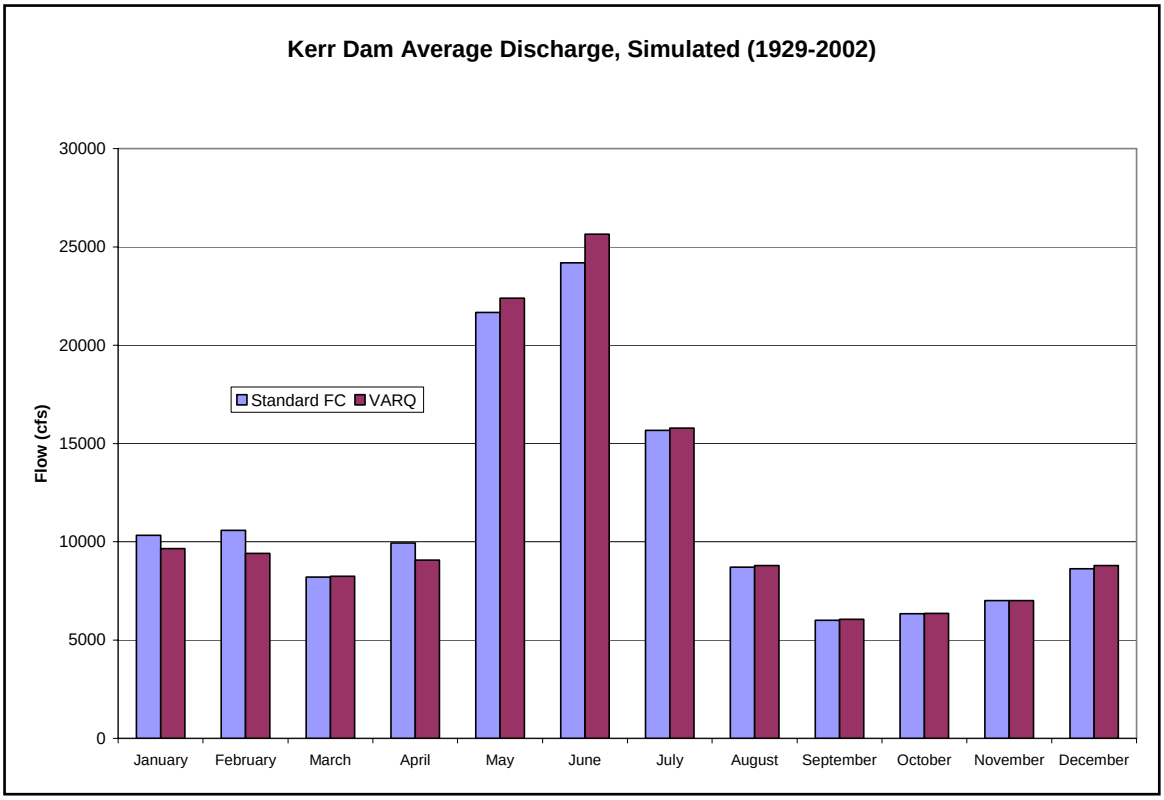

Figure 19: Kerr Dam Average Monthly Discharges.

Peak discharges below Kerr Dam were also analyzed for the VARQ and Standard FC simulations. The peak 1-day flow frequency analysis for the Flathead River below Kerr Dam is shown in Figure 20. There are only minor differences between Standard FC and VARQ.

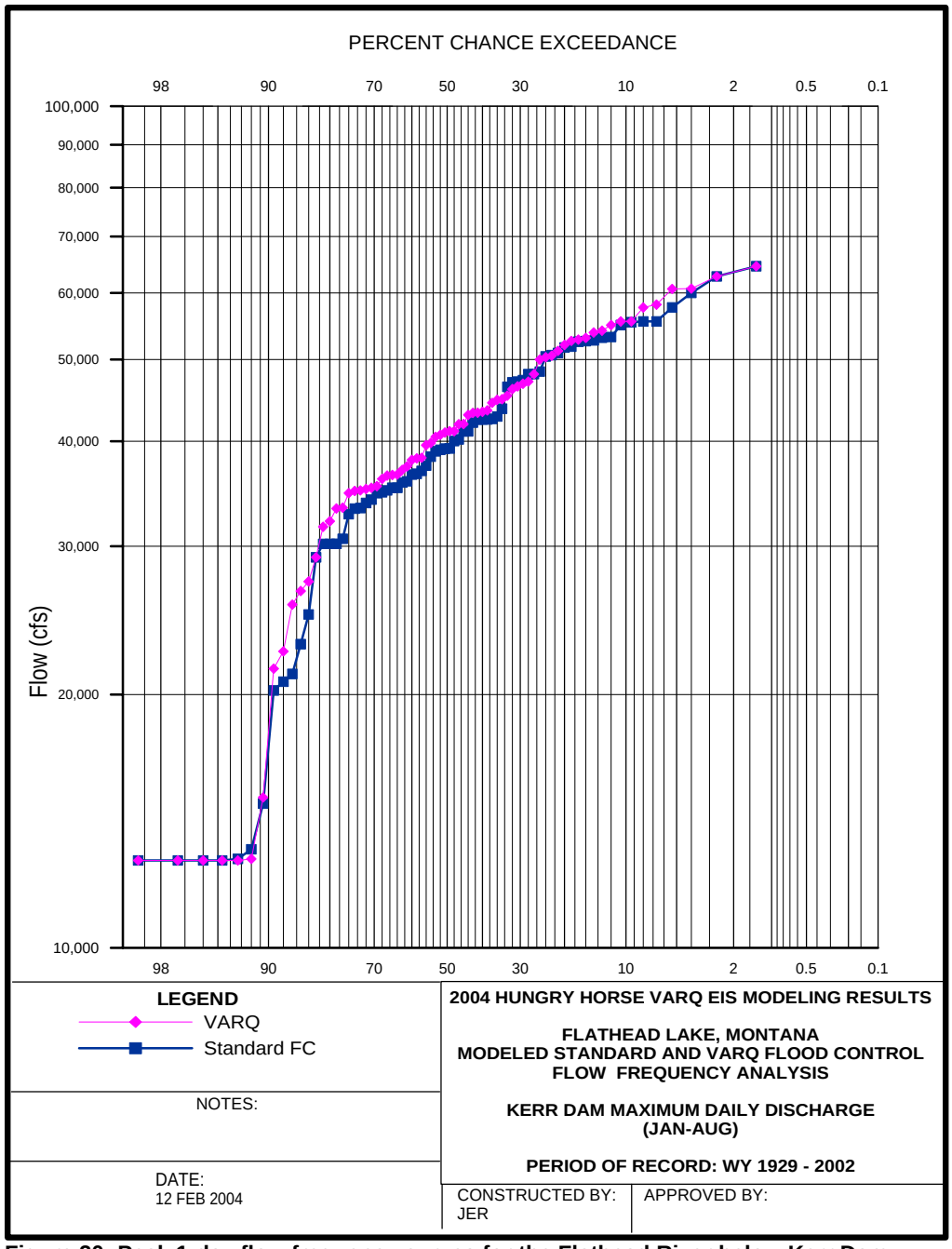

Figure 20: Peak 1-day flow frequency curves for the Flathead River below Kerr Dam.

There is evidence to show that flooding can occur above Flathead Lake along the southern portion of the Flathead plain during times when Flathead Lake elevation in combination with flow at Columbia Falls reaches a certain level.[8] Flooding can occur when Flathead Lake is at or above elevation 2893 feet and flows at Columbia Falls

[8] Based on Corps nomograph chart No. 4515 dated 2-4-1947, "Non-damaging Flow Flathead River at Columbia Falls, Montana"

exceed 48,000 cfs. In the simulations, Flathead Lake was above elevation 2893 feet and Columbia Falls flow exceeded 48,000 cfs 16 times in 4 years for Standard FC and 31 times in 7 years for VARQ. All instances occurred in June and amounted to 0.7% of the total days in June for Standard FC and 1.4% of the total days in June for VARQ.

2.4.4 Effects at Albeni Falls Dam and Pend Oreille Lake.

VARQ effects on Lake elevations and releases were analyzed at Albeni Falls Dam. For the purpose of modeling these effects at Albeni Falls Dam, the following guidelines and assumptions were followed in the simulations:

1) Target elevations for Pend Oreille Lake include flood control elevations, winter target elevations, and summer normal operating elevations. For this analysis, two different winter target elevations were used for Pend Oreille Lake. One analysis looked at a winter target elevation of 2055.0 feet for the period of record (1929-2002). Another analysis looked at elevation 2051.0 feet for a winter target elevation.

2) Minimum release below Albeni Falls Dam is 4,000 cfs.

3) Maximum discharges are limited by the natural lake and channel configurations.

4) Discharge ramping rates limited to 10,000 cfs/day.

2.4.4.1 Winter Target Elevation (2055.0 feet)

VARQ operations at Hungry Horse had a negligible effect on the summer operating elevation of 2062.5 feet or the winter target elevation of 2055.0 feet at Pend Oreille Lake. This is evidenced by the elevation duration curves shown in Figures 21 and 22.

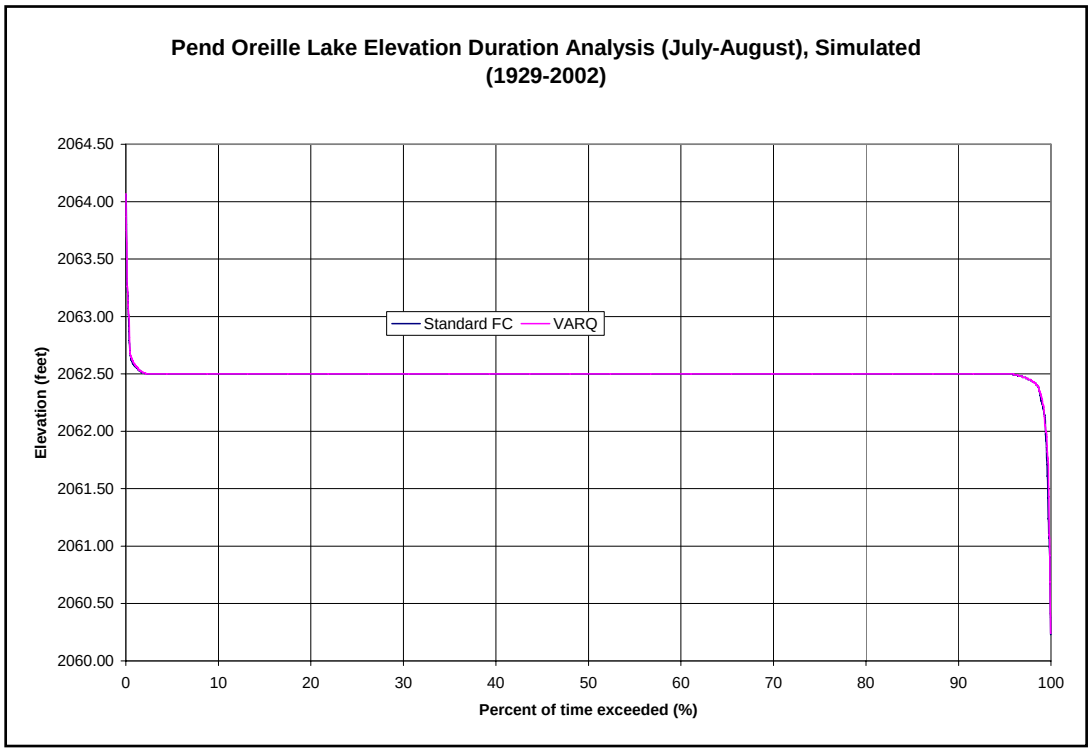

Figure 21: Elevation Duration Analysis at Pend Oreille Lake for July – August (winter target el. 2055 ft.).

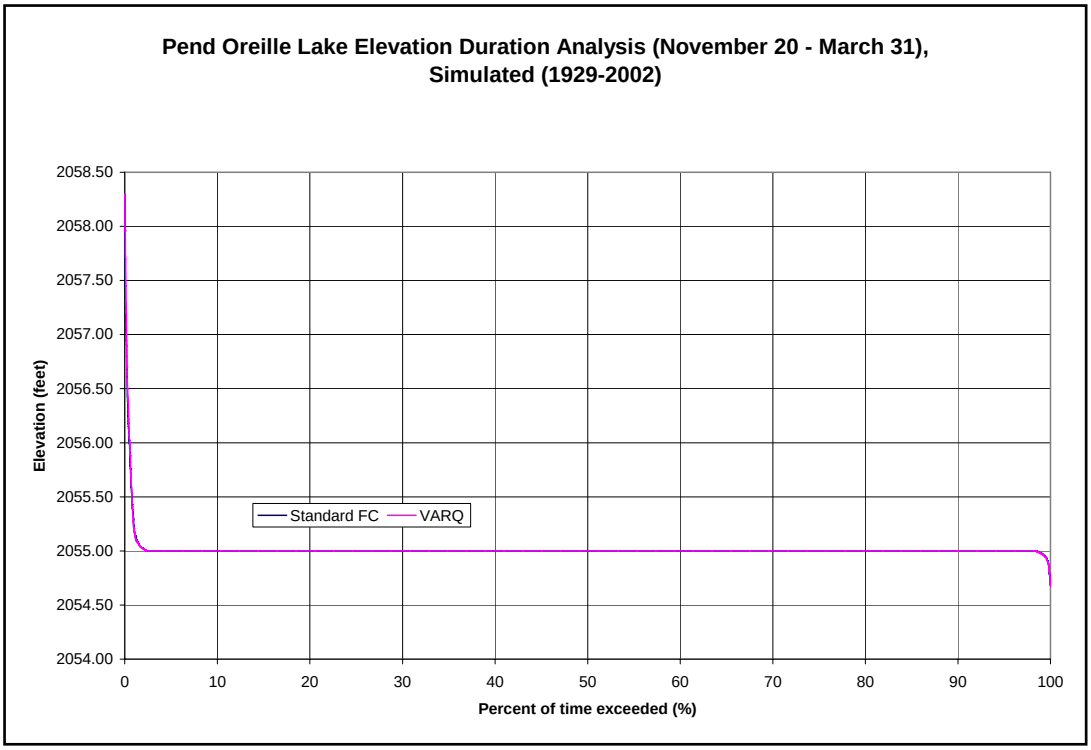

Figure 22: Elevation Duration Analysis at Pend Oreille Lake for November 20 - March 31 (winter target el. 2055 ft.).

Average Albeni Falls discharges are slightly higher in June and lower in January, February, and April for VARQ. Figure 23 shows average monthly discharges for Albeni Falls Dam.

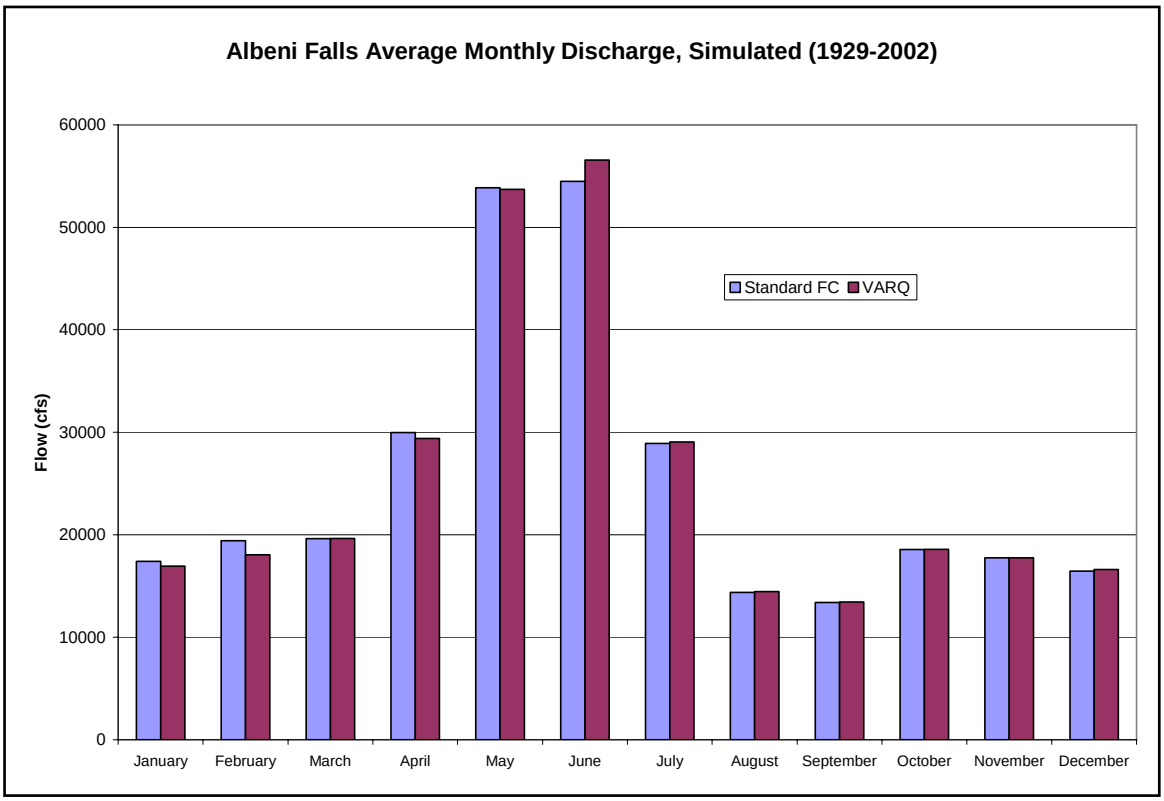

Figure 23: Albeni Falls Dam Average Monthly Discharges (winter target el. 2055 ft.)

The area below Albeni Falls Dam can be impacted by two types of flooding: 1) agricultural flooding in March and April as a result of early spring runoff from Calispell and Trimble Creeks and 2) flooding in June due to high flows in the Pend Oreille River from high elevation snowmelt.

The agricultural flooding in the Cusick, Washington area is due to a combination of early spring runoff from Calispell and Trimble Creeks and high river levels due to the operation of Box Canyon and Albeni Falls Dams. Farmers near Cusick may have problems draining their fields in late March and April when Calispell and Trimble Creeks are running high. Pend Oreille PUD operates Box Canyon Dam and pumping facilities at the mouth of the creeks to minimize backwater effects on agricultural lands.

Problems with flooding can occur at Cusick, Washington if flows in excess of 43,000 cfs are passed through Lake Pend Oreille[9]. Figure 24 is a duration analysis for Albeni Falls

[9] U.S. Army Corps of Engineers, Seattle District, Seattle, Washington, "Analysis of the Kokanee Experiment at Lake Pend Oreille on Water Levels in the Cusick, Washington Area", September 1999.

discharges (March-April). Flows below Albeni Falls Dam are slightly lower with VARQ. Flows exceed 43,000 cfs about 9% of the time for VARQ and about 10% of the time for Standard FC during the period March 1-April 30. In relation to the field drainage issue, this is the period of most concern to farmers near Cusick.

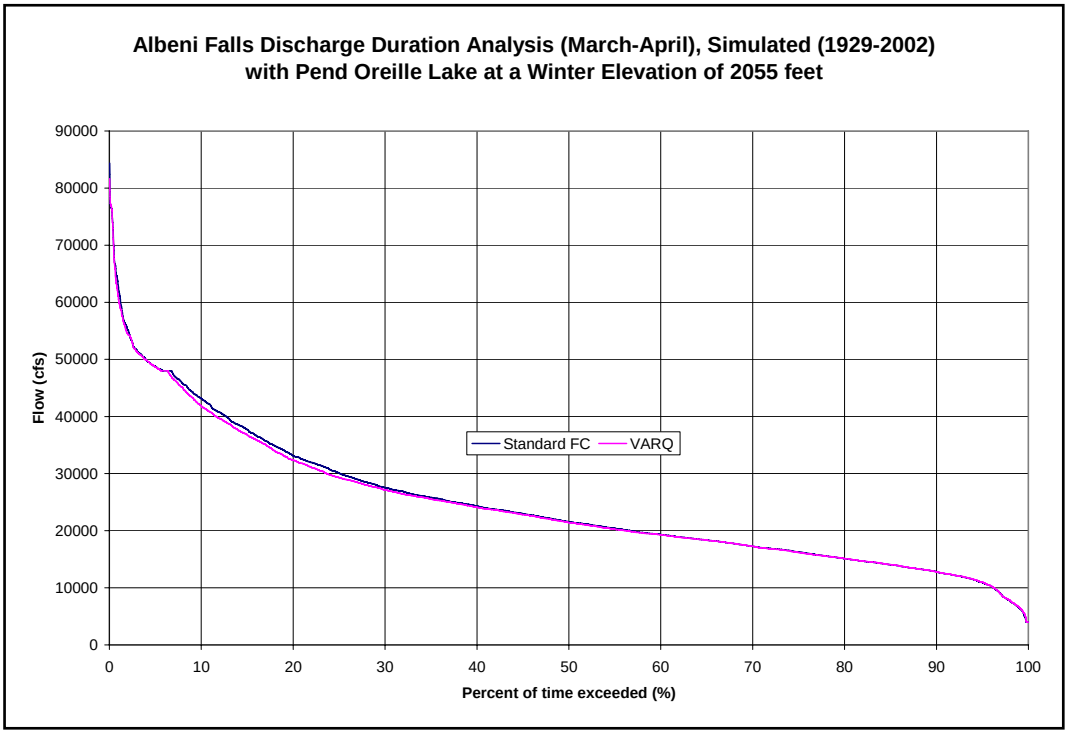

Figure 24: Simulated Albeni Falls Discharge Duration Curves for March-April (winter target el. 2055 ft.)

Figure 25 is a duration analysis for Albeni Falls discharges (May-June). Flows are slightly higher for VARQ when compared to Standard FC.

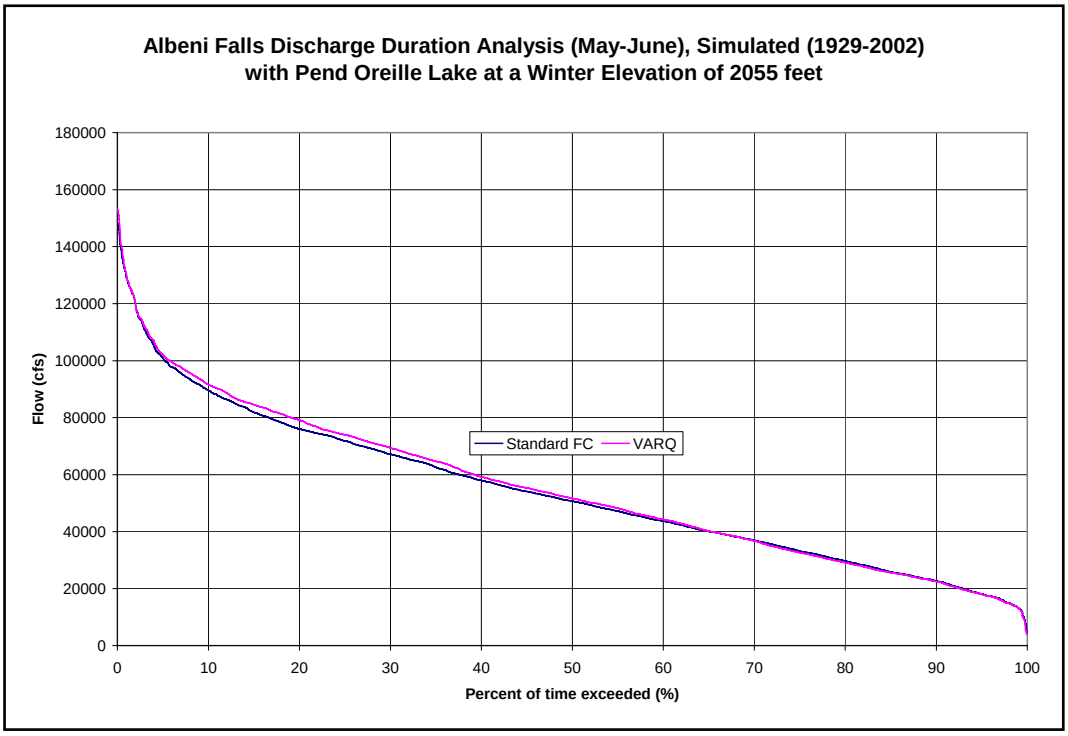

Figure 25: Simulated Albeni Falls Discharge Duration Curves for May-June (winter target el. 2055 ft.)

Flooding below Albeni Falls Dam in June is due to spring snowmelt, and is a relatively common occurrence happening historically about one year in four. The National Weather Service issues flood warnings when the releases from Albeni Falls Dam are expected to exceed 100,000 cfs. The peak 1-day flow frequency analysis for the Pend Oreille River below Albeni Falls Dam is shown in Figure 26 for the Standard FC and VARQ simulations. No significant differences exist between the two flood control simulations when comparing years with peak flows above flood stage. The annual peak flow exceeded 100,000 cfs about 27% of the time for both Standard FC and VARQ.

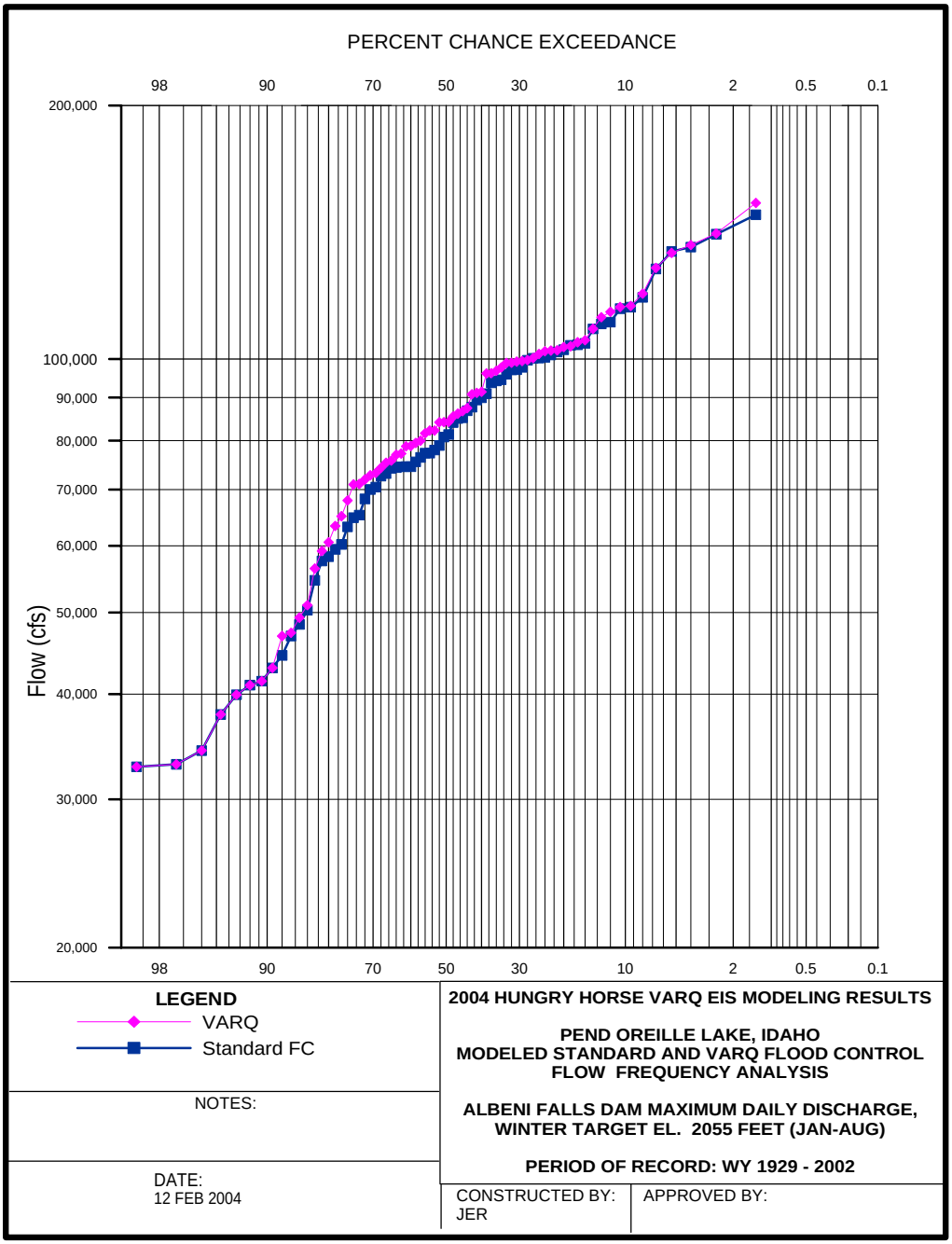

Figure 26: Peak 1-day flow frequency curves for the Pend Oreille River below Albeni Falls Dam (winter target el. 2055 ft.)

2.4.4.2 Winter Target Elevation (2051.0 feet)

At elevation 2051 feet Pend Oreille Lake has 353,000 acre-feet more space than at elevation 2055 feet. VARQ operations at Hungry Horse had a negligible effect on the summer operating elevation of 2062.5 feet or the winter target elevation of 2051feet at Pend Oreille Lake. This is evidenced by the elevation duration curves shown in Figures 27 and 28.

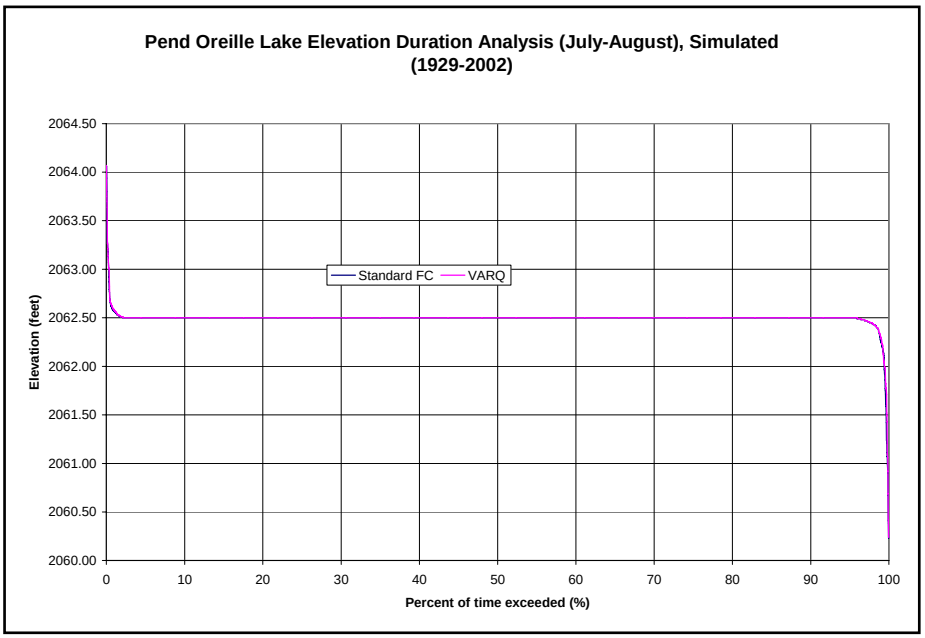

Figure 27: Elevation Duration Analysis at Pend Oreille Lake for July – August (winter target el. 2051 ft.).

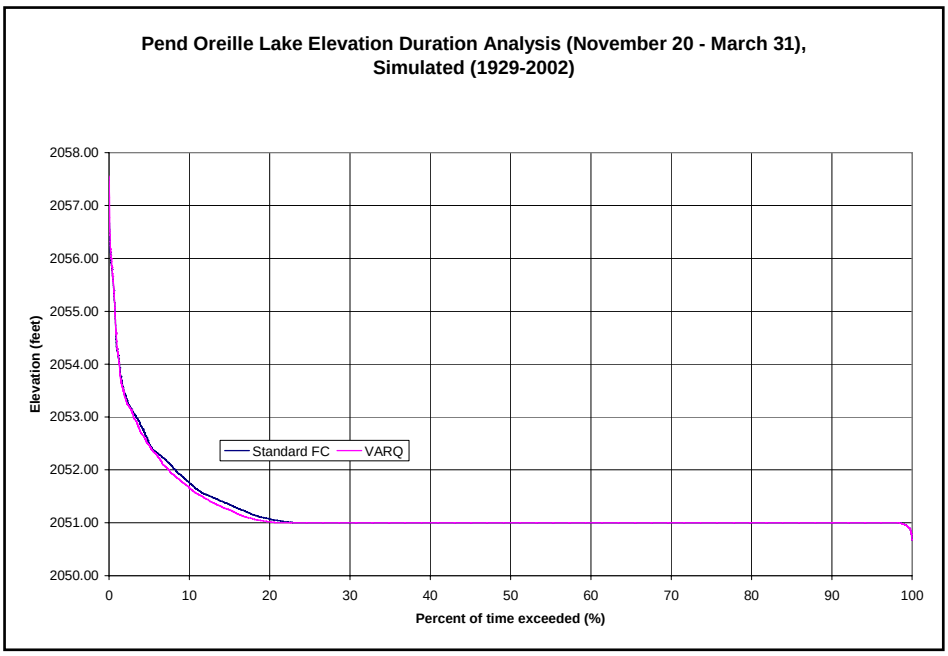

Figure 28: Elevation Duration Analysis at Pend Oreille Lake for November 20 - March 31 (winter target el. 2051 ft.).

Average monthly discharges are shown in Figure 29. Discharges are slightly higher in June and lower in January, February, and April for VARQ. Comparing to the simulations using a winter target elevation of 2055 feet, the only monthly differences occur in April and November.

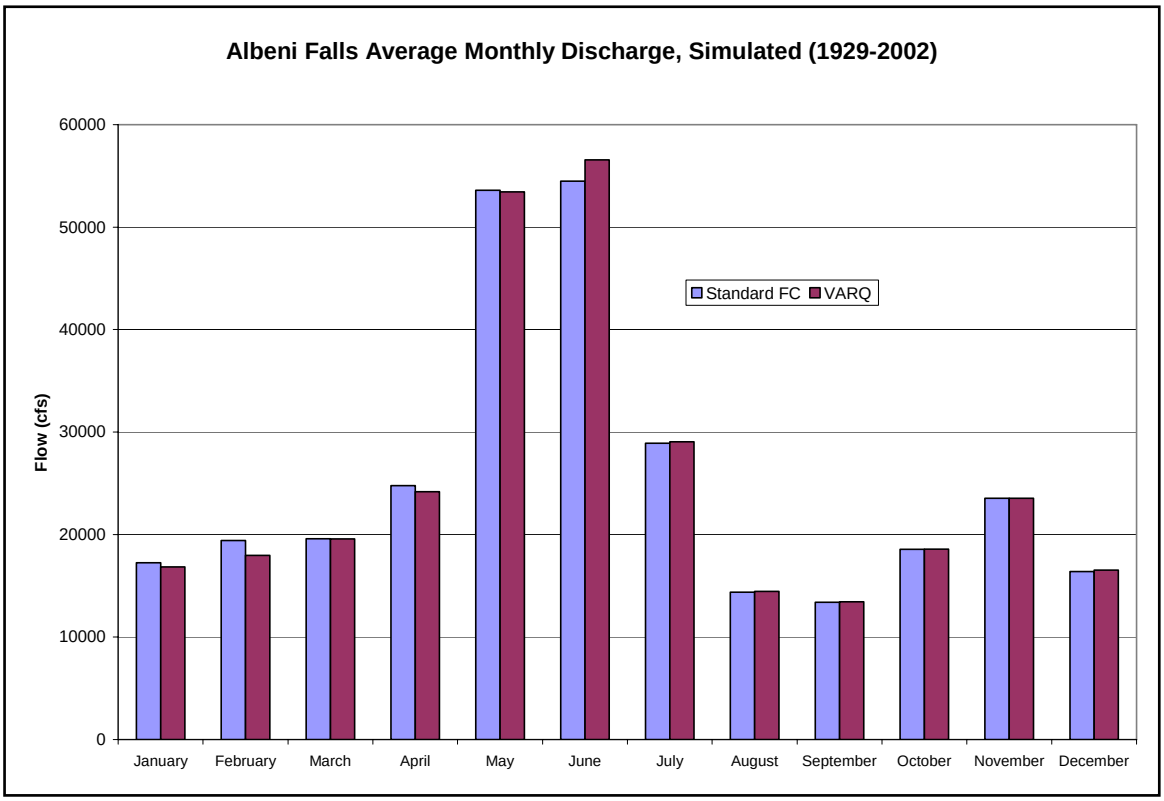

Figure 29: Albeni Falls Dam Average Monthly Discharges (winter target el. 2051 ft.)

Figure 30 is a duration analysis for Albeni Falls discharges (March-April). Flows below Albeni Falls Dam are slightly lower when comparing VARQ to Standard FC. Flows exceed 43,000 cfs about 6% of the time for both VARQ and Standard FC during the period March 1-April 30. The duration analysis for Albeni Falls discharges (March-April) is also shown for a winter target elevation of 2055.0 feet (for Pend Oreille Lake) on the same graph. This comparison shows that there is a noticeable effect on Albeni Falls March-April discharges between the two different winter target elevations. The extra four feet of space, in the winter target of 2051.0 feet analysis, translated into decreased flows during March and April. The difference between VARQ and Standard FC is insignificant in either winter target scenario.

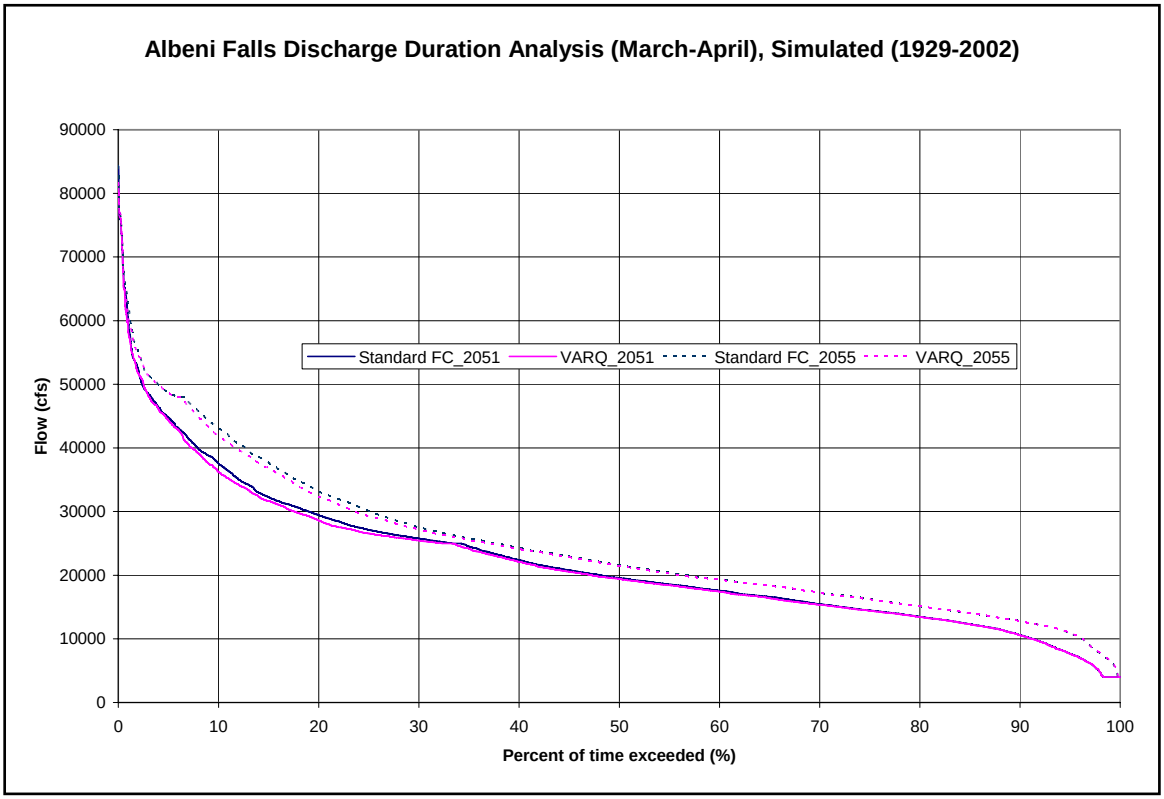

Figure 30: Simulated Albeni Falls Discharge Duration Curves for March – April, Both winter target elevations of 2051.0 feet and 2055.0 feet are shown.

Figure 31 is a duration analysis for Albeni Falls discharges (May-June) for the winter target elevation of 2051 feet. Flows are slightly higher for VARQ when compared to Standard FC. Results using a winter target elevation of 2055 feet (Figure 25) were essentially the same and are therefore not compared here.

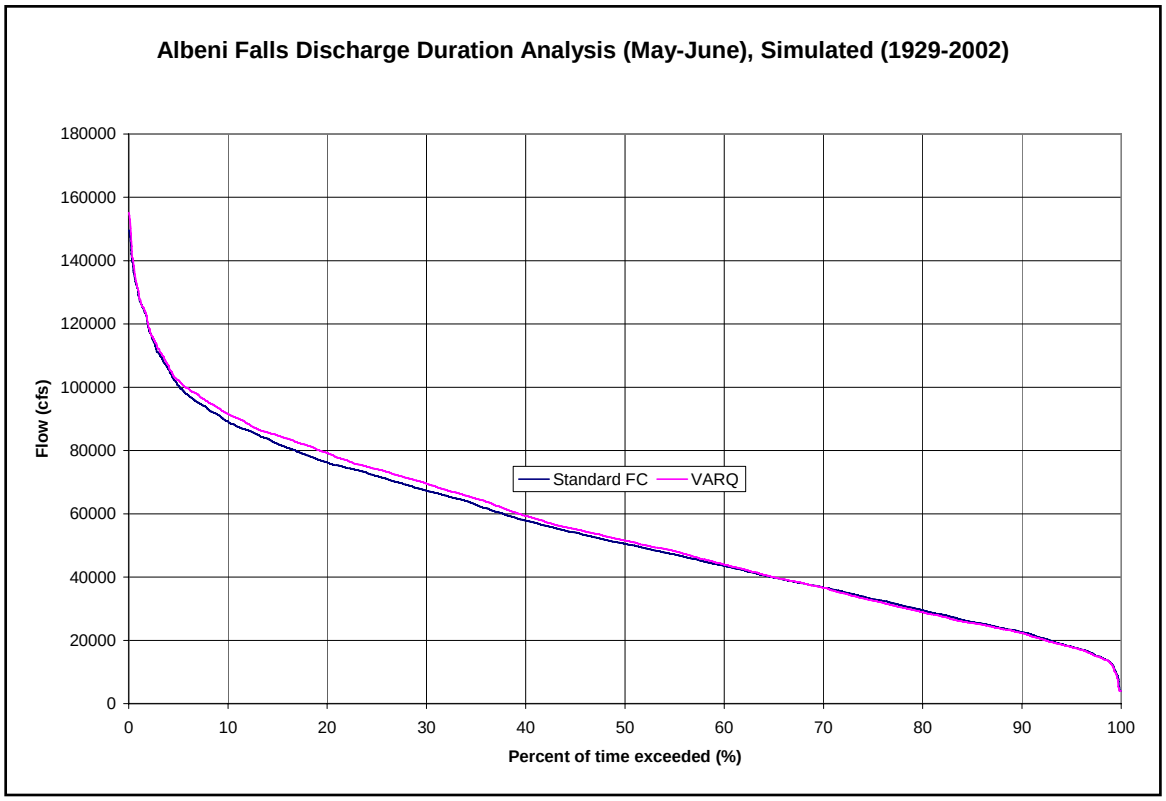

Figure 31: Simulated Albeni Falls Discharge Duration Curves for May-June (winter target el. 2051 ft.)

The peak 1-day flow frequency analysis for the Pend Oreille River below Albeni Falls Dam is shown in Figure 32 for the Standard FC and VARQ simulations. No significant differences exist between the two flood control simulations when comparing years with peak flows above flood stage. The annual peak flow exceeded 100,000 cfs about 27% of the time for both Standard FC and VARQ, which is essentially the same result as in target elevation of 2055 feet (see Figure 24).

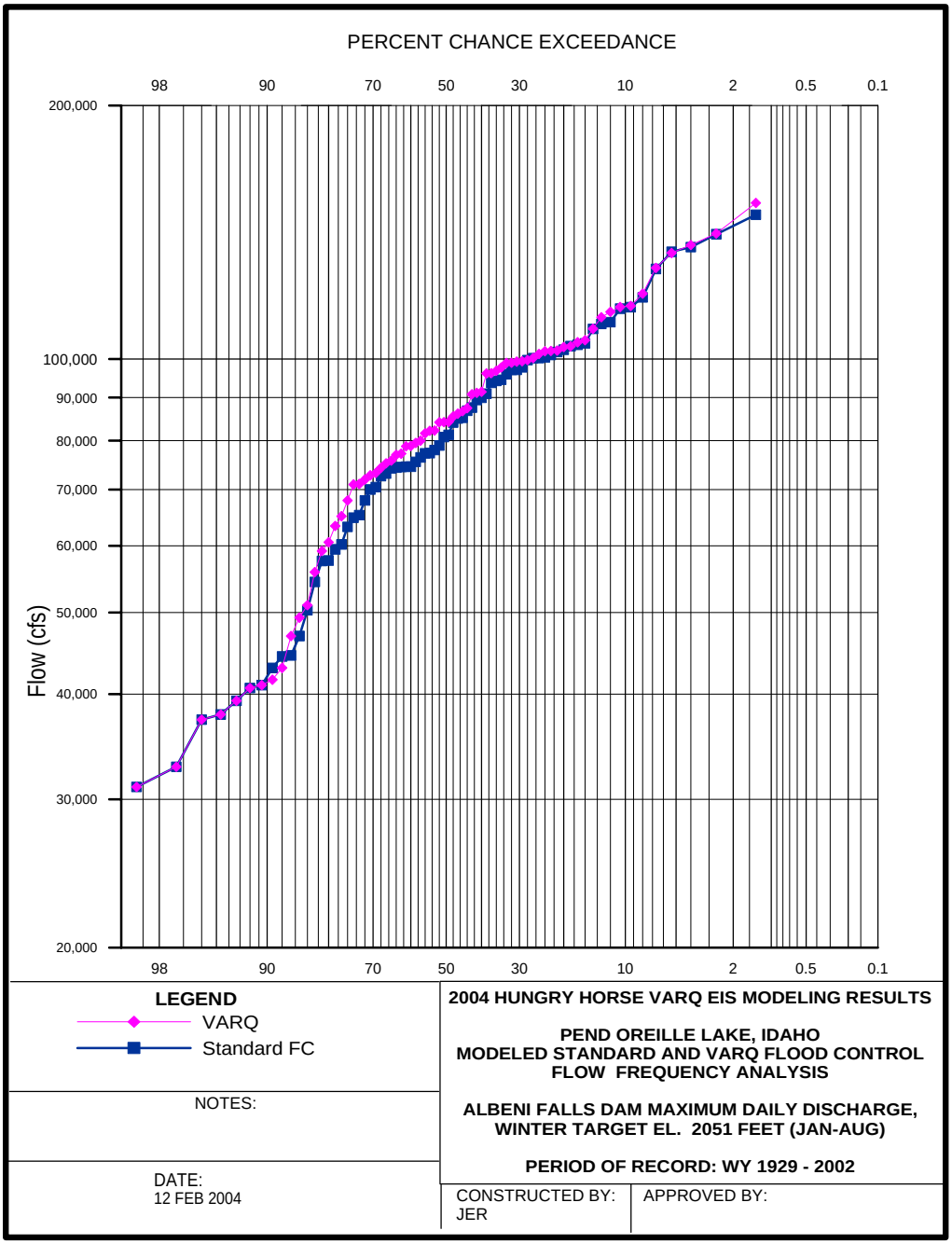

Figure 32: Peak 1-day flow frequency curves for the Pend Oreille River below Albeni Falls Dam (winter target el. 2051 ft.)

3.0 Summary

The hydrologic analysis of the VARQ flood control plan at Hungry Horse Dam has shown that there are only small impacts to reservoir elevations and river flows when compared to the Standard flood control plan. This is true not only at Hungry Horse Reservoir but also at all points from Hungry Horse Dam downstream to the Pend Oreille River below Albeni Falls Dam.

Refill probabilities are slightly higher at Hungry Horse Reservoir and at Flathead Lake under VARQ. Flathead Lake also can stay full a little longer in the summer under VARQ. The discharges from Hungry Horse under the VARQ rule curves are generally higher in May and June and lower in April when compared to Standard FC. These discharges are reflected in the release patterns at Kerr and Albeni Falls Dams where flows are slightly higher in June and slightly lower in April under VARQ.

Generation restrictions at Hungry Horse Dam due to transmission limitations or unit outages can cause some increase in the amount of spill past the power plant which will cause subsequent increases in the total dissolved gas saturation. Occurrences of total dissolved gases exceeding 110% saturation are minor with the exception of the case of limiting generation to three units (321 MW). Note that incidence of harm to fish from elevated gas saturation is governed by several factors in addition to the saturation level.

There is no increase in the occurrence of flooding on the Flathead River at Columbia Falls, Montana under VARQ. The river stage at Columbia Falls exceeded 14 feet a total of 35 days in 14 different years for both VARQ and Standard FC. VARQ resulted in slightly lower flows in the Pend Oreille River below Albeni Falls Dam during the March-April time period when flooding at Cusick, Washington can be a problem. Flows in the Pend Oreille River below Albeni Falls Dam are slightly higher in June under VARQ when high flows from snowmelt can cause flooding problems, but the frequency of exceeding the flood warning threshold of 100,000 cfs is essentially the same for VARQ or Stanfield FC.

APPENDIX I

Software, Water Supply Forecasts, and Periods-of-Record Used in the Hydroregulation Modeling

APPENDIX I – SOFTWARE, WATER SUPPLY FORECASTS, AND PERIODS-OF-RECORD USED IN THE HYDROREGULATION MODELING

The alternatives evaluated in this EIS change the way river flows and reservoir levels fluctuate over time in the Columbia River basin. To support of the EIS, the Corps and Reclamation performed hydroregulation modeling to simulate how the different alternatives would affect river flows and reservoir levels over a range of years, or period-of-record. Software and assumptions were selected to accommodate circumstances unique to the different areas of Corps and Reclamation responsibility and to best address the primary question at hand. This appendix explains the similarities and differences between various hydroregulation modeling efforts, and explains how they inter-relate.

ISSUE 1: Why are there so many hydroregulation models?

There are 4 major hydroregulation modeling efforts:

1) Columbia basin system-wide flood control modeling using SSARR/Autoreg;

2) Kootenai basin modeling using SSARR/Autoreg;

3) Flathead/ Clark Fork/ Pend Oreille modeling using RiverWare™; and

4) Columbia basin system-wide multi-purpose modeling using HYSSR.

If flood-related impacts need to be captured, a daily time-step model like SSARR/Autoreg (modeling efforts 1 and 2) or RiverWare™ (modeling effort 3) should be used. The Corps of performed daily modeling for the Kootenai basin, and system-wide flood control modeling for the Columbia basin as a whole. For the Kootenai basin, the Corps' SSARR program (with Autoreg pre-/post-processor) has a built-in ability to simulate special rules relating to Kootenay Lake. Likewise, SSARR (with Autoreg) was used for flood control modeling of the entire Columbia basin because of its built-in ability simulate US and Canadian reservoirs in accordance with the Columbia River Treaty Flood Control Operating Plan. The Bureau of Reclamation performed daily modeling for the Flathead/ Clark Fork/ Pend Oreille basins using a software package called RiverWare™, a general river basin modeling tool developed by CADSWES University of Colorado, Boulder. RiverWare™ is a widely-used and accepted simulation model.

Modeling effort 1 was conducted in support of the Environmental Assessment for interim implementation of VARQ (Corps 2002), and remains valid for its purpose of reporting system flood control impacts as part of this EIS. The SSARR/Autoreg simulations for modeling effort 1 provided daily conditions at the primary system flood control points of Birchbank, The Dalles, and Portland/Vancouver and relied on the assumption that Hungry Horse and Libby Dams would begin refilling on May 1 every year under VARQ operations. The May 1 assumption is acceptable on a system-wide basis, but local impacts (such as in the Kootenai or Flathead basin)

can be sensitive to this assumption. Likewise, local basin impacts can be quite sensitive to the water supply forecast used to determine flood storage needs. This is explained in the response to Issue 2.

Modeling efforts 2 and 3 were performed to best portray the local effects of the different alternatives. These efforts were consistent with the regional modeling done for the system flood control analysis (modeling effort 1) and incorporated some aspects of Libby and Hungry Horse operations that were not captured in the system flood control analysis.

The dams in the entire Columbia system do much more than provide flood protection -- they are multi-purpose dams with hydropower, fish and wildlife, recreational, and other uses. To capture the broader multi-purpose operations of Columbia system as a whole, the Corps' HYSSR model was used. HYSSR operates on about a monthly time step (14 periods per year) and is traditionally used to model power output from dams. However, it also incorporates flood control rules and accommodates user-defined operations such as providing flow augmentation from certain dams.

The information obtained from modeling efforts 2 and 3 listed above was used as input to modeling effort 4. For example, daily modeling results for Hungry Horse and Libby Dams were used to tell the HYSSR model what to do. Basically, the HYSSR model targeted the end-of-month reservoir elevations that were achieved in daily modeling (for Libby, the daily modeling was used as HYSSR inputs from May through August; for Hungry Horse, the daily modeling provided the HYSSR inputs for the entire year. Although the HYSSR model doesn't report conditions on a day-by-day basis, the end-of-month conditions it does report are consistent with the daily Libby and Hungry Horse operations.

ISSUE 2: Why are there different water supply forecasts and simulation periods?

Seasonal storage requirements for many dams in the Columbia system are based on water supply forecasts. The forecasting technique for a basin changes with time as data collection and tools for analysis improve. Modeling efforts 1-4 listed above all required some set of assumed water supply forecasts, which are shown for comparison in the Figure I-1.

All of the modeling studies simulated river and reservoir conditions over a period of record with a wide range of water supply conditions. However, the periods of record for the different modeling studies differed based primarily on the availability of the specific water supply forecasts available as model inputs.

For system flood control studies, the Corps has customarily used the Kuehl-Moffitt forecasts and the 61-year period from 1929-1989 (note that the last several years in the 1980s use the forecasts that were actually made and used during those years, including the Wortman-Morrow forecasts for Libby Dam). The Kuehl-Moffitt forecasts are preferred because there can be consistency and comparability with previous flood control studies.

For the Kootenai basin (modeling effort 2), the Corps used a 52-year time period covering 1948-1999. This period was chosen based on the availability of Wortman-Morrow water supply forecasts for Libby Dam (the Wortman-Morrow forecasts only go back through 1948). The selection of water supply forecasts used for Libby Dam modeling is very important when evaluating local basin impacts. For example, compared to the Kuehl-Moffitt technique, the Wortman-Morrow forecast provides a substantial improvement for the water supply forecast in

1948 (a very wet year) and therefore allows the modeling to provide a more representative estimate of flood impacts in the Kootenai basin. At The Dalles, the improved Libby forecast would have also reduced differences in peak flows between Standard and VARQ FC.

For the Flathead/ Clark Fork/ Pend Oreille basin modeling (effort 3), the Bureau of Reclamation used a combination of forecasts to model the period from 1929 through 2002. In real-time operations, Reclamation operates to Reclamations forecast (as opposed to the Kuehl-Moffitt that was used in the system flood studies).

For the system-wide multipurpose modeling, the 52-year period from 1948-1999 was used because this is the common period between the Flathead/ Clark Fork/ Pend Oreille modeling and the Kootenai Modeling (common period shaded with hatch-mark). Reclamation forecasts were used for Hungry Horse, Wortman-Morrow forecasts were used for Libby, and Kuehl-Moffitt and actual forecasts were used for the remaining projects in the Columbia basin.

ISSUE 3: Why does all of this matter?

The results reported in this EIS are based on several modeling efforts, and together they depict the best information available at this time. There is no single integrated system model, so multiple models must be used together to accomplish the various required purposes. The models provide a tool to evaluate and compare how the alternative dam operations may affect reservoir and river conditions. As with any model, the inputs and assumptions that go into the model will influence the output of the model. Although the various hydroregulation models may differ in terms of water supply forecast inputs and periods of records, they provide a reasonable depiction of the hydrologic effects of the various alternative dam operations.

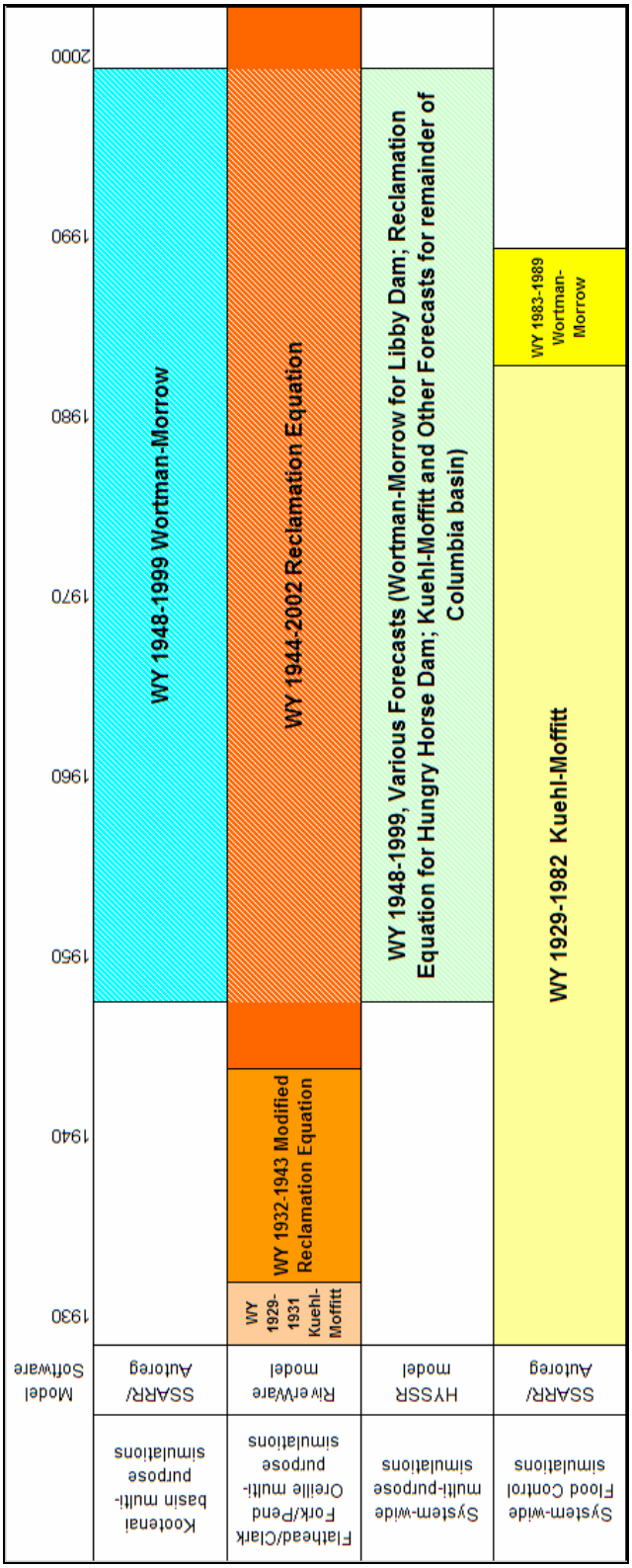

FIGURE I-1. PERIODS OF RECORD, WATER SUPPLY FORECAST, AND MODELING SOFTWARE USED FOR SIMULATIONS IN THIS EIS

APPENDIX J

Power Generation Report

Hydropower Impacts Analysis of Upper Columbia VARQ Flood Control and Fish Operations for Environmental Impact Statement

June 3, 2005

Prepared by

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Table of Contents

Page J-

1 Introduction.....1
1.1 Purpose and Scope.....1
1.2 Prior Related Hydropower Studies.....2
1.3 Major Hydropower Study Changes from the EA.....2
1.4 General Hydroregulation Assumptions.....3
2 Description of Alternative Combinations.....4
2.1 Benchmark Combination: LS+HS Standard Flood Control without Libby Fish Flows.....4
2.2 Benchmark Combination LV+HV: VARQ Flood Control without Libby Fish Flows.....8
2.3 Alternative Combination LS1+HS: Standard Flood Control with Libby Fish Flows at QPHC.....9
2.4 Alternative Combination LV1+HV: VARQ Flood Control with Libby Fish Flows at QPHC.....9
2.5 Alternative Combination LS2+HS: Standard Flood Control with Libby Fish Flows at QPHC+10.....9
2.6 Alternative Combination LV2+HV: VARQ Flood Control with Libby Fish Flows at QPHC+10.....10
3 Comparison of Alternative Combinations.....10
3.1 System Generation.....10
3.2 System Generation Differences.....11
3.3 Federal Generation Differences.....21
3.4 Non-Federal Generation Differences.....25
3.5 Spill for Federal Projects.....29
3.6 Spill Differences for Federal Projects.....31
3.7 Spill for Non-Federal Projects.....34
3.8 Spill Differences for Non-federal Projects.....36
4 Results of Libby Operation.....39
4.1 Results of Libby Operation in September and October.....39
4.2 Results of Libby Operation in December and January.....42
5 Results of Grand Coulee Operation.....43
5.1 Grand Coulee Elevation Differences, January – May.....43
5.2 Results of Grand Coulee End of April Operation.....44
6 Priest Rapids Flow Objectives.....47
7 McNary Flow Objectives.....50
8 Summary of Results.....54

List of Tables

Page J-

Table 1. 52-Year Average Pacific Northwest Coordinated System Loads (aMW).....5
Table 2. Project Period Average Spill Cap (cfs) and Percent Spill 6
Table 3. 52-Year Average System Generation for Alternative/Benchmark Combinations LS+HS through LV2+HV (aMW).....11
Table 4. System Generation Differences (aMW), Benchmark Combination LV+HV minus LS+HS.....14
Table 5. System Generation Differences (aMW), Alternative Combination LV1+HV minus LS1+HS.....15
Table 6. System Generation Differences (aMW), Alternative Combination LV2+HV minus LS2+HS.....16
Table 7. System Generation Differences (aMW), Alternative/Benchmark Combination LS1+HS minus LS+HS.....17
Table 8. System Generation Differences (aMW), Alternative/Benchmark Combination LS2+HS minus LS+HS.....18
Table 9. System Generation Differences (aMW), Alternative Combination LV1+HV minus LV+HV 19
Table 10. System Generation Differences (aMW), Alternative Combination LV2+HV minus LV+HV 20
Table 11. 52-Year Average Difference in Generation for Federal Projects (aMW), Alternative/Benchmark Combination LV+HV minus LS+HS.....23
Table 12. 52-Year Difference in Generation for Federal Projects (aMW), Alternative Combination LV1+HV minus LS1+HS 23
Table 13. 52-Year Avg. Difference in Generation for Federal Projects (aMW), Alternative Combination LV2+HV minus LS2+HS 24
Table 14. 52-Year Avg. Difference in Generation for Federal Projects (aMW), Alternative/Benchmark Combination LS1+HS minus LS+HS 24
Table 15. 52-Year Avg. Difference in Generation for Federal Projects (aMW), Alternative/Benchmark Combination LS2+HS minus LS+HS 24
Table 16. 52-Year Avg. Difference in Generation for Federal Projects (aMW), Alternative/Benchmark Combination LV1+HV minus LV+HV.....24
Table 17. 52-Year Avg. Difference in Generation for Federal Projects (aMW), Alternative/Benchmark Combination LV2+HV minus LV+HV.....25
Table 18. 52-Year Avg. Difference in Generation for Non-Federal Projects (aMW), Benchmark Combination LV+HV minus LS+HS 26
Table 19. 52-Year Avg. Difference in Generation for Non-Federal Projects (aMW), Alternative Combination LV1+HV minus LS1+HS 27
Table 20. 52-Year Avg. Difference in Generation for Non-Federal Projects (aMW), Alternative Combination LV2+HV minus LS2+HS 27
Table 21. 52-Year Avg. Difference in Generation for Non-Federal Projects (aMW), Alternative/Benchmark Combination LS1+HS minus LS+HS 27
Table 22. 52-Year Avg. Difference in Generation for Non-Federal Projects (aMW), Alternative/Benchmark Combination LS2+HS minus LS+HS 28

Table 23. 52-Year Avg. Difference in Generation for Non-Federal Projects (aMW), Alternative/Benchmark Combination LV1+HV minus LV+HV 28
Table 24. 52-Year Avg. Difference in Generation for Non-Federal Projects (aMW), Alternative/Benchmark Combination LV2+HV minus LV+HV 29
Table 25. Spill at Federal Projects for Alternative/Benchmark Combinations LS+HS through LV2+HV (cfs) 30
Table 26. 52-Year Avg. Difference in Spill for Federal Projects (cfs), Benchmark Combination LV+HV minus LS+HS 32
Table 27. 52-Year Avg. Difference in Spill for Federal Projects (cfs), Alternative Combination LV1+HV minus LS1+HS 32
Table 28. 52-Year Avg. Difference in Spill for Federal Projects (cfs), Alternative Combination LV2+HV minus LS2+HS 33
Table 29. 52-Year Avg. Difference in Spill for Federal Projects (cfs), Alternative/Benchmark Combination LS1+HS minus LS+HS 33
Table 30. 52-Year Avg. Difference in Spill for Federal Projects (cfs), Alternative/Benchmark Combination LS2+HS minus LS+HS 33
Table 31. 52-Year Avg. Difference in Spill for Federal Projects (cfs), Alternative/Benchmark Combination LV1+HV minus LV+HV 33
Table 32. 52-Year Avg. Difference in Spill for Federal Projects (cfs), Alternative/Benchmark Combination LV2+HV minus LV+HV 34
Table 33. Spill for Non-Federal Projects (cfs) 34
Table 34. 52-Year Avg. Difference in Spill for Non-Federal Projects (cfs), Benchmark Combinations LV+HV minus LS+HS 36
Table 35. 52-Year Avg. Difference in Spill for Non-Federal Projects (cfs), Alternative Combinations LV1+HV minus LS1+HS 37
Table 36. 52-Year Avg. Difference in Spill for Non-Federal Projects (cfs), Alternative Combinations LV2+HV minus LS2+HS 37
Table 37. 52-Year Avg. Difference in Spill for Non-Federal Projects (cfs), Alternative/Benchmark Combinations LS1+HS minus LS+HS 37
Table 38. 52-Year Avg. Difference in Spill for Non-Federal Projects (cfs), Alternative/Benchmark Combinations LS2+HS minus LS+HS 38
Table 39. 52-Year Avg. Difference in Spill for Non-Federal Projects (cfs), Alternative/Benchmark Combinations LV1+HV minus LV+HV 38
Table 40. 52-Year Avg. Difference in Spill for Non-Federal Projects (cfs), Alternative/Benchmark Combinations LV2+HV minus LV+HV 38
Table 41. Grand Coulee Min., Max., and Avg. Elevations for All Alternative/Benchmark Combinations 44
Table 42. Grand Coulee End of April Elevation Percent Non-Exceedance, All Alternative/Benchmark Combinations 45
Table 43. Number of Years of 52 that Priest Rapids Flow Objective was Missed 47
Table 44. Average Flow By Which Priest Rapid Flow Objective was Missed (cfs) 47
Table 45. Number of Years out of 52 that McNary Flow Objective was Missed 50
Table 46. Average Flow By Which McNary Flow Objective was Missed (cfs) 50

List of Figures

Page J-

Figure 1. Libby Elevation Percent Exceedance Curves for September 40
Figure 2. Libby Elevation Percent Exceedance Curves for October 40
Figure 3. Libby Flow Percent Exceedance Curves for September 41
Figure 4. Libby Flow Percent Exceedance Curves for October 41
Figure 5. Libby Flow Percent Exceedance Curves for December.....42
Figure 6. Libby Flow Percent Exceedance Curves for January.....43
Figure 7. Grand Coulee Elevation Percent Non-Exceedance Curves for April 30.....46
Figure 8. Grand Coulee Elevation Differences Standard minus VARQ Flood Control Exceedance Curves for April 30 46
Figure 9. Priest Rapids Flow Percent Exceedance Curves for April 1-15.....48
Figure 10. Priest Rapids Flow Percent Exceedance Curves for April 16-30.....48
Figure 11. Priest Rapids Flow Percent Exceedance Curves for May 49
Figure 12. Priest Rapids Flow Percent Exceedance Curves for June 49
Figure 13. McNary Flow Percent Exceedance Curves for April 1-15.....51
Figure 14. McNary Flow Percent Exceedance Curves for April 16-30.....51
Figure 15. McNary Flow Percent Exceedance Curves for May 52
Figure 16. McNary Flow Percent Exceedance Curves for June 52
Figure 17. McNary Flow Percent Exceedance Curves for July.....53
Figure 18. McNary Flow Percent Exceedance Curves for August 1-15.....53
Figure 19. McNary Flow Percent Exceedance Curves for August 16-31.....54

1 Introduction.

The Seattle District (NWS) of the US Army Corps of Engineers (Corps), and the US Bureau of Reclamation (Reclamation) are preparing an Environmental Impact Statement (EIS), called the Upper Columbia Alternative Flood Control (VARQ) and Fish Operations EIS, or UCEIS. VARQ stands for variable discharge, with Q being engineering shorthand for discharge. The proposed operational changes would take place at Libby and Hungry Horse dams in Montana. This operational proposal is in response to the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) Biological Opinions of December 2000. Both Biological Opinions recommended VARQ as a flood control operations strategy for Libby and Hungry Horse. These operational changes would also result in changes in operations at Grand Coulee Dam on the Columbia River in Washington. The UCEIS will be used to help determine whether to implement VARQ at Libby and Hungry Horse on a permanent basis beginning in January 2006. In addition, the UCEIS documents the effects of providing flow augmentation for Kootenai River white sturgeon, bull trout in the Kootenai and Flathead rivers, and salmon and steelhead in the lower Columbia River. As part of that, the USFWS Biological Opinion calls for increasing flow capacity from Libby by 10,000 cubic feet per second (cfs) above current powerhouse capacity, within Montana's dissolved gas standard of 110% saturation. Although the mechanism for achieving that has not been worked out, the UCEIS evaluates the effects of the flow capacity increase itself.

This hydropower study was prepared by the Corps of Engineers, North Pacific Division, Water Management Division, Power Branch and will be used for input to the UCEIS. This study includes the regulation of projects in the Columbia River coordinated hydropower system that consist of federal, private, and public utility projects in the Columbia and Snake River basins.

1.1 Purpose and Scope

The purpose of this study is to assess the monthly hydropower impacts to the Columbia River system due to the implementation of VARQ flood control as compared to standard flood control for each, with and without fish flows. Data from this study will be input into the UCEIS. Four alternative combinations and two benchmark combinations were modeled:

Benchmark Combination LS+HS- Standard Flood Control without Libby fish flows

Benchmark Combination LV+HV- VARQ Flood Control without Libby fish flows

Alternative Combination LS1+HS- Standard Flood Control, with fish flows at Libby including sturgeon flows up to current powerhouse capacity (QPHC)

Alternative Combination LV1+HV- VARQ Flood Control, with fish flows at Libby including sturgeon flows up to QPHC

Alternative Combination LS2+HS- Standard Flood Control, with fish flows at Libby including sturgeon flows up to powerhouse capacity + 10 thousand cubic feet per second (kcfs) (QPHC+10)

Alternative Combination LV2+HV- VARQ Flood Control, with fish flows at Libby including sturgeon flows up to QPHC+10

Studies were prepared using the Corps' Hydro System Seasonal Regulation (HYSSR) monthly model. Hungry Horse operations provided fish flows under all of the alternative combinations, but depended on VARQ or Standard Flood Control. All studies included a power operation.

To compare the effects of VARQ to Standard Flood Control, alternative/benchmark combinations LV+HV vs. LS+HS, LV1+HV vs. LS1+HS, and LV2+HV vs. LS2+HS were compared. To assess the effects of 2 fish flow alternative combinations for Standard Flood Control from Libby, alternative/benchmark combinations LS1+HS vs. LS+HS, and LS2+HS vs. LS+HS were compared. To assess the effects of the 2 fish flow alternative combinations for VARQ flood control, alternative/benchmark combinations LV1+HV vs. LV+HV and LV2+HV vs. LV2+HV were compared. Detailed descriptions of alternative/benchmark combinations are provided in Section 2. Tables and figures are provided to display the results of the modeling.

Metrics for comparisons include:

- Differences in Columbia River coordinated hydropower system generation
- Differences in generation at select federal and non-federal projects
- Differences in spill at select federal and non-federal projects
- Libby discharge and flow exceedance curves in September, October, December, and January.
- Grand Coulee elevation non-exceedance curves for the end of April
- Ability to meet McNary and Priest Rapids fish flow objectives

1.2 Prior Related Hydropower Studies.

The Power Branch prepared a study entitled, "Hydropower Impacts Analysis of Upper Columbia Alternative Flood Control and Fish Operations and Detailed Operating Plan Alternative Combinations including Hydropower Considerations and VARQ on the Columbia River System, dated October 28, 2002." This hydropower study was used in the Environmental Assessment (EA) that was prepared by the Seattle District entitled, "Upper Columbia Alternative Flood Control and Fish Operations Interim Implementation, Libby and Hungry Horse Dams, Montana, Idaho, and Washington, Final Environmental Assessment", dated December, 2002.

1.3 Major Hydropower Study Changes from the EA.

The following are major changes from the hydropower study prepared for the EA.

- Mica/Arrow flood control allocation changed from 2.08 million-acre-ft (Maf)/5.1 Maf to 4.08Maf/3.6Maf for Standard and VARQ flood control curves to reflect the allocation now used in actual operations.
- VARQ and Standard Flood Control curves were updated with the Wortman-Morrow forecast procedure for Libby, and with Reclamation's forecast for Hungry Horse, for system flood control in the drawdown period, and used Seattle District's (NWS) and Reclamation's refill curves.
- VARQ refill dates were determined by the initial controlled flow. They were set at May 1st for the EA.
- Historic natural flows were updated from the 1990 level to the 2000 level.
- The study period was changed from 1928-1987 to 1947-1999. The study period is defined by the availability of the Wortman-Morrow water supply forecasts for Libby, which have been developed back to 1948.
- Canadian operation was updated from the operating year (OY) 2002-03 to 2007-08 to reflect an operation resulting in flows at the US/Canadian border that is planned for the future.
- U.S. system critical rule curves and project operating criteria was updated from OY 2002-03 to OY 2003-04, which is the most current data available.
- Loads were updated to use 52 years of different Pacific Northwest Coordination Agreement (PNCA) coordinated system loads instead of one set of federal loads used for each year. This will allow the total coordinated system to draft for load as needed depending on water year. In the EA, federal projects served the same federal firm energy load carrying capability (FELCC) in every year, regardless of water availability. In the UCEIS, the Pacific Northwest Coordination Agreement (PNCA) coordinated system serves the coordinated system load to better simulate the system operation for each alternative combination.
- Updated operations for Libby and Hungry Horse from NWS and Reclamation, respectively, for all alternative combinations as detailed in Section 2.

1.4 General Hydroregulation Assumptions.

The Pacific Northwest reservoir system was modeled using the Corps' HYSSR model. HYSSR is a FORTRAN model with a monthly time step. There are 14 periods, one period for each month except April and August, which are split in half months (AP1 and APR are the first and second halves of April, and AG1, and AUG are the first and second halves of August). Model runs cover a 52-year period from August 1, 1947 through July 31, 1999, (August through July is the operating year for hydropower planning studies). All alternative combinations are "continuous" type studies where the July end-of-month elevations are the start elevations for the following August. All reservoirs started full on July 31st of 1947, except for Grand Coulee, Hungry Horse, and Dworshak in all alternative combinations and Libby in the fish flow alternative combinations, which started at their draft limits for McNary flow objectives. Libby started full in the alternative combinations without fish flows.

All alternative combinations modeled the system using power operations for all projects as submitted in accordance with the PNCA except for Libby and Hungry Horse which

were modeled to target elevations specific for this study. The PNCA was ratified in 1964, and the owners of the projects in the Columbia River coordinated hydropower system have agreed to plan, coordinate, and operate their systems for flood control and to optimize power production taking into consideration non-power uses. Operating criteria for non-federal projects are as submitted by project owners for the operating year 2003-2004, or as otherwise stated in this report. Project operation for federal projects are as described in this report.

The model operates so that projects run to their operating rule curve (ORC) or draft as necessary to meet the load. The ORC is a combination of curves made up of flood control curves, refill curves, and power critical rule curves. The projects that operate for power first run to their ORCs, and if the energy produced is greater than the load, then the model run is complete. If the energy produced by running to the ORC is less than the load, then the projects draft until the load is just met. Projects that operate specifically for fish flows do not operate to ORCs, but still produce generation, which contributes toward meeting the load.

2 Description of Alternative Combinations

2.1 Benchmark Combination: LS+HS Standard Flood Control without Libby Fish Flows.

This alternative combination used Standard Flood Control as the maximum reservoir elevations. Hungry Horse was operated to target simulated elevations with fish flows for Standard Flood Control year around, and Libby was operated to target system flood control in January through April and simulated Standard Flood Control elevations in May through August. All other projects used PNCA 2003-2004 operating criteria or as described below. Grand Coulee flood control curves and Variable Draft Limits (VDLs) were adjusted for upstream power drafts.

Flood control. The data sources for the Standard Flood Control Curves were provided by the Corps' Hydrologic Engineering Branch (HEB) Northwestern Division, Reclamation, and NWS. The following are the file names, the source, and periods in which they were used.

- "Hyssrst.txt" from HEB—Used for all projects and periods except as stated below
- "ForPwrBr.DSS, EIS2FCBA, LIB ELEV" from NWS—for Libby in May and June
- "Varq_nepa_analysis_alf3up1down_toACOE_021004.xls, Standard FC Simulation Data, Hungry Horse Rule Curves," from Reclamation-- for Hungry Horse in May and June (flood control was at full pool in all years). Flood control for April 30 was set equal to the target elevations from the Hungry Horse Pool Elevations from the same file to facilitate the project to meet elevation targets by spilling.

Flood control curves are upper limits for project forebay elevations. Flood control curves take precedence over any targeted elevations that may have been above these flood control curves. Exceptions to regulate above flood control curves may occur for local flood protection, approach channel capacity, and Libby may be above system flood control elevations due to the Kootenay Lake IJC operation.

Grand Coulee Flood Control Adjustments. An initial model run was made and the resulting drafts at projects upstream of Grand Coulee were used to determine the flood control adjustment at Grand Coulee. The adjustment was made such that when the drafts at upstream projects at the end of April are below their flood control curves, Grand Coulee's flood control curves are adjusted upwards. After the Grand Coulee curves were adjusted, a final model run was made to incorporate the adjustment.

Critical Rule Curves. Critical Rule Curves are the projects' ending elevations from the PNCA 2003-2004 critical period Final Regulation. For the PNCA 2004 operating year, the critical period regulation is from August 1936 through July 1937. The ending elevations reflect the Firm Energy Load Carrying Capability (FELCC) produced by the system, which is the generation the system can be expected to produce in a critical water year. The Critical Rule Curves were developed with Hungry Horse and Libby VARQ flood control, however for purposes of computing differences between alternative combinations, these critical rule curves were used for all alternative combinations.

Loads. PNCA coordinated system loads were computed for each year of the 52-year model run. The loads were based on the Firm Energy Load Carrying Capability (FELCC) from the PNCA 2003-2004 operating year. The PNCA critical year is not within the period of record of this study, but is considered to be applicable for the purposes of this study. The FELCC was adjusted for each year due to the generation capability of the hydro-independent projects, which are projects that serve load in the northwest, but are not in the PNCA coordinated system. Table 1 shows the month average load over the 52-year period and was developed with Libby and Hungry Horse VARQ Flood Control.

Table 1. 52-Year Average Pacific Northwest Coordinated System Loads (aMW)

52-Year Average Pacific Northwest Coordinated System Loads (aMW).													
AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL
10564	9075	6601	8463	8968	10613	9089	8843	7510	7883	8313	10359	12870	11539

Fish Spill. Fish spill for federal projects are as shown in Table 2, and are based on the Corps of Engineers' PNCAOY04 Data Submittal, which is based on the 2000 NMFS Biological Opinion. The spill caps and percentages are developed based on meeting total dissolved gas standards and fish passage criteria.

Table 2. Project Period Average Spill Cap (cfs) and Percent Spill

Project	Apr 1-15	Apr 15-30	May	June	July	Aug 1-15	Aug 16-31
Wells	0%	6.5%	6.5%	0%	6.5%	2.5%	0%
Rocky Reach	0%	15%	21.8%	15%	15%	15%	0%
Rock Island	0%	20%	20%	20%	20%	20%	0%
Wanapum	0%	43%	43%	46%	49%	49%	49%
Priest Rapids	0%	61%	61%	50%	39%	39%	39%
L. Granite	16,467	19,000	19,000	12,667			
Little Goose	13,000	15,000	15,000	10,000			
L.Monumental	34,667	40,000	40,000	26,667			
Ice Harbor	62,833	72,500	72,500	72,500	72,500	72,500	72,500
McNary	34,000	85,000	85,000	85,000			
John Day	28,000	70,000	66,801	64,167	64,167	70,000	70,000
John Day %	12%	30%	29%	28%	28%	30%	30%
The Dalles	42,800	107,000	107,000	107,000	107,000	107,000	107,000
The Dalles%	40%	40%	40%	40%	40%	40%	40%
Bonneville	38,483	95,292	95,474	93,906	93,750	95,375	95,938

Note: 1) Spill caps and percentages are prorated for the number of spill days in the period.
2) The spill is as developed for the Feb 1 2004 PNCA Data Submittal. Federal projects' spill is based on instantaneous gas caps and maximum spill for day-time and night-time hours provided by the Corps' Reservoir Control Center, Northwestern Division. Day-time and night-time hours are from the Corps' Fish Passage Plan. Spill for non-federal projects are as submitted by project owners in the Feb 2004 Data Submittal

Canadian Treaty Projects Operation. The Canadian Treaty projects, Mica, Duncan and Arrow, are on their 2008 Assured Operation Plan (AOP08) operations including a few changes agreed to by the Canadian Entity for this study. These changes include Brilliant expansion data, and a January maximum outflow of 80 kcfs at Arrow. The AOP was developed in accordance with the Columbia River Treaty, an agreement between the United States and Canadian governments to coordinate the operation of the Columbia River. The Canadian Treaty projects were modeled to target the operation resulting from the 52-year Treaty Storage Regulation and determined the flow across the United States and Canadian border. The flood control used to develop the Canadian operation includes Standard Flood Control for Libby and VARQ for Hungry Horse, as this was used in the AOP08.

Libby. For January through April, Libby was operated to target flood control elevations based on the system flood control curves from HEB. For May-August, Libby was modeled to target the simulated Standard Flood Control elevations provided by NWS. For September through November, Libby operated for power to the operating rule curves as needed to meet load. In December, Libby operated to target the flood control elevation 2411 feet. Modeling includes following the IJC rules for Kootenay Lake. At times the target elevations were not achieved because of minimum flow requirements or the operation of Kootenay Lake to meet the IJC rule curve may have controlled. Data sources for target elevations for January through August are as follows:

- "Hyssrst.txt" from HEB, for January through April
- "ForPwrBr.DSS, EIS2FCBA, LIB ELEV" from NWS, for May through August

Hungry Horse. Hungry Horse was modeled year around to target the simulated elevations from the fish flow regulations for standard flood control provided by Reclamation. The data source for the target elevations is "Varq_neap_analysis_alf3up1down_toACOE_021004.xls, Standard FC Simulation Data, Hungry Horse Pool Elevation," from Reclamation. These simulations include VDLs, which provide draft limits for winter power operations.

Albeni Falls. Albeni Falls was modeled to operate on a four-year cycle winter cycle. Albeni Falls operated to target elevation 2051 in the winter of 1948-49, and every 4 years thereafter. The project targeted elevation 2055 in the winter in all other years. Albeni Falls fills in April through June to elevation 2062.5 and drafts in September through November to the winter elevation.

Grand Coulee. Data on pumping from Lake Roosevelt to Banks Lake was modeled based on Reclamation's PNCA OY04 Data Submittal. In January through March, the project operated for power to the draft limits of the higher of the VDLs and the resident fish limits of elevation 1260, 1250, and 1240 ft in January, February, and March, respectively. The VDLs were adjusted for upstream power drafts after the initial model run and incorporated into the final run. In December through May, Grand Coulee drafted as needed to meet the Vernita Bar requirement. Grand Coulee augmented for McNary and Priest Rapids flows in April 15, April 30, May, June, July, August 15, and August 31 to draft limits of elevation 1280, 1280, 1280, 1288, 1285, 1280, and 1280/1278 feet, respectively. The project drafted for power in September, October, November and December, with draft limits of Els.1283, 1283, 1275, and 1270 feet, respectively. Chum flow objectives of 125 kcfs at Bonneville were met by drafting Grand Coulee, but were subject to draft limits of elevation 1275, 1270, in November and December, and VDLs in January through March.

McNary. McNary flow objectives for salmon are those recommended from the NMFS Biological Opinion. The flow objective for April 10th through June 30th varies between 220 kcfs and 260 kcfs. If the April runoff volume forecast at The Dalles Dam for April through August is less than 80 Maf, the flow objective is 220 kcfs. If the volume forecast is greater than 92 Maf, the flow objective is 260 kcfs. If the forecasted volume is between 80 and 92 Maf, the flow objective is linearly interpolated between 220 kcfs and 260 kcfs. The flow objective for July and August is 200 kcfs.

Priest Rapids. Priest Rapids flow objectives to meet needs for steelhead, are for the period April 10 through June 30. The flow objectives are 90 kcfs for the first half of April, and 135 kcfs for the second half of April, May and June. The Vernita Bar requirement is dependant on the October and November flows at Wanapum Dam and is between 50 kcfs and 70 kcfs in December through May.

Brownlee. Brownlee was operated to the fixed elevation operation used in the PNCA studies.

Dworshak. In January through June the project operated to target flood control. Dworshak drafted to meet Lower Granite flow objectives in July through August. In September through December, the project operated on minimum flow of 1300 cfs or flood control. Although the NMFS Biological Opinion discusses flow objectives at Lower Granite in the spring that would be met by drafting of Dworshak, the Biological Opinion places priority on June refill rather than meeting spring flow objectives, therefore Dworshak was modeled to refill in June.

Lower Granite. Lower Granite flow objectives in July and August range from 50 kcfs to 55 kcfs and are based on the April through July volume forecast (determined in June) at Lower Granite. Flow objectives are based on recommendations contained in the NMFS Biological Opinion.

Lower Snake Projects Minimum Operating Pool (MOP). The Lower Snake River projects operated as run-of-river projects, and run to MOP in April-August, except for Lower Granite that runs to MOP in April-October. The projects run to full pool in all other periods.

2.2 Benchmark Combination LV+HV: VARQ Flood Control without Libby Fish Flows.

This Alternative Combination LV+HV is similar to Benchmark Combination LS+HS, except VARQ Flood Control is used as the upper rule curve, Hungry Horse was operated to target simulated elevations with fish flows for VARQ Flood Control, and Libby was operated to target VARQ system flood control elevations in January through April and simulated VARQ Flood Control elevations in May through August. Grand Coulee flood control curves and VDLs were adjusted for upstream power drafts determined for this alternative combination.

Flood Control. The VARQ flood control curves were provided by the HEB, Reclamation, and NWS. The following are the file names, the source, and periods in which they were used.

- "Hyssrvq.txt" from HEB—For all projects and periods except as stated below
- "ForPwrBr.DSS, EIS2FCVQ, LIB ELEV" from NWS—for Libby May and June
- "Varq_nepa_analysis_alf3up1down_toACOE_021004.xls, VARQ Simulation Data, Hungry Horse Rule Curves", for Hungry Horse in May through June (flood control was at full pool in all years). Flood control for April 30 was set to the target elevations from the Hungry Horse Pool Elevation data from the same file.

Libby. For January through April, Libby was operated to target flood control elevations based on the system VARQ flood control curves from HEB. For May-August, Libby was

modeled to target the simulated VARQ flood control elevations provided by NWS. The data sources are as follows:

- "Hyssrvq.txt" from HEB, for January through April
- "ForPwrBr.DSS, EIS2FCVQ, LIB ELEV" from NWS, for May through August

Hungry Horse. Hungry Horse was modeled year around to target the simulated elevations from the fish flow regulations for VARQ flood control provided by Reclamation. The data source is "Varq_nepa_analysis_alf3up1down_toACOE_021004.xls, VARQ Simulation Data, Hungry Horse Pool Elevations," from Reclamation.

2.3 Alternative Combination LS1+HS: Standard Flood Control with Libby Fish Flows at QPHC

This Alternative Combination LS1+HS is similar to Benchmark Combination LS+HS except that Libby's May through August target elevations are based on a regulation using fish flows with a maximum flow during the sturgeon pulse of powerhouse capacity for Standard Flood Control (the average powerhouse capacity is approximately 25 kcfs). The data source for these target elevations is "ForPwrBr.DSS, EIS2F1BA, LIB ELEV" from NWS. The model run incorporated Grand Coulee flood control curves and VDLs adjusted for upstream power drafts determined for this alternative combination.

2.4 Alternative Combination LV1+HV: VARQ Flood Control with Libby Fish Flows at QPHC

Same as Alternative Combination LV+HV, except that Libby's May through August target elevations were based on a regulation using fish flows with a maximum flow during the sturgeon pulse of powerhouse capacity for VARQ flood control. The data source for these target elevations is "ForPwrBr.DSS, EIS2F1VQ, LIB ELEV" from NWS. Grand Coulee flood control curves and Variable Draft Limits were adjusted for upstream power drafts determined for this alternative combination.

2.5 Alternative Combination LS2+HS: Standard Flood Control with Libby Fish Flows at QPHC+10

Same as Benchmark Combination LS+HS, except Libby's May through August target elevations were based on a regulation using fish flows with a maximum flow during the sturgeon pulse of powerhouse capacity plus 10 kcfs for Standard Flood Control. The data source for these target elevations is "ForPwrBr.DSS, EIS2F2BA, LIB ELEV" from NWS. Grand Coulee flood control curves and Variable Draft Limits were adjusted for upstream power drafts determined for this alternative combination.

2.6 Alternative Combination LV2+HV: VARQ Flood Control with Libby Fish Flows at QPHC+10

Same as Alternative Combination LV+HV, except Libby's May through August target elevations was based on a regulation using fish flows with a maximum flow during the sturgeon pulse of powerhouse capacity plus 10 kcfs for VARQ flood control. The data source for these target elevations is "ForPwrBr.DSS, EIS2F2VQ, LIB ELEV" from NWS. Grand Coulee flood control curves and VDLs were adjusted for upstream power drafts determined for this alternative combination.

3 Comparison of Alternative/Benchmark Combinations

System, federal, and non-federal generation are compared. Spill for federal and non-federal projects are compared. Libby elevation and flow exceedance curves in September, October, and flow exceedance curves in December and January are provided for each alternative combination. Grand Coulee elevation non-exceedance curves and elevation difference (VARQ minus Standard) exceedance curves for April are provided. Priest Rapids, and McNary flow objective and exceedance curves during fish flow periods are provided.

3.1 System Generation

Table 3 shows the 52-year average system generation for each alternative combination. It should be noted that the generation values are approximations of system generation based on operating year 2003-04, PNCA coordinated projects, stated operating criteria specific to this report, and limitations of the monthly HYSSR model. This data is appropriate for comparison of alternative combinations for this report and other related evaluations, and should not be used for any other purpose.

Values shown in May, June and July for Alternative Combinations LS2+HS and LV2+HV were adjusted from the HYSSR model output to reflect the lost generation due to spilling 10,000 cfs over powerhouse capacity that show up in the daily regulations, but would not show in a monthly model. This is explained in Section 3.2, in the discussion relating to Table 6.

Table 3. 52-Year Average System Generation for Alternative/Benchmark Combinations LS+HS through LV2+HV (aMW)

Alternative Combination	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL
LS1+HS	13743	11600	8712	10557	12566	14166	19849	15831	14716	15290	16366	19337	19279	16683
LV1+HV	13965	11846	8755	10586	12631	14229	19025	15394	14711	15390	16106	19698	19521	16885
LS2+HS	13703	11551	8705	10549	12558	14159	19847	15831	14715	15290	16366	19365	19259	16655
LV2+HV	13927	11808	8743	10583	12626	14227	19024	15393	14710	15391	16106	19717	19497	16858
Benchmark Combination														
LS+HS	13627	11244	10061	10603	12570	14217	19882	15833	14715	15299	16365	19155	18769	16503
LV+HV	13655	11246	10068	10610	12611	14263	19053	15410	14704	15362	16110	19594	19264	16662

3.2 System Generation Differences

Differences in generation for the PNCA Coordinated System are provided in Tables 3 through 9.

Table 4 shows the generation differences for Benchmark Combination LV+HV minus LS+HS, VARQ without Libby fish flows minus Standard Flood Control without Libby fish flows. Both alternative combinations included power operations and fish operations for all projects except for Libby, which was modeled to target VARQ or Standard Flood Control elevations. In Table 4, a negative number means there is less generation in the VARQ alternative combination. There is less system generation with VARQ in January through March and the second half of April because there is less water released from Hungry Horse in Jan, Feb, and the second half of April, and from Libby in January through March in order to achieve the higher flood control elevations by the end of April with VARQ flood control. There was slightly more flow from Libby and Hungry Horse in the first half of April because in some years, they had to draft more to meet flood control with VARQ than with Standard (at Libby, there were 6 years where there was more outflow in the first half of April and 5 years where there was less flow). In May and June, more water is released, therefore more generation. In August, Libby targeted elevation 2459 in both alternative combinations. The pool was higher at the end of July in 7 years under VARQ, which caused slightly more outflow in August in those years, and therefore more system generation. The largest impact by month was in January, which had 828 MW less generation with VARQ, which is a 4.2 % reduction of generation from the Standard flood control alternative combination. The average annual loss in generation due to VARQ under flood control only alternative combinations is 12 MW.

Table 5 shows generation differences for Alternative Combination LV1+HV minus LS1+HS, VARQ Flood Control with Libby fish flows at QPHC minus Standard Flood Control with Libby fish flows at QPHC. In January through April, differences between Table 5 and 4 are similar because Hungry Horse's resulting operation is the same in the

standard alternative combinations and the same in the VARQ alternative combinations, and Libby's resulting operation is nearly the same. In May through August, Libby and Hungry Horse pass more flow under VARQ resulting in more generation. For September through December, more water was released and more generation was produced with VARQ because Libby's ending elevation in August was higher under VARQ, and Libby ended at the December target elevation of elevation 2411 in both VARQ and Standard. Also, since Libby produced more flow in August, this allowed other projects in the system to draft less when the system was drafting to just meet load. This produced higher elevations in August at these projects (for example, Kerr), which provided more water in the fall that passes through the run of river projects, resulting in more generation. The average annual loss in generation due to VARQ under fish flows at QPHC is 8 MW.

Table 6 shows generation differences between Alternative Combination LV2+HV minus LS2+HS, VARQ Flood Control with QPHC+10 minus Standard Flood Control with QPHC+10. Results are similar to that explained for Table 4. The generation differences that are italicized in May, June, and July were adjusted from the HYSSR model output to reflect the lost generation due to spill as shown in the daily regulations, and as explained below.

The USFWS Biological Opinion calls for increasing flow capacity from Libby by 10,000 cubic feet per second (cfs) above current powerhouse capacity, within Montana's dissolved gas standard of 110% saturation. Although the mechanism for achieving that has not been determined, the UCEIS evaluates the effects of the flow capacity increase itself. Considering that spill may in fact be the method used to achieve the additional 10,000 cfs, the potential generation lost due to voluntary spill was evaluated.[1]

Adjustments were made to the generation computed by the HYSSR model to account for loss of generation due to spill shown in daily regulations that would not be evident in a monthly model. The generation computed by the HYSSR model uses the average flow and other factors. If the month average flow is less than the powerhouse capacity computed by HYSSR, then HYSSR will show the project not spilling. The QPHC + 10 kcfs daily simulations provided by NWS show that spill occurred in part of the months in May in 24 years and in June in 34 years, with the month average being less than powerhouse capacity. To estimate the May and June generation that includes the loss due to spill, daily spill in MW was computed, then averaged over each of the months and subtracted from the corresponding month generation from the HYSSR model. To compute spill in MW on a daily basis, first the spill flow was computed to be the total regulated flow minus the powerhouse capacity. The powerhouse capacity was computed based on powerhouse capacity vs. forebay table provided by NWS. The spill flow was converted to MW by a conversion factor, MW/Kcfs. The conversion factor varies with

[1] Installation of additional generating units at Libby would also be considered to achieve the additional flow capacity for 10,000 cfs, in which case generation would not be lost to provide the additional 10,000 cfs. Both spill and installation of additional units present logistical and funding challenges. Any decisions on the method used to pass the additional water would include further studies on design, benefits, and impacts, and subsequent documentation under the National Environmental Policy Act, including a public comment period.

head and the head was computed to be the daily forebay elevation minus an assumed tailwater elevation 2124 feet. The MW/Kcfs conversion factor vs. head table used was that submitted for use for the PNCA. This method is intended only to provide an estimate. The average annual loss in generation due to VARQ under fish flows at QPHC + 10 is 7 MW.

Table 7 shows differences in generation for Alternative/Benchmark Combination LS1+HS minus LS+HS, Standard Flood control with Libby fish flows at QPHC minus Standard Flood Control without Libby fish flows. For May and June, there was more flow and generation in the fish flow alternative combination because the targeted elevations produced more flow than in the flood control only alternative combination, which was trying to fill to the flood control elevation. In July, 58% of the time Libby's fish flow targeted elevations produced less flow than that flow needed to fill from the June flood control elevation to full in July in the flood control only alternative combination. This resulted in less overall flow at Libby, however, Kootenay Lake still attempted to operate to meet its IJC rule curves, and drafted as it could within the channel capacity limitations. This resulted in more flow released from Kootenay Lake in July, which carried through the system and resulted in higher system generation in July. In both halves of August, Libby released more flows from the fish flow alternative combination than the flood control only alternative combination because the flood control only alternative combination operated to maintain elevation 2459 from the end of July through the end of August just passing natural flows. For September, in the fish flow alternative combination, Libby drafted 1.1 feet from elevation 2439 at the end of August to elevation 2437.9 (the power operating rule curve) at the end of September in most years. In the fish flow alternative combination, Libby drafted 21.1 feet from elevation 2459 at the end of August to elevation 2437.9 at the end of September. This resulted in less flow and generation in the fish flow alternative combination in September. For October through December, on average, small generation differences occurred when the system drafted to just meet load. The average annual loss in generation due to fish flows at QPHC with Standard Flood Control is 31 MW with most of the loss occurring in September. In a few years in January through April, some residual effects of the prior year show up, but for the most part, the projects operated the same in both alternative combinations.

Table 8 shows differences in generation for Alternative/Benchmark Combination LS2+HS minus LS+HS, Libby with fish flows at QPHC+10 and Standard Flood Control minus Standard Flood Control without Libby fish flows. The explanation of the results is similar to that for Table 7. The average annual loss in generation due to fish flows up to QPHC + 10 under Standard Flood Control is 38 MW.

Tables 9 and 10 show differences in generation for Libby with fish flows at QPHC, and at QPHC+10, respectively, minus Libby on VARQ Flood Control. The explanation of the results is similar to that for Table 6. The average annual loss in generation due to fish flows up QPHC under VARQ Flood Control is 27 MW. The average annual generation lost due to fish flows up to QPHC+10 under VARQ flood control is 33 MW.

Table 4. System Generation Differences (aMW), Benchmark Combination LV+HV minus LS+HS

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
47-48	100	0	0	0	0	0	-489	-1452	7	244	115	588	20	131	-84
48-49	0	0	0	0	0	0	-1285	-60	-794	675	-650	878	956	58	-19
49-50	0	0	95	23	35	45	-758	120	-303	160	-62	306	409	82	8
50-51	-1	-34	0	0	0	17	162	-532	-66	353	-154	65	173	-67	-13
51-52	-7	14	0	0	0	0	-10	-994	-384	103	-163	245	495	664	0
52-53	182	0	0	0	0	0	0	-861	-281	17	-500	403	631	178	-6
53-54	-59	0	0	0	0	0	-1149	63	341	484	-251	154	313	45	-12
54-55	62	-1	5	0	0	0	-1899	-118	11	-155	230	-421	835	573	-78
55-56	-4	-209	0	0	0	0	69	-569	267	206	-83	22	-5	-27	-23
56-57	115	0	0	0	0	0	-1422	-1033	-23	-99	-596	530	1394	244	-50
57-58	0	0	0	0	0	0	-1156	-741	396	-46	-293	418	1153	12	-7
58-59	0	0	0	0	0	0	-392	-443	-179	341	145	546	379	-84	5
59-60	38	0	0	0	0	401	-1473	-512	1	-201	27	839	816	-7	0
60-61	0	0	0	0	0	0	-993	-962	-144	-355	-540	502	781	240	-85
61-62	0	0	0	0	0	0	-1774	-252	32	-46	-291	626	790	644	-8
62-63	0	0	0	0	0	0	-1644	-325	-15	-197	-347	752	911	274	-26
63-64	315	0	0	0	0	0	-1035	-448	9	-84	-834	516	621	503	-11
64-65	2	-28	0	0	0	0	-157	-617	355	442	-16	251	248	-125	12
65-66	142	0	0	0	0	0	-1276	12	19	-325	-456	526	676	319	-3
66-67	2	0	0	0	0	0	-630	192	667	634	-323	-63	108	-178	21
67-68	-120	0	0	0	0	0	-1153	-1004	-368	469	-540	698	932	505	-40
68-69	56	0	0	0	0	241	-466	-119	-232	-259	191	323	242	181	13
69-70	272	0	0	0	0	0	-68	-300	-31	-557	-539	351	163	107	-15
70-71	0	0	0	0	0	0	-1280	57	-6	544	190	309	446	73	-2
71-72	2	1	0	0	0	0	-742	343	182	253	-322	373	-59	-333	-22
72-73	146	39	0	0	87	-89	-1383	-470	-180	0	-1	411	210	162	-96
73-74	0	-1	1	151	810	202	8	-164	252	520	-83	45	70	-102	124
74-75	-147	-30	0	0	0	0	-1154	-864	108	164	-465	627	615	510	-33
75-76	291	0	0	0	0	35	-249	-2027	628	477	230	238	446	330	-8
76-77	114	15	2	0	0	4	-226	1	1	0	1	54	45	-42	-8
77-78	3	1	-32	-1	11	139	-768	-1242	18	385	-470	158	694	1241	14
78-79	0	0	0	0	-796	504	-529	-196	-662	-28	-8	614	73	0	-84
79-80	0	-1	114	0	220	430	-1469	57	303	367	-601	668	581	-43	62
80-81	0	0	0	0	0	0	-360	-1563	408	-56	-745	488	612	139	-56
81-82	-11	-66	0	0	0	0	-1274	-620	-336	478	-119	538	918	330	-25
82-83	-6	-41	0	0	0	0	-1167	-1080	22	-150	-656	545	1446	632	-2
83-84	0	0	0	0	0	0	-1342	-652	199	315	-611	393	1176	-1	-31
84-85	0	0	0	0	0	0	-1197	-125	-157	511	-421	184	402	0	-70
85-86	0	0	82	108	370	574	-1956	-60	-215	200	-768	308	1244	751	76
86-87	0	1	-1	0	0	0	-1375	-247	-130	17	-650	1097	1	0	-80
87-88	0	0	-1	-1	-1	0	-1	1099	121	-1543	211	624	-86	-1	90
88-89	0	0	-3	-9	497	-57	-2122	-538	11	-746	-119	1046	630	-15	-82
89-90	116	173	69	96	348	277	-1195	122	-130	-177	206	577	747	-117	79
90-91	-16	0	0	0	0	5	178	64	-83	-106	-176	-3	135	-113	2
91-92	-118	-22	0	0	0	0	-1007	-989	13	-7	-288	1024	0	423	-62
92-93	365	265	0	1	1	-1	-418	-1	31	21	4	425	37	21	35
93-94	0	0	0	0	0	0	-328	2	2	-164	-942	673	133	-1	-6
94-95	0	0	0	0	22	-5	-801	-456	-386	448	-586	858	605	-11	-20
95-96	0	0	0	0	0	184	41	-49	-54	-268	-115	119	14	-79	-1
96-97	10	36	0	0	0	0	-434	22	-6	259	-79	49	343	331	34
97-98	-304	0	0	0	0	0	-483	-720	167	-202	-25	716	521	-421	-40
98-99	0	0	0	0	540	-545	-1065	-736	-3	-42	48	661	712	353	-6
Ave MW	27	2	6	7	41	45	-828	-422	-11	62	-255	439	495	159	-12
% Diff	0.2%	0.0%	0.1%	0.1%	0.3%	0.3%	-4.2%	-2.7%	-0.1%	0.4%	-1.6%	2.3%	2.6%	1.0%	-0.1%

Table 5. System Generation Differences (aMW), Alternative Combination LV1+HV minus LS1+HS

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
47-48	0	0	0	0	0	0	-489	-1452	7	244	115	588	5	147	-84
48-49	17	78	-7	0	0	0	-1285	-60	-794	675	-650	633	483	391	-48
49-50	221	1	0	0	150	388	-775	119	-303	165	-63	306	260	57	30
50-51	32	134	30	0	0	17	162	-532	-66	353	-154	65	177	-62	-2
51-52	4	18	-7	0	0	0	-10	-994	-384	81	-163	246	476	103	-50
52-53	84	67	265	65	94	233	0	-861	-281	17	-499	269	174	260	4
53-54	792	516	-15	0	0	0	-1149	63	341	484	-251	154	247	37	37
54-55	164	66	7	0	0	0	-1899	-118	11	-155	230	-556	502	639	-105
55-56	165	1031	0	0	0	0	56	-569	267	206	-83	22	127	-62	41
56-57	-56	-143	7	0	0	0	-1422	-1033	-23	-99	-596	452	572	572	-110
57-58	690	1	385	127	0	0	-1156	-741	396	-46	-293	297	207	516	17
58-59	604	521	22	0	0	0	-342	-443	-179	341	145	540	294	-97	50
59-60	263	104	-14	0	0	401	-1473	-512	1	-214	27	839	395	72	-16
60-61	125	130	282	0	0	0	-993	-962	-144	-355	-540	502	614	343	-56
61-62	211	95	30	0	0	0	-1774	-252	32	-46	-291	560	157	438	-68
62-63	493	457	263	223	78	0	-1644	-325	-15	-197	-347	596	431	316	10
63-64	1347	301	0	0	0	0	-1035	-448	9	-84	-834	443	58	555	-4
64-65	228	1452	-7	0	0	0	-157	-617	355	442	-16	247	151	-242	65
65-66	9	-12	31	313	0	0	-1276	12	19	-325	-456	526	416	320	-2
66-67	312	251	0	0	0	0	-630	192	667	634	-323	-75	58	-112	44
67-68	-77	-64	15	0	0	0	-1153	-1004	-368	469	-540	583	130	563	-111
68-69	1144	878	7	0	0	241	-470	-119	-232	-259	191	309	128	284	93
69-70	207	116	15	0	0	0	-68	-300	-31	-557	-539	278	33	121	-28
70-71	239	190	-8	0	0	0	-1275	57	-6	544	190	303	228	63	-4
71-72	290	294	-30	0	0	0	-742	343	185	253	-322	361	115	-305	15
72-73	-203	-62	-211	0	87	-89	-1383	-470	-180	0	-1	285	0	170	-160
73-74	0	0	0	56	1055	498	1	-185	235	513	-113	-31	23	-29	151
74-75	-80	-67	-10	0	0	0	-1154	-864	108	164	-465	627	358	186	-81
75-76	265	256	454	173	0	35	-249	-2027	628	477	230	202	195	267	24
76-77	342	276	139	0	0	4	-226	1	1	0	1	54	45	30	29
77-78	56	81	0	0	0	2	-857	-1242	18	385	-470	27	287	1147	-49
78-79	735	605	22	0	-796	504	-529	-196	-662	-28	-8	428	0	0	-48
79-80	-2	1	0	-1	446	634	-1465	19	302	366	-603	807	394	-93	77
80-81	71	62	-15	0	0	0	-360	-1563	408	-56	-745	393	325	88	-88
81-82	30	359	270	0	0	0	-1274	-637	-336	478	-119	538	561	318	-15
82-83	112	682	-22	0	0	0	-1167	-1080	13	-150	-656	545	754	560	-33
83-84	142	917	306	11	0	0	-1342	-652	199	315	-611	197	472	417	0
84-85	628	532	-7	0	0	0	-1197	-125	-157	511	-421	108	0	0	-62
85-86	-1	1	0	508	954	357	-2007	-203	-261	190	-767	69	596	1163	74
86-87	725	516	-30	0	0	0	-1375	-247	-130	17	-650	781	-1	0	-58
87-88	0	0	1	-1	-1	-1	165	527	304	347	1	438	13	-87	127
88-89	-1	-1	1	-1	575	-59	-2216	-631	97	-746	-119	916	0	577	-97
89-90	654	482	50	43	123	243	-1207	122	-130	-177	206	584	175	239	68
90-91	253	207	-15	0	0	5	178	64	-83	-106	-176	-3	57	-46	20
91-92	-41	-86	7	0	0	0	-1136	-841	13	-7	-288	727	0	134	-108
92-93	194	955	0	0	-1	0	138	0	29	35	-5	212	165	63	99
93-94	-69	-26	-1	1	8	0	-328	2	2	-164	-942	453	1	0	-38
94-95	-31	0	-1	0	78	236	-938	-449	-257	535	-586	577	597	293	8
95-96	25	47	7	0	0	184	41	-49	-54	-268	-115	103	117	-88	8
96-97	-21	-116	7	0	0	0	-434	22	-6	259	-79	49	19	232	-7
97-98	284	678	22	0	0	0	-483	-720	167	-202	-25	509	553	-241	14
98-99	-12	50	-8	0	540	-545	-1065	-736	-3	-42	48	661	424	276	-36
Ave MW	222	246	43	29	65	63	-824	-436	-5	100	-260	360	241	201	-8
% Diff	1.6%	2.1%	0.5%	0.3%	0.5%	0.4%	-4.2%	-2.8%	0.0%	0.7%	-1.6%	1.9%	1.3%	1.2%	-0.1%

Table 6. System Generation Differences (aMW), Alternative Combination LV2+HV minus LS2+HS

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
47-48	0	1	0	0	0	0	-489	-1452	7	244	115	588	11	213	-72
48-49	36	228	-207	0	0	0	-1285	-60	-794	675	-650	597	531	391	-58
49-50	220	0	-1	-2	149	396	-775	119	-303	164	-63	306	248	21	25
50-51	44	252	7	0	0	17	162	-532	-66	353	-154	65	178	-72	4
51-52	5	-1	0	0	0	0	-10	-994	-384	103	-163	245	483	78	-47
52-53	33	43	258	63	95	299	0	-861	-281	17	-499	291	181	211	11
53-54	826	523	-45	0	0	0	-1149	63	341	484	-251	154	253	23	35
54-55	166	105	34	0	0	0	-1899	-118	11	-155	230	-556	503	656	-102
55-56	170	1072	7	0	0	0	56	-569	267	206	-83	22	120	-60	48
56-57	-69	-80	-15	0	0	0	-1422	-1033	-23	-99	-596	459	557	534	-108
57-58	635	1	383	195	0	0	-1156	-741	396	-46	-293	297	212	502	24
58-59	604	521	22	0	0	0	-346	-443	-179	341	145	540	303	-68	56
59-60	158	130	-7	0	0	401	-1473	-512	1	-205	27	839	390	30	-21
60-61	89	79	312	79	0	0	-993	-962	-144	-355	-540	502	466	377	-55
61-62	312	183	-15	0	0	0	-1774	-252	32	-46	-291	566	164	388	-67
62-63	457	417	248	224	179	0	-1644	-325	-15	-197	-347	590	404	326	14
63-64	1258	497	-37	0	0	0	-1035	-448	9	-84	-834	458	93	520	1
64-65	222	1399	0	0	0	0	-157	-617	355	442	-16	247	138	-239	69
65-66	5	14	1	309	34	0	-1276	12	19	-325	-456	526	440	296	-2
66-67	271	261	7	0	0	0	-630	192	667	634	-323	-75	56	-111	43
67-68	-65	-53	-7	0	0	0	-1153	-1004	-368	469	-540	575	120	598	-108
68-69	1187	897	0	0	0	241	-506	-119	-232	-259	191	309	151	263	95
69-70	171	129	15	0	0	0	-68	-300	-31	-557	-539	259	40	131	-26
70-71	212	192	15	0	0	0	-1275	57	-6	544	190	303	249	90	-2
71-72	149	272	-7	0	0	0	-742	343	185	253	-322	361	106	-305	8
72-73	-147	-72	-179	0	87	-89	-1383	-470	-180	0	-1	236	0	167	-159
73-74	0	1	0	37	1098	499	5	-182	239	516	-110	3	19	-32	158
74-75	-36	-75	6	0	0	0	-1154	-864	108	164	-465	627	371	163	-74
75-76	238	231	461	247	0	35	-249	-2027	628	477	230	202	208	252	38
76-77	350	290	126	0	0	4	-226	1	1	0	1	54	45	23	29
77-78	42	70	-1	1	0	6	-847	-1242	18	385	-470	49	86	1104	-59
78-79	1108	759	0	0	-796	504	-529	-196	-662	-28	-8	375	0	0	-30
79-80	0	0	1	0	426	704	-1456	19	301	366	-603	813	354	-66	81
80-81	28	26	7	0	0	0	-360	-1563	408	-56	-745	327	281	150	-82
81-82	39	389	313	0	0	0	-1274	-633	-336	478	-119	538	578	314	-6
82-83	110	656	-15	0	0	0	-1167	-1080	13	-150	-656	545	809	520	-25
83-84	129	809	276	104	0	0	-1342	-652	199	315	-611	94	491	540	5
84-85	573	504	-15	0	0	0	-1197	-125	-157	511	-421	80	0	1	-70
85-86	0	0	0	492	964	387	-2006	-201	-233	190	-767	56	550	1239	80
86-87	736	561	-75	0	0	0	-1375	-247	-130	17	-650	749	0	-1	-61
87-88	0	0	0	-1	0	0	278	466	250	348	1	426	21	-52	129
88-89	2	0	1	0	571	-65	-2236	-631	97	-746	-119	928	13	533	-99
89-90	644	462	80	41	117	243	-1207	122	-130	-177	206	584	193	230	69
90-91	220	209	0	0	0	5	178	64	-83	-106	-176	-3	54	-51	20
91-92	-11	-57	-7	0	0	0	-1136	-841	13	-7	-288	675	0	176	-105
92-93	200	955	0	1	1	0	126	-1	28	23	-5	211	151	79	101
93-94	-69	-51	1	-1	16	7	-328	2	2	-164	-942	444	-1	0	-39
94-95	-50	0	1	0	31	289	-938	-446	-257	535	-586	516	537	281	-1
95-96	204	124	37	0	0	184	41	-49	-54	-268	-115	103	101	-74	22
96-97	-13	-92	0	0	0	0	-434	22	-6	259	-79	49	30	270	-3
97-98	313	581	-44	0	0	0	-483	-720	167	-202	-25	494	593	-263	12
98-99	-70	14	8	0	540	-545	-1065	-736	-3	-42	48	661	440	289	-34
Ave MW	223	257	37	34	67	67	-823	-437	-5	100	-260	351	236	203	-7
% Diff	1.6%	2.2%	0.4%	0.3%	0.5%	0.5%	-4.3%	-2.8%	0.0%	0.6%	-1.6%	1.8%	1.2%	1.2%	0.0%

Table 7. System Generation Differences (aMW), Alternative/Benchmark Combination LS1+HS minus LS+HS

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
47-48	-19	1	-1596	0	0	0	0	0	0	0	0	0	63	259	-106
48-49	158	1363	-1581	0	0	0	0	0	0	0	0	447	908	0	44
49-50	-1	0	-686	-208	-267	-552	12	2	-1	-12	2	0	592	357	-63
50-51	-5	-163	-1601	0	0	0	0	0	0	0	0	0	731	125	-69
51-52	76	544	-1575	0	0	0	0	0	0	0	0	0	867	1061	55
52-53	-78	14	-1880	-65	-94	-233	0	0	0	0	0	271	661	-76	-120
53-54	-76	565	-1585	0	0	0	0	0	0	0	0	0	461	263	-51
54-55	-161	433	-1238	-12	0	0	0	0	0	0	0	206	365	-72	-51
55-56	140	839	-1571	0	0	0	0	0	0	0	0	0	473	162	-37
56-57	233	776	-1592	0	0	0	0	0	0	0	0	230	1011	-166	-1
57-58	-17	0	-1717	0	0	0	0	0	0	0	0	260	1166	-307	-50
58-59	40	69	-1536	1	0	0	-27	0	0	0	0	6	480	154	-72
59-60	249	667	-958	-537	0	0	0	0	0	13	0	0	1020	510	41
60-61	-281	115	-1862	0	0	0	0	0	0	0	0	0	164	280	-125
61-62	738	822	-1613	0	0	0	0	0	0	0	0	245	920	679	84
62-63	-294	5	-1855	-223	-78	0	0	0	0	0	0	537	629	-162	-108
63-64	-205	621	-1577	0	0	0	0	0	0	0	0	239	678	-81	-44
64-65	1	244	-1558	0	0	0	0	0	0	0	0	5	918	603	7
65-66	313	309	-2048	-313	0	0	0	0	0	0	0	0	953	44	-87
66-67	74	366	-1597	0	0	0	0	0	0	0	0	11	598	70	-58
67-68	3	539	-1587	0	0	0	0	0	0	0	0	446	719	-144	-24
68-69	47	235	-1554	0	0	0	0	0	0	0	0	14	610	-106	-74
69-70	660	293	-1312	0	0	0	0	0	0	0	0	569	478	-153	4
70-71	157	180	-1428	0	2	1	-4	0	0	0	0	6	633	213	-34
71-72	-204	743	-1572	0	0	0	0	0	-3	0	0	12	59	285	-79
72-73	349	479	-1144	0	0	0	0	0	0	0	0	545	210	1	2
73-74	0	-1	0	-266	-104	-670	7	21	17	7	30	88	143	133	-51
74-75	296	1248	-1532	0	0	0	0	0	0	0	0	0	885	834	79
75-76	-8	-216	-2045	-173	0	0	0	0	0	0	0	46	1128	658	-41
76-77	-550	-524	-1635	-19	0	0	0	0	0	0	0	0	0	518	-139
77-78	608	550	-32	-1	1	-632	-331	-11	-8	-1	-1	177	571	351	55
78-79	34	121	-1556	0	0	0	0	0	0	0	0	493	74	0	-76
79-80	1	-1	-1089	1	273	19	22	36	-6	1	3	14	300	381	-3
80-81	674	654	-1583	0	0	0	0	0	0	0	0	457	348	-299	-34
81-82	147	1157	-1526	0	0	0	0	0	0	0	0	0	940	265	27
82-83	-61	-95	-1543	0	0	0	0	0	0	0	0	0	1009	626	1
83-84	-110	-307	-1861	-11	0	0	0	0	0	0	0	509	603	-97	-88
84-85	-5	299	-1580	0	0	0	0	0	0	0	0	474	402	0	-46
85-86	0	-1	-1220	-538	133	225	55	148	115	10	0	498	593	-181	-13
86-87	148	99	-1391	2	0	0	0	0	0	0	0	555	1	0	-59
87-88	1	1	-1	0	1	1	-165	-217	-31	-347	-7	-145	-83	87	-60
88-89	0	1	-176	-65	261	-38	-200	0	0	0	0	257	631	224	74
89-90	-119	-139	-1574	76	260	34	12	0	0	0	0	0	993	177	-12
90-91	-197	186	-1587	0	0	0	0	0	0	0	0	6	734	259	-49
91-92	-321	591	-1592	0	0	0	0	0	0	0	0	568	0	593	-24
92-93	278	190	1	0	0	0	-1071	-1	-25	-139	-4	-70	-437	125	-109
93-94	1180	1193	-705	-38	-569	-202	0	-77	-19	0	0	494	-2	0	5
94-95	228	-1	0	0	-43	-617	0	-4	9	-1	-1	509	-46	-87	-13
95-96	765	917	-1582	0	0	0	0	0	0	0	0	50	309	102	-23
96-97	172	1287	-1571	0	0	0	0	0	0	0	0	2	421	194	-18
97-98	76	667	-1564	0	0	0	0	0	0	0	0	455	-311	157	-74
98-99	887	550	-1380	9	0	0	0	0	0	0	0	0	946	541	69
Ave MW	115	355	-1348	-45	-4	-51	-32	-1	0	-9	0	182	509	180	-31
% Diff	0.8%	3.2%	-13.4%	-0.4%	0.0%	-0.4%	-0.2%	0.0%	0.0%	-0.1%	0.0%	1.0%	2.7%	1.1%	-0.2%

Table 8. System Generation Differences (aMW), Alternative/Benchmark Combination LS2+HS minus LS+HS

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
47-48	-19	1	-1596	0	0	0	0	0	0	0	0	0	26	237	-109
48-49	138	1195	-1567	0	0	0	0	0	0	0	0	523	775	0	37
49-50	0	0	-687	-207	-275	-578	12	2	-1	-12	2	0	580	367	-66
50-51	-16	-281	-1587	0	0	0	0	0	0	0	0	0	757	143	-69
51-52	35	233	-1583	0	0	0	0	0	0	0	0	0	808	1076	39
52-53	-67	14	-1880	-63	-95	-299	0	0	0	0	0	315	629	-137	-128
53-54	-123	539	-1577	0	0	0	0	0	0	0	0	0	442	305	-49
54-55	-315	338	-1290	-12	0	0	0	0	0	0	0	291	314	-169	-69
55-56	136	786	-1578	0	0	0	0	0	0	0	0	0	476	137	-39
56-57	164	711	-1585	0	0	0	0	0	0	0	0	265	969	-215	-8
57-58	-4	0	-1722	-68	0	0	0	0	0	0	0	306	1112	-383	-63
58-59	13	43	-1536	1	0	0	-23	0	0	0	0	6	489	123	-75
59-60	181	600	-972	-537	0	0	0	0	0	4	0	0	983	544	35
60-61	-282	114	-1906	-79	0	0	0	0	0	0	0	0	162	252	-135
61-62	650	746	-1590	0	0	0	0	0	0	0	0	304	888	635	81
62-63	-285	5	-1855	-224	-179	0	0	0	0	0	0	642	611	-216	-111
63-64	-464	595	-1577	0	0	0	0	0	0	0	0	289	618	-136	-59
64-65	14	268	-1580	0	0	0	0	0	0	0	0	5	881	627	9
65-66	312	297	-2049	-394	-34	0	0	0	0	0	0	0	929	21	-101
66-67	7	292	-1582	0	0	0	0	0	0	0	0	11	605	13	-65
67-68	-61	476	-1564	0	0	0	0	0	0	0	0	552	708	-293	-30
68-69	20	183	-1561	0	0	0	0	0	0	0	0	14	613	-131	-79
69-70	562	204	-1312	0	0	0	0	0	0	0	0	620	465	-238	-5
70-71	157	166	-1443	0	2	1	-4	0	0	0	0	6	632	173	-38
71-72	-249	617	-1572	0	0	0	0	0	-3	0	0	12	37	290	-84
72-73	141	443	-1270	0	0	0	0	0	0	0	0	628	210	1	-8
73-74	-1	-2	1	-266	-203	-711	7	19	14	5	27	52	144	152	-66
74-75	218	1119	-1580	0	0	0	0	0	0	0	0	0	852	845	70
75-76	-21	-215	-2046	-247	0	0	0	0	0	0	0	46	1105	664	-48
76-77	-639	-598	-1645	-19	0	0	0	0	0	0	0	0	0	525	-145
77-78	622	560	-32	-2	1	-637	-342	-11	-8	-1	-1	228	546	265	49
78-79	-19	83	-1549	0	0	0	0	0	0	0	0	568	74	0	-70
79-80	0	1	-1090	0	215	-85	14	36	-5	1	3	49	242	309	-25
80-81	660	641	-1583	0	0	0	0	0	0	0	0	566	314	-451	-39
81-82	143	1158	-1545	0	0	0	0	0	0	0	0	0	906	247	25
82-83	-72	-159	-1536	0	0	0	0	0	0	0	0	0	957	653	-2
83-84	-111	-308	-1861	-104	0	0	0	0	0	0	0	549	583	-175	-100
84-85	-19	274	-1565	0	0	0	0	0	0	0	0	543	402	-1	-38
85-86	0	-1	-1220	-558	41	194	54	146	87	10	0	604	566	-346	-36
86-87	134	85	-1406	2	0	0	0	0	0	0	0	609	0	1	-54
87-88	0	0	0	0	0	1	-278	-217	-31	-348	-7	-146	-95	51	-74
88-89	-1	1	-176	-66	266	-31	-178	0	0	0	0	306	594	170	73
89-90	-111	-134	-1649	82	265	34	12	0	0	0	0	0	961	157	-21
90-91	-259	134	-1587	0	0	0	0	0	0	0	0	6	754	281	-49
91-92	-452	358	-1577	0	0	0	0	0	0	0	0	617	1	552	-33
92-93	272	188	1	0	0	0	-1091	-1	-37	-144	-4	-77	-437	109	-116
93-94	1180	1218	-706	-37	-578	-209	0	-78	-19	0	0	523	-1	-1	12
94-95	222	-1	-1	1	-43	-704	0	-7	9	-1	-1	602	1	-156	-16
95-96	577	833	-1619	0	0	0	0	0	0	0	0	50	362	108	-30
96-97	134	990	-1579	0	0	0	0	0	0	0	0	2	408	199	-30
97-98	-38	607	-1557	0	0	0	0	0	0	0	0	471	-382	157	-81
98-99	887	550	-1380	9	0	0	0	0	0	0	0	0	941	541	71
Ave MW	75	307	-1355	-53	-11	-58	-34	-2	0	-9	0	210	490	151	-38
% Diff	0.6%	2.7%	-13.5%	-0.5%	-0.1%	-0.4%	-0.2%	0.0%	0.0%	-0.1%	0.0%	1.1%	2.6%	0.9%	-0.3%

Table 9. System Generation Differences (aMW), Alternative/Benchmark Combination LV1+HV minus LV+HV

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
47-48	-19	0	-1596	0	0	0	0	0	0	0	0	0	48	274	-106
48-49	175	1441	-1589	0	0	0	0	0	0	0	0	201	434	333	15
49-50	220	1	-781	-231	-151	-209	-5	1	0	-7	2	0	443	332	-41
50-51	28	6	-1572	0	0	0	0	0	0	0	0	0	735	130	-57
51-52	87	547	-1583	0	0	0	0	0	0	-23	0	0	848	500	5
52-53	-177	81	-1615	0	0	0	0	0	0	0	0	137	204	6	-109
53-54	774	1081	-1600	0	0	0	0	0	0	0	0	0	396	254	-1
54-55	-60	500	-1236	-12	0	0	0	0	0	0	0	71	32	-6	-77
55-56	309	2078	-1571	0	0	0	-13	0	0	0	0	0	606	127	28
56-57	62	633	-1585	0	0	0	0	0	0	0	0	153	190	162	-61
57-58	673	1	-1332	127	0	0	0	0	0	0	0	139	220	196	-26
58-59	645	590	-1514	1	0	0	22	0	0	0	0	0	396	141	-28
59-60	473	771	-972	-537	0	0	0	0	0	0	0	0	599	589	25
60-61	-156	245	-1580	0	0	0	0	0	0	0	0	0	-3	383	-96
61-62	949	918	-1582	0	0	0	0	0	0	0	0	179	286	473	24
62-63	199	463	-1592	0	0	0	0	0	0	0	0	382	149	-119	-70
63-64	827	923	-1577	0	0	0	0	0	0	0	0	166	115	-29	-37
64-65	228	1724	-1566	0	0	0	0	0	0	0	0	0	820	486	59
65-66	181	298	-2017	0	0	0	0	0	0	0	0	0	693	44	-86
66-67	385	617	-1597	0	0	0	0	0	0	0	0	0	547	136	-34
67-68	46	475	-1572	0	0	0	0	0	0	0	0	332	-84	-86	-95
68-69	1135	1113	-1547	0	0	0	-4	0	0	0	0	0	496	-2	5
69-70	595	409	-1297	0	0	0	0	0	0	0	0	497	349	-138	-7
70-71	396	370	-1435	0	2	1	0	0	0	0	0	0	415	204	-35
71-72	83	1037	-1601	0	0	0	0	0	0	0	0	0	233	313	-41
72-73	0	377	-1354	0	0	0	0	0	0	0	0	419	0	8	-61
73-74	0	0	-1	-361	141	-374	1	0	0	0	0	13	96	205	-23
74-75	362	1212	-1542	0	0	0	0	0	0	0	0	0	628	511	32
75-76	-35	41	-1592	0	0	0	0	0	0	0	0	10	877	595	-8
76-77	-322	-263	-1498	-19	0	0	0	0	0	0	0	0	0	590	-101
77-78	661	629	0	0	-10	-769	-420	-11	-8	-1	-1	47	165	257	-8
78-79	770	726	-1535	0	0	0	0	0	0	0	0	306	1	0	-40
79-80	-1	1	-1203	0	498	222	26	-1	-7	0	0	153	114	330	11
80-81	745	716	-1598	0	0	0	0	0	0	0	0	361	62	-351	-66
81-82	187	1582	-1256	0	0	0	0	-17	0	0	0	0	583	254	37
82-83	57	629	-1565	0	0	0	0	0	-9	0	0	0	317	554	-30
83-84	32	610	-1555	0	0	0	0	0	0	0	0	313	-101	320	-58
84-85	622	831	-1587	0	0	0	0	0	0	0	0	398	0	0	-38
85-86	0	1	-1302	-138	718	8	4	5	69	0	0	260	-55	231	-16
86-87	874	614	-1420	2	0	0	0	0	0	0	0	239	-1	0	-36
87-88	1	0	1	0	0	1	1	-788	152	1543	-217	-330	17	1	-23
88-89	-1	1	-172	-58	339	-39	-294	-93	85	0	0	127	1	816	59
89-90	419	170	-1592	22	34	0	0	0	0	0	0	8	421	533	-23
90-91	72	393	-1603	0	0	0	0	0	0	0	0	6	655	326	-32
91-92	-244	527	-1584	0	0	0	-129	148	0	0	0	270	0	304	-70
92-93	107	879	1	-1	-2	1	-515	0	-26	-125	-12	-283	-309	167	-45
93-94	1112	1167	-706	-37	-561	-202	0	-77	-19	0	0	275	-134	0	-26
94-95	197	0	0	0	13	-376	-137	2	138	87	0	228	-54	217	14
95-96	789	965	-1574	0	0	0	0	0	0	0	0	34	412	93	-13
96-97	140	1136	-1564	0	0	0	0	0	0	0	0	3	97	95	-60
97-98	664	1345	-1542	0	0	0	0	0	0	0	0	249	-280	337	-19
98-99	875	600	-1387	9	0	0	0	0	0	0	0	0	657	463	39
Ave MW	310	600	-1312	-23	19	-33	-28	-15	7	28	-4	103	256	222	-27
% Diff	2.3%	5.3%	-13.0%	-0.2%	0.2%	-0.2%	-0.1%	-0.1%	0.0%	0.2%	0.0%	0.5%	1.3%	1.3%	-0.2%

Table 10. System Generation Differences (aMW), Alternative/Benchmark Combination LV2+HV minus LV+HV

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
47-48	-19	1	-1596	0	0	0	0	0	0	0	0	0	17	318	-103
48-49	175	1423	-1773	0	0	0	0	0	0	0	0	242	350	333	1
49-50	220	1	-782	-231	-161	-226	-6	1	0	-7	2	0	421	306	-47
50-51	29	5	-1579	0	0	0	0	0	0	0	0	0	763	138	-54
51-52	46	218	-1583	0	0	0	0	0	0	0	0	0	796	489	-12
52-53	-217	57	-1622	0	0	0	0	0	0	0	0	204	180	-103	-116
53-54	761	1063	-1622	0	0	0	0	0	0	0	0	0	382	283	0
54-55	-212	444	-1261	-12	0	0	0	0	0	0	0	157	-17	-87	-89
55-56	309	2067	-1571	0	0	0	-13	0	0	0	0	0	602	104	31
56-57	-20	631	-1599	0	0	0	0	0	0	0	0	194	133	75	-71
57-58	631	0	-1339	127	0	0	0	0	0	0	0	185	171	106	-35
58-59	617	565	-1514	1	0	0	22	0	0	0	0	0	412	138	-27
59-60	300	730	-980	-537	0	0	0	0	0	0	0	0	557	581	13
60-61	-193	193	-1594	0	0	0	0	0	0	0	0	0	-154	389	-110
61-62	962	929	-1605	0	0	0	0	0	0	0	0	245	260	379	23
62-63	171	422	-1607	0	0	0	0	0	0	0	0	480	103	-163	-71
63-64	478	1092	-1614	0	0	0	0	0	0	0	0	230	90	-119	-48
64-65	235	1695	-1580	0	0	0	0	0	0	0	0	0	770	513	61
65-66	175	311	-2047	-85	0	0	0	0	0	0	0	0	694	-3	-98
66-67	276	553	-1575	0	0	0	0	0	0	0	0	0	553	80	-42
67-68	-6	423	-1572	0	0	0	0	0	0	0	0	428	-104	-199	-100
68-69	1151	1080	-1561	0	0	0	-41	0	0	0	0	0	522	-48	2
69-70	461	333	-1297	0	0	0	0	0	0	0	0	528	343	-213	-18
70-71	368	358	-1428	0	2	1	0	0	0	0	0	0	437	191	-34
71-72	-103	888	-1579	0	0	0	0	0	0	0	0	0	202	318	-51
72-73	-151	331	-1450	0	0	0	0	0	0	0	0	453	-1	7	-72
73-74	0	0	0	-381	85	-415	4	0	0	0	0	11	94	221	-33
74-75	329	1074	-1574	0	0	0	0	0	0	0	0	0	607	498	23
75-76	-74	16	-1584	0	0	0	0	0	0	0	0	10	869	586	-10
76-77	-403	-324	-1520	-19	0	0	0	0	0	0	0	0	0	590	-107
77-78	661	629	0	0	-10	-769	-420	-11	-8	-1	-1	120	-62	128	-33
78-79	1089	842	-1549	0	0	0	0	0	0	0	0	329	1	0	-18
79-80	1	1	-1203	0	422	189	26	-1	-7	0	0	195	15	285	-4
80-81	688	668	-1576	0	0	0	0	0	0	0	0	405	-16	-440	-76
81-82	193	1612	-1232	0	0	0	0	-13	0	0	0	0	566	231	42
82-83	44	538	-1551	0	0	0	0	0	-9	0	0	0	319	541	-31
83-84	18	501	-1585	0	0	0	0	0	0	0	0	250	-101	366	-63
84-85	554	779	-1580	0	0	0	0	0	0	0	0	440	0	1	-36
85-86	0	0	-1302	-175	635	8	4	5	69	0	0	352	-129	141	-31
86-87	870	645	-1481	2	0	0	0	0	0	0	0	261	-1	0	-35
87-88	0	0	1	0	1	1	1	-850	97	1543	-217	-344	12	0	-33
88-89	1	1	-172	-58	340	-39	-292	-93	85	0	0	187	-24	718	56
89-90	417	154	-1637	26	34	0	0	0	0	0	0	8	406	503	-29
90-91	-23	343	-1587	0	0	0	0	0	0	0	0	6	671	343	-32
91-92	-345	323	-1584	0	0	0	-129	148	0	0	0	268	0	304	-81
92-93	107	878	0	-1	0	1	-547	-1	-41	-142	-12	-290	-324	167	-51
93-94	1112	1167	-705	-38	-562	-202	0	-77	-19	0	0	295	-135	0	-21
94-95	172	-1	0	1	-34	-410	-137	2	138	87	0	261	-67	136	1
95-96	781	957	-1582	0	0	0	0	0	0	0	0	34	449	112	-7
96-97	110	863	-1579	0	0	0	0	0	0	0	0	3	95	138	-68
97-98	578	1188	-1600	0	0	0	0	0	0	0	0	249	-310	315	-33
98-99	816	563	-1372	9	0	0	0	0	0	0	0	0	667	476	41
Ave MW	271	562	-1324	-26	14	-35	-29	-17	5	28	-4	122	232	195	-33
% Diff	2.0%	5.0%	-13.2%	-0.2%	0.1%	-0.2%	-0.2%	-0.1%	0.0%	0.2%	0.0%	0.6%	1.2%	1.2%	-0.2%

3.3 Federal Generation Differences

Differences in generation for individual federal projects are as shown in Tables 11 through 17. Abbreviations for projects are as follows:

LIB—Libby
HGH—Hungry Horse
GCL—Grand Coulee
CHJ—Chief Joseph
MCN—McNary
JDA – John Day
TDA—The Dalles
BON – Bonneville

LIB, HGH, and GCL are reservoir projects that store and release water by allowing the forebay to draft and fill for flood control, fish flows and power. The rest of these projects are run-of- river projects (JDA has some storage for flood control, but for the most part is treated as a run-of-river project). These run-of-river projects pass the flow that comes into their forebay and maintains a steady forebay elevation. They do not draft to meet power loads or for fish flows. The generation differences in Tables 10-16 for these run-of-river projects are a result of the difference in flow passing through their projects.

Table 11 shows the 52-year average difference in generation for Benchmark Combination LV+HV minus LS+HS, VARQ flood control without Libby fish flows minus Standard flood control without Libby fish flows. For Libby, in January and February, on an average annual basis, Libby produced less energy in VARQ than in Standard Flood Control because it was filling to a higher flood control elevation. In March, Libby's average outflow is less in VARQ but the generation is more because of the higher head. In April through July, Libby released more flow in VARQ because the VARQ flood control curves start higher, requiring less volume to fill in these months than with standard flood control, which, along with the higher head, produced more generation. In August through December, Libby operated similarly between alternative combinations however there were some effects in August due to a difference in July ending elevations between alternative combinations.

There is less generation at Hungry Horse in January and February in the VARQ alternative combination because the VARQ Flood Control Curves and simulated elevations are typically higher than the Standard Flood Control Curves and simulated elevations. In March, on average there was slightly more flow in the VARQ alternative combination, thus more generation. In the first half of April, on average, Hungry Horse released slightly more flow with VARQ than with Standard (the target elevations received by Reclamation were overridden by the system flood control which caused the project to draft), but there was less generation because of head effects. In the second half of April, less flow was released in VARQ, therefore less generation. In May, June and July, on average, there was more water available in the VARQ alternative combination so

there was more generation. In August through November, there was no difference in the project's operation because the target elevations were the same. In December, there are 8 years where the VARQ alternative combination produced more flow than the standard alternative combination. In December, the target elevation for VARQ is lower than the target elevation for Standard (the VARQ and Standard Flood Control elevations are elevation 3449.4 and 3555.7, respectively), therefore, the project drafted more in the VARQ alternative combination which accounted for more flow and generation in this month. Differences in generation at CHJ, MCN, JDA, TDA, and BON are a result of the differences of flows from LIB, HGH, GCL, and other reservoir projects upstream of them.

For Grand Coulee, in most years in January, the project ended at the higher of elevation 1260 or the VDL in both alternative combinations. With less incoming flow due to VARQ at Libby and Hungry Horse, Grand Coulee produced less generation in VARQ in January. In February and March the VDLs in the VARQ alternative combination are lower than in the Standard Flood Control alternative combination, which would produce more generation, but with less inflow from Libby in February and March and from Hungry Horse in February, the net effect is that less generation is produced at Grand Coulee. The VDLs are lower with VARQ because the Grand Coulee upper rule curve adjustment lowers Grand Coulee's flood control curve at the end of April to compensate for Libby and Hungry Horse's VARQ operation that raises their flood control curves at the end of April. Grand Coulee's VDLs are based on Grand Coulee's April 10th flood control curve, which is interpolated between the March 31st and April 15th curves.

Tables 12 and 13 show differences in generation for VARQ minus Standard Flood Control for Libby fish flows at QPHC and QPHC+10, respectively. These tables are similar to Table 11 except in May through August at Libby when the project releases fish flows. In May through August, there is more generation due to VARQ.

Table 14 shows differences in generation for Libby with fish flows at QPHC and Standard Flood Control minus Libby on Standard Flood Control without fish flows. There are no differences for Libby in February through April because the elevation targets are the same. Differences in May through December and January are as addressed in the explanation for Table 7.

There are no differences at Hungry Horse because the target elevations are from the fish flow regulations for standard flood control in both alternative combinations.

For Grand Coulee in February through April, Grand Coulee's VDLs are the same so its operation is nearly the same in both alternative combinations. In both alternative combinations in May through August 15th, the project generally operated to its draft limits of elevation 1280, and elevation1280 or elevation 1278 on August 31st. In both alternative combinations, Grand Coulee just passes the additional flow from Libby and Hungry Horse under VARQ, producing more generation in these months. In September, Grand Coulee operated to nearly the same elevations in both alternative combinations, but the reduced inflow from Libby in September as described in the section for Table 7

reduced the generation at Grand Coulee in this month. The project recovered by operating to its operating rule curve in October. In November and December, the project drafted when needed to the draft limits of elevation 1275 and 1270 respectively, to attempt to meet chum flows at Bonneville. This occurred in 9 years in November and 7 years in December.

Table 15 shows differences in generation for Libby with fish flows at QPHC+10 and Standard Flood Control minus Libby on Standard Flood Control. This table has similar explanations as for Table 14 but indicates in bold italics, the generation that is affected by the loss in generation due to spill at Libby with fish flows up to QPHC + 10.

Tables 16 and 17 show differences in generation for Libby with fish flows at QPHC, and at QPHC+10, respectively, minus Libby on VARQ Flood Control. The explanation of the results is similar to that for Table 14.

Table 11. 52-Year Average Difference in Generation for Federal Projects (aMW), Alternative/Benchmark Combination LV+HV minus LS+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
LIB	4	2	0	0	0	1	-137	-45	4	15	20	139	108	15	9
HGH	0	0	0	0	0	7	-31	-37	6	-6	-132	81	45	4	1
GCL	7	-1	0	0	3	3	-184	-81	-11	3	-39	50	137	41	-5
CHJ	3	0	0	0	2	2	-96	-45	-3	9	-12	38	67	19	-1
MCN	1	0	0	0	0	0	-30	-16	0	2	-5	11	20	3	-1
JDA	1	0	0	0	0	1	-64	-27	-1	5	-6	22	41	11	-1
TDA	1	0	0	0	0	1	-47	-20	-1	4	-4	15	29	7	-1
BON	1	0	0	0	0	0	-26	-10	0	2	-3	9	16	6	0

Table 12. 52-Year Difference in Generation for Federal Projects (aMW), Alternative Combination LV1+HV minus LS1+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
LIB	66	54	9	4	2	5	-135	-45	4	15	20	115	27	70	11
HGH	0	0	0	0	0	7	-31	-37	6	-6	-132	81	45	4	1
GCL	54	66	6	5	10	9	-184	-86	-7	15	-39	34	71	43	-4
CHJ	28	35	3	2	5	5	-96	-49	-1	15	-13	30	31	20	-1
MCN	12	14	1	0	2	2	-30	-18	0	5	-5	8	9	5	0
JDA	12	15	2	1	3	3	-64	-29	0	9	-6	18	20	11	-2
TDA	8	10	1	1	2	2	-47	-22	0	7	-4	12	16	7	-1
BON	10	9	1	0	1	1	-26	-11	0	4	-3	7	6	7	0

Table 13. 52-Year Avg. Difference in Generation for Federal Projects (aMW), Alternative Combination LV2+HV minus LS2+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
LIB	65	55	8	5	2	6	-135	-45	4	15	20	***111***	***28***	70	***12***
HGH	0	0	0	0	0	7	-31	-37	6	-6	-132	81	45	4	1
GCL	54	67	5	6	10	10	-183	-86	-7	15	-39	33	70	43	-4
CHJ	28	36	3	3	5	5	-96	-49	-1	15	-13	29	31	20	-1
MCN	11	14	1	1	2	2	-30	-18	0	5	-5	8	9	5	0
JDA	12	15	1	1	3	3	-64	-29	-1	9	-6	17	20	12	-2
TDA	8	10	1	1	2	2	-47	-22	0	7	-4	12	16	7	-1
BON	10	10	0	0	1	1	-26	-11	0	4	-3	6	6	7	0

Table 14. 52-Year Avg. Difference in Generation for Federal Projects (aMW), Alternative/Benchmark Combination LS1+HS minus LS+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
LIB	55	96	-338	-13	-7	-18	-3	0	0	0	0	64	164	-37	-9
HGH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GCL	28	98	-296	-14	-8	-18	-7	0	0	-1	0	37	137	77	-3
CHJ	15	52	-161	-7	-4	-9	-3	0	0	-1	0	20	70	38	-2
MCN	6	23	-67	-2	-1	-4	-1	0	0	0	0	6	19	6	-3
JDA	5	22	-94	-4	-2	-6	-2	0	0	0	0	11	41	22	-2
TDA	4	15	-74	-3	-2	-4	-2	0	0	0	0	8	28	14	-2
BON	5	14	-48	-1	-1	-2	-1	0	0	0	0	5	16	11	-1

Table 15. 52-Year Avg. Difference in Generation for Federal Projects (aMW), Alternative/Benchmark Combination LS2+HS minus LS+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
LIB	44	86	-338	-14	-7	-19	-3	0	0	0	0	***58***	***113***	***-49***	***-16***
HGH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GCL	18	86	-298	-16	-9	-19	-7	0	0	-1	0	47	145	72	-3
CHJ	10	46	-162	-8	-4	-10	-3	0	0	-1	0	26	73	36	-2
MCN	5	20	-67	-3	-2	-4	-1	0	0	0	0	8	20	5	-3
JDA	3	19	-95	-4	-3	-6	-2	0	0	0	0	15	43	20	-2
TDA	2	13	-74	-3	-2	-4	-2	0	0	0	0	10	30	14	-2
BON	3	11	-48	-2	-1	-2	-1	0	0	0	0	7	17	10	-1

Table 16. 52-Year Avg. Difference in Generation for Federal Projects (aMW), Alternative/Benchmark Combination LV1+HV minus LV+HV

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
LIB	116	148	-329	-9	-4	-14	-1	0	0	0	0	40	82	17	-7
HGH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GCL	75	165	-290	-9	-1	-12	-6	-5	3	10	0	21	71	79	-2
CHJ	40	88	-158	-4	0	-6	-3	-3	1	5	0	11	34	39	-2
MCN	17	38	-66	-1	0	-2	-1	-1	0	2	0	3	8	8	-2
JDA	16	37	-92	-2	0	-4	-2	-2	0	2	0	7	20	22	-2
TDA	11	25	-73	-2	0	-3	-1	-2	0	2	0	4	15	14	-2
BON	14	24	-47	-1	0	-1	-1	-1	0	1	0	3	7	12	-1

Table 17. 52-Year Avg. Difference in Generation for Federal Projects (aMW), Alternative/Benchmark Combination LV2+HV minus LV+HV

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
LIB	105	140	-330	-9	-4	-15	-1	0	0	0	0	***30***	***33***	***5***	***-13***
HGH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GCL	65	154	-292	-9	-2	-12	-6	-5	3	10	0	30	79	73	-2
CHJ	35	82	-159	-4	-1	-6	-3	-3	1	5	0	17	37	36	-2
MCN	16	35	-66	-1	0	-2	-1	-1	0	2	0	5	9	7	-2
JDA	14	35	-93	-2	0	-4	-2	-2	0	2	0	10	22	21	-2
TDA	10	24	-73	-2	0	-3	-2	-2	0	2	0	7	17	14	-2
BON	12	22	-47	-1	0	-1	-1	-1	0	1	0	4	7	11	-1

3.4 Non-Federal Generation Differences

Generation differences for Non-Federal Projects are provided in Tables 18 through 24. Abbreviations for these projects are as follows:

KER—Kerr
TOM—Thompson Falls
NOX—Noxon
CAB—Cabinet Gorge
BOX—Box Canyon
BND—Boundary
PRD—Priest Rapids
WAN—Wanapum
RIS—Rock Island
RRH—Rocky Reach
WEL—Wells

KER and NOX are the only reservoirs in this set of projects that draft for power, so they are affected by the system power needs. The rest of the projects are run-of-river type projects and the increase or decrease of incoming flow between alternative combinations shows up as an increase or decrease in generation. KER is directly affected by flows from Hungry Horse, and TOM, NOX, CAB, are directly affected by flows from KER, which include operation for flood control. BOX and BND are directly affected by Albeni Falls, which is indirectly affected by flows from Hungry Horse. PRD, WAN, RIS, RRH, and WEL projects are directly affected by flows released from Grand Coulee. Section 5 discusses detailed results of Grand Coulee's operation.

Table 18 shows the difference in generation for VARQ minus Standard Flood Control without Libby fish flows. The table shows that for all of the projects, there is less generation in January through March and the second half of April because of reduced flows from Hungry Horse and Libby with VARQ. There is more generation in May through July due to VARQ because of the higher elevations at the end of April for VARQ resulting in more water being released through the end of July. For KER in March, different years show that there is higher or lower generation in VARQ**,** but the average difference in generation is zero. There is no difference in generation at KER, TOM, CAB, and BOX in May and June because these projects are at powerhouse capacity in both cases and spill to pass additional flow.

Tables 19 and 20 show the generation differences between VARQ and Standard Flood Control with Libby fish flows at QPHC and QPHC+10, respectively. Results are similar

to that for Table 18 except in August where there is more flow released from Libby and Hungry Horse under VARQ, therefore, there is more generation.

Tables 21 and 22 show the difference in generation for Libby with fish flows at QPHC and at QPHC+10 with Standard Flood Control, respectively, minus Libby on Standard Flood Control. There are basically no differences in January through April because Libby and Hungry Horse each target the same elevations in both alternative combinations. There are no differences in May through July for projects upstream of BND because Hungry Horse targets the same elevations in both alternative combinations so that the flow releases and generation are the same. In May through August for PRD and projects downstream, fish flows are released from Libby in the fish flow alternative combination rather than filling to the flood control elevations, producing more generation in the fish flow alternative combination. In August at KER, there is slightly less flow and generation with VARQ in years where the load is just met. Due to increased flow and generation at Libby and projects downstream, under VARQ, KER can reduce generation in August in some years.

Tables 23 and 24 show the difference in generation for Libby with fish flows at QPHC and QPHC+10, respectively, with VARQ Flood Control minus Libby on VARQ Flood Control. The explanation is similar to that for Tables 21 and 22.

Table 18. 52-Year Avg. Difference in Generation for Non-Federal Projects (aMW), Benchmark Combination LV+HV minus LS+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
KER	0	0	0	0	1	1	-11	-9	0	-1	-13	-1	0	0	-2
TOM	0	0	0	0	0	0	-3	-3	0	0	-2	0	0	0	-1
NOX	0	0	0	0	1	1	-10	-11	0	3	-12	5	7	0	-1
CAB	0	0	0	0	0	1	-6	-7	0	2	-7	0	0	0	-1
BOX	0	0	0	0	0	0	-2	-2	0	0	-1	0	0	0	-1
BND	0	0	0	0	1	2	-16	-20	-1	5	-19	7	7	1	-2
PRD	0	0	0	0	0	0	-27	-18	-1	3	-2	7	17	5	-1
WAN	0	0	0	0	0	1	-34	-20	-1	3	-3	11	20	5	-1
RIS	0	0	0	0	0	0	-18	-9	0	1	-2	6	10	3	-1
RRH	1	0	0	0	0	1	-47	-22	-1	4	-5	15	26	8	-2
WEL	1	0	0	0	0	0	-29	-16	-1	3	-4	11	18	6	-1

Table 19. 52-Year Avg. Difference in Generation for Non-Federal Projects (aMW), Alternative Combination LV1+HV minus LS1+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
KER	-1	-1	0	0	2	1	-11	-8	-1	-1	-13	-1	0	-1	-2
TOM	0	0	0	0	0	0	-3	-3	0	0	-2	0	0	0	-1
NOX	-1	-1	0	0	2	2	-10	-11	0	2	-12	5	7	0	-1
CAB	-1	0	0	0	1	1	-6	-6	0	1	-7	0	0	0	-1
BOX	0	0	0	0	0	0	-2	-2	0	0	-1	0	0	0	-1
BND	-3	-2	0	0	4	3	-17	-18	-1	4	-19	7	7	0	-2
PRD	7	9	1	1	2	2	-28	-20	0	5	-2	5	9	5	-1
WAN	7	8	1	1	2	2	-35	-21	0	6	-3	8	11	5	-1
RIS	4	7	0	0	1	1	-18	-10	0	3	-2	4	5	3	0
RRH	12	17	1	1	2	2	-47	-24	0	7	-5	11	12	8	-1
WEL	9	12	1	1	2	1	-29	-17	0	5	-4	8	8	6	-1

Table 20. 52-Year Avg. Difference in Generation for Non-Federal Projects (aMW), Alternative Combination LV2+HV minus LS2+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
KER	-1	-1	0	0	2	1	-11	-8	-1	-1	-13	-1	0	-1	-2
TOM	0	0	0	0	0	0	-3	-3	0	0	-2	0	0	0	-1
NOX	-1	-1	0	0	2	2	-10	-11	0	2	-12	5	7	0	-1
CAB	-1	0	0	0	1	1	-6	-6	0	1	-7	0	0	0	-1
BOX	0	0	0	0	0	0	-2	-2	0	0	-1	0	0	0	-1
BND	-2	-2	0	0	4	3	-16	-18	-1	4	-19	7	7	0	-2
PRD	7	9	1	1	2	2	-28	-20	0	5	-2	5	9	5	-1
WAN	7	8	1	1	2	2	-34	-21	0	6	-3	8	10	5	-1
RIS	5	7	0	0	1	1	-18	-10	0	3	-2	4	4	3	0
RRH	12	17	1	1	2	2	-47	-24	0	7	-5	11	12	8	-1
WEL	9	12	1	1	2	2	-29	-17	0	5	-4	7	8	6	-1

Table 21. 52-Year Avg. Difference in Generation for Non-Federal Projects (aMW), Alternative/Benchmark Combination LS1+HS minus LS+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
KER	-1	-5	1	0	1	0	0	0	0	0	0	0	0	0	0
TOM	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0
NOX	-1	-5	1	0	1	0	0	0	0	0	0	0	0	0	0
CAB	0	-3	0	0	0	0	0	0	0	0	0	0	0	0	0
BOX	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0
BND	-2	-8	2	0	2	0	1	0	0	0	0	0	0	0	0
PRD	3	14	-66	-2	-1	-4	-1	0	0	0	0	3	16	10	-3
WAN	3	12	-72	-3	-2	-4	-1	0	0	0	0	5	19	10	-3
RIS	2	10	-35	-1	-1	-2	0	0	0	0	0	3	10	6	-1
RRH	6	25	-81	-3	-2	-4	-1	0	0	0	0	8	26	16	-2
WEL	5	19	-60	-2	-1	-3	-1	0	0	0	0	6	19	11	-2

Table 22. 52-Year Avg. Difference in Generation for Non-Federal Projects (aMW), Alternative/Benchmark Combination LS2+HS minus LS+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
KER	-1	-5	1	0	1	0	0	0	0	0	0	0	0	0	0
TOM	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0
NOX	-1	-4	1	0	1	0	0	0	0	0	0	0	0	0	0
CAB	0	-3	0	0	0	0	0	0	0	0	0	0	0	0	0
BOX	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0
BND	-2	-8	2	0	1	0	1	0	0	0	0	0	0	0	0
PRD	2	12	-66	-3	-2	-4	-1	0	0	0	0	4	17	9	-3
WAN	2	11	-72	-3	-2	-4	-1	0	0	0	0	7	20	9	-3
RIS	1	9	-35	-1	-1	-2	0	0	0	0	0	4	11	6	-1
RRH	4	22	-82	-3	-2	-5	-1	0	0	0	0	10	27	15	-2
WEL	3	16	-61	-3	-1	-3	-1	0	0	0	0	8	19	10	-2

Table 23. 52-Year Avg. Difference in Generation for Non-Federal Projects (aMW), Alternative/Benchmark Combination LV1+HV minus LV+HV

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
KER	-3	-6	1	0	3	0	0	0	0	0	0	0	0	-1	0
TOM	-1	-2	0	0	1	0	0	0	0	0	0	0	0	0	0
NOX	-3	-6	1	0	2	0	0	0	0	0	0	0	0	-1	0
CAB	-2	-3	1	0	1	0	0	0	0	0	0	0	0	0	0
BOX	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0
BND	-6	-10	2	0	4	1	0	1	0	-1	0	0	0	-1	0
PRD	10	23	-65	-1	0	-2	-1	-1	0	2	0	2	8	10	-3
WAN	9	21	-70	-1	0	-3	-1	-1	0	2	0	3	10	10	-3
RIS	6	18	-34	0	0	-1	0	0	0	1	0	1	5	6	-1
RRH	16	42	-80	-2	0	-3	-1	-2	0	2	0	4	12	16	-2
WEL	13	31	-59	-1	0	-2	-1	-1	0	2	0	3	9	11	-2

Table 24. 52-Year Avg. Difference in Generation for Non-Federal Projects (aMW), Alternative/Benchmark Combination LV2+HV minus LV+HV

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
KER	-3	-6	1	0	3	0	0	0	0	0	0	0	0	0	0
TOM	-1	-2	0	0	0	0	0	0	0	0	0	0	0	0	0
NOX	-3	-5	1	0	2	0	0	0	0	0	0	0	0	0	0
CAB	-2	-3	1	0	1	0	0	0	0	0	0	0	0	0	0
BOX	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0
BND	-5	-9	2	0	4	1	0	0	0	-1	0	0	0	-1	0
PRD	9	22	-65	-1	0	-2	-1	-1	0	2	0	3	9	10	-3
WAN	8	20	-71	-2	0	-3	-1	-1	0	2	0	4	11	9	-3
RIS	6	16	-34	-1	0	-1	0	0	0	1	0	2	5	6	-1
RRH	14	40	-80	-2	0	-3	-1	-2	0	2	0	6	13	15	-2
WEL	11	29	-60	-1	0	-2	-1	-1	0	2	0	4	9	10	-2

3.5 Spill for Federal Projects

Table 25 shows the 52-year average spill flow at federal projects from Grand Coulee through Bonneville. Differences in spill between various alternative combinations are provided in Section 3.6. This data will be used to aid in the water quality evaluation for the UCEIS study.

Table 25. Spill at Federal Projects for Alternative/Benchmark Combinations LS+HS through LV2+HV (cfs)

Grand Coulee														
Alternative/Benchmark Combination	**AG1**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**AP1**	**APR**	**MAY**	**JUN**	**JUL**
LS+HS	0	0	0	0	0	0	0	0	0	0	0	316	553	0
LV+HV	0	0	0	0	0	0	0	0	0	0	0	322	700	0
LS1+HS	0	0	0	0	0	0	0	0	0	0	0	317	597	0
LV1+HV	0	0	0	0	0	0	0	0	0	0	0	324	735	0
LS2+HS	0	0	0	0	0	0	0	0	0	0	0	317	615	0
LV2+HV	0	0	0	0	0	0	0	0	0	0	0	324	753	0
Chief Joseph														
Alternative/Benchmark Combination	**AG1**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**AP1**	**APR**	**MAY**	**JUN**	**JUL**
LS+HS	0	0	0	0	0	0	199	0	0	0	0	743	2480	0
LV+HV	0	0	0	0	0	0	197	0	0	0	0	738	3460	94
LS1+HS	0	0	0	0	0	0	199	0	0	0	0	744	2885	0
LV1+HV	0	0	0	0	0	0	197	0	0	0	0	740	3891	91
LS2+HS	0	0	0	0	0	0	199	0	0	0	0	744	2994	0
LV2+HV	0	0	0	0	0	0	197	0	0	0	0	740	3978	56
McNary														
Alternative/Benchmark Combination	**AG1**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**AP1**	**APR**	**MAY**	**JUN**	**JUL**
LS+HS	840	392	0	0	0	838	11971	3923	3688	36119	87067	107379	112903	17627
LV+HV	892	397	0	0	0	857	10066	3501	3594	36370	87037	108444	115703	18615
LS1+HS	672	282	0	0	0	838	11875	3923	3688	36119	87067	107745	115479	19615
LV1+HV	759	343	0	0	0	857	10003	3468	3594	36345	87037	108711	117312	20328
LS2+HS	595	265	0	0	0	838	11864	3923	3688	36119	87067	107907	115704	19582
LV2+HV	708	329	0	0	0	857	9943	3473	3594	36370	87041	108797	117553	20375
John Day														
Alternative/Benchmark Combination	**AG1**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**AP1**	**APR**	**MAY**	**JUN**	**JUL**
LS+HS	51251	40362	0	0	0	0	55	0	0	22458	63033	67384	66463	54963
LV+HV	51313	40348	0	0	0	0	78	0	0	22507	62795	67592	67297	55230
LS1+HS	51653	41708	0	0	0	0	84	0	0	22443	63032	67474	67022	55371
LV1+HV	52347	42562	0	0	0	0	73	0	0	22555	62789	67650	67722	55729
LS2+HS	51551	41547	0	0	0	0	69	0	0	22443	63032	67506	67082	55307
LV2+HV	52252	42423	0	0	0	0	54	0	0	22554	62790	67674	67786	55668
The Dalles														
Alternative/Benchmark Combination	**AG1**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**AP1**	**APR**	**MAY**	**JUN**	**JUL**
LS+HS	70394	55742	0	0	0	0	361	235	178	42615	91994	103621	103121	85068
LV+HV	70501	55725	0	0	0	0	389	244	211	42615	91668	104227	104631	85623
LS1+HS	70847	57488	0	0	0	0	396	235	178	42615	91993	103945	104412	85941
LV1+HV	71821	58655	0	0	0	0	383	244	211	42615	91659	104414	105203	86585
LS2+HS	70687	57267	0	0	0	0	378	235	178	42615	91993	104033	104501	85805
LV2+HV	71672	58463	0	0	0	0	360	244	211	42615	91661	104485	105274	86498

Bonneville														
Alternative/Benchmark Combination	**AG1**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**AP1**	**APR**	**MAY**	**JUN**	**JUL**
LS+HS	95375	89984	0	0	0	140	5158	1923	2014	38651	95754	102082	106875	93585
LV+HV	95375	90029	0	0	0	140	4801	1926	1877	38578	95751	102579	108491	93575
LS1+HS	95375	91143	0	0	0	140	5162	1923	2052	38438	95754	102139	108228	93695
LV1+HV	95375	91803	0	0	0	140	4766	1785	2005	38578	95751	102643	109521	93700
LS2+HS	95375	91109	0	0	0	140	5142	1923	2052	38578	95754	102140	108358	93696
LV2+HV	95375	91721	0	0	0	140	4742	1785	2005	38578	95755	102656	109727	93700

3.6 Spill Differences for Federal Projects

Differences in month average spill for federal projects are provided in Tables 26 through 32. For the alternative combinations with Libby fish flows up to QPHC +10, it is assumed that the additional 10 kcfs above existing powerhouse capacity is passed as spill at Libby.

For Tables 26 through 28, spill differences in January through March for all the projects reflect differences in forced spill (if inflow is greater than powerhouse capacity, the project will be forced to spill, and this is called “forced spill”). Differences for April through July for LIB, HGH, GCL, and CHJ, reflect forced spill differences. There was forced spill in only a few years in these months and this occurs after relatively big water years. Generally there is less spill flow in January through April, and more spill in May through July with VARQ. Voluntary spill for fish occurs at MCN in the first half of April through June, and at JDA, TDA, and BON in the first half of April through August. The differences in the voluntary spill periods reflect the differences in forced spill for MCN and BON, as these projects operate to a fixed spill discharge shown in Table 2. For JDA and TDA, spill is based on percent of regulated flow up to the spill cap. The spill differences are due to a percent of the difference of the regulated flow, or due to forced spill. There was only 3 or 4 years in each May and June where there was forced spill at TDA and JDA in both alternative combinations.

Table 26 shows the difference in spill for VARQ minus Standard Flood Control without Libby fish flows. On average, VARQ reduces spill at Libby in January and February. There is spill in 4 years with VARQ and 10 years with Standard Flood Control in January, and no spill in February with VARQ and 1 year with Standard flood control. In the years where there are differences, the differences range from approximately 500 to 2700 cfs. In June and July, there were only a few years where there were differences in spill, where differences were about 800 to 4000 cfs. For Hungry Horse there was more spill in the first half of April in 9 years with VARQ. The increased spill under VARQ was caused by the project needing to draft for system flood control, more so than it needed to for Standard Flood control. In the second half of April, there was less spill as HGH was targeting their respective elevations for VARQ or Standard flood control with fish flows.

Tables 27 and 28 show differences in spill for VARQ minus Standard Flood Control for Libby with fish flows at QPHC and at QPHC+10, respectively. The explanations are

similar to Table 26 except for August where there is more fish flow released from Libby with VARQ, and therefore, more spill flow occurs.

Tables 29 and 30 show differences in spill for Libby with fish flows at QPHC and QPHC+10, respectively, with Standard Flood Control minus Libby on Standard Flood Control. There are little or no differences in spill in February through April. In May through August, there is more spill flow with the fish flow alternative combinations for projects downstream of MCN due to higher fish flows from Libby. Table 30 shows an adjustment for spill based on the daily regulations provided by NWS. The adjustments are shown italicized and bolded.

Tables 31 and 32 show difference in spill for Libby with fish flows at QPHC and QPHC+10, respectively, with VARQ Flood Control minus Libby on VARQ Flood Control. The explanation of results is similar to that for Tables 29 and 30.

Table 26. 52-Year Avg. Difference in Spill for Federal Projects (cfs), Benchmark Combination LV+HV minus LS+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
LIB	0	0	0	0	0	0	-178	-14	0	0	0	0	20	32	-12
HGH	0	0	0	0	0	0	2	-9	0	283	-216	0	0	0	2
GCL	0	0	0	0	0	0	0	0	0	0	0	6	147	0	13
CHJ	0	0	0	0	0	0	-2	0	0	0	0	-4	979	94	89
MCN	52	4	0	0	0	19	-1904	-421	-94	250	-30	1064	2800	988	216
JDA	62	-14	0	0	0	0	23	0	0	49	-237	208	833	266	105
TDA	106	-17	0	0	0	0	27	9	32	0	-326	606	1510	555	219
BON	0	44	0	0	0	0	-357	3	-137	-73	-3	496	1616	-9	133

Table 27. 52-Year Avg. Difference in Spill for Federal Projects (cfs), Alternative Combination LV1+HV minus LS1+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
LIB	0	0	0	0	0	0	-178	-14	0	0	0	0	20	0	-14
HGH	0	0	0	0	0	0	2	-9	0	283	-216	0	0	0	2
GCL	0	0	0	0	0	0	0	0	0	0	0	6	137	0	12
CHJ	0	0	0	0	0	0	-2	0	0	0	0	-4	1005	91	91
MCN	87	60	0	0	0	19	-1871	-455	-94	225	-30	966	1833	713	107
JDA	694	854	0	0	0	0	-10	0	0	111	-243	176	700	357	161
TDA	974	1166	0	0	0	0	-13	9	32	0	-334	468	791	643	236
BON	0	659	0	0	0	0	-395	-137	-47	140	-3	504	1293	5	135

Table 28. 52-Year Avg. Difference in Spill for Federal Projects (cfs), Alternative Combination LV2+HV minus LS2+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
LIB	0	0	0	0	0	0	-178	-14	0	0	0	***72***	***-146***	***1***	***-22***
HGH	0	0	0	0	0	0	2	-9	0	283	-216	0	0	0	2
GCL	0	0	0	0	0	0	0	0	0	0	0	6	138	0	12
CHJ	0	0	0	0	0	0	-2	0	0	0	0	-4	984	56	86
MCN	113	63	0	0	0	19	-1920	-450	-94	250	-25	890	1849	792	107
JDA	700	875	0	0	0	0	-14	0	0	110	-241	168	704	361	162
TDA	985	1196	0	0	0	0	-17	9	32	0	-332	452	773	693	239
BON	0	611	0	0	0	0	-400	-137	-47	0	1	515	1368	3	134

Table 29. 52-Year Avg. Difference in Spill for Federal Projects (cfs), Alternative/Benchmark Combination LS1+HS minus LS+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
LIB	0	0	0	0	0	0	0	0	0	0	0	0	0	-86	-7
HGH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GCL	0	0	0	0	0	0	0	0	0	0	0	1	44	0	4
CHJ	0	0	0	0	0	0	0	0	0	0	0	1	405	0	34
MCN	-168	-109	0	0	0	0	-96	0	0	0	0	365	2576	1988	391
JDA	401	1345	0	0	0	0	29	0	0	-14	0	89	559	408	163
TDA	452	1745	0	0	0	0	35	0	0	0	0	324	1290	872	302
BON	0	1159	0	0	0	0	4	0	38	-213	0	56	1352	110	170

Table 30. 52-Year Avg. Difference in Spill for Federal Projects (cfs), Alternative/Benchmark Combination LS2+HS minus LS+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
LIB	0	0	0	0	0	0	0	0	0	0	0	***1239***	***2187***	***-43***	***281***
HGH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GCL	0	0	0	0	0	0	0	0	0	0	0	1	61	0	5
CHJ	0	0	0	0	0	0	0	0	0	0	0	1	513	0	43
MCN	-244	-126	0	0	0	0	-107	0	0	0	0	527	2801	1955	416
JDA	300	1185	0	0	0	0	14	0	0	-14	0	122	618	343	153
TDA	292	1524	0	0	0	0	16	0	0	0	0	412	1379	737	288
BON	0	1124	0	0	0	0	-15	0	38	-73	0	57	1483	111	183

Table 31. 52-Year Avg. Difference in Spill for Federal Projects (cfs), Alternative/Benchmark Combination LV1+HV minus LV+HV

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
LIB	0	0	0	0	0	0	0	0	0	0	0	0	0	-118	-10
HGH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GCL	0	0	0	0	0	0	0	0	0	0	0	1	34	0	3
CHJ	0	0	0	0	0	0	0	0	0	0	0	1	431	-3	36
MCN	-133	-53	0	0	0	0	-63	-33	0	-25	0	267	1609	1713	282
JDA	1034	2214	0	0	0	0	-4	0	0	47	-6	58	425	499	219
TDA	1320	2929	0	0	0	0	-5	0	0	0	-8	186	571	961	320
BON	0	1774	0	0	0	0	-34	-140	128	0	0	64	1029	125	172

Table 32. 52-Year Avg. Difference in Spill for Federal Projects (cfs), Alternative/Benchmark Combination LV2+HV minus LV+HV

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
LIB	0	0	0	0	0	0	0	0	0	0	0	***1311***	***2021***	***-74***	***271***
HGH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GCL	0	0	0	0	0	0	0	0	0	0	0	1	52	0	5
CHJ	0	0	0	0	0	0	0	0	0	0	0	1	518	-37	40
MCN	-183	-67	0	0	0	0	-123	-28	0	0	4	352	1850	1759	307
JDA	939	2075	0	0	0	0	-23	0	0	46	-5	82	490	438	210
TDA	1171	2737	0	0	0	0	-28	0	0	0	-7	258	642	875	308
BON	0	1692	0	0	0	0	-58	-140	128	0	4	76	1236	125	185

3.7 Spill for Non-Federal Projects

Table 33 shows the 52-year average spill flow at non-federal projects in the mid-Columbia. Differences in spill between various alternative combinations are provided in Section 3.8. This data will be used to aid in the water quality evaluation for the UCEIS study.

Table 33. Spill for Non-Federal Projects (cfs)

Wells														
Alternative Combination	**AG1**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**AP1**	**APR**	**MAY**	**JUN**	**JUL**
LS1+HS	3173	0	0	0	0	0	1665	0	0	0	8792	13508	10967	10006
LV1+HV	3233	0	0	0	0	0	1288	0	0	0	8741	13919	12235	10136
LS2+HS	3162	0	0	0	0	0	1665	0	0	0	8792	13558	11144	10022
LV2+HV	3223	0	0	0	0	0	1288	0	0	0	8741	13978	12392	10158
Benchmark Combination														
LS+HS	3142	0	0	0	0	0	1665	0	0	0	8792	13379	9686	9551
LV+HV	3150	0	0	0	0	0	1288	0	0	0	8742	13782	11386	9685
Chelan														
Alternative Combination	**AG1**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**AP1**	**APR**	**MAY**	**JUN**	**JUL**
LS1+HS	240	28	0	5	42	15	0	0	0	0	15	916	3707	1757
LV1+HV	240	28	0	5	42	15	0	0	0	0	15	957	3736	1757
LS2+HS	240	28	0	5	42	15	0	0	0	0	15	915	3705	1757
LV2+HV	240	28	0	5	42	15	0	0	0	0	15	955	3736	1757
Benchmark Combination														
LS+HS	240	28	0	5	42	15	0	0	0	0	15	962	3765	1757
LV+HV	240	28	0	5	42	15	0	0	0	0	15	975	3797	1757

Table 33. Continued

Rocky Reach														
Alternative Combination	**AG1**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**AP1**	**APR**	**MAY**	**JUN**	**JUL**
LS1+HS	19338	0	0	0	0	0	646	0	0	0	21406	39168	30764	23323
LV1+HV	19700	0	0	0	0	0	683	0	0	0	21239	39807	32223	23683
LS2+HS	19273	0	0	0	0	0	646	0	0	0	21406	39287	30955	23289
LV2+HV	19638	0	0	0	0	0	683	0	0	0	21240	39913	32386	23620
Benchmark Combination														
LS+HS	19159	0	0	0	0	0	646	0	0	0	21407	38770	29070	22779
LV+HV	19207	0	0	0	0	0	683	0	0	0	21243	39574	31180	23134
Rock Island														
Alternative Combination	**AG1**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**AP1**	**APR**	**MAY**	**JUN**	**JUL**
LS1+HS	26285	0	0	0	0	0	311	0	0	0	29402	37490	39247	32117
LV1+HV	26768	0	0	0	0	0	308	0	0	0	29178	38078	40650	32514
LS2+HS	26198	0	0	0	0	0	311	0	0	0	29402	37599	39407	32071
LV2+HV	26685	0	0	0	0	0	308	0	0	0	29179	38175	40797	32467
Benchmark Combination														
LS+HS	26046	0	0	0	0	0	311	0	0	0	29402	37124	37807	31391
LV+HV	26110	0	0	0	0	0	308	0	0	0	29183	37863	39788	31779
Wanapum														
Alternative Combination	**AG1**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**AP1**	**APR**	**MAY**	**JUN**	**JUL**
LS1+HS	64477	51615	0	0	0	0	7180	0	0	492	63100	80003	85059	78802
LV1+HV	65660	53044	0	0	0	0	5448	0	0	574	62620	81256	86934	79774
LS2+HS	64264	51344	0	0	0	0	7177	0	0	492	63100	80238	85276	78690
LV2+HV	65456	52809	0	0	0	0	5448	0	0	574	62622	81465	87129	79661
Benchmark Combination														
LS+HS	63890	49476	0	0	0	0	7268	0	0	492	63101	79219	81981	77025
LV+HV	64048	49456	0	0	0	0	5448	0	0	574	62629	80797	85303	77974
Priest Rapids														
Alternative Combination	**AG1**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**AP1**	**APR**	**MAY**	**JUN**	**JUL**
LS1+HS	51753	41296	0	0	0	0	7058	87	0	377	90366	114322	93240	63247
LV1+HV	52694	42433	0	0	0	0	5534	96	0	461	89685	116100	95268	64020
LS2+HS	51583	41080	0	0	0	0	7055	87	0	377	90366	114655	93475	63158
LV2+HV	52531	42246	0	0	0	0	5534	96	0	461	89688	116397	95480	63930
Benchmark Combination														
LS+HS	51285	39594	0	0	0	0	7148	87	0	377	90368	113211	89898	61832
LV+HV	51411	39577	0	0	0	0	5534	96	0	461	89699	115449	93498	62588

3.8 Spill Differences for Non-federal Projects

Table 34 shows spill differences for Standard minus VARQ for Libby without fish flows. The table shows generally less spill flow in January through April and more spill in May through August 15th due to VARQ.

Tables 35 and 36 show spill differences for VARQ minus Standard for Libby with fish flows at QPHC and QPHC + 10, respectively. Hungry Horse was operated to the same Standard simulated target elevations in all Standard Flood Control alternative combinations and the same simulated VARQ target elevations in the VARQ alternative combinations, therefore data in Tables 34, 35, and 36 for KER, TOM, NOX, CAB, BOX, and BND are nearly the same. The tables show similar patterns as Table 34 except in August where there is more flow released from Libby, and more spill at Priest Rapids and projects downstream because spill at these projects is based on a percent of regulated flow.

Tables 37 and 38 show spill differences for Libby with fish flows at QPHC, and at QPHC+10, respectively, with Standard Flood Control minus Libby on Standard Flood Control. More spill flow occurs with VARQ in May through August due to higher flows with VARQ and because spill is based on a percentage of regulated flow.

Tables 39 and 40 show spill differences for Libby with fish flows at QPHC, and at QPHC+10 respectively, with VARQ Flood Control minus Libby on VARQ Flood Control. The explanation for these tables is the same as that for Tables 37 and 38.

Table 34. 52-Year Avg. Difference in Spill for Non-Federal Projects (cfs), Benchmark Combinations LV+HV minus LS+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
KER	0	0	0	0	0	59	-16	-233	28	411	0	354	1743	101	187
TOM	0	0	0	0	0	54	9	-124	10	283	-319	284	1793	75	174
NOX	0	0	0	0	0	0	0	0	0	0	0	-183	877	0	58
CAB	0	0	0	0	0	8	0	0	0	-33	-1	220	1748	-16	162
BOX	0	0	0	0	0	21	2	-118	11	320	-348	272	1768	83	169
BND	0	0	0	0	0	0	0	0	0	0	0	-126	1165	-13	85
PRD	125	-16	0	0	0	0	-1614	8	0	83	-669	2238	3600	755	396
WAN	158	-20	0	0	0	0	-1819	0	0	81	-471	1577	3322	949	325
RIS	64	0	0	0	0	0	-2	0	0	0	-219	739	1980	387	252
RRH	48	0	0	0	0	0	36	0	0	0	-164	804	2110	355	271
WEL	8	0	0	0	0	0	-377	0	0	0	-49	402	1699	134	153

Table 35. 52-Year Avg. Difference in Spill for Non-Federal Projects (cfs), Alternative Combinations LV1+HV minus LS1+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
KER	0	0	0	0	3	59	-16	-233	28	411	0	354	1743	101	187
TOM	0	0	0	0	0	54	9	-124	10	283	-322	284	1793	75	174
NOX	0	0	0	0	0	0	0	0	0	0	0	-183	877	0	58
CAB	0	0	0	0	0	8	0	0	0	-33	-1	220	1759	-16	163
BOX	0	0	0	0	0	21	2	-118	11	320	-400	272	1779	83	168
BND	0	0	0	0	0	0	0	0	0	0	0	-126	1165	-13	85
PRD	941	1137	0	0	0	0	-1524	8	0	83	-681	1777	2028	773	317
WAN	1182	1429	0	0	0	0	-1732	0	0	81	-480	1253	1875	972	290
RIS	482	0	0	0	0	0	-2	0	0	0	-223	588	1403	396	210
RRH	361	0	0	0	0	0	36	0	0	0	-167	639	1458	359	216
WEL	60	0	0	0	0	0	-377	0	0	0	-50	410	1268	130	120

Table 36. 52-Year Avg. Difference in Spill for Non-Federal Projects (cfs), Alternative Combinations LV2+HV minus LS2+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
KER	0	0	0	0	0	59	-16	-233	28	411	0	354	1743	101	187
TOM	0	0	0	0	0	54	9	-124	10	283	-322	284	1793	75	174
NOX	0	0	0	0	0	0	0	0	0	0	0	-183	877	0	58
CAB	0	0	0	0	0	8	0	0	0	-33	-1	220	1759	-16	163
BOX	0	0	0	0	0	21	2	-118	11	320	-400	272	1779	83	168
BND	0	0	0	0	0	0	0	0	0	0	0	-126	1165	-13	85
PRD	948	1166	0	0	0	0	-1521	8	0	83	-678	1741	2004	772	314
WAN	1191	1465	0	0	0	0	-1729	0	0	81	-478	1227	1853	970	288
RIS	486	0	0	0	0	0	-2	0	0	0	-222	576	1389	396	208
RRH	364	0	0	0	0	0	36	0	0	0	-166	626	1431	330	210
WEL	60	0	0	0	0	0	-377	0	0	0	-50	420	1248	136	119

Table 37. 52-Year Avg. Difference in Spill for Non-Federal Projects (cfs), Alternative/Benchmark Combinations LS1+HS minus LS+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
KER	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NOX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CAB	0	0	0	0	0	0	0	0	0	0	0	0	-16	0	-1
BOX	0	0	0	0	0	0	0	0	0	0	0	0	-16	0	-1
BND	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PRD	467	1702	0	0	0	0	-89	0	0	0	-1	1111	3342	1414	572
WAN	587	2139	0	0	0	0	-87	0	0	0	0	783	3077	1777	576
RIS	239	0	0	0	0	0	0	0	0	0	0	365	1439	725	221
RRH	179	0	0	0	0	0	0	0	0	0	0	397	1694	544	227
WEL	30	0	0	0	0	0	0	0	0	0	0	128	1280	455	157

Table 38. 52-Year Avg. Difference in Spill for Non-Federal Projects (cfs), Alternative/Benchmark Combinations LS2+HS minus LS+HS

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
KER	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NOX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CAB	0	0	0	0	0	0	0	0	0	0	0	0	-15	0	-1
BOX	0	0	0	0	0	0	0	0	0	0	0	0	-15	0	-1
BND	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PRD	297	1486	0	0	0	0	-92	0	0	0	-1	1444	3577	1325	596
WAN	374	1867	0	0	0	0	-90	0	0	0	0	1018	3295	1665	584
RIS	152	0	0	0	0	0	0	0	0	0	0	474	1599	679	236
RRH	114	0	0	0	0	0	0	0	0	0	0	516	1885	509	247
WEL	19	0	0	0	0	0	0	0	0	0	0	178	1458	470	176

Table 39. 52-Year Avg. Difference in Spill for Non-Federal Projects (cfs), Alternative/Benchmark Combinations LV1+HV minus LV+HV

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
KER	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
TOM	0	0	0	0	0	0	0	0	0	0	-2	0	0	0	0
NOX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CAB	0	0	0	0	0	0	0	0	0	0	0	0	-4	0	0
BOX	0	0	0	0	0	0	0	0	0	0	-51	0	-5	0	-3
BND	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PRD	1282	2856	0	0	0	0	0	0	0	0	-13	650	1770	1432	493
WAN	1611	3588	0	0	0	0	0	0	0	0	-9	458	1630	1799	540
RIS	657	0	0	0	0	0	0	0	0	0	-4	214	862	734	178
RRH	493	0	0	0	0	0	0	0	0	0	-3	233	1042	548	172
WEL	83	0	0	0	0	0	0	0	0	0	0	137	849	451	123

Table 40. 52-Year Avg. Difference in Spill for Non-Federal Projects (cfs), Alternative/Benchmark Combinations LV2+HV minus LV+HV

	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	AVE
KER	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOM	0	0	0	0	0	0	0	0	0	0	-2	0	0	0	0
NOX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CAB	0	0	0	0	0	0	0	0	0	0	0	0	-4	0	0
BOX	0	0	0	0	0	0	0	0	0	0	-51	0	-4	0	-3
BND	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PRD	1120	2669	0	0	0	0	0	0	0	0	-10	947	1981	1342	513
WAN	1407	3353	0	0	0	0	0	0	0	0	-7	667	1826	1686	546
RIS	574	0	0	0	0	0	0	0	0	0	-3	312	1008	688	191
RRH	430	0	0	0	0	0	0	0	0	0	-2	339	1205	485	187
WEL	72	0	0	0	0	0	0	0	0	0	0	196	1006	472	143

4 Results of Libby Operation

4.1 Results of Libby Operation in September and October

For recreational interests, Libby's operation for September and October is addressed.

Figure 1 shows Libby's elevation percent exceedance curves for September. Libby operates for power in September. As shown in Figure 1, Libby operates to its normal operating rule curve of elevation 2437.9, about 70% to 90% of the time over all alternatives. The remainder of the time, the system does not meet load when drafting to its ORC, so projects that operate for power draft below their ORC. Figure 1 shows that the alternatives without fish flows are able to meet the system load for a higher percentage of time. This is because Libby starts at elevation 2459 instead of elevation 2439 at the end of August and has more water available for September. The figure also shows that the VARQ alternatives also provide more water for September. The data points for VQ FC and St. FC at 0% shows Libby at elevation 2445.7, and that is due to Libby reaching powerhouse capacity.

Figure 2 shows Libby's elevation percent exceedance curves for October. Libby operates for power to the ORC for October at elevation 2436.5 at least 76% of the time for all alternatives. The explanation for this figure is similar to that for Figure 1.

Figure 3 shows Libby flow percent exceedance curves for September. Flows are higher in September without Libby fish flows because of the higher starting elevation at the end of August as described for Figure 1. The average flows in September for alternatives without fish flows at Libby, is about 22,000 cfs and alternatives with fish flows is about 8,600 cfs. All fish flow alternatives produce similar results for September, except there are about 8 years where the flows are higher with VARQ.

Figure 4 shows Libby flow percent exceedance curves for October. The curves for all alternatives are similar to each other because the October and November end of month elevations are similar.

The average flow for October is about 7,000 cfs for all alternatives.

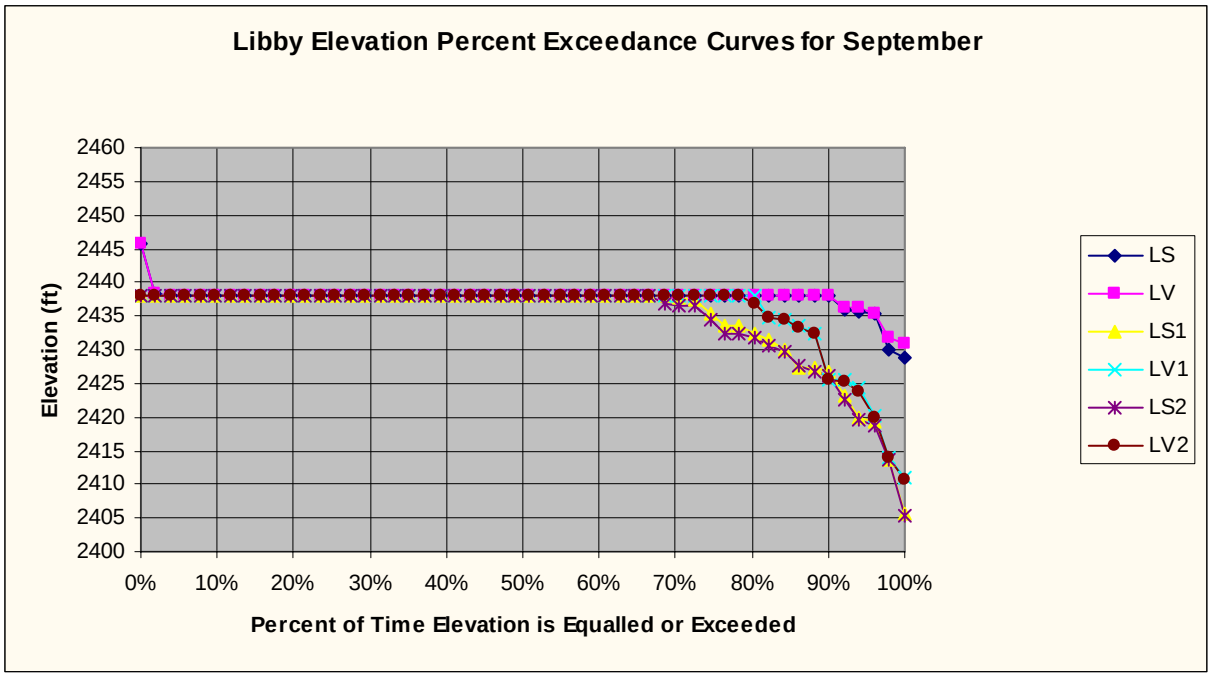

Figure 1. Libby Elevation Percent Exceedance Curves for September

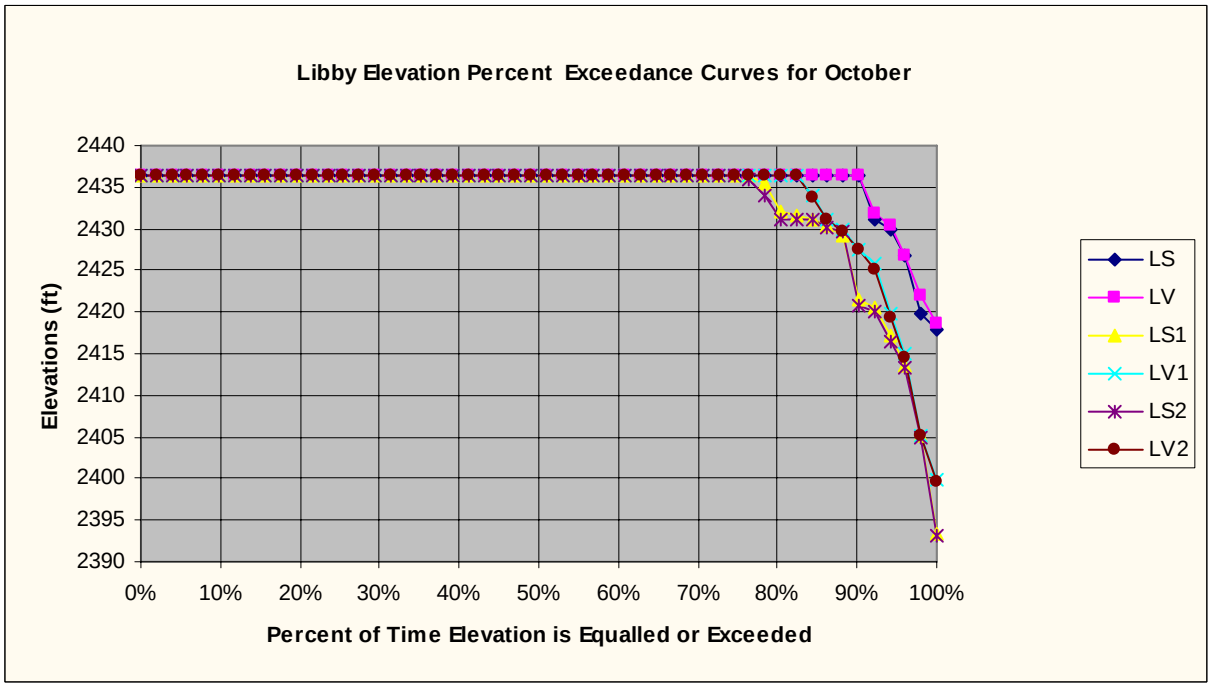

Figure 2. Libby Elevation Percent Exceedance Curves for October

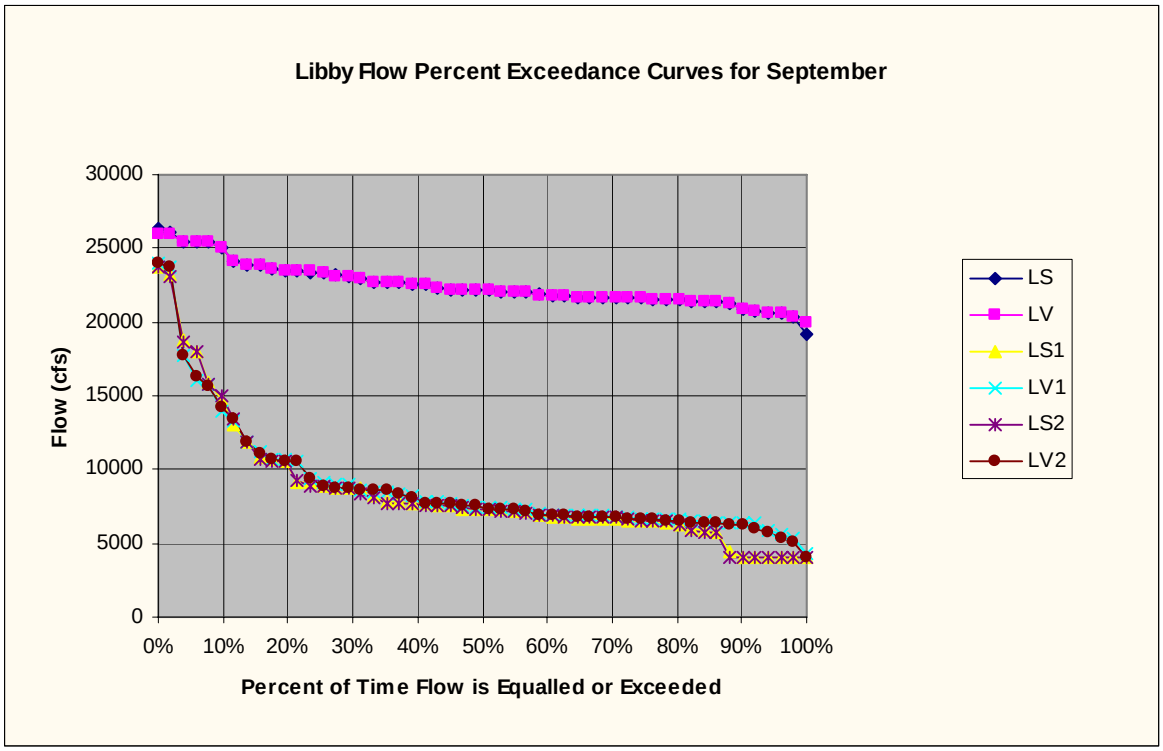

Figure 3. Libby Flow Percent Exceedance Curves for September

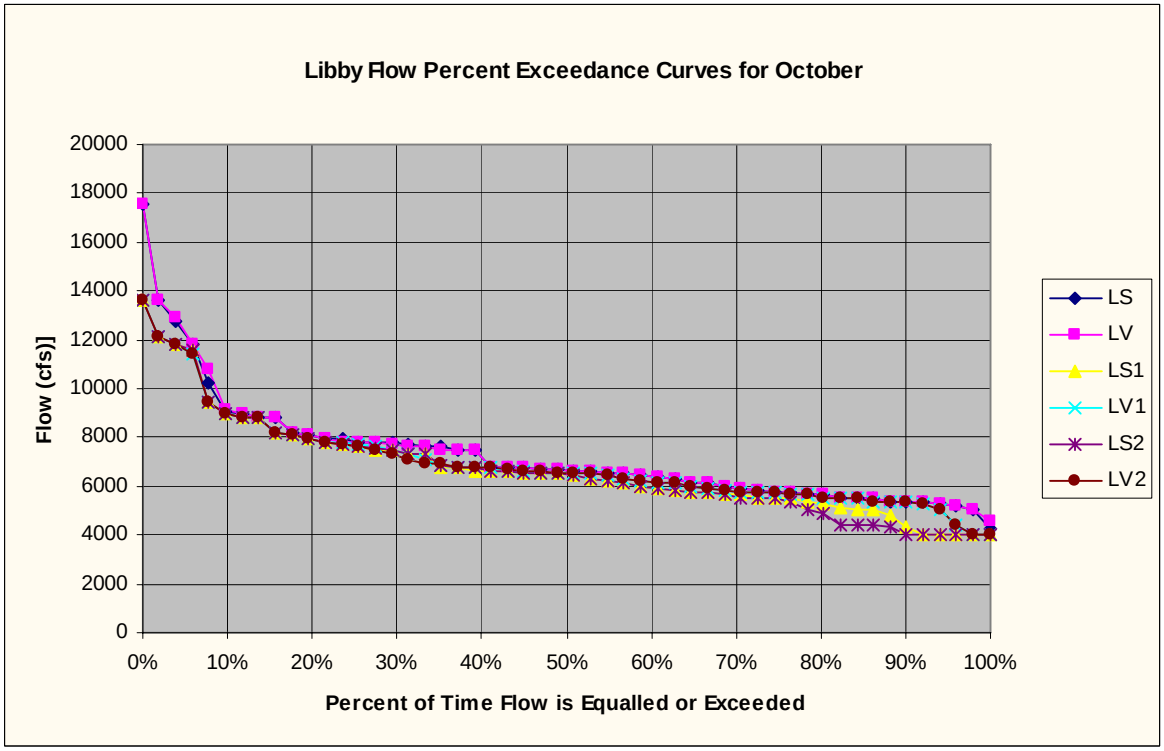

Figure 4. Libby Flow Percent Exceedance Curves for October

4.2 Results of Libby Operation in December and January

For burbot interests, flow exceedance curves for December and January are shown in figures 5 and 6.

Figure 5 shows Libby flow percent exceedance curves for December. Libby operates for power in November to its operating rule curve of elevation 2434.0, or drafts additionally as needed to meet firm load (this occurs in 5 to 11 years depending on alternative). In December, Libby targets elevation 2411 and meets the target in every year in the alternatives without fish flows. The project is below the elevation 2411 target in 3 years in the Standard Flood Control with fish flow alternatives and in 2 years in the VARQ with fish flows alternatives. Figure 5 shows less flow available in December in the fish flow alternatives as a result of a lower starting elevations at the end of August.

Figure 6 shows the Libby flow percent exceedance curves for January. The curves for alternatives with standard flood control are nearly the same as each other because they are all targeting the same flood control curves. Small differences occur because of elevation differences in December between alternatives. This explanation is the same for the VARQ Flood Control alternatives.

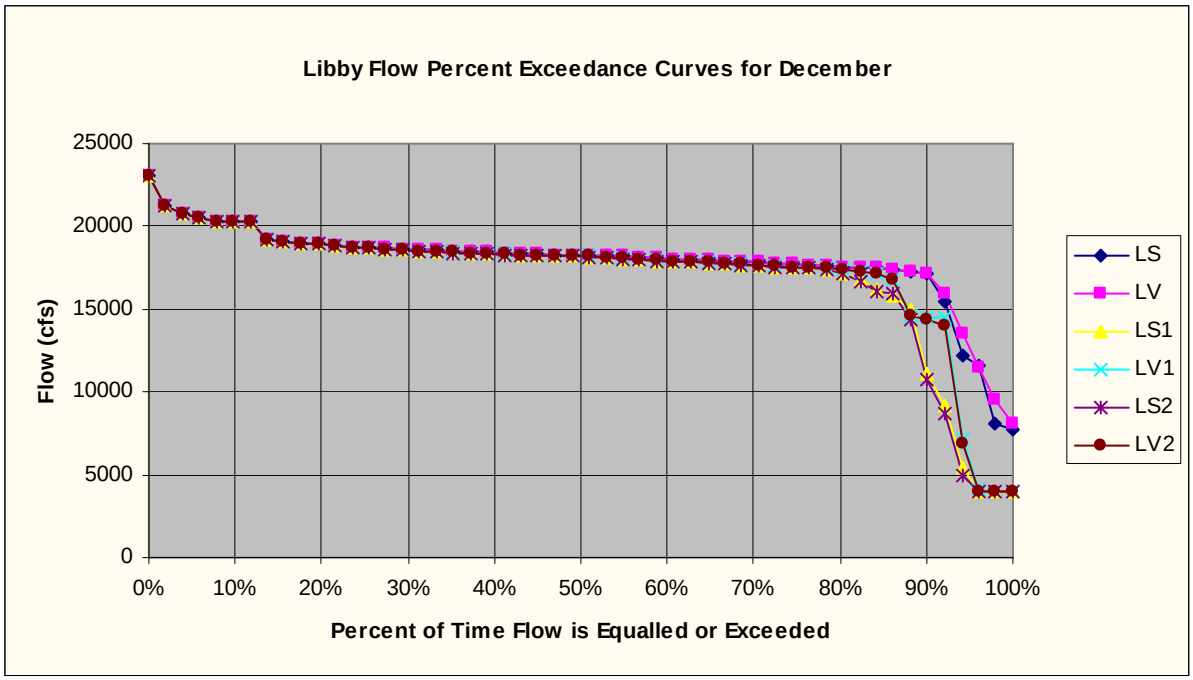

Figure 5. Libby Flow Percent Exceedance Curves for December

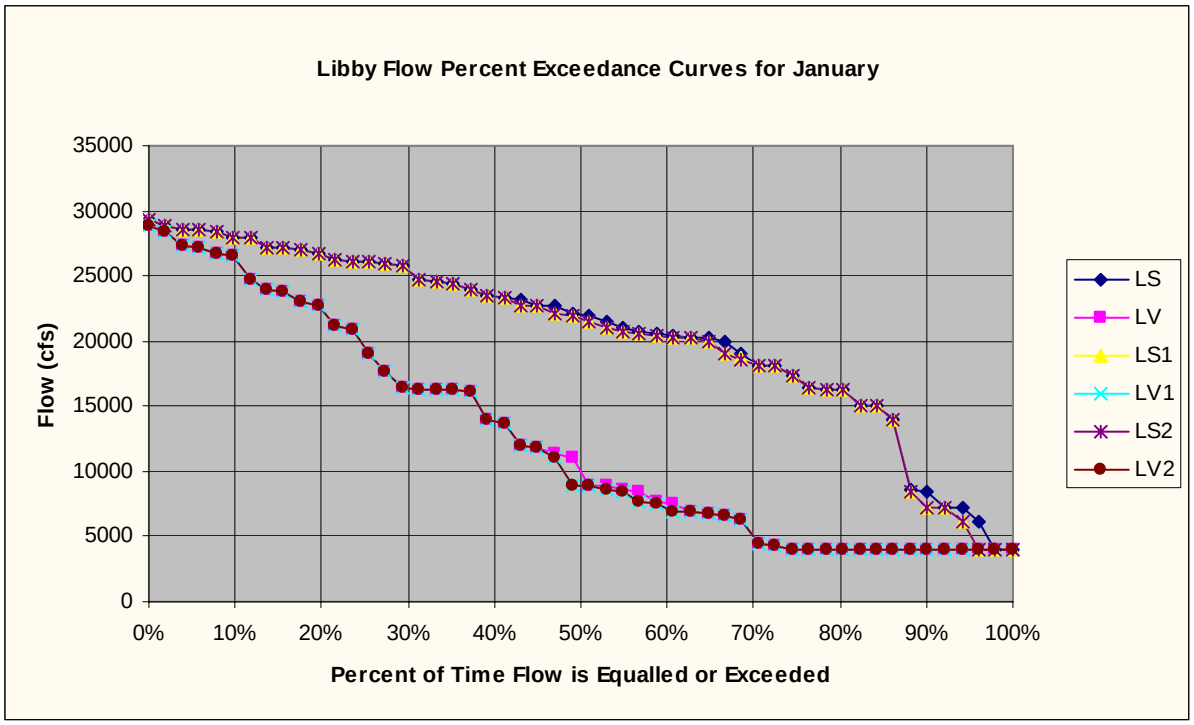

Figure 6. Libby Flow Percent Exceedance Curves for January

5 Results of Grand Coulee Operation

5.1 Grand Coulee Elevation Differences, January – May

The differences in the minimum, maximum and average forebay elevations at Grand Coulee for all alternative combinations are provided in Table 38. The values in the tables are very similar between standard flood control alternative combinations and between VARQ alternative combinations because January through April operations at Libby and Hungry Horse are the same. For January, the minimum elevation is elevation 1260 in all alternative combinations, which is the draft limits for resident fish. For February, the minimum elevation is the draft needed to meet the Vernita Bar flow requirement. For March through May, the minimum elevation are flood control elevations. In January through the first half of April, the maximum elevations are flood control elevations. In the second half of April, Grand Coulee needed to draft to elevation 1280 to meet McNary flow objectives in 7 to 9 years depending on alternative combination, and this became the maximum elevation in that period. In all other years, in the second half of April the project was on flood control except in a few years when it drafted for Vernita Bar. For May, the maximum elevation was a flood control elevation.

Table 41. Grand Coulee Min., Max., and Avg. Elevations for All Alternative/Benchmark Combinations

	Jan	Feb	Mar	Ap1	Apr	May
Alternative Combination						
LS1+HS						
Min	1260.0	1246.3	1220.4	1212.2	1208.0	1208.0
Max	1290.0	1290.0	1283.1	1283.1	1280.0	1288.6
Avg	1268.3	1264.1	1260.8	1253.5	1244.0	1254.0
LV1+HV						
Min	1260.0	1245.0	1220.3	1212.3	1208.0	1208.0
Max	1290.0	1290.0	1283.1	1283.1	1280.0	1288.5
Avg	1268.4	1263.6	1259.6	1251.9	1242.4	1252.8
LS2+HS						
Min	1260.0	1246.3	1220.4	1212.2	1208.0	1208.0
Max	1290.0	1290.0	1283.1	1283.1	1280.0	1288.6
Avg	1268.3	1264.1	1260.8	1253.5	1244.0	1254.0
LV2+HV						
Min	1260.0	1245.0	1220.3	1212.3	1208.0	1208.0
Max	1290.0	1290.0	1283.1	1283.1	1280.0	1288.5
Avg	1268.4	1263.5	1259.6	1251.9	1242.4	1252.8
Benchmark Combination						
LS+HS						
Min	1260.0	1246.3	1220.4	1212.2	1208.0	1208.0
Max	1290.0	1290.0	1283.1	1283.1	1280.0	1288.6
Avg	1268.3	1264.1	1260.9	1253.5	1244.0	1254.0
LV+HV						
Min	1260.0	1245.0	1220.3	1212.3	1208.0	1208.0
Max	1290.0	1290.0	1283.1	1283.1	1280.7	1288.5
Avg	1268.4	1263.2	1259.4	1251.9	1242.4	1252.8

5.2 Results of Grand Coulee End of April Operation

The April, end of month elevations are of interest because of bank exposure issues. Table 42 and Figure 7 show the Grand Coulee Elevation Percent Non-Exceedance Curves for the end of April for each alternative combination. All Standard Flood Control alternative combinations are similar to each other and all VARQ alternative combinations are similar to each other because operation of the projects upstream of Grand Coulee are nearly the same for each type of flood control. Generally, Grand Coulee operated on flood control curves about 85% of the time, drafted for McNary flows in 7 to 9 years, and drafted for Vernita Bar 1 to 3 years, depending on alternative combination. Grand

Coulee flood control operations are dependent on upstream space available. As VARQ rule curves are higher in both Libby and Hungry Horse than standard rule curves (meaning less space is available), more flood control space is necessary in Grand Coulee's pool. The flood control curves are adjusted based on the April 30 ending elevations for upstream projects. There was little variation of power drafts between each of the VARQ alternative combinations and the Standard FC alternative combinations because projects operated nearly the same for each set of alternative combinations. There were only 2 years, 1988 and 1993, where there were differences in Libby's April 30 Elevation, between fish flow alternative combinations and flood control only alternative combinations. Grand Coulee drafted to elevation 1280 for McNary flows in those years in all alternative combinations except alternative combination LV+HV where it drafted to 1280.7.

Figure 8 shows the difference in elevations (VARQ minus Standard) for the flood control only, Libby fish flows at QPHC, and Libby fish flows at QPHC+10. Again, the differences are the same because operation of upstream projects is nearly the same for VARQ and for Standard.

Table 42. Grand Coulee End of April Elevation Percent Non-Exceedance, All Alternative/Benchmark Combinations

	Benchmark Combination		Alternative Combination			
Elevation (ft)	**LS+HS**	**LV+HV**	**LS1+HS**	**LV1+HV**	**LS2+HS**	**LV2+HV**
1280	85%	88%	85%	88%	85%	88%
1270	81%	83%	81%	83%	81%	83%
1260	73%	77%	73%	77%	73%	77%
1250	62%	71%	62%	71%	62%	71%
1240	52%	54%	52%	54%	52%	54%
1230	33%	35%	33%	35%	33%	35%
1220	10%	10%	10%	10%	10%	10%
1210	4%	4%	4%	4%	4%	4%

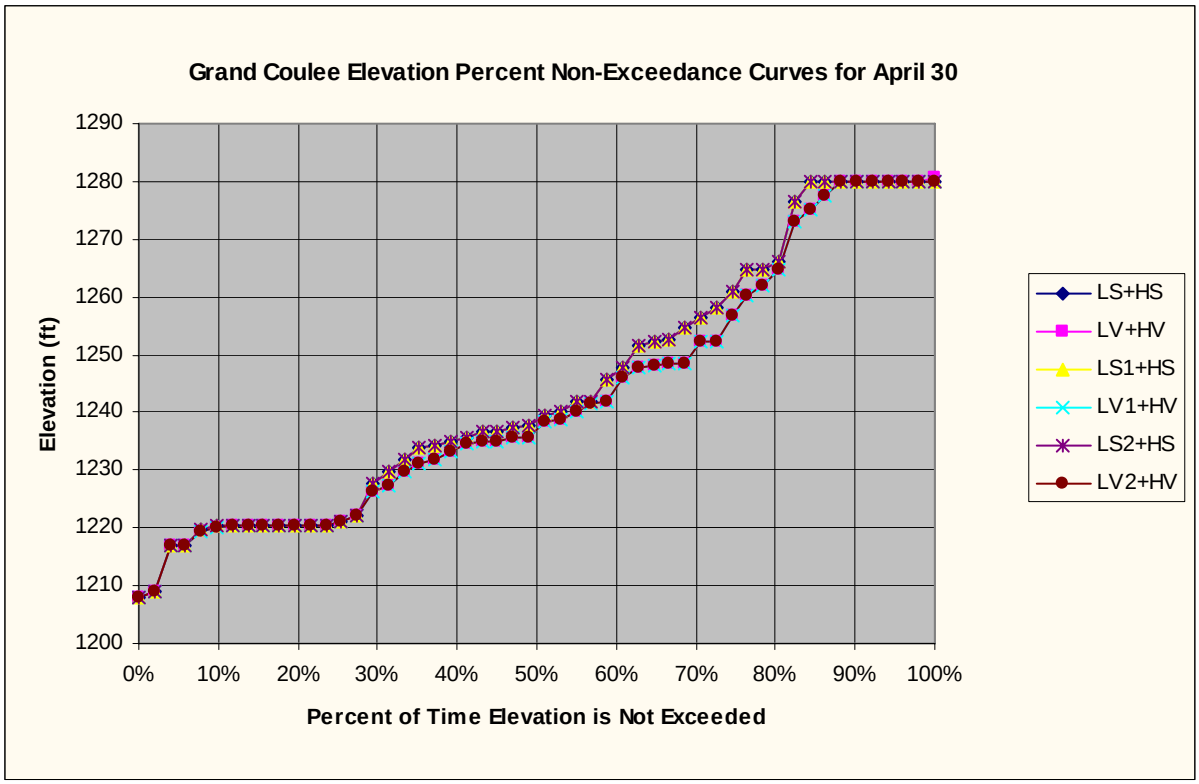

Figure 7. Grand Coulee Elevation Percent Non-Exceedance Curves for April 30

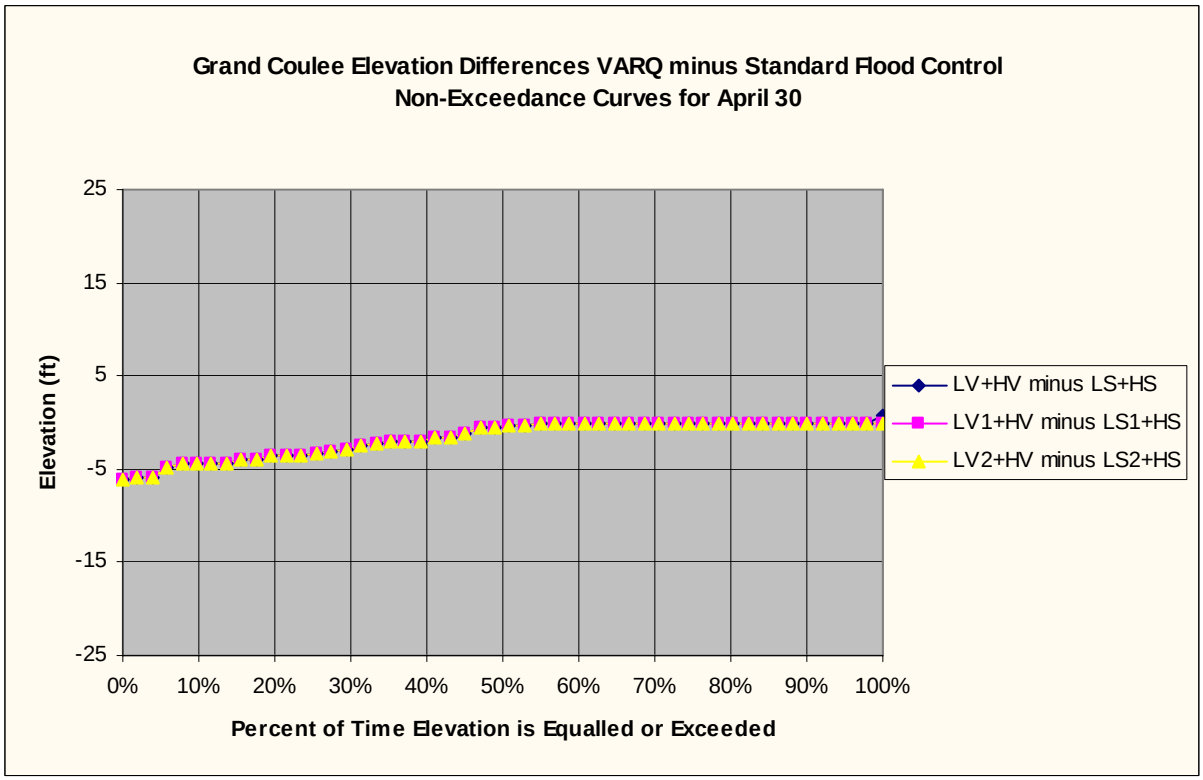

Figure 8. Grand Coulee Elevation Differences Standard minus VARQ Flood Control Exceedance Curves for April 30

6 Priest Rapids Flow Objectives

Tables 43 and 44 show the number of years of 52 that Priest Rapids flow objectives (90 kcfs in the first half of April and 135 kcfs for the second half of April through June) were missed and the average amount in cfs that the flow objectives were missed.

For the alternative combinations with no fish flow at Libby, VARQ increased the flow miss in the first and second halves of April by about 500 cfs (2%) and 1800 cfs (7%), respectively, while the number of years the objectives were missed stayed the same. In May, VARQ increased the flow amount missed by about 11,000 cfs (64%) but decreased the number of years missed by 2. In June, VARQ reduced the flow amount miss by 2800 cfs (14%) and decreased the number of years missed by 3.

In the alternative combinations with fish flows at Libby, VARQ did not change the number of years the flow objectives were missed in the first half of April through June. For the first half of April, VARQ decreased the average amount of flow miss by about 1000 cfs (5%). In the second half of April, VARQ increased the flow amount missed by about 1800 cfs (7%). For May, VARQ reduced the flow miss by about 1300 cfs (5%), with no change in the number of years missed (about 90% of the time Grand Coulee was operated for flood control, with the remainder of the time drafting to elevation1280 for McNary flow objectives). In June, VARQ reduced the flow miss by 3600 cfs (19%).

Figures 9 through 12 show the flow exceedance curves for each month that flow objectives occur. The curves are similar for all alternative combinations.

Table 43. Number of Years of 52 that Priest Rapids Flow Objective was Missed

Alternative Combination	Ap1	Apr	May	Jun
LS1+HS	17	20	3	10
LV1+HV	17	20	3	10
LS2+HV	17	20	3	10
LV2+HV	17	20	3	10
Benchmark Combination				
LS+HS	17	20	5	13
LV+HV	17	20	3	10

Table 44. Average Flow By Which Priest Rapid Flow Objective was Missed (cfs)

Alternative Combination	Ap1	Apr	May	Jun
LS1+HS	18498	26118	25584	19719
LV1+HV	17499	27932	26922	16033
LS2+HV	18501	26118	24614	19734
LV2+HV	17512	27930	26174	16083
Benchmark Combination				
LS+HS	18131	26118	17304	20312
LV+HV	18640	27925	28486	17515

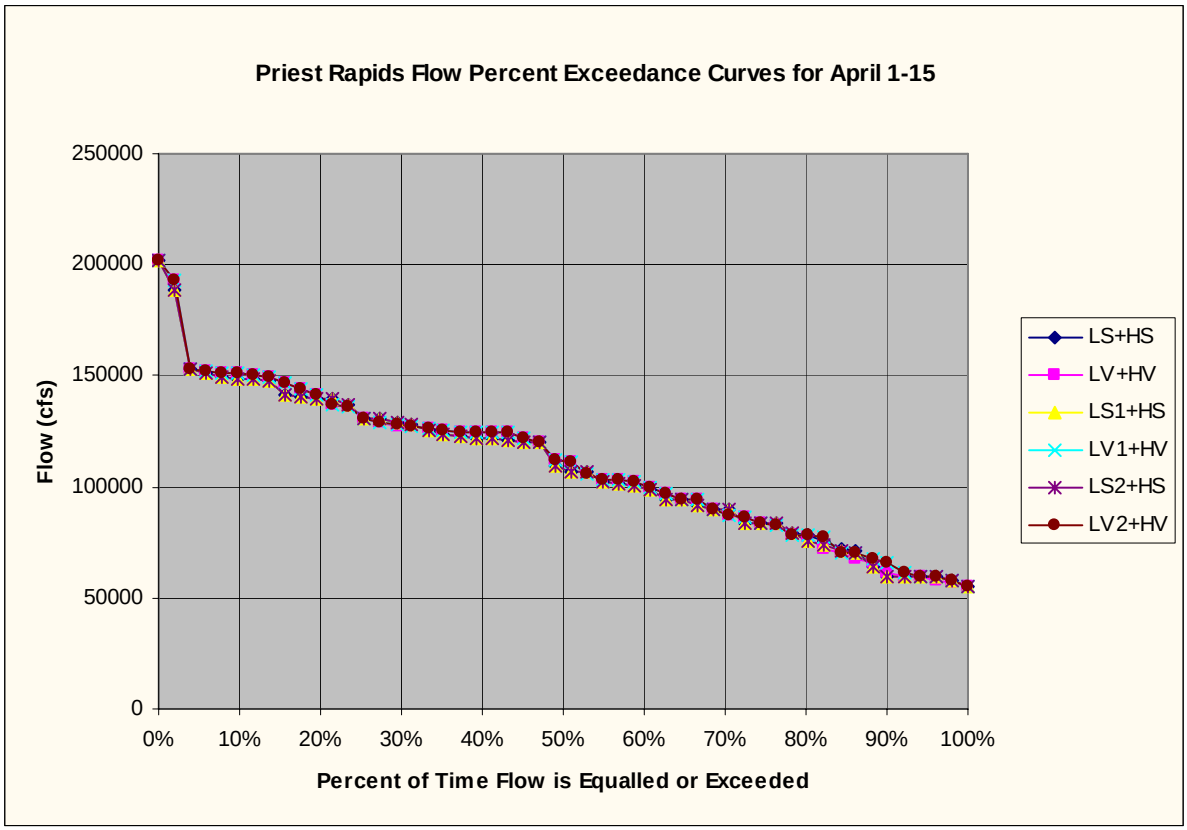

Figure 9. Priest Rapids Flow Percent Exceedance Curves for April 1-15

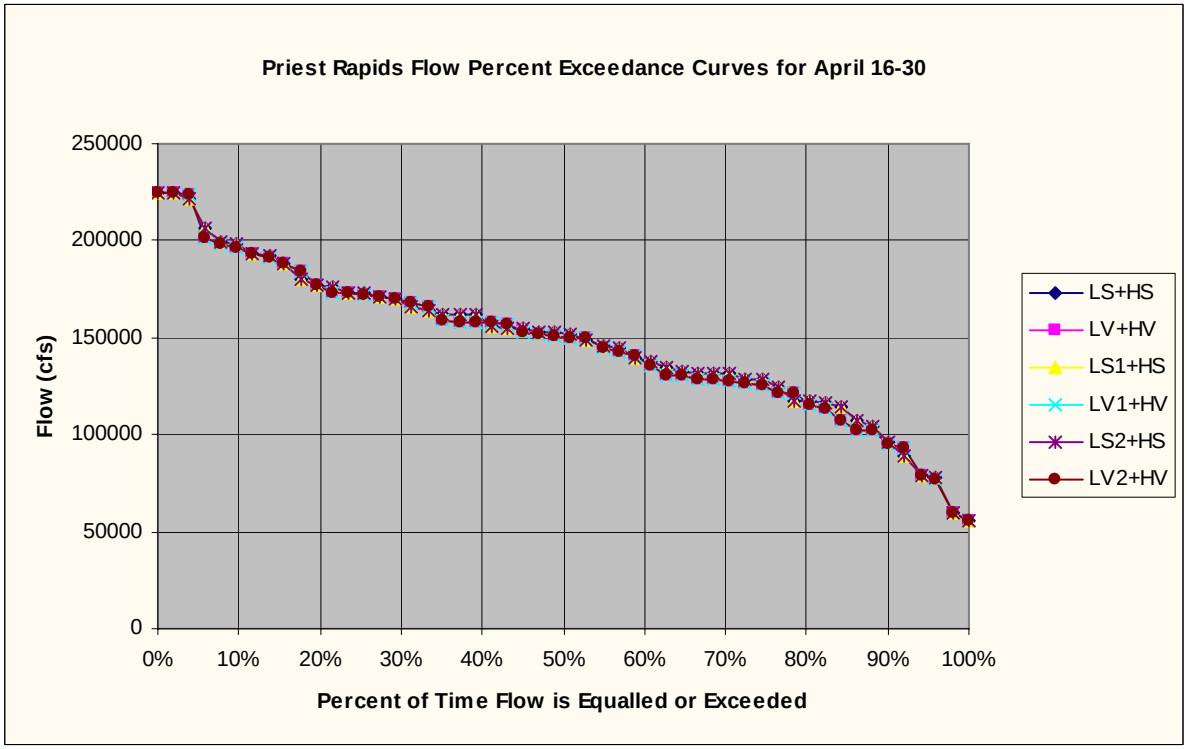

Figure 10. Priest Rapids Flow Percent Exceedance Curves for April 16-30

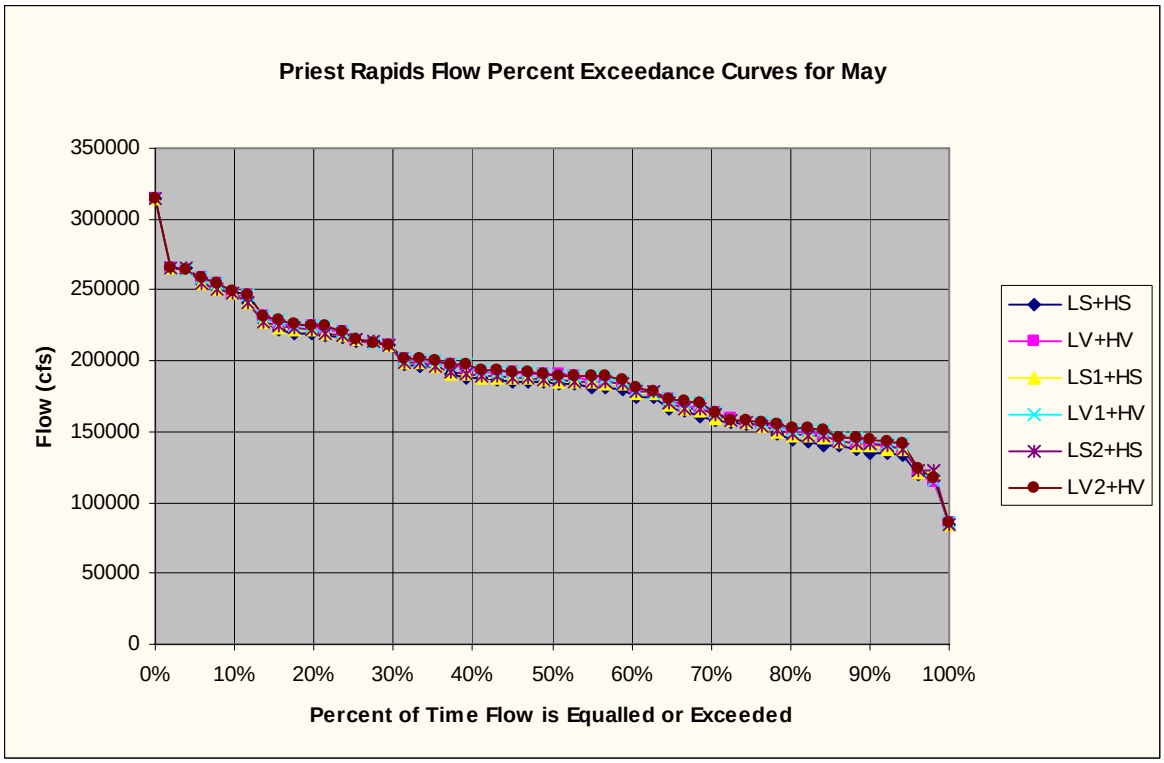

Figure 11. Priest Rapids Flow Percent Exceedance Curves for May

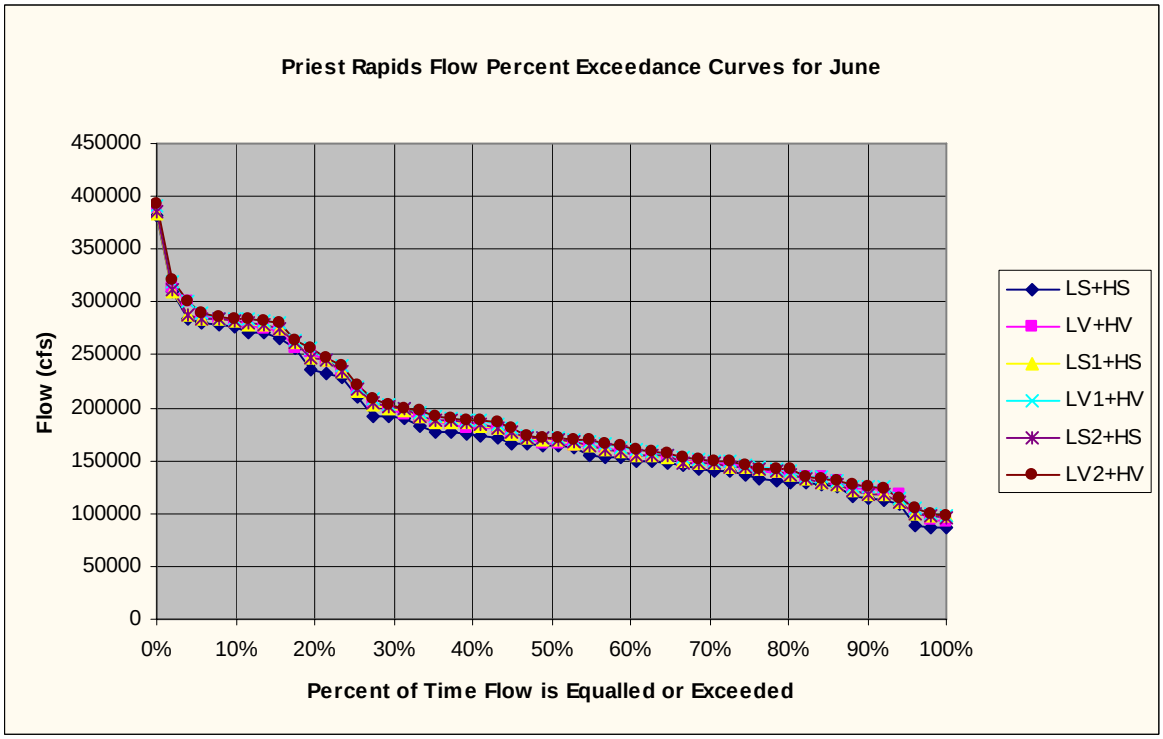

Figure 12. Priest Rapids Flow Percent Exceedance Curves for June

7 McNary Flow Objectives

Tables 45 and 46 show the number of years that the McNary flow objectives were missed and the average flow that the flow objective were missed by in the years that the flow objectives were not met. VARQ does not change the number of years the flow objectives were missed in the first and second halves of April. In May through the first half of August, VARQ reduces the number of years the flow objectives missed by zero to 3 years. In the second half of August, VARQ increases the number of years missed by zero to 2. The difference in the average amount the flow objectives were missed between VARQ and Standard alternative combinations only varied by a few percent.

Figures 13-19 show McNary flow exceedance curves for each month that flow objectives occur. All curves are very similar, however there is a slight improvement in the ability to meet the McNary flow objectives with VARQ and fish flow alternative combinations in July and August.

Table 45. Number of Years out of 52 that McNary Flow Objective was Missed

Alternative Combination	Ap1	Apr	May	Jun	Jul	AG1	Aug
LS1+HS	10	30	16	19	21	40	48
LV1+HV	10	30	15	18	21	38	48
LS2+HV	10	30	16	19	22	39	48
LV2+HV	10	30	15	18	20	36	49
Benchmark Combination							
LS+HS	10	30	16	23	23	40	49
LV+HV	10	30	15	21	21	42	50

Table 46. Average Flow by Which McNary Flow Objective was Missed (cfs)

Alternative Combination	Ap1	Apr	May	Jun	Jul	AG1	Aug
LS1+HS	23008	71598	35193	51386	40896	37384	64012
LV1+HV	22217	73125	34368	50775	38931	36270	60944
LS2+HV	23008	71598	34412	51307	39463	38667	64570
LV2+HV	22217	73124	33704	50780	41268	38639	60177
Benchmark Combination							
LS+HS	22584	71594	37826	48555	39683	39301	67373
LV+HV	24335	73087	35972	45998	42383	36965	66075

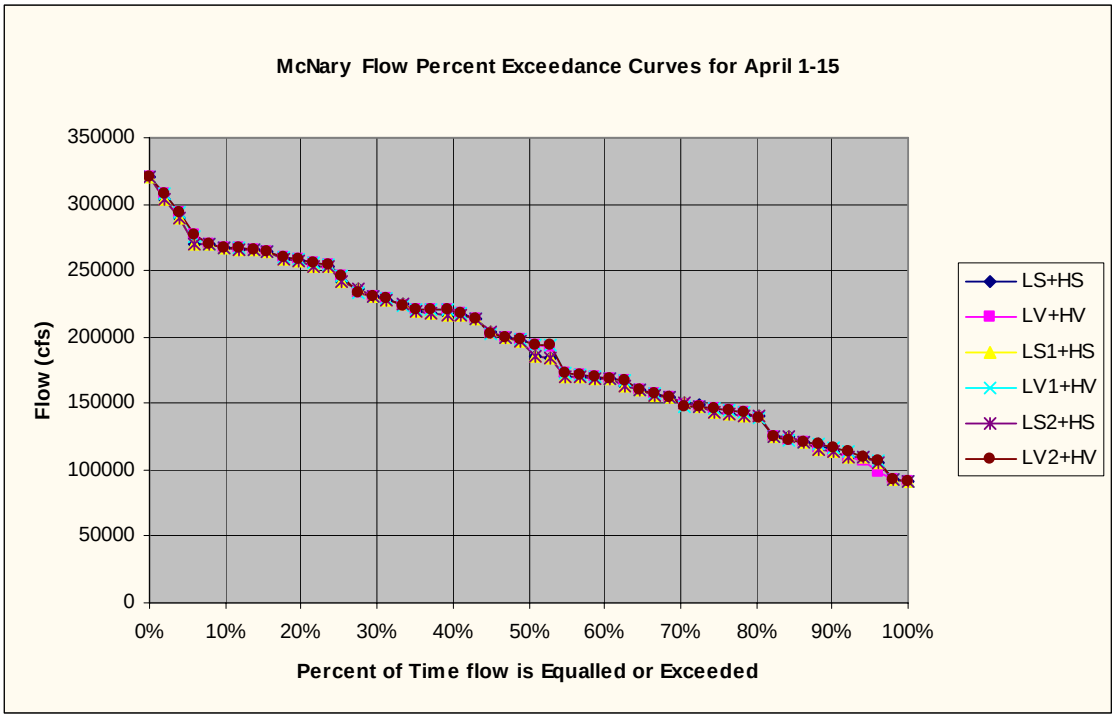

Figure 13. McNary Flow Percent Exceedance Curves for April 1-15

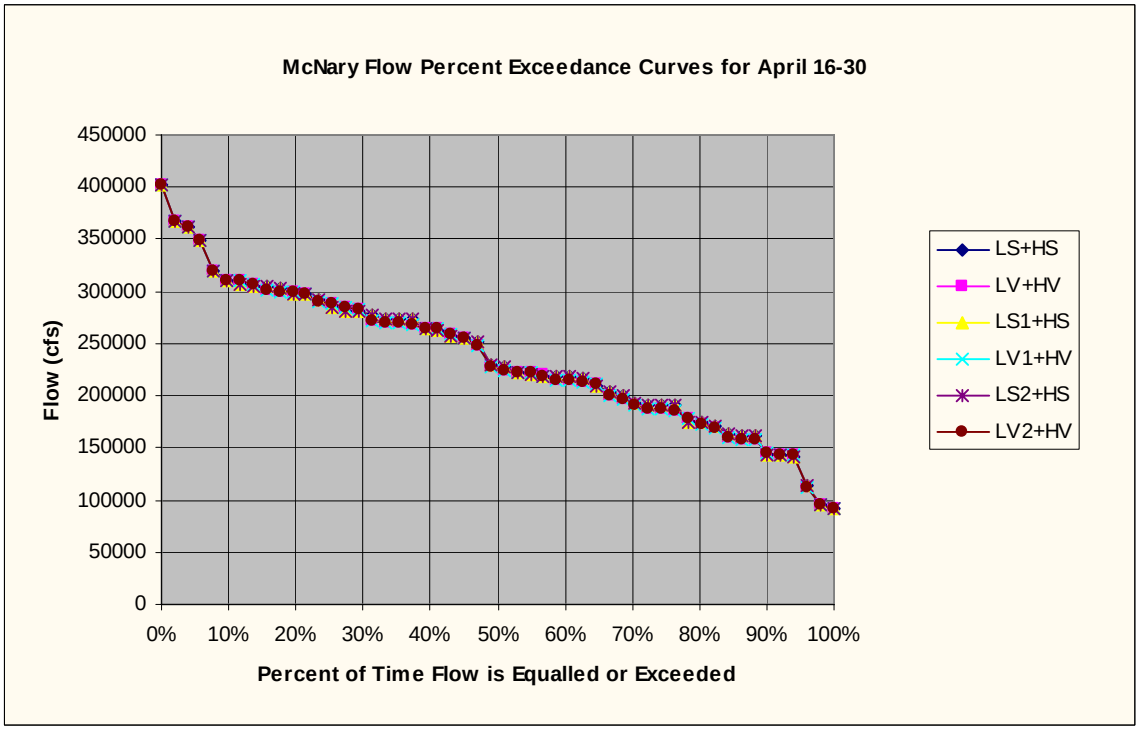

Figure 14. McNary Flow Percent Exceedance Curves for April 16-30

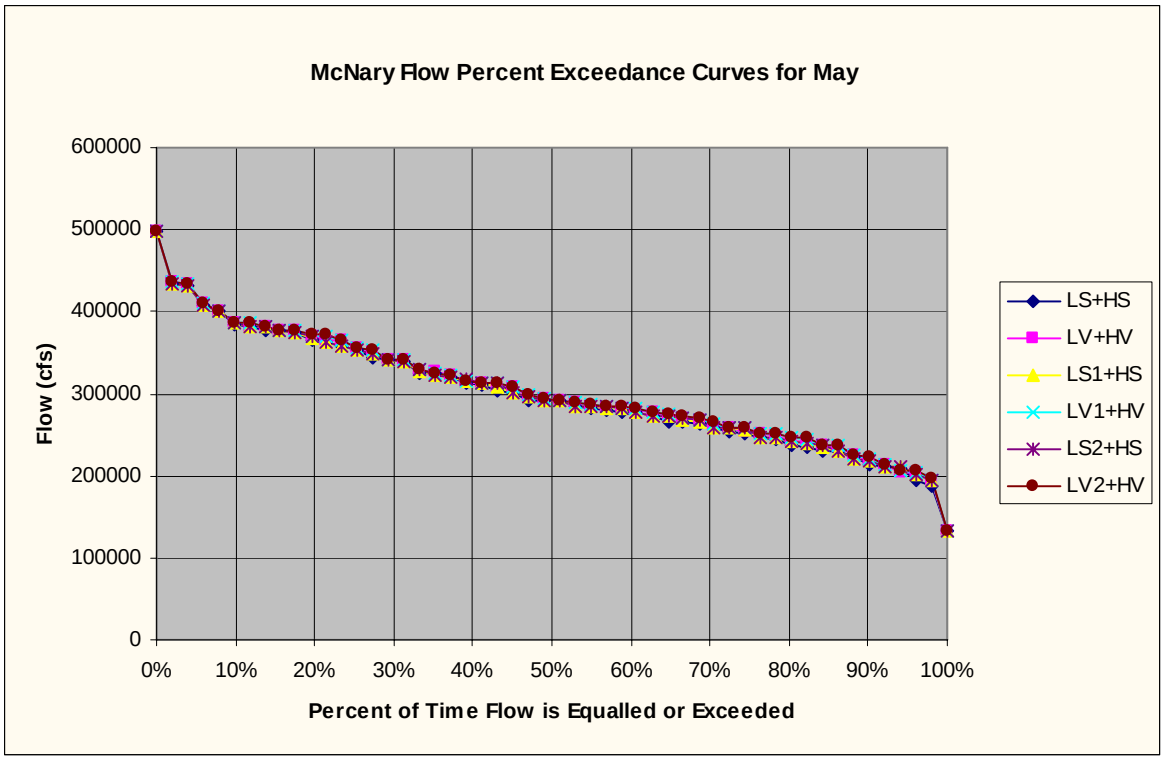

Figure 15. McNary Flow Percent Exceedance Curves for May

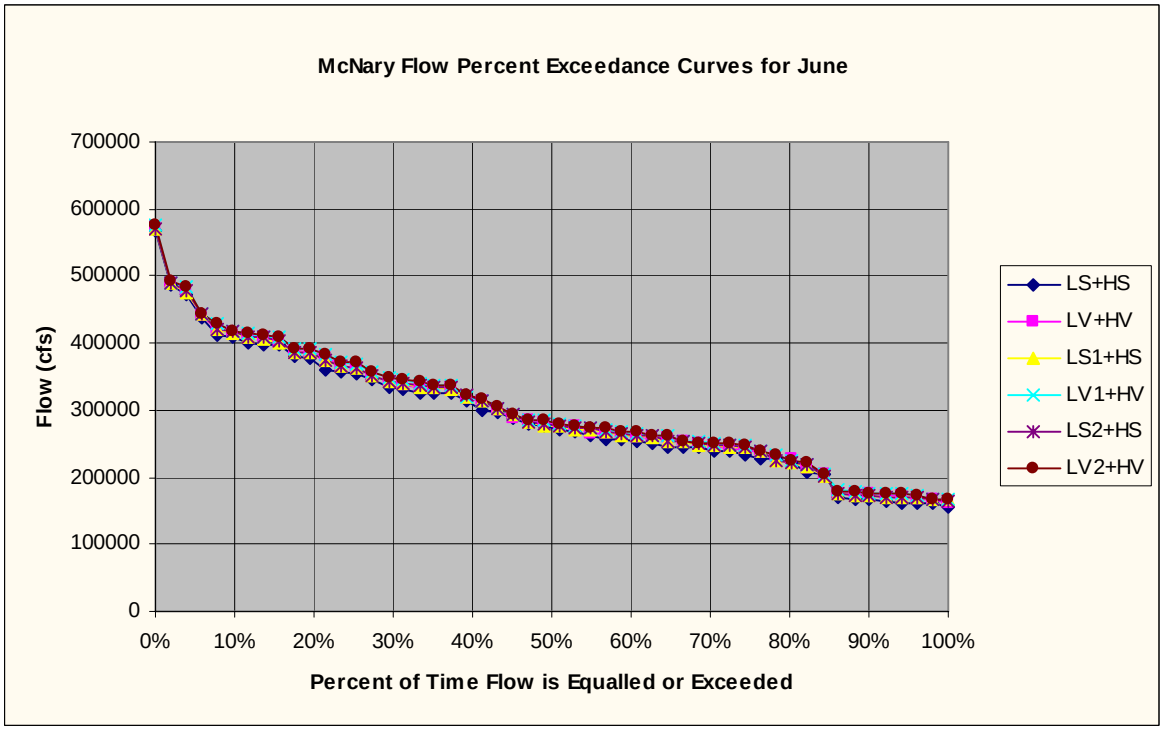

Figure 16. McNary Flow Percent Exceedance Curves for June

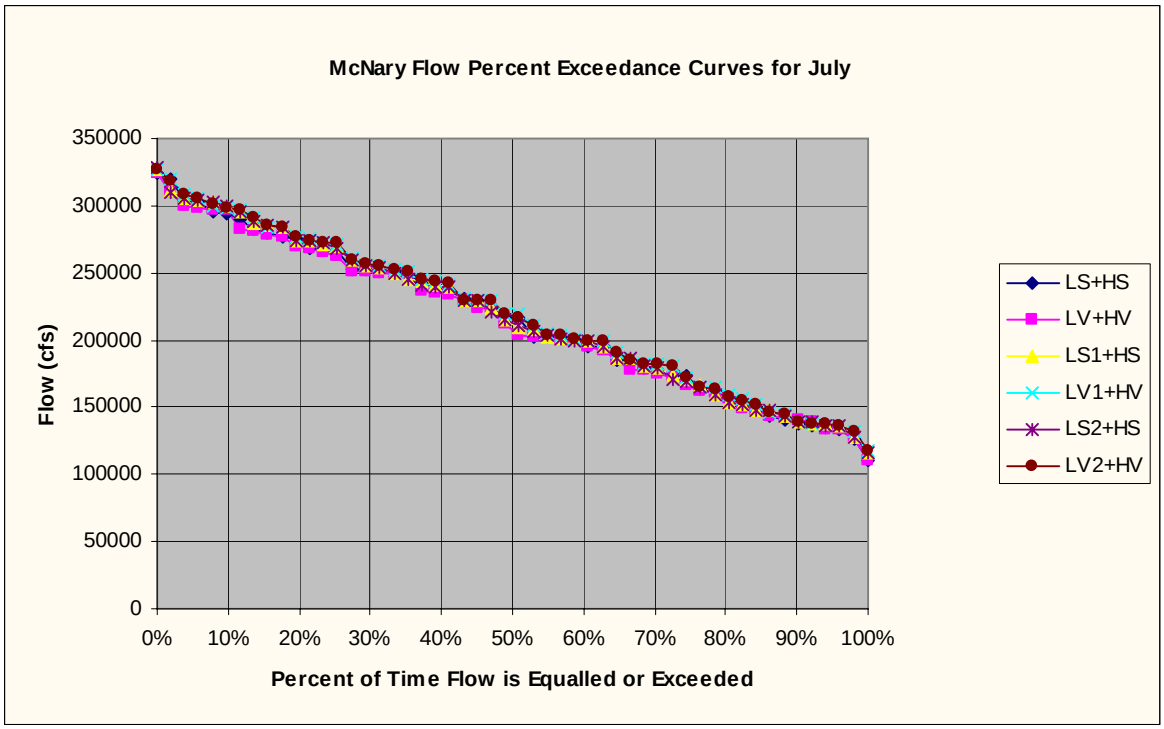

Figure 17. McNary Flow Percent Exceedance Curves for July

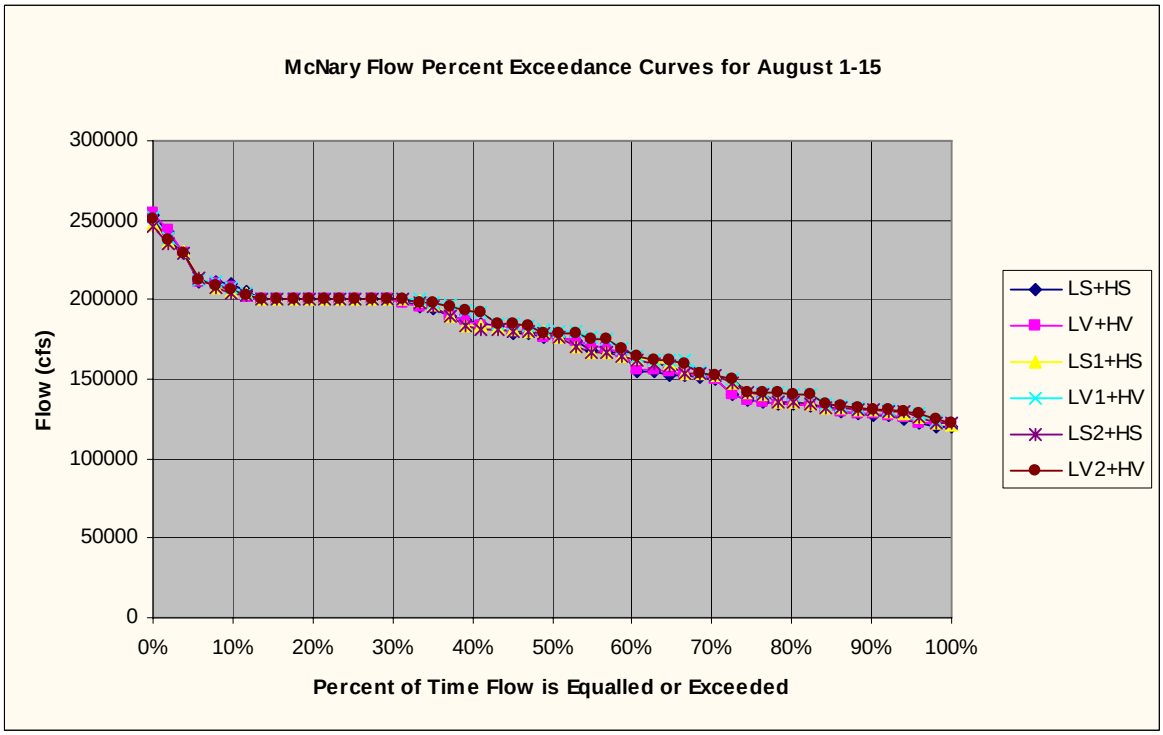

Figure 18. McNary Flow Percent Exceedance Curves for August 1-15

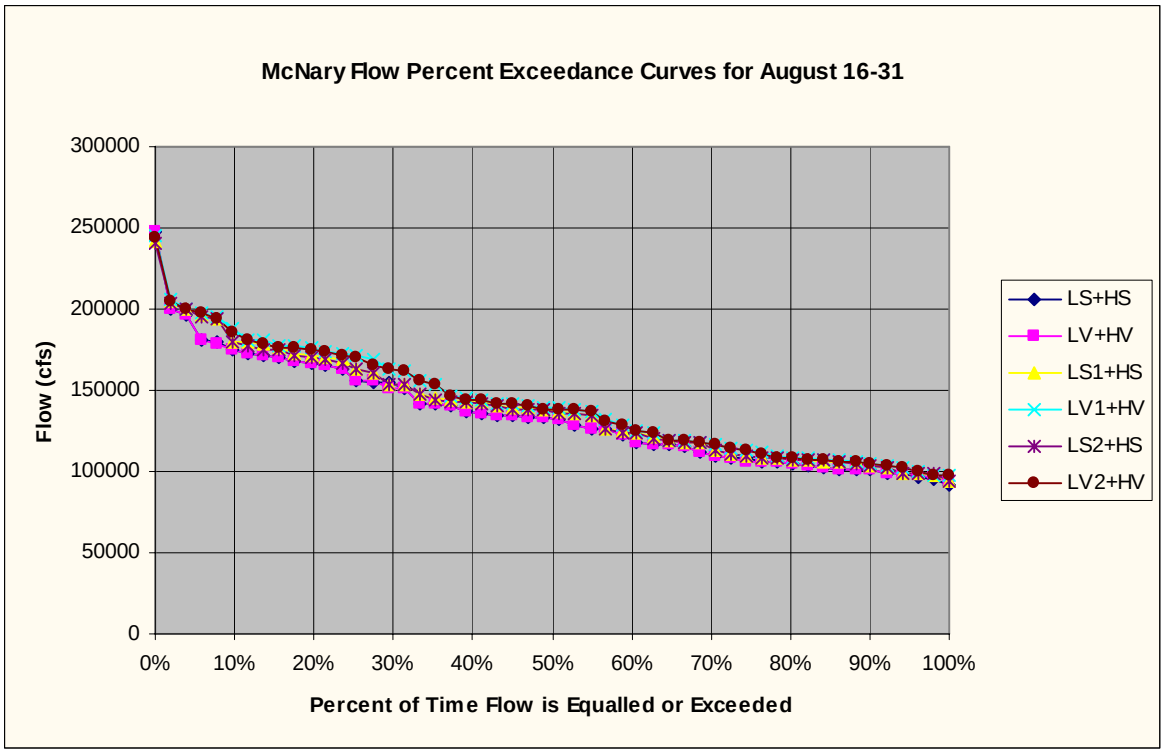

Figure 19. McNary Flow Percent Exceedance Curves for August 16-31

8 Summary of Results

For system generation, in comparing all VARQ to Standard Flood Control with and without fish flows at Libby, VARQ reduces average annual system generation by 7 to 12 MW. Comparing alternative combinations with Libby fish flows at QPHC to alternative combinations with no fish flows, fish flows reduce average annual generation by 27 to 31 MW. Comparing alternative combinations with Libby fish flows at QPHC+10 to alternative combinations with no fish flows, the fish flow alternative combinations reduce system generation by 33 to 38 MW. By these comparisons, Libby with fish flows at QPHC+10 has a greater impact on generation than Libby fish flows at QPHC, and the effects of VARQ on system generation are about one-third the impacts of the fish flows.

For all alternative combinations that compare VARQ to Standard, the largest impact to system generation occurred in January, with a reduction of 825 MW, which is about a 4.2% reduction. The largest increase occurs in May of 351-439 MW, which is about a 2 % increase.

For Standard Flood Control alternative combinations that compare Libby fish flows at QPHC and QPHC+10 to Libby without fish flows, the largest system generation impact occurs in September with a reduction of about 1350 MW, which is about a 13.5% reduction and the largest increase in generation occurs in June for 500 MW at about a 2.7% increase.

For VARQ Flood Control alternative combinations that compare Libby fish flows at QPHC and QPHC+10 to Libby without fish flows, the largest system generation impact occurs in September with a reduction of about 1320 MW, which is about a 13.1% reduction and the largest increase in generation occurs in the second half of August of 562-600 MW at about a 5.2% increase.

For VARQ compared to Standard, comparisons of generation for federal and non-federal projects generally follow the same patterns as for system generation with less generation in January through March and more generation in May through August, however, generation for projects on the Pend Oreille and Flathead Rivers were minimally affected in May through October. Additional flow was passed through these projects in May through July but had to spill due to reaching powerhouse capacity.

For spill at the federal and non-federal projects, in general, comparing the VARQ to Standard alternative combinations, VARQ reduced forced spill in January through March, and increased voluntary spill for fish in May through August. Voluntary spill increased because many projects spill based on a percent of regulated flow, which increased with VARQ. Differences between alternative combinations were relatively small (generally a 2% difference) in the comparison of alternative combinations.

Libby discharge and flow exceedance curves for September and October were provided. Libby operated to its normal operating rule curves of elevation 2437.9 at least 70% of the time and at elevation 2436.5 in October at least 76% of the time for all alternative combinations. The remainder of the time, Libby drafted to meet the system load. The average flows in September for alternative combinations without fish flows at Libby, is about 22,000 cfs and alternative combinations with fish flows is about 7300 cfs. The average flows for October is about 7,600 cfs for all alternative combinations.

Libby flow exceedance curves for December and January were provided. For all alternative combinations in December, at least 80% of the time the flow was greater than about 17,200 cfs. For January, the average flow for the Standard and VARQ alternative combinations is about 22,000 cfs, and 9,000 cfs respectively, however, the median flow for January with VARQ is about 8,900 cfs.

Grand Coulee elevation non-exceedance curves for the end of April were provided to evaluate bank exposure issues. About 85% of the time Grand Coulee operated to its flood control elevation. The remainder of the time, Grand Coulee had operated to elevation 1280 for McNary flow objectives or drafted to meet the Vernita Bar requirement. The average end of April elevation for VARQ and Standard Flood Control alternative combinations is elevation 1242.4 and 1244.0 ft respectively.

For Priest Rapids fish flow objectives in April through June, VARQ very slightly improved the ability to meet the flow objectives.

For McNary fish flow objectives in April through August, VARQ slightly improved the ability to meet the flow objectives. In the first and second halves of April, there is basically no difference. The flow amount misses were reduced only a few percent, and the number of years missed was reduced by 1 to 3 years.

APPENDIX K

Hydropower Economic Benefits Report

US Army Corps of Engineers ®
Northwestern Division

UPPER COLUMBIA ALTERNATIVE FLOOD CONTROL (VARQ) AND FISH OPERATIONS

HYDROPOWER BENEFITS IMPACT ANALYSIS

SUPPLEMENTAL REPORT TO THE ENVIRONMENTAL IMPACT STATEMENT

August 2005

Prepared for

U.S. Army Corps of Engineers
Seattle District
Seattle, Washington

PREPARED BY

HYDROPOWER ANALYSIS CENTER

TABLE OF CONTENTS

Page K-

K.1 INTRODUCTION....1
K.1.1 Purpose and Scope....1
K.1.2 Study Participants....2
K.1.3 Alternatives and Alternative Combinations Evaluated....2
K.1.4 Study Assumptions....5
K.2 DETAILED DESCRIPTION OF ALTERNATIVE COMBINATIONS EVALUATED....6
K.2.1 General....6
K.2.2 Alternative Combination LS1+HS: Standard Flood Control At Libby And Hungry Horse With Fish Flows, Including Sturgeon Flows At Libby Up To Current Powerhouse Capacity (QPHC)....6
K.2.3 Alternative Combination LV1+HV: VARQ Flood Control At Libby And Hungry Horse With Fish Flows, Including Sturgeon Flows At Libby Up To QPHC....12
K.2.4 Alternative Combination LS2+HS: Standard Flood Control At Libby And Hungry Horse With Fish Flows, Including Sturgeon Flows At Libby Up To QPHC + 10 Thousand Cubic Feet Per Second (Kcfs) (QPHC+10)....12
K.2.5 Alternative Combination LV2+HV: VARQ Flood Control At Libby And Hungry Horse With Fish Flows, Including Sturgeon Flows At Libby Up To QPHC+10....13
K.2.6 Benchmark Combination LS+HS: Standard Flood Control At Libby And Hungry Horse Without Libby Fish Flows....13
K.2.7 Benchmark Combination LV+HV: VARQ Flood Control At Libby And Hungry Horse, Without Libby Fish Flows....13
K.3 ANNUAL ENERGY BENEFITS IMPACTS....14
K.3.1 General....14
K.3.2 Comparison of Alternative and Benchmark Combinations....14
K.3.3 Heavy Load and Light Load Hours Distribution....37
K.3.4 Heavy Load and Light Load Hours Generation....39
K.3.5 Derivation of Monthly Energy Values....48
K.4 COMPUTATION OF HYDROPOWER BENEFITS IMPACTS....51
K.4.1 Computation of System Hydropower Benefits Impacts....51
K.5 COMPUTATION OF FEDERAL HYDROPOWER BENEFITS IMPACTS....54
K.5.1 Computation of Non-Federal Hydropower Benefits Impacts....57
K.5.2 Hydropower Benefits Impacts at Libby and Hungry Horse....60
K.6 SUMMARY OF HYDROPOWER BENEFITS IMPACTS....66
K.6.1 System Hydropower Benefits Impacts....67
K.6.2 Federal Hydropower Benefits Impacts....68
K.6.3 Non-Federal Hydropower Benefits Impacts....69
K.6.4 Libby and Hungry Horse Hydropower Benefits Impacts....70

LIST OF TABLES

Page K-

TABLE K.2-1. 52-YEAR AVERAGE PACIFIC NORTHWEST COORDINATED SYSTEM LOADS.....8

TABLE K.2-2. PROJECT PERIOD AVERAGE SPILL CAP (CFS) AND PERCENT SPILL.....9

TABLE K.3-1. 52-YEAR AVERAGE SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LS1+HS (GWH)16

TABLE K.3-2. 52-YEAR AVERAGE SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LV1+HV (GWH) 17

TABLE K.3-3. 52-YEAR AVERAGE SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LS2+HS (GWH)18

TABLE K.3-4. 52-YEAR AVERAGE SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LV2+HV (GWH) 19

TABLE K.3-5. 52-YEAR AVERAGE SYSTEM GENERATION FOR BENCHMARK COMBINATION LS+HS (GWH)20

TABLE K.3-6. 52-YEAR AVERAGE SYSTEM GENERATION FOR BENCHMARK COMBINATION LV+HV (GWH)21

TABLE K.3-7. DIFFERENCE IN SYSTEM GENERATION FOR BENCHMARK COMBINATION LV+HV MINUS BENCHMARK COMBINATION LS+HS (GWH) 22

TABLE K.3-8. DIFFERENCE IN SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LV1+HV MINUS ALTERNATIVE COMBINATION LS1+HS (GWH) 23

TABLE K.3-9. DIFFERENCE IN SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LV2+HV MINUS ALTERNATIVE COMBINATION LS2+HS (GWH) 24

TABLE K.3-10. DIFFERENCE IN SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LS1+HS MINUS BENCHMARK COMBINATION LS+HS (GWH) 25

TABLE K.3-11. DIFFERENCE IN SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LS2+HS MINUS BENCHMARK COMBINATION LS+HS (GWH) 26

TABLE K.3-12. DIFFERENCE IN SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LV1+HV MINUS BENCHMARK COMBINATION LV+HV (GWH).....27

TABLE K.3-13. DIFFERENCE IN SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LV2+HV MINUS BENCHMARK COMBINATION LV+HV (GWH).....28

TABLE K.3-14. 52-YEAR AVERAGE DIFFERENCE IN FEDERAL GENERATION FOR BENCHMARK COMBINATION LV+HV MINUS BENCHMARK COMBINATION LS+HS (MWH).....29

TABLE K.3-15. 52-YEAR AVERAGE DIFFERENCE IN FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LV1+HV MINUS ALTERNATIVE COMBINATION LS1+HS (MWH).....29

TABLE K.3-16. 52-YEAR AVERAGE DIFFERENCE IN FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LV2+HV MINUS ALTERNATIVE COMBINATION LS2+HS 30

TABLE K.3-17. 52-YEAR AVERAGE DIFFERENCE IN FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LS1+HS MINUS BENCHMARK COMBINATION LS+HS (MWH) 30

TABLE K.3-18. 52-YEAR AVERAGE DIFFERENCE IN FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LS2+HS MINUS BENCHMARK COMBINATION LS+HS (MWH) 31

TABLE K.3-19. 52-YEAR AVERAGE DIFFERENCE IN FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LV1+HV MINUS BENCHMARK COMBINATION LV+HV (MWH) 31

TABLE K.3-20. 52-YEAR AVERAGE DIFFERENCE IN FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LV2+HV MINUS BENCHMARK COMBINATION LV+HV (MWH) 32

TABLE K.3-21. 52-YEAR AVERAGE DIFFERENCE IN NON-FEDERAL GENERATION FOR BENCHMARK COMBINATION LV+HV MINUS BENCHMARK COMBINATION LS+HS (MWH) 32

TABLE K.3-22. 52-YEAR AVERAGE DIFFERENCE IN NON-FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LV1+HV MINUS ALTERNATIVE COMBINATION LS1+HS (MWH) 33

TABLE K.3-23. 52-YEAR AVERAGE DIFFERENCE IN NON-FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LV2+HV MINUS ALTERNATIVE COMBINATION LS2+HS (MWH) 33

TABLE K.3-24. 52-YEAR AVERAGE DIFFERENCE IN NON-FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LS1+HS MINUS BENCHMARK COMBINATION LS+HS (MWH) 34

TABLE K.3-25. 52-YEAR AVERAGE DIFFERENCE IN NON-FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LS2+HS MINUS BENCHMARK COMBINATION LS+HS (MWH) 34

TABLE K.3-26. 52-YEAR AVERAGE DIFFERENCE IN NON-FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LV1+HV MINUS BENCHMARK COMBINATION LV+HV (MWH) 35

TABLE K.3-27. 52-YEAR AVERAGE DIFFERENCE IN NON-FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LV2+HV MINUS BENCHMARK COMBINATION LV+HV (MWH) 35

TABLE K.3-28. 52-YEAR AVERAGE GENERATION DIFFERENCE AT LIBBY (MWH) 36

TABLE K.3-29. 52-YEAR AVERAGE GENERATION DIFFERENCE AT HUNGRY HORSE (MWH) 36

TABLE K.3-30. MONTHLY LIGHT AND HEAVY LOAD HOURS DISTRIBUTION FACTORS 38

TABLE K.3-31. SYSTEM HEAVY LOAD HOURS GENERATION BY ALTERNATIVE COMBINATION AND BENCHMARK COMBINATION (GWH) 40

TABLE K.3-32. FEDERAL HEAVY LOAD HOURS GENERATION BY ALTERNATIVE COMBINATION AND BENCHMARK COMBINATION (GWH) 40

TABLE K.3-33. NON-FEDERAL HEAVY LOAD HOURS GENERATION BY ALTERNATIVE COMBINATION AND BENCHMARK COMBINATION (GWH) 41

TABLE K.3-34. SYSTEM LIGHT LOAD HOURS GENERATION BY ALTERNATIVE COMBINATION AND BENCHMARK COMBINATION (GWH) 41

TABLE K.3-35. FEDERAL LIGHT LOAD HOURS GENERATION BY ALTERNATIVE COMBINATION AND BENCHMARK COMBINATION (GWH) 42

TABLE K.3-36. NON-FEDERAL LIGHT LOAD HOURS GENERATION BY ALTERNATIVE COMBINATION AND BENCHMARK COMBINATION (GWH) 42

TABLE K.3-37. SYSTEM HEAVY LOAD HOURS GENERATION DIFFERENCES (MWH) 43

TABLE K.3-38. FEDERAL HEAVY LOAD HOURS GENERATION DIFFERENCES (MWH) 43

TABLE K.3-39. NON-FEDERAL HEAVY LOAD HOURS GENERATION DIFFERENCES (MWH) 44

TABLE K.3-40. LIBBY HEAVY LOAD HOURS GENERATION DIFFERENCES (MWH) 44

TABLE K.3-41. HUNGRY HORSE HEAVY LOAD HOURS GENERATION DIFFERENCES (MWH) 45

TABLE K.3-42. SYSTEM LIGHT LOAD HOURS GENERATION DIFFERENCES (MWH) 45

TABLE K.3-43. FEDERAL LIGHT LOAD HOURS GENERATION DIFFERENCES (MWH) 46

TABLE K.3-44. NON-FEDERAL LIGHT LOAD HOURS GENERATION DIFFERENCES (MWH) 46

TABLE K.3-45. LIBBY LIGHT LOAD HOURS GENERATION DIFFERENCES (MWH) 47

TABLE K.3-46. HUNGRY HORSE LIGHT LOAD HOURS GENERATION DIFFERENCES (MWH) 47

TABLE K.3-47. AVERAGE MONTHLY ENERGY VALUES ($/MWH).....50

TABLE K.4-1. SYSTEM HLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000) 52

TABLE K.4-2. SYSTEM LLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000) 52

TABLE K.4-3. SYSTEM HLH COMPARISON OF ALTERNATIVE AND BENCHMARK COMBINATIONS HYDROPOWER BENEFITS ($1,000) 53

TABLE K.4-4. SYSTEM LLH COMPARISON OF ALTERNATIVE AND BENCHMARK COMBINATIONS HYDROPOWER BENEFITS ($1,000).....53

TABLE K.5-1. FEDERAL HLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000).....55

TABLE K.5-2. FEDERAL LLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000) 55

TABLE K.5-3. FEDERAL HLH COMPARISON OF ALTERNATIVE AND BENCHMARK COMBINATIONS HYDROPOWER BENEFITS ($1,000) 56

TABLE K.5-4. FEDERAL LLH COMPARISON OF ALTERNATIVE AND BENCHMARK COMBINATIONS HYDROPOWER BENEFITS ($1,000) 56

TABLE K.5-5. NON-FEDERAL HLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000).....58

TABLE K.5-6. NON-FEDERAL LLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000).....58

TABLE K.5-7. NON-FEDERAL HLH COMPARISON OF ALTERNATIVE AND BENCHMARK COMBINATIONS HYDROPOWER BENEFITS ($1,000) 59

TABLE K.5-8. NON-FEDERAL LLH COMPARISON OF ALTERNATIVE AND BENCHMARK COMBINATIONS HYDROPOWER BENEFITS ($1,000) 59

TABLE K.5-9. LIBBY HLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000) 61

TABLE K.5-10. LIBBY LLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000) 61

TABLE K.5-11. LIBBY HLH COMPARISON OF ALTERNATIVE AND BENCHMARK COMBINATIONS HYDROPOWER BENEFITS ($1,000) 62

TABLE K.5-12. LIBBY LLH COMPARISON OF ALTERNATIVE AND BENCHMARK COMBINATIONS HYDROPOWER BENEFITS ($1,000) 62

TABLE K.5-13. HUNGRY HORSE HLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000).....64

TABLE K.5-14. HUNGRY HORSE LLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000).....64

TABLE K.5-15. HUNGRY HORSE HLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000).....65

TABLE K.5-16. HUNGRY HORSE LLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000) 65

TABLE K.6-1. SUMMARY OF SYSTEM ANNUAL HYDROPOWER BENEFITS BY ALTERNATIVE AND BENCHMARK COMBINATION ($1,000) 67

TABLE K.6-2. SUMMARY OF COMPARISONS OF SYSTEM ALTERNATIVE AND BENCHMARK COMBINATIONS ANNUAL HYDROPOWER BENEFITS IMPACTS ($1,000) 67

TABLE K.6-3. SUMMARY OF FEDERAL ANNUAL HYDROPOWER BENEFITS BY ALTERNATIVE AND BENCHMARK COMBINATION ($1,000) 68

TABLE K.6-4. SUMMARY OF COMPARISONS OF FEDERAL ALTERNATIVE AND BENCHMARK COMBINATIONS ANNUAL HYDROPOWER BENEFITS IMPACTS ($1,000) 68

TABLE K.6-5. SUMMARY OF NON-FEDERAL ALTERNATIVE AND BENCHMARK COMBINATIONS ANNUAL HYDROPOWER BENEFITS ($1,000) 69

TABLE K.6-6. SUMMARY OF COMPARISONS OF NON-FEDERAL ALTERNATIVE AND BENCHMARK COMBINATIONS ANNUAL HYDROPOWER BENEFITS IMPACTS ($1,000) 69

TABLE K.6-7. SUMMARY OF COMPARISONS OF LIBBY & HUNGRY HORSE AVERAGE ANNUAL HYDROPOWER BENEFITS IMPACTS ($1,000) 70

Appendix K HYDROPOWER ECONOMIC BENEFITS REPORT

K.1 INTRODUCTION

K.1.1 Purpose and Scope

The purpose of this report is to quantify the economic impact on the Columbia River basin hydropower system associated with proposed operational changes at Libby and Hungry Horse dams in Montana. Hydropower benefits impacts are quantified for the Columbia River hydropower system as a whole, for Federal system projects (dams and powerplants), and for the non-Federal projects below Libby and Hungry Horse dams. At-site hydropower benefits impacts are quantified at Libby and Hungry Horse, also. The term "benefits" refers to the value of system hydropower.

The impacts of these changes are being evaluated as a supplemental report to an Environmental Impact Statement (EIS) entitled Upper Columbia Alternative Flood Control (VARQ) and Fish Operations EIS, or UCEIS. These operational changes are in response to the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) Biological Opinions dated December 2000[1]. Both Biological Opinions recommended VARQ as a flood control operation strategy for Libby and Hungry Horse. These operational changes would also result in changes in operations at Grand Coulee Dam on the Columbia River in eastern Washington. The UCEIS will be used to help determine whether to implement VARQ at Libby and Hungry Horse on a permanent basis beginning in January 2006. In addition, the UCEIS documents the effects of providing flow augmentation for Kootenai River white sturgeon, bull trout in the Kootenai and Flathead rivers, and salmon and steelhead in the lower Columbia River. As

[1] Note that there has been a new Biological Opinion from NMFS (NOAA Fisheries) as of November 2004, It responds to an Updated Proposed Action (UPA) from the Bonneville Power Administration, Corps of Engineers, and Bureau of Reclamation, which includes actions to meet flow requirements for salmon. Modeling for the UCEIS was initiated before November 2004, and UPA provisions are not different enough from the 2000 Biological Opinion Reasonable and Prudent Alternative to warrant revisiting the model for purposes of the UCEIS. Furthermore, the 2004 Biological Opinion is currently under litigation in *National Wildlife Federation v National Marine Fisheries Service, No. CV-01-00640-RE (D. Oregon)*. This Biological Opinion was subject to an unfavorable ruling, but no final rulings have been made in the case. However, it is anticipated that implementation of VARQ flood control would be carried forward in any future consultation.

part of that, the USFWS Biological Opinion calls for increasing flow capacity from Libby by 10 thousand cubic feet per second (kcfs) above current powerhouse capacity, within Montana's dissolved gas standard of 110% saturation.

K.1.2 Study Participants

This report was prepared by the Hydropower Analysis Center (HAC) of the Northwestern Division, North Pacific Region, Corps of Engineers for the Seattle District, Corps of Engineers (NWS). Jeff Laufle, Seattle District, served as the Project Manager for the EIS study process, and Evan Lewis of Seattle District was the Environmental Coordinator. Patti Etzel, Power Branch, Northwestern Division, performed the hydrologic and power system modeling. John Johannis, HAC, performed the Independent Technical Review for this report. The primary HAC point of contact for this analysis was Kamau Sadiki, HAC Technical Manager (now at telephone: 202-761-4889; e-mail: kamau.b.sadiki@usace.army.mil).

K.1.3 Alternatives and Alternative Combinations Evaluated

Four alternatives involving fish flows at Libby and two at Hungry Horse, integrated into four alternative combinations for the overall system, are evaluated in this report to determine the impact of VARQ operations, and fish flow operations at Libby Dam, on the Columbia River hydropower system, the Federal projects, and the non-Federal projects below Libby and Hungry Horse. At-site impacts at Libby and Hungry Horse are evaluated, also. Two non-fish-flow benchmarks at Libby were integrated with the two alternatives at Hungry Horse to form two benchmark combinations for this analysis, which function as comparative baselines to derive effects of fish flows from Libby.

The four Libby alternatives are:

Alternative LS1 - Standard Flood Control with Fish Flows up to Powerhouse Capacity (no-action alternative)

Alternative LV1 - VARQ Flood Control with Fish Flows up to Powerhouse Capacity (preferred alternative)

Alternative LS2 - Standard Flood Control with Fish Flows up to Powerhouse Capacity plus 10 kcfs

Alternative LV2 - VARQ Flood Control with Fish Flows up to Powerhouse Capacity plus 10 kcfs

The two benchmarks at Libby are:

Benchmark LS - Standard Flood Control without Fish Flows

Benchmark LV - VARQ Flood Control without Fish Flows

Benchmarks LS and LV are evaluated for comparison purposes only to determine the effects of fish flows. Because they do not incorporate fish flows, these benchmarks do not meet the of the proposed actions under the National Environmental Policy Act (NEPA).

The two Hungry Horse alternatives are:

Alternative HS - Standard Flood Control with Fish Flows (no-action alternative)

Alternative HV - VARQ Flood Control with Fish Flows (preferred alternative)

The four alternative combinations evaluated in this report are:

Alternative Combination LS1+HS - Standard Flood Control at Libby and Hungry Horse with fish flows, including sturgeon flows at Libby up to current powerhouse capacity (QPHC) (no-action)

Alternative Combination LV1+HV - VARQ Flood Control at Libby and Hungry Horse with fish flows, including sturgeon flows at Libby up to QPHC (preferred)

Alternative Combination LS2+HS - Standard Flood Control at Libby and Hungry Horse with fish flows, including sturgeon flows at Libby up to 10,000 cubic feet per second (10 kcfs) above QPHC (QPHC+10)

Alternative Combination LV2+HV - VARQ Flood Control at Libby and Hungry Horse with fish flows, including sturgeon flows at Libby up to QPHC+10

The two benchmark combinations evaluated herein are:

Benchmark Combination LS+HS - Standard Flood Control at Libby and Hungry Horse without Libby fish flows

Benchmark Combination LV+HV - VARQ Flood Control at Libby and Hungry Horse, without Libby fish flows

The Northwestern Division, Water Management Division, Power Branch simulated the six combinations using the Hydro Seasonal Regulation (HYSSR) hydrologic routing model. HYSSR is a FORTRAN model that utilizes a monthly time step to simulate reservoir operations. There are actually 14 periods in HYSSR, one period for each month except April and August, which are split in half months to better simulate the significant flow variability during those months. A 52-year hydrologic record was used for the model simulation, starting from August 1, 1947 through July 31, 1999. All HYSSR simulations are "continuous" type studies where the July end-of-month elevations are the start elevations for the following August. Additionally, in each of the alternative and benchmark combinations, all reservoirs were assumed to start full, except for Grand Coulee, Hungry Horse, and Dworshak in all alternative and benchmark combinations and Libby in the Libby alternative combinations, which started at their draft limits for McNary flow objectives. Libby started full in the benchmark combinations (without Libby fish flows).

All alternative and benchmark combinations were modeled in the system using operations for the projects as submitted in accordance with the Pacific Northwest Coordination Agreement (PNCA), except for Libby and Hungry Horse which were modeled to target elevations specific to this study. The PNCA was ratified in 1964, and the owners of projects in the Columbia River coordinated hydropower system have agreed to plan, coordinate, and operate their systems for flood control, and to optimize power production while taking into consideration non-power uses. Operating criteria for non-Federal projects were as submitted by project owners under the PNCA for the operating year 2003-2004. Project operation for Federal projects is as described in this report (See Section K.2.0).

The HYSSR model simulated the projects operating to their Operating Rule Curve (ORC) or drafted as necessary to meet the power demand. The ORC is a combination of curves made up of flood control curves, refill curves, and power critical rule curves. The projects that operate for power first run to their ORCs, and if the energy produced is greater than the load, then the model run is complete. If the energy produced by running to the ORC is less than the load, then the projects draft until the load is met. Projects that operate specifically for fish flows do not operate to ORCs, but still generate power, which contributes toward meeting the power demand. A detailed description of each combination modeled in HYSSR is in Section K.2.0 of this report.

System and project generation output from the HYSSR model was used for the hydropower benefits impact evaluation in this report. HYSSR outputs project generation in units of average megawatts (aMW), which was converted to megawatt-hours (MWh) or gigawatt-hours (GWh, one thousand megawatt-hours) for this analysis.

K.1.4 Study Assumptions

The following assumptions were made in order to perform this analysis:

Price Level: Energy prices utilized in this analysis were developed at the 2010 price level. These prices were deflated to 2004 to quantify the economic impacts on hydropower benefits. These prices are assumed Market Prices for the Mid-Columbia Trading Hub.

Discount Rate: The interest rate used in this analysis is the fiscal year 2005 Federal interest rate of 5.375 percent.

Rounding and Totals: Some parts of this analysis were performed using spreadsheet software. Arithmetic operations and totals were taken to full decimal accuracy within the spreadsheet. Tables found within this report have been rounded to a specified level of accuracy after the mathematical computations have been performed. Therefore, rounded totals may not equal the summation of rounded values. In addition, generation and generation differences were derived directly from HYSSR generation and generation difference output tables. Due to rounding in the HYSSR output tables, values in generation difference tables may vary slightly from differences that would be calculated from total generation tables.

K.2 DETAILED DESCRIPTION OF ALTERNATIVE COMBINATIONS EVALUATED

K.2.1 General

The alternative combinations described below (2.2-2.5) were formulated to evaluate the impact of VARQ flood control operation versus the Standard Flood Control operation on the Columbia River Basin hydropower system below Libby and Hungry Horse dams, as well as to derive the effects of Libby fish flows. Each of these combinations was modeled in HYSSR, which provided output generation data for the hydropower analysis. The descriptions below summarize the assumptions for each combination and how the HYSSR simulations were modeled.

In addition, benchmark combinations (2.6-2.7) were used as baselines to evaluate the effects of Libby fish flows, and were compared with the alternative combinations for this purpose.

K.2.2 Alternative Combination LS1+HS: Standard Flood Control At Libby And Hungry Horse With Fish Flows, Including Sturgeon Flows At Libby Up To Current Powerhouse Capacity (QPHC)

This alternative combination used the Standard Flood Control operations for maximum reservoir elevations at Libby and Hungry Horse. Hungry Horse was modeled to target simulated elevations with fish flows for Standard Flood Control year around. Libby was operated to target system flood control in January through April and simulated target elevations in May through August based on using fish flows with a maximum flow during the sturgeon pulse of powerhouse capacity for Standard Flood Control operations. The powerhouse capacity at Libby is approximately 25 kcfs. Grand Coulee flood control curves and Variable Draft Limits (VDLs) were adjusted for upstream power drafts. All other projects used PNCA 2003-2004 operating criteria or as described below.

Flood control. The data source for the Standard Flood Control Curves was provided by the Corps' Hydrologic Engineering Branch (HEB), Northwestern Division,

Bureau of Reclamation (Reclamation), and NWS. Flood control curves are upper limits for project forebay elevations. Flood control curves take precedence over any targeted elevations that may have been above flood control curves used in this analysis. Exceptions to regulate above flood control curves may occur for local flood protection, approach channel capacity, and Libby may be above system flood control elevations due to the Kootenay Lake International Joint Commission (IJC) operation.

Grand Coulee Flood Control Adjustments. An initial HYSSR model run was made and the resulting drafts at projects upstream of Grand Coulee were used to determine the flood control adjustment at Grand Coulee. The adjustment was made such that when drafts at upstream projects at the end of April are below their flood control curves, Grand Coulee's flood control curves are adjusted upwards. After the Grand Coulee curves were adjusted, a final model run was made to incorporate the adjustment.

Critical Rule Curves. Critical Rule Curves are the projects' ending elevations from the PNCA 2003-2004 critical period Final Regulation. For the PNCA 2004 operating year, the critical period regulation is from August 1936 through July 1937. The ending elevations reflect the Firm Energy Load Carrying Capability (FELCC) produced by the system, which is the generation the system can be expected to produce in a critical water year. The Critical Rule Curves were developed with Hungry Horse and Libby VARQ flood control; however, for purposes of computing differences between combinations, these critical rule curves were used for all combinations.

Loads. The PNCA coordinated system loads were computed for each year of the 52-year model run. The loads were based on the FELCC from the PNCA 2003-2004 operating year. The PNCA critical year is not within the period of record of this study, but is considered to be applicable for the purposes of this study. The FELCC was adjusted for each year due to the generation capability of the hydro-independent projects, which are projects that serve load in the Pacific Northwest, but are not in the PNCA coordinated system. Table K.2-1 shows the month average load over the 52-year period developed with Libby and Hungry Horse VARQ Flood Control.

TABLE K.2-1. 52-YEAR AVERAGE PACIFIC NORTHWEST COORDINATED SYSTEM LOADS

Period	Load (MWh)
AG1	3,803,040
AUG	3,484,800
SEP	4,752,720
OCT	6,296,470
NOV	6,456,960
DEC	7,896,070
JAN	6,762,220
FEB	5,995,550
MAR	5,587,440
AP1	2,837,880
APR	2,992,680
MAY	7,707,100
JUN	9,266,400
JUL	8,585,020

Fish Spill. Fish spills for federal projects are as shown in Table K.2-2, and are based on the Corps of Engineers' PNCA Operating Year 2004 Data Submittal, which is based on the 2000 National Marine Fisheries Service Biological Opinion. The spill caps and percentages are developed based on meeting total dissolved gas standards and fish passage criteria.

TABLE K.2-2. PROJECT PERIOD AVERAGE SPILL CAP (CFS) AND PERCENT SPILL

Project	Apr 1-15	Apr 15-30	May	June	July	Aug 1-15	Aug 16-31
Wells	0%	6.5%	6.5%	0%	6.5%	2.5%	0%
Rocky Reach	0%	15%	21.8%	15%	15%	15%	0%
Rock Island	0%	20%	20%	20%	20%	20%	0%
Wanapum	0%	43%	43%	46%	49%	49%	49%
Priest Rapids	0%	61%	61%	50%	39%	39%	39%
L. Granite	16,467	19,000	19,000	12,667			
Little Goose	13,000	15,000	15,000	10,000			
L.Monumental	34,667	40,000	40,000	26,667			
Ice Harbor	62,833	72,500	72,500	72,500	72,500	72,500	72,500
McNary	34,000	85,000	85,000	85,000			
John Day	28,000	70,000	66,801	64,167	64,167	70,000	70,000
John Day %	12%	30%	29%	28%	28%	30%	30%
The Dalles	42,800	107,000	107,000	107,000	107,000	107,000	107,000
The Dalles%	40%	40%	40%	40%	40%	40%	40%
Bonneville	38,483	95,292	95,474	93,906	93,750	95,375	95,938

Note: 1) Spill caps and percentages are prorated for the number of spill days in the period.

2) The spill is as developed for the Feb 1 2004 PNCA Data Submittal. Federal project spill is based on instantaneous gas caps and maximum spill for day-time and night-time hours provided by the Corps' Reservoir Control Center, Northwestern Division. Day-time and night-time hours are from the Corps' Fish Passage Plan. Spill for non-federal projects is as submitted by project owners in the Feb 2004 Data Submittal

Canadian Treaty Projects Operation. The Canadian Columbia River Treaty projects, which include Mica, Duncan and Arrow, are on their 2008 Assured Operation Plan (AOP08). An AOP is agreed upon annually by the US and Canadian Entities under the requirements of the Columbia River Treaty, an agreement between the United States and Canadian governments to coordinate the operation of the Columbia River. This AOP operation includes a few changes agreed to by the U.S. and Canadian Entities for this study. These changes include Brilliant Dam expansion data, and a January maximum outflow of 80 kcfs at Arrow. The Canadian Treaty projects were modeled to target the operation resulting from the 52-year Treaty Storage Regulation and determined the flow across the United States and Canadian border. The flood control used to develop the Canadian operation includes Standard Flood Control for Libby and VARQ for Hungry Horse, as this was used in the AOP08.

Libby. For January through April, Libby was operated to target flood control elevations based on the system flood control curves from the Corps' HEB office. For May-August, Libby was modeled to target the simulated target elevations provided by NWS that are based on a regulation using fish flows with a maximum flow during the sturgeon pulse of powerhouse capacity for Standard Flood Control operations. For September through November, Libby operated for power to the operating rule curves as

needed to meet load. For the end of December, Libby operated to target flood control elevation 2411. Modeling includes following the International Joint Commission (IJC) rules for Kootenay Lake. At times the target elevations were not achieved because of minimum flow requirements or the operation of Kootenay Lake to meet the IJC rule curve may have controlled the operation.

Hungry Horse. Hungry Horse was modeled year around to target the simulated elevations from the fish flow regulations for standard flood control provided by Reclamation. The objectives for the targets are to meet Columbia Falls and Hungry Horse minimum flows for resident fish year around, allow draft to VDLs for January through March which provide draft limits for winter power operations, attempt to be full in June, and to target El. 3552.3, 3546.4, and 3540, in July, the first half of August, and the second half of August, respectively to help augment flows at McNary. The data source for the target elevations is "Varq_neap_analysis_alf3up1down_toACOE_021004.xls, Standard FC Simulation Data, Hungry Horse Pool Elevation," from Reclamation.

Albeni Falls. Albeni Falls was modeled to operate on a four-year winter cycle. Albeni Falls operated to target elevation 2051 in the winter of 1948-49, and every 4 years thereafter. The project targeted elevation 2055 during the winter in all other years. This was to address kokanee access to shoreline spawning gravels, with the lower-pool years provided to allow wave action to clean the gravels. Albeni Falls fills in April through June to elevation 2062.5 and drafts in September through November to the winter elevation.

Grand Coulee. Pumping data for Grand Coulee was modeled based on Reclamation's PNCA Operating Year 2004 Data Submittal. In January through March, the project operated for power to the draft limits of the higher of the VDLs and the resident fish limits of elevations 1260, 1250, and 1240 in January, February, and March, respectively. The VDLs were adjusted for upstream power drafts after the initial model run and incorporated into the final run. In December through May, Grand Coulee drafted as needed to meet the downstream flow requirement for salmon spawning and incubation at Vernita Bar in the mid-Columbia river. Grand Coulee is augmented for McNary and Priest Rapids salmon flows on April 15, April 30, May 31, June 30, July 31, August 15, and August 31 to draft limits of elevations 1280, 1280, 1280, 1288, 1285, 1280, and 1280/1278, respectively. The project drafted for power in September, October, November and December, with draft limits of elevation 1283, 1283, 1275, and 1270, respectively. Chum salmon spawning and incubation flow objectives of 125 kcfs at Bonneville were met by drafting Grand Coulee, but were subject to draft limits of elevation 1275, and 1270, in November and December, and VDLs in January through March.

McNary. McNary flow objectives for salmon are those recommended in the NMFS 2000 Biological Opinion. The flow objective for April 10th through June 30th varies between 220 kcfs and 260 kcfs. If the April runoff volume forecast at The Dalles Dam for April through August is less than 80 million acre-feet (Maf), the flow objective is 220 kcfs. If the volume forecast is greater than 92 Maf, the flow objective is 260 kcfs. If the forecasted volume is between 80 and 92 Maf, the flow objective is linearly interpolated between 220 kcfs and 260 kcfs. The flow objective for July and August is 200 kcfs.

Priest Rapids. Priest Rapids flow objectives to meet needs for steelhead are for the period April 10 through June 30. The flow objectives are 90 kcfs for the first half of April, and 135 kcfs for the second half of April, May and June. The Vernita Bar requirement is dependent on the October and November flows at Wanapum Dam and is between 50 kcfs and 70 kcfs in December through May.

Brownlee. Brownlee was operated to the fixed elevation operation used in the PNCA studies.

Dworshak. In January through June the project operated to target flood control. Dworshak attempts to meet Lower Granite flow objectives in July through August subject to a maximum flow of 14,000 cfs and a draft limit of El. 1520. In September through December, the project operated on minimum flow of 1300 cfs or flood control. Although the NMFS 2000 Biological Opinion discusses flow objectives at Lower Granite in the spring that would be met by drafting of Dworshak, the Biological Opinion places priority on June refill rather than meeting spring flow objectives. Therefore Dworshak was modeled to refill in June.

Lower Granite. Lower Granite flow objectives in July and August range from 50 kcfs to 55 kcfs and are based on the April through July volume forecast (determined in June) at Lower Granite. Flow objectives are based on recommendations contained in the NMFS Biological Opinion.

Lower Snake Projects Minimum Operating Pool (MOP). The Lower Snake River projects operated as run-of-river projects, and run to MOP in April-August, except for Lower Granite that runs to MOP in April-October. The projects run to full pool in all other periods.

K.2.3 Alternative Combination LV1+HV: VARQ Flood Control At Libby And Hungry Horse With Fish Flows, Including Sturgeon Flows At Libby Up To QPHC

Alternative Combination LV1+HV is similar to Alternative Combination LS1+HS, except the VARQ Flood Control operation is used as the upper rule curve for Libby and Hungry Horse. Hungry Horse was modeled to target simulated elevations for VARQ Flood Control with year-round fish flows. Libby was operated to target VARQ system flood control elevations in January through April and simulated VARQ Flood Control elevations in May through August based on a regulation using fish flows with a maximum flow during the sturgeon pulse of powerhouse capacity for VARQ Flood Control operations. Grand Coulee flood control curves and VDLs were adjusted for upstream power drafts determined for this combination.

Flood Control. The HEB, Reclamation, and Seattle District (NWS) provided the VARQ flood control curves.

Libby. For January through April, Libby was operated to target flood control elevations based on the system VARQ flood control curves from HEB. For May-August, Libby was modeled to target the simulated VARQ flood control elevations provided by NWS.

Hungry Horse. Hungry Horse was modeled to target simulated elevations for VARQ Flood Control with year-round fish flows.

K.2.4 Alternative Combination LS2+HS: Standard Flood Control At Libby And Hungry Horse With Fish Flows, Including Sturgeon Flows At Libby Up To QPHC + 10 Thousand Cubic Feet Per Second (Kcfs) (QPHC+10)

Alternative Combination LS2+HS is similar to Alternative Combination LS1+HS, except Libby's May through August target elevations were based on a regulation using fish flows with a maximum flow during the sturgeon pulse of powerhouse capacity plus 10 kcfs for Standard Flood Control operations. Grand Coulee flood control curves and Variable Draft Limits were adjusted for upstream power drafts determined for this combination.

K.2.5 Alternative Combination LV2+HV: VARQ Flood Control At Libby And Hungry Horse With Fish Flows, Including Sturgeon Flows At Libby Up To QPHC+10

Alternative Combination LV2+HV is similar to Alternative Combination LV1+HV, except Libby's May through August target elevations were based on a regulation using fish flows with a maximum flow during the sturgeon pulse of powerhouse capacity plus 10 kcfs for VARQ Flood Control operations. Grand Coulee flood control curves and VDLs were adjusted for upstream power drafts determined for this combination.

K.2.6 Benchmark Combination LS+HS: Standard Flood Control At Libby And Hungry Horse Without Libby Fish Flows

Benchmark Combination LS+HS is similar to Benchmark Combination LS1+HS except that Libby's May through August target elevations are based on a regulation for Standard Flood Control operations without fish flow operations. The HYSSR model simulation incorporated Grand Coulee flood control curves and VDLs adjusted for upstream power drafts determined for this combination.

K.2.7 Benchmark Combination LV+HV: VARQ Flood Control At Libby And Hungry Horse, Without Libby Fish Flows

Benchmark Combination LV+HV is similar to Benchmark Combination LV1+HV except that Libby's May through August target elevations are based on a regulation for VARQ Flood Control operations without fish flow operations. The model run incorporated Grand Coulee flood control curves and VDLs adjusted for upstream power drafts determined for this combination.

K.3 ANNUAL ENERGY BENEFITS IMPACTS

K.3.1 General

The impact on annual hydropower benefits of the alternative and benchmark combinations, and comparisons of alternative and benchmark combinations evaluated were determined for the Columbia River basin hydropower system, including Libby and Hungry Horse (System), for the Federal Columbia River Power System projects (Federal), for non-federal public and private projects (Non-Federal) downstream of Libby and Hungry Horse, and for the Libby and Hungry Horse projects individually.

K.3.2 Comparison of Alternative and Benchmark Combinations

Different alternative and benchmark combinations were compared to fully quantify hydropower benefits impacts of VARQ Flood Control and Libby fish flow operations on the Columbia River basin hydropower system. Listed below are the alternative combination comparisons evaluated in this report. See Sections 2.2 through K.2.7 for a detailed description of each combination.

These alternative combinations were compared to evaluate the full effect of VARQ Flood Control operations (alternative combinations LV1+HV, LV2+HV; benchmark combination LV+HV) versus Standard Flood Control operations (alternative combinations LS1+HS, LS2+HS; benchmark combination LS+HS), as well as to compare the effects of fish flows at Libby (alternative combinations LS1+HS, LV1+HV, LS2+HS, LV2+HV) to their non-fish-flow counterparts (benchmark combinations LS+HS, LV+HV). The following comparisons were evaluated in this report for energy benefits impacts:

Benchmark Combination LV+HV minus Benchmark Combination LS+HS

Alternative Combination LV1+HV minus Alternative Combination LS1+HS

Alternative Combination LV2+HV minus Alternative Combination LS2+HS

Alternative Combination LS1+HS minus Benchmark Combination LS+HS

Alternative Combination LS2+HS minus Benchmark Combination LS+HS

Alternative Combination LV1+HV minus Benchmark Combination LV+HV

Alternative Combination LV2+HV minus Benchmark Combination LV+HV

Hydropower benefits impacts were summarized using the above comparisons of alternative and benchmark combinations for three groupings of projects. The three groupings evaluated were the Columbia River basin hydropower system, and the Federal and non-Federal hydropower projects downstream of Libby and Hungry Horse.

Initially, 52 years of monthly system generation for each alternative and benchmark combination from the HYSSR model was converted from average megawatts (aMW) to megawatt-hours (MWh), the units normally used in the power industry to quantify energy. Each monthly system generation value in MWh was obtained by multiplying the number of hours in the month by the corresponding monthly system generation in aMW. Tables K.3-1 through K.3-6 summarize the converted 52-year average system generation for each alternative and benchmark combination. The system generation values shown in these tables are expressed in gigawatt-hours (GWh), which is equivalent to 1,000 MWh, due to their magnitude.

The monthly power values used in this study to determine the dollar value of the energy impacts were derived from hourly power prices data from the Pacific Northwest Mid-Columbia energy trading hub. These power values are traditionally grouped into two sub-periods: “on-peak” (referred to as Heavy Load Hours) and “off-peak” (referred to as Light Load Hours). To apply these power values, generation differences were distributed to these periods using factors for the Federal hydropower system that relate average monthly generation to on-peak and off-peak generation. The value of energy is generally higher in the on-peak period and lower in the off-peak period. The total combined energy for the two sub-periods is equal to the total monthly average energy. After the energy change for each sub-period is determined, the average monthly energy price for each sub-period is used to quantify the energy benefits differences in 2004 level dollars for each period of the year. This approach is explained in detail in Sections 3-3 through K.3-5.

TABLE K.3-1. 52-YEAR AVERAGE SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LS1+HS (GWH)

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	TOTAL	YEAR
47-48	4,454	3,483	6,041	11,009	10,395	10,994	16,627	10,362	10,184	4,873	6,214	17,186	19,539	13,938	145,298	47-48
48-49	5,723	5,571	6,613	7,735	8,752	9,075	12,916	9,123	13,173	5,112	6,902	16,169	11,991	8,569	127,425	48-49
49-50	3,801	3,489	4,768	6,305	8,803	9,807	15,114	12,229	14,320	6,507	6,126	14,278	18,132	14,402	138,081	49-50
50-51	5,727	5,418	6,675	9,467	11,263	14,211	18,120	15,548	11,449	7,270	6,964	17,185	12,169	13,572	155,039	50-51
51-52	5,640	4,591	6,712	10,560	9,168	10,914	15,875	10,927	10,080	7,227	6,698	18,029	13,688	10,565	140,675	51-52
52-53	4,370	3,651	5,126	6,363	7,991	8,589	9,489	15,113	9,562	3,320	5,355	12,987	16,287	13,403	121,607	52-53
53-54	5,169	4,605	6,155	7,671	8,773	10,496	15,026	12,667	10,529	5,692	5,565	15,334	16,755	15,271	139,707	53-54
54-55	6,615	6,399	9,490	7,904	9,547	10,416	11,369	8,032	6,655	4,315	3,489	11,286	18,168	16,825	130,511	54-55
55-56	5,619	5,103	6,081	8,688	10,508	13,902	18,473	10,889	14,101	6,841	8,790	19,085	18,079	14,118	160,278	55-56
56-57	5,186	4,587	6,263	8,469	8,761	10,889	14,526	9,161	10,197	6,816	5,330	16,931	17,567	9,238	133,921	56-57
57-58	3,829	3,491	5,094	7,165	8,490	8,768	13,835	11,427	10,074	4,895	6,691	15,977	15,599	9,179	124,514	57-58
58-59	3,846	3,529	5,672	7,800	9,336	12,018	18,378	12,685	9,922	6,250	5,183	13,538	16,316	15,159	139,631	58-59
59-60	5,500	4,579	9,684	11,987	11,771	12,467	15,842	9,705	11,687	8,182	6,027	11,603	13,396	12,175	144,607	59-60
60-61	5,146	3,785	5,908	7,197	9,045	9,442	14,818	11,275	11,702	6,041	5,129	13,902	18,132	11,678	133,200	60-61
61-62	4,343	4,032	5,271	7,409	8,513	8,614	14,687	8,569	7,394	7,519	6,916	12,484	12,238	10,930	118,919	61-62
62-63	4,788	4,179	5,292	7,932	9,670	12,063	14,353	11,181	9,301	4,442	4,386	12,389	13,123	11,597	124,696	62-63
63-64	4,739	4,320	6,313	7,130	8,946	8,890	14,500	8,495	7,811	5,611	4,747	11,803	18,099	15,137	126,539	63-64
64-65	5,608	4,551	6,965	8,777	9,393	14,073	18,751	14,080	13,099	4,601	7,298	15,949	15,916	11,622	150,683	64-65
65-66	5,684	5,295	6,426	8,388	8,624	9,637	15,306	7,605	8,494	6,897	5,217	10,956	11,797	12,629	122,956	65-66
66-67	5,000	3,928	5,651	6,753	8,631	10,069	16,158	13,207	8,900	4,540	3,738	12,118	18,168	15,291	132,150	66-67
67-68	5,571	4,335	6,355	8,411	8,983	9,972	15,506	11,212	12,098	3,391	4,359	11,027	13,414	12,523	127,158	67-68
68-69	5,028	4,846	8,203	9,467	10,727	11,047	18,016	11,935	11,767	6,998	6,907	17,639	14,674	11,935	149,189	68-69
69-70	4,671	3,610	6,103	7,872	8,744	8,837	13,597	10,023	9,486	3,829	4,560	12,794	15,371	9,974	119,471	69-70
70-71	3,862	3,569	5,494	7,021	8,891	9,651	17,821	15,390	12,851	6,704	6,552	18,980	17,245	14,453	148,485	70-71
71-72	6,027	5,574	6,945	7,897	8,824	9,892	17,006	14,120	18,152	7,822	5,453	18,418	18,766	16,515	161,413	71-72
72-73	6,527	6,232	7,622	8,403	8,667	10,249	13,515	7,218	7,927	2,933	3,073	10,018	9,406	8,660	110,448	72-73
73-74	3,818	3,506	4,797	6,331	8,592	12,399	20,330	15,199	15,106	7,402	7,707	18,298	18,916	17,503	159,903	73-74
74-75	6,148	6,213	6,654	7,280	8,637	8,897	15,116	10,257	11,243	4,168	4,881	13,132	16,206	16,115	134,948	74-75
75-76	4,763	4,909	6,719	9,379	10,791	15,638	18,113	12,363	11,218	7,317	6,356	17,560	13,136	15,139	153,402	75-76
76-77	6,778	7,223	10,979	7,862	8,490	8,427	8,173	6,272	6,146	2,910	2,969	7,460	8,882	7,022	99,593	76-77
77-78	3,822	3,459	4,835	6,352	6,389	9,539	15,742	10,744	11,379	6,257	5,293	13,573	11,915	11,516	120,815	77-78
78-79	4,770	4,400	9,164	8,325	8,605	8,462	11,539	7,836	11,411	3,230	4,813	14,735	9,365	8,621	115,275	78-79
79-80	3,823	3,503	4,780	6,343	6,873	9,498	12,662	7,834	7,720	4,174	7,032	16,523	11,384	9,967	112,116	79-80
80-81	4,112	3,787	6,108	7,263	9,040	13,378	16,297	10,274	9,456	3,281	4,726	15,456	14,516	14,149	131,843	80-81
81-82	5,695	5,892	6,013	7,813	8,793	10,685	13,406	15,347	15,878	6,255	6,057	16,139	15,623	16,275	149,872	81-82
82-83	5,669	5,210	8,083	9,078	8,725	11,104	17,433	11,455	16,096	5,589	6,002	14,669	11,520	13,905	144,537	82-83
83-84	5,630	4,953	6,552	7,697	11,400	10,838	16,675	10,245	12,660	5,795	7,352	14,736	14,707	13,623	142,862	83-84
84-85	5,338	4,048	6,636	7,944	9,221	9,522	14,982	7,602	9,072	4,647	6,398	13,547	9,243	8,600	116,799	84-85
85-86	3,811	3,501	4,782	7,108	9,294	9,124	15,930	11,419	16,976	5,589	6,441	13,472	11,892	10,070	129,412	85-86
86-87	4,420	3,526	5,674	7,564	8,850	9,258	11,138	7,210	10,045	4,136	4,637	12,709	9,403	8,646	107,215	86-87
87-88	3,813	3,502	4,830	6,394	6,634	7,962	6,834	5,428	5,859	3,760	5,348	11,013	10,324	8,722	90,424	87-88
88-89	3,813	3,502	4,829	6,395	8,515	8,829	13,546	6,855	9,499	6,508	6,799	13,036	9,366	9,076	110,569	88-89
89-90	3,903	3,944	5,353	6,394	9,899	11,603	16,394	9,856	10,659	4,804	6,722	12,748	12,941	13,801	129,022	89-90
90-91	5,148	4,362	5,185	6,843	11,521	11,310	16,032	12,727	10,240	5,086	5,757	14,084	12,064	15,524	135,883	90-91
91-92	5,812	5,606	5,728	6,305	8,191	8,845	10,641	9,215	7,552	3,476	3,383	10,168	9,406	8,583	102,911	91-92
92-93	3,771	3,146	4,796	6,332	6,313	7,777	7,900	6,070	7,853	4,167	3,722	15,313	10,932	11,157	99,248	92-93
93-94	4,749	4,498	4,782	6,370	6,857	8,823	9,121	6,761	6,981	3,705	5,637	11,929	9,273	8,645	98,129	93-94
94-95	3,939	3,502	4,830	6,395	6,634	8,581	13,439	11,075	11,179	5,114	4,715	13,389	12,606	11,612	117,009	94-95
95-96	5,282	4,315	5,884	8,600	12,439	18,258	18,132	17,554	14,406	7,259	8,222	15,907	14,020	15,816	166,095	95-96
96-97	5,567	5,226	6,099	7,561	8,997	11,185	19,595	15,135	15,391	6,846	7,897	18,527	18,423	16,335	162,783	96-97
97-98	5,710	5,471	8,453	11,472	10,241	10,772	13,134	9,280	10,849	4,564	5,286	17,512	13,722	11,068	137,534	97-98
98-99	4,813	3,702	5,518	6,321	8,573	11,081	16,974	11,775	14,857	5,767	6,817	14,165	15,342	15,545	141,251	98-99
AVE	4,950	4,455	6,250	7,798	9,033	10,515	14,787	10,730	10,974	5,393	5,743	14,382	14,022	12,431	131,463	AVE

TABLE K.3-2. 52-YEAR AVERAGE SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LV1+HV (GWH)

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	TOTAL	YEAR
47-48	4,454	3,483	6,041	11,009	10,395	10,994	16,261	9,389	10,189	4,945	6,296	17,681	19,560	14,007	144,704	47-48
48-49	5,729	5,601	6,608	7,735	8,752	9,075	11,964	9,083	12,584	5,345	6,755	16,602	12,296	8,860	126,990	48-49
49-50	3,880	3,489	4,767	6,305	8,878	10,134	14,632	12,192	14,107	6,597	6,075	14,545	18,302	14,448	138,352	49-50
50-51	5,737	5,470	6,697	9,467	11,263	14,225	18,244	15,194	11,400	7,318	6,909	17,267	12,213	13,526	154,930	50-51
51-52	5,642	4,598	6,706	10,560	9,168	10,914	15,960	10,147	9,825	7,225	6,659	18,235	13,945	10,641	140,225	51-52
52-53	4,400	3,677	5,316	6,364	8,487	8,572	9,302	14,469	9,475	3,401	5,114	13,242	16,345	13,597	121,761	52-53
53-54	5,454	4,803	6,144	7,671	8,773	10,496	14,188	12,687	10,758	5,867	5,508	15,459	16,908	15,299	140,015	53-54
54-55	6,674	6,424	9,495	7,904	9,547	10,416	9,958	7,156	6,687	4,902	3,723	10,897	18,527	17,298	129,609	54-55
55-56	5,679	5,499	6,081	8,688	10,508	13,902	18,515	10,507	14,300	6,849	8,801	19,079	18,181	14,072	160,663	55-56
56-57	5,166	4,532	6,268	8,469	8,761	10,889	13,466	8,468	10,188	6,786	5,132	17,346	17,889	9,664	133,023	56-57
57-58	4,078	3,491	5,372	7,260	8,490	8,768	12,978	10,931	10,370	4,878	6,586	16,242	15,723	9,563	124,730	57-58
58-59	4,064	3,729	5,689	7,800	9,336	12,018	18,178	12,240	9,813	6,252	5,241	14,033	16,533	15,087	140,011	58-59
59-60	5,595	4,619	9,673	11,987	11,771	12,765	14,783	9,258	11,749	8,162	6,019	12,178	13,682	12,235	144,476	59-60
60-61	5,191	3,835	6,111	7,197	9,045	9,442	14,082	10,631	11,595	5,948	4,910	14,373	18,523	11,934	132,817	60-61
61-62	4,419	4,068	5,293	7,409	8,590	8,611	13,297	8,411	7,407	7,490	6,825	12,894	12,358	11,254	118,325	61-62
62-63	4,965	4,355	5,481	8,098	9,726	12,063	13,092	11,020	9,281	4,391	4,246	12,629	13,627	11,832	124,808	62-63
63-64	5,224	4,436	6,313	7,130	8,946	8,890	13,730	8,209	7,817	5,573	4,450	12,085	18,148	15,557	126,507	63-64
64-65	5,690	5,108	6,959	8,777	9,393	14,073	18,708	13,492	13,387	4,736	7,306	16,161	16,021	11,443	151,254	64-65
65-66	5,688	5,290	6,448	8,621	8,624	9,637	14,466	7,459	8,524	6,830	5,149	11,199	12,100	12,867	122,902	65-66
66-67	5,112	4,024	5,651	6,753	8,631	10,069	15,781	13,240	9,325	4,775	3,646	12,084	18,197	15,208	132,493	66-67
67-68	5,543	4,311	6,366	8,411	8,983	9,972	14,637	10,572	11,811	3,573	4,176	11,202	13,671	12,941	126,168	67-68
68-69	5,440	5,183	8,208	9,467	10,727	11,226	17,750	11,517	11,817	6,907	6,980	17,863	14,751	12,146	149,983	68-69
69-70	4,745	3,654	6,114	7,872	8,744	8,839	13,384	9,974	9,490	3,672	4,322	13,087	15,343	10,065	119,305	69-70
70-71	3,948	3,642	5,489	7,021	8,891	9,651	16,901	15,428	12,891	6,832	6,589	19,235	17,405	14,500	148,425	70-71
71-72	6,132	5,687	6,924	7,897	8,824	9,892	16,563	14,226	18,289	7,798	5,338	18,741	18,847	16,288	161,446	71-72
72-73	6,454	6,208	7,471	8,403	8,667	10,249	12,487	6,934	7,759	2,933	3,073	10,227	9,406	8,793	109,063	72-73
73-74	3,829	3,506	4,796	6,332	9,392	12,781	20,330	15,074	15,279	7,438	7,739	18,296	18,938	17,494	161,223	73-74
74-75	6,119	6,188	6,646	7,280	8,637	8,897	14,256	9,677	11,387	4,181	4,684	13,559	16,485	16,256	134,253	74-75
75-76	4,858	5,008	7,045	9,508	10,791	15,664	17,930	11,262	11,382	7,436	6,442	17,771	13,216	15,338	153,650	75-76
76-77	6,902	7,329	11,078	7,862	8,490	8,430	8,003	6,273	6,147	2,910	2,969	7,501	8,914	7,043	99,852	76-77
77-78	3,842	3,491	4,835	6,352	7,484	8,285	15,046	9,919	11,398	6,429	5,192	13,531	12,147	12,370	120,320	77-78
78-79	5,035	4,633	9,179	8,325	8,605	8,462	10,660	7,777	11,131	3,181	4,853	15,139	9,365	8,620	114,964	78-79
79-80	3,824	3,503	4,779	6,344	8,191	9,049	11,574	7,877	7,733	4,188	6,813	17,164	11,676	9,897	112,613	79-80
80-81	4,138	3,810	6,098	7,263	9,040	13,378	15,419	10,054	9,755	3,264	4,498	15,863	14,627	14,216	131,423	80-81
81-82	5,706	6,030	6,209	7,813	8,793	10,685	12,461	14,916	15,627	6,416	6,004	16,560	16,025	16,512	149,755	81-82
82-83	5,709	5,472	8,067	9,078	8,725	11,104	16,599	10,711	16,108	5,561	5,755	15,017	12,100	14,322	144,329	82-83
83-84	5,681	5,305	6,772	7,706	11,400	10,838	15,596	9,975	12,739	5,911	7,130	14,881	15,054	13,931	142,919	83-84
84-85	5,564	4,252	6,630	7,944	9,221	9,522	14,098	7,518	8,955	4,828	6,286	13,593	9,290	8,599	116,300	84-85
85-86	3,811	3,501	4,782	7,661	9,770	9,400	14,256	11,351	16,873	5,677	6,214	13,347	12,451	10,841	129,933	85-86
86-87	4,681	3,724	5,652	7,564	8,850	9,258	10,117	6,982	10,011	4,141	4,509	13,194	9,403	8,646	106,733	86-87
87-88	3,813	3,502	4,830	6,394	6,635	7,962	6,834	6,032	5,980	3,783	5,352	11,422	10,305	8,645	91,490	87-88
88-89	3,813	3,502	4,830	6,394	8,496	8,802	12,340	6,401	9,653	6,215	6,742	13,693	9,396	9,438	109,715	88-89
89-90	4,099	4,134	5,414	6,503	9,928	11,790	15,510	9,871	10,633	4,788	6,765	13,138	13,069	13,972	129,614	89-90
90-91	5,239	4,442	5,175	6,843	11,521	11,314	16,165	12,724	10,232	5,036	5,703	14,080	12,100	15,489	136,063	90-91
91-92	5,797	5,573	5,733	6,305	8,191	9,013	9,534	8,749	7,562	3,475	3,275	10,726	9,405	8,661	102,000	91-92
92-93	3,818	3,506	4,795	6,332	6,313	7,777	8,044	6,070	7,885	4,175	3,721	15,359	11,145	11,249	100,190	92-93
93-94	4,724	4,487	4,782	6,371	6,863	8,822	8,877	6,762	6,982	3,663	5,385	12,260	9,476	8,645	98,100	93-94
94-95	3,911	3,502	4,829	6,394	6,629	8,973	12,607	11,027	10,882	5,620	4,419	13,661	12,309	11,830	116,592	94-95
95-96	5,291	4,333	5,890	8,600	12,439	18,390	18,165	17,607	14,182	7,488	8,069	15,757	14,096	15,766	166,074	95-96
96-97	5,559	5,182	6,104	7,561	8,997	11,185	19,354	15,012	15,387	6,958	7,852	18,606	18,456	16,498	162,711	96-97
97-98	5,813	5,732	8,469	11,472	10,241	10,772	13,001	9,234	10,263	5,208	5,797	17,789	12,578	10,888	137,256	97-98
98-99	4,809	3,721	5,512	6,321	8,573	11,081	16,250	11,178	14,868	5,768	6,868	14,504	15,697	15,749	140,900	98-99
AVE	5,029	4,550	6,281	7,823	9,118	10,527	14,160	10,440	10,959	5,456	5,670	14,635	14,158	12,578	131,384	AVE

TABLE K.3-3. 52-YEAR AVERAGE SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LS2+HS (GWH)

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	TOTAL	YEAR
47-48	4,454	3,483	6,041	11,009	10,395	10,994	16,627	10,362	10,184	4,873	6,214	17,186	19,554	13,922	145,297	47-48
48-49	5,716	5,507	6,624	7,735	8,752	9,075	12,916	9,123	13,173	5,112	6,902	16,270	11,895	8,569	127,369	48-49
49-50	3,801	3,489	4,768	6,306	8,798	9,788	15,114	12,229	14,320	6,507	6,126	14,278	18,145	14,409	138,076	49-50
50-51	5,723	5,373	6,686	9,467	11,263	14,211	18,120	15,548	11,449	7,270	6,964	17,185	12,259	13,586	155,104	50-51
51-52	5,630	4,467	6,706	10,560	9,168	10,914	15,875	10,927	10,080	7,228	6,698	18,029	13,714	10,575	140,571	51-52
52-53	4,374	3,651	5,126	6,365	7,989	8,540	9,489	15,113	9,562	3,320	5,355	13,050	16,292	13,358	121,585	52-53
53-54	5,152	4,595	6,161	7,671	8,773	10,496	15,026	12,667	10,529	5,692	5,565	15,334	16,790	15,303	139,752	53-54
54-55	6,559	6,362	9,453	7,904	9,547	10,416	11,369	8,032	6,655	4,315	3,489	11,391	18,148	16,753	130,394	54-55
55-56	5,618	5,083	6,076	8,688	10,508	13,902	18,473	10,889	14,101	6,841	8,790	19,085	18,117	14,100	160,270	55-56
56-57	5,161	4,562	6,268	8,469	8,761	10,889	14,526	9,161	10,197	6,816	5,330	16,988	17,564	9,202	133,894	56-57
57-58	3,834	3,491	5,091	7,115	8,490	8,768	13,835	11,427	10,074	4,895	6,691	16,043	15,593	9,123	124,469	57-58
58-59	3,836	3,519	5,672	7,800	9,336	12,018	18,378	12,685	9,922	6,250	5,183	13,538	16,376	15,136	139,648	58-59
59-60	5,476	4,553	9,673	11,987	11,771	12,467	15,842	9,705	11,687	8,182	6,027	11,603	13,439	12,199	144,613	59-60
60-61	5,146	3,784	5,876	7,138	9,045	9,442	14,818	11,275	11,702	6,041	5,129	13,902	18,169	11,658	133,125	60-61
61-62	4,311	4,002	5,288	7,409	8,513	8,614	14,687	8,569	7,394	7,519	6,916	12,547	12,254	10,896	118,920	61-62
62-63	4,791	4,179	5,291	7,932	9,597	12,063	14,353	11,181	9,301	4,442	4,386	12,519	13,110	11,557	124,702	62-63
63-64	4,646	4,310	6,313	7,130	8,946	8,890	14,500	8,495	7,811	5,611	4,747	11,865	18,076	15,097	126,435	63-64
64-65	5,613	4,560	6,949	8,777	9,393	14,073	18,751	14,080	13,099	4,601	7,298	15,949	15,959	11,641	150,743	64-65
65-66	5,684	5,290	6,425	8,327	8,618	9,618	15,306	7,605	8,494	6,897	5,217	10,956	11,850	12,612	122,899	65-66
66-67	4,976	3,899	5,661	6,753	8,631	10,069	16,158	13,207	8,900	4,540	3,738	12,118	18,207	15,249	132,104	66-67
67-68	5,548	4,311	6,371	8,411	8,983	9,972	15,506	11,212	12,098	3,391	4,359	11,157	13,407	12,412	127,139	67-68
68-69	5,018	4,826	8,198	9,467	10,727	11,047	18,016	11,935	11,767	6,998	6,907	17,639	14,746	11,916	149,207	68-69
69-70	4,635	3,575	6,103	7,872	8,744	8,837	13,597	10,023	9,486	3,829	4,560	12,870	15,361	9,912	119,405	69-70
70-71	3,862	3,564	5,483	7,021	8,891	9,651	17,821	15,390	12,851	6,704	6,552	18,980	17,315	14,423	148,507	70-71
71-72	6,011	5,526	6,945	7,897	8,824	9,892	17,006	14,120	18,152	7,822	5,453	18,418	18,825	16,519	161,411	71-72
72-73	6,452	6,218	7,531	8,403	8,667	10,249	13,515	7,218	7,927	2,933	3,073	10,123	9,406	8,660	110,374	72-73
73-74	3,818	3,506	4,796	6,331	8,520	12,368	20,330	15,197	15,104	7,401	7,706	18,273	18,932	17,557	159,839	73-74
74-75	6,120	6,164	6,619	7,280	8,637	8,897	15,116	10,257	11,243	4,168	4,881	13,132	16,238	16,122	134,875	74-75
75-76	4,758	4,910	6,718	9,324	10,791	15,638	18,113	12,363	11,218	7,317	6,356	17,560	13,193	15,143	153,404	75-76
76-77	6,746	7,195	10,971	7,862	8,490	8,427	8,173	6,272	6,146	2,910	2,969	7,460	8,882	7,026	99,530	76-77
77-78	3,828	3,463	4,835	6,352	6,388	9,536	15,734	10,744	11,379	6,257	5,293	13,641	11,922	11,452	120,823	77-78
78-79	4,751	4,386	9,169	8,325	8,605	8,462	11,539	7,836	11,411	3,230	4,813	14,829	9,365	8,621	115,341	78-79
79-80	3,823	3,503	4,781	6,343	6,813	9,435	12,662	7,834	7,720	4,174	7,032	16,581	11,370	9,913	111,985	79-80
80-81	4,107	3,782	6,108	7,263	9,040	13,378	16,297	10,274	9,456	3,281	4,726	15,556	14,490	14,044	131,802	80-81
81-82	5,693	5,892	6,000	7,813	8,793	10,685	13,406	15,347	15,878	6,255	6,057	16,139	15,654	16,262	149,875	81-82
82-83	5,665	5,186	8,088	9,078	8,725	11,104	17,433	11,455	16,096	5,589	6,002	14,669	11,552	13,925	144,566	82-83
83-84	5,630	4,953	6,551	7,627	11,400	10,838	16,675	10,245	12,660	5,795	7,352	14,802	14,699	13,564	142,790	83-84
84-85	5,333	4,038	6,646	7,944	9,221	9,522	14,982	7,602	9,072	4,647	6,398	13,638	9,244	8,600	116,885	84-85
85-86	3,811	3,501	4,782	7,081	9,217	9,105	15,930	11,419	16,976	5,589	6,441	13,606	11,873	9,947	129,277	85-86
86-87	4,415	3,521	5,663	7,564	8,850	9,258	11,138	7,210	10,045	4,136	4,637	12,795	9,403	8,645	107,279	86-87
87-88	3,813	3,502	4,830	6,394	6,634	7,962	6,834	5,391	5,824	3,760	5,348	10,990	10,310	8,700	90,294	87-88
88-89	3,813	3,502	4,830	6,395	8,520	8,833	13,561	6,855	9,499	6,508	6,799	13,103	9,366	9,041	110,625	88-89
89-90	3,903	3,944	5,299	6,397	9,899	11,603	16,394	9,856	10,659	4,804	6,722	12,748	12,989	13,786	129,003	89-90
90-91	5,126	4,342	5,185	6,843	11,521	11,310	16,032	12,727	10,240	5,086	5,757	14,084	12,149	15,540	135,942	90-91
91-92	5,765	5,517	5,738	6,305	8,191	8,845	10,641	9,215	7,552	3,476	3,383	10,245	9,405	8,559	102,838	91-92
92-93	3,757	3,145	4,796	6,332	6,312	7,776	7,883	6,070	7,845	4,165	3,722	15,309	10,932	11,146	99,191	92-93
93-94	4,749	4,507	4,782	6,370	6,850	8,819	9,121	6,761	6,981	3,705	5,637	11,993	9,273	8,645	98,191	93-94
94-95	3,919	3,502	4,829	6,395	6,634	8,552	13,439	11,075	11,179	5,114	4,715	13,495	12,640	11,560	117,048	94-95
95-96	5,215	4,282	5,857	8,600	12,439	18,258	18,132	17,554	14,406	7,259	8,222	15,907	14,110	15,834	166,076	95-96
96-97	5,553	5,112	6,093	7,561	8,997	11,185	19,595	15,135	15,391	6,846	7,897	18,527	18,456	16,338	162,686	96-97
97-98	5,668	5,449	8,459	11,472	10,241	10,772	13,134	9,280	10,849	4,564	5,286	17,553	13,671	11,068	137,465	97-98
98-99	4,813	3,702	5,518	6,321	8,573	11,081	16,974	11,775	14,857	5,767	6,817	14,165	15,393	15,545	141,303	98-99
AVE	4,935	4,436	6,245	7,792	9,027	10,510	14,786	10,729	10,973	5,393	5,743	14,420	14,040	12,411	131,441	AVE

TABLE K.3-4. 52-YEAR AVERAGE SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LV2+HV (GWH)

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	TOTAL	YEAR
47-48	4,454	3,483	6,041	11,009	10,395	10,994	16,261	9,389	10,189	4,945	6,296	17,681	19,576	14,042	144,755	47-48
48-49	5,729	5,594	6,476	7,735	8,752	9,075	11,964	9,083	12,584	5,345	6,755	16,663	12,236	8,860	126,851	48-49
49-50	3,880	3,489	4,767	6,305	8,875	10,117	14,632	12,192	14,107	6,597	6,075	14,545	18,313	14,429	138,322	49-50
50-51	5,737	5,469	6,692	9,467	11,263	14,225	18,244	15,194	11,400	7,318	6,909	17,267	12,306	13,533	155,023	50-51
51-52	5,627	4,472	6,706	10,560	9,168	10,914	15,960	10,147	9,825	7,232	6,659	18,235	13,977	10,633	140,115	51-52
52-53	4,386	3,668	5,311	6,364	8,487	8,572	9,302	14,469	9,475	3,401	5,114	13,330	16,348	13,516	121,744	52-53
53-54	5,449	4,796	6,129	7,671	8,773	10,496	14,188	12,687	10,758	5,867	5,508	15,457	16,943	15,320	140,042	53-54
54-55	6,619	6,402	9,477	7,904	9,547	10,416	9,958	7,156	6,687	4,902	3,723	11,013	18,498	17,241	129,544	54-55
55-56	5,679	5,494	6,081	8,688	10,508	13,902	18,515	10,507	14,300	6,849	8,801	19,079	18,218	14,055	160,677	55-56
56-57	5,136	4,531	6,257	8,469	8,761	10,889	13,466	8,468	10,188	6,786	5,132	17,413	17,871	9,599	132,967	56-57
57-58	4,063	3,491	5,367	7,260	8,490	8,768	12,978	10,931	10,370	4,878	6,586	16,317	15,711	9,496	124,705	57-58
58-59	4,053	3,719	5,689	7,800	9,336	12,018	18,178	12,240	9,813	6,252	5,241	14,033	16,590	15,085	140,046	58-59
59-60	5,532	4,603	9,668	11,987	11,771	12,765	14,783	9,258	11,749	8,162	6,019	12,178	13,721	12,229	144,425	59-60
60-61	5,178	3,815	6,101	7,197	9,045	9,442	14,082	10,631	11,595	5,948	4,910	14,373	18,523	11,938	132,777	60-61
61-62	4,424	4,072	5,277	7,409	8,513	8,881	13,119	8,411	7,407	7,490	6,825	12,997	12,339	11,188	118,351	61-62
62-63	4,955	4,339	5,471	8,098	9,726	12,063	13,092	11,020	9,281	4,391	4,246	12,756	13,594	11,799	124,832	62-63
63-64	5,099	4,500	6,286	7,130	8,946	8,890	13,730	8,209	7,817	5,573	4,450	12,167	18,135	15,492	126,424	63-64
64-65	5,693	5,097	6,949	8,777	9,393	14,073	18,708	13,492	13,387	4,736	7,306	16,161	16,058	11,462	151,292	64-65
65-66	5,686	5,295	6,426	8,557	8,624	9,637	14,466	7,459	8,524	6,830	5,149	11,199	12,174	12,832	122,859	65-66
66-67	5,073	3,999	5,666	6,753	8,631	10,069	15,781	13,240	9,325	4,775	3,646	12,084	18,231	15,166	132,438	66-67
67-68	5,524	4,291	6,366	8,411	8,983	9,972	14,637	10,572	11,811	3,573	4,176	11,331	13,656	12,857	126,160	67-68
68-69	5,446	5,171	8,198	9,467	10,727	11,226	17,724	11,517	11,817	6,907	6,980	17,863	14,841	12,112	149,996	68-69
69-70	4,697	3,625	6,114	7,872	8,744	8,839	13,384	9,974	9,490	3,672	4,322	13,149	15,338	10,008	119,229	69-70
70-71	3,938	3,638	5,494	7,021	8,891	9,651	16,901	15,428	12,891	6,832	6,589	19,235	17,483	14,490	148,483	70-71
71-72	6,065	5,630	6,940	7,897	8,824	9,892	16,563	14,226	18,289	7,798	5,338	18,741	18,892	16,291	161,388	71-72
72-73	6,400	6,190	7,402	8,403	8,667	10,249	12,487	6,934	7,759	2,933	3,073	10,298	9,406	8,785	108,985	72-73
73-74	3,818	3,506	4,796	6,332	9,349	12,760	20,332	15,074	15,278	7,438	7,739	18,296	18,947	17,545	161,209	73-74
74-75	6,107	6,135	6,623	7,280	8,637	8,897	14,256	9,677	11,387	4,181	4,684	13,559	16,507	16,247	134,177	74-75
75-76	4,844	4,999	7,051	9,508	10,791	15,664	17,930	11,262	11,382	7,436	6,442	17,771	13,284	15,331	153,694	75-76
76-77	6,872	7,306	11,062	7,862	8,490	8,430	8,003	6,273	6,149	2,910	2,972	7,499	8,915	7,043	99,787	76-77
77-78	3,842	3,491	4,835	6,352	7,485	8,284	15,046	9,919	11,398	6,429	5,192	13,630	12,000	12,274	120,176	77-78
78-79	5,150	4,678	9,169	8,325	8,605	8,462	10,660	7,777	11,131	3,181	4,853	15,199	9,365	8,621	115,175	78-79
79-80	3,824	3,503	4,780	6,343	7,140	9,452	12,182	7,877	7,733	4,188	6,813	17,240	11,624	9,864	112,562	79-80
80-81	4,117	3,792	6,114	7,263	9,040	13,378	15,419	10,054	9,755	3,264	4,498	15,954	14,571	14,149	131,370	80-81
81-82	5,707	6,042	6,226	7,813	8,793	10,685	12,461	14,918	15,627	6,416	6,004	16,560	16,063	16,495	149,810	81-82
82-83	5,704	5,437	8,078	9,078	8,725	11,104	16,599	10,711	16,108	5,561	5,755	15,017	12,167	14,312	144,356	82-83
83-84	5,676	5,263	6,751	7,706	11,400	10,838	15,596	9,975	12,739	5,911	7,130	14,881	15,054	13,966	142,885	83-84
84-85	5,539	4,232	6,636	7,944	9,221	9,522	14,098	7,520	8,953	4,828	6,286	13,659	9,287	8,599	116,324	84-85
85-86	3,811	3,501	4,782	7,600	9,745	9,400	14,256	11,351	16,873	5,677	6,214	13,475	12,421	10,749	129,854	85-86
86-87	4,680	3,736	5,608	7,564	8,850	9,258	10,117	6,983	10,010	4,141	4,509	13,260	9,403	8,645	106,764	86-87
87-88	3,813	3,502	4,829	6,395	6,635	7,962	6,833	6,004	5,957	3,789	5,514	11,382	10,305	8,645	91,567	87-88
88-89	3,813	3,502	4,830	6,395	8,496	8,808	12,334	6,401	9,653	6,215	6,742	13,778	9,404	9,358	109,729	88-89
89-90	4,098	4,128	5,382	6,503	9,928	11,790	15,510	9,871	10,633	4,788	6,765	13,138	13,123	13,949	129,608	89-90
90-91	5,205	4,422	5,185	6,843	11,521	11,314	16,165	12,724	10,232	5,036	5,703	14,080	12,179	15,502	136,111	90-91
91-92	5,761	5,495	5,733	6,305	8,191	9,013	9,534	8,749	7,562	3,475	3,275	10,766	9,405	8,661	101,926	91-92
92-93	3,818	3,506	4,795	6,332	6,313	7,777	8,023	6,070	7,874	4,172	3,721	15,354	11,133	11,249	100,139	92-93
93-94	4,724	4,487	4,782	6,370	6,862	8,823	8,877	6,762	6,982	3,663	5,385	12,321	9,410	8,646	98,094	93-94
94-95	3,918	3,502	4,829	6,394	6,626	8,560	13,017	11,027	10,882	5,620	4,419	13,731	12,300	11,769	116,594	94-95
95-96	5,288	4,330	5,884	8,600	12,439	18,390	18,165	17,607	14,182	7,488	8,069	15,757	14,193	15,753	166,146	95-96
96-97	5,548	5,077	6,093	7,561	8,997	11,185	19,354	15,012	15,387	6,958	7,852	18,606	18,507	16,531	162,668	96-97
97-98	5,782	5,672	8,427	11,472	10,241	10,772	13,001	9,234	10,263	5,208	5,797	17,833	12,555	10,872	137,128	97-98
98-99	4,788	3,708	5,523	6,321	8,573	11,081	16,250	11,178	14,868	5,768	6,868	14,504	15,752	15,759	140,941	98-99
AVE	5,015	4,535	6,272	7,821	9,095	10,532	14,175	10,439	10,958	5,456	5,674	14,670	14,170	12,558	131,370	AVE

TABLE K.3-5. 52-YEAR AVERAGE SYSTEM GENERATION FOR BENCHMARK COMBINATION LS+HS (GWH)

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	TOTAL	YEAR
47-48	4,460	3,483	7,190	11,009	10,395	10,994	16,627	10,362	10,184	4,873	6,214	17,186	19,494	13,739	146,210	47-48
48-49	5,666	5,048	7,752	7,735	8,752	9,075	12,916	9,123	13,173	5,112	6,902	15,838	11,341	8,569	127,003	48-49
49-50	3,800	3,489	5,230	6,384	8,937	10,380	15,107	12,228	14,320	6,511	6,125	14,278	17,771	14,136	138,696	49-50
50-51	5,727	5,483	7,829	9,467	11,263	14,211	18,120	15,548	11,449	7,270	6,964	17,185	11,644	13,479	155,639	50-51
51-52	5,613	4,383	7,846	10,560	9,168	10,914	15,875	10,927	10,080	7,228	6,698	18,029	13,056	9,777	140,154	51-52
52-53	4,398	3,646	6,480	6,364	8,133	8,762	9,489	15,113	9,562	3,320	5,355	12,777	15,804	13,460	122,665	52-53
53-54	5,197	4,388	7,297	7,671	8,773	10,496	15,026	12,667	10,529	5,692	5,565	15,334	16,425	15,076	140,134	53-54
54-55	6,673	6,232	10,382	7,913	9,547	10,416	11,369	8,032	6,655	4,315	3,489	11,121	17,913	16,876	130,935	54-55
55-56	5,570	4,781	7,212	8,688	10,508	13,902	18,473	10,889	14,101	6,841	8,790	19,085	17,742	13,998	160,580	55-56
56-57	5,102	4,289	7,409	8,469	8,761	10,889	14,526	9,161	10,197	6,816	5,330	16,751	16,843	9,362	133,904	56-57
57-58	3,833	3,491	6,332	7,165	8,490	8,768	13,835	11,427	10,074	4,895	6,691	15,781	14,809	9,408	124,998	57-58
58-59	3,829	3,503	6,779	7,799	9,335	12,018	18,378	12,685	9,922	6,250	5,183	13,533	15,963	15,044	140,221	58-59
59-60	5,411	4,323	10,374	12,386	11,771	12,467	15,842	9,705	11,687	8,182	6,027	11,603	12,661	11,795	144,236	59-60
60-61	5,247	3,741	7,249	7,197	9,045	9,442	14,818	11,275	11,702	6,041	5,129	13,902	18,017	11,470	134,275	60-61
61-62	4,077	3,716	6,433	7,409	8,513	8,614	14,687	8,569	7,394	7,519	6,916	12,290	11,598	10,422	118,158	61-62
62-63	4,893	4,177	6,628	8,098	9,726	12,063	14,353	11,181	9,301	4,442	4,386	11,977	12,684	11,720	125,630	62-63
63-64	4,807	4,081	7,449	7,130	8,946	8,890	14,500	8,495	7,811	5,611	4,747	11,610	17,629	15,194	126,899	63-64
64-65	5,608	4,457	8,087	8,777	9,393	14,073	18,751	14,080	13,099	4,601	7,298	15,945	15,281	11,173	150,625	64-65
65-66	5,572	5,176	7,901	8,621	8,624	9,637	15,306	7,605	8,494	6,897	5,217	10,956	11,111	12,597	123,714	65-66
66-67	4,973	3,787	6,800	6,753	8,631	10,069	16,158	13,207	8,900	4,540	3,738	12,109	17,752	15,239	132,655	66-67
67-68	5,570	4,128	7,498	8,411	8,983	9,972	15,506	11,212	12,098	3,391	4,359	10,679	12,920	12,626	127,354	67-68
68-69	5,011	4,756	9,322	9,467	10,727	11,047	18,016	11,935	11,767	6,998	6,907	17,628	14,230	12,013	149,825	68-69
69-70	4,433	3,497	7,049	7,872	8,744	8,837	13,597	10,023	9,486	3,829	4,560	12,361	15,038	10,086	119,413	69-70
70-71	3,806	3,500	6,519	7,021	8,889	9,650	17,821	15,390	12,851	6,704	6,552	18,980	16,791	14,294	148,769	70-71
71-72	6,101	5,289	8,077	7,897	8,824	9,892	17,006	14,120	18,152	7,822	5,453	18,410	18,724	16,304	162,071	71-72
72-73	6,402	6,048	8,446	8,403	8,667	10,249	13,515	7,218	7,927	2,933	3,073	9,576	9,352	8,661	110,467	72-73
73-74	3,819	3,506	4,796	6,424	8,686	12,909	20,323	15,183	15,092	7,399	7,693	18,221	18,812	17,406	160,268	73-74
74-75	6,042	5,734	7,757	7,280	8,637	8,897	15,116	10,257	11,243	4,168	4,881	13,132	15,569	15,494	134,208	74-75
75-76	4,766	4,992	8,191	9,508	10,791	15,638	18,113	12,363	11,218	7,317	6,356	17,527	12,319	14,649	153,750	75-76
76-77	6,977	7,424	12,155	7,876	8,490	8,427	8,173	6,272	6,146	2,910	2,969	7,460	8,882	6,636	100,797	76-77
77-78	3,604	3,248	4,834	6,352	6,389	9,999	16,042	10,750	11,384	6,257	5,293	13,442	11,486	11,254	120,334	77-78
78-79	4,758	4,354	10,284	8,325	8,605	8,462	11,539	7,836	11,411	3,230	4,813	14,362	9,365	8,621	115,964	78-79
79-80	3,824	3,503	5,545	6,344	6,579	9,542	12,642	7,835	7,726	4,174	7,033	16,543	11,191	9,683	112,165	79-80
80-81	3,869	3,537	7,249	7,263	9,040	13,378	16,297	10,274	9,456	3,281	4,726	15,094	14,275	14,372	132,111	80-81
81-82	5,642	5,448	7,113	7,813	8,793	10,685	13,406	15,348	15,878	6,255	6,057	16,139	14,952	16,078	149,606	81-82
82-83	5,691	5,247	9,194	9,078	8,725	11,104	17,433	11,455	16,096	5,589	6,002	14,669	10,794	13,440	144,515	82-83
83-84	5,670	5,071	7,892	7,706	11,400	10,838	16,675	10,245	12,660	5,795	7,352	14,194	14,426	13,673	143,596	83-84
84-85	5,340	3,933	7,773	7,944	9,221	9,522	14,982	7,602	9,072	4,647	6,398	13,193	9,243	8,600	117,469	84-85
85-86	3,811	3,501	5,637	7,480	8,878	8,977	15,925	11,390	16,863	5,588	6,441	13,051	11,618	10,064	129,223	85-86
86-87	4,366	3,488	6,675	7,562	8,850	9,258	11,138	7,210	10,045	4,136	4,637	12,286	9,403	8,646	107,700	86-87
87-88	3,813	3,502	4,829	6,395	6,635	7,962	6,834	5,807	5,953	3,763	5,348	11,094	10,353	8,645	90,932	87-88
88-89	3,813	3,502	4,931	6,395	8,297	8,882	13,756	6,855	9,499	6,508	6,799	12,831	9,304	8,735	110,106	88-89
89-90	3,889	3,977	6,445	6,311	9,604	11,577	16,385	9,856	10,659	4,804	6,722	12,748	12,227	13,670	128,876	89-90
90-91	5,219	4,290	6,329	6,843	11,521	11,310	16,032	12,727	10,240	5,086	5,757	14,079	11,537	15,331	136,301	90-91
91-92	5,927	5,379	6,875	6,305	8,191	8,845	10,641	9,215	7,552	3,476	3,383	9,741	9,406	8,209	103,146	91-92
92-93	3,653	3,073	4,795	6,332	6,313	7,777	8,613	6,070	7,884	4,215	3,724	15,371	11,241	11,109	100,171	92-93
93-94	4,324	4,040	5,259	6,369	7,310	9,022	9,121	6,795	6,981	3,705	5,637	11,557	9,273	8,646	98,038	93-94
94-95	3,813	3,502	4,830	6,394	6,839	8,958	13,439	11,075	11,179	5,115	4,715	12,985	12,653	11,674	117,169	94-95
95-96	5,007	3,962	7,024	8,600	12,439	18,258	18,132	17,554	14,406	7,259	8,222	15,881	13,780	15,764	166,290	95-96
96-97	5,509	4,726	7,230	7,561	8,997	11,185	19,595	15,135	15,391	6,846	7,897	18,526	18,099	16,190	162,886	96-97
97-98	5,683	5,215	9,580	11,472	10,241	10,772	13,134	9,280	10,849	4,564	5,286	17,174	13,946	10,951	138,146	97-98
98-99	4,494	3,491	6,512	6,322	8,571	11,077	16,974	11,775	14,857	5,767	6,817	14,165	14,661	15,143	140,625	98-99
AVE	4,906	4,318	7,217	7,825	9,031	10,557	14,809	10,737	10,974	5,394	5,743	14,238	13,681	12,292	131,724	AVE

TABLE K.3-6. 52-YEAR AVERAGE SYSTEM GENERATION FOR BENCHMARK COMBINATION LV+HV (GWH)

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	TOTAL	YEAR
47-48	4,460	3,483	7,190	11,009	10,395	10,994	16,261	9,389	10,189	4,945	6,296	17,681	19,525	13,794	145,612	47-48
48-49	5,666	5,048	7,752	7,735	8,752	9,075	11,964	9,083	12,584	5,345	6,755	16,452	11,982	8,613	126,806	48-49
49-50	3,801	3,489	5,300	6,401	9,019	10,355	14,638	12,191	14,108	6,601	6,074	14,545	17,993	14,201	138,715	49-50
50-51	5,727	5,467	7,829	9,467	11,263	14,225	18,244	15,194	11,400	7,318	6,909	17,267	11,685	13,429	155,424	50-51
51-52	5,611	4,388	7,846	10,560	9,168	10,914	15,960	10,147	9,825	7,232	6,659	18,235	13,213	10,405	140,162	51-52
52-53	4,464	3,646	6,480	6,364	8,487	8,572	9,302	14,469	9,475	3,401	5,114	13,138	16,196	13,592	122,701	52-53
53-54	5,175	4,388	7,297	7,671	8,773	10,496	14,188	12,687	10,758	5,867	5,508	15,459	16,628	15,109	140,004	53-54
54-55	6,695	6,232	10,385	7,913	9,547	10,416	9,958	7,156	6,687	4,902	3,723	10,848	18,502	17,303	130,269	54-55
55-56	5,568	4,701	7,212	8,688	10,508	13,902	18,525	10,507	14,300	6,849	8,801	19,079	17,764	13,978	160,382	55-56
56-57	5,143	4,289	7,409	8,469	8,761	10,889	13,466	8,468	10,188	6,786	5,132	17,233	17,754	9,543	133,531	56-57
57-58	3,835	3,491	6,332	7,165	8,490	8,768	12,978	10,931	10,370	4,878	6,586	16,135	15,546	9,418	124,922	57-58
58-59	3,831	3,503	6,779	7,799	9,335	12,018	18,178	12,240	9,813	6,252	5,241	14,033	16,245	14,982	140,249	58-59
59-60	5,424	4,323	10,374	12,386	11,771	12,765	14,783	9,258	11,749	8,162	6,019	12,178	13,260	11,797	144,248	59-60
60-61	5,247	3,741	7,249	7,197	9,045	9,442	14,082	10,631	11,595	5,948	4,910	14,373	18,523	11,649	133,631	60-61
61-62	4,077	3,716	6,433	7,409	8,590	8,611	13,297	8,411	7,584	7,323	6,825	12,768	12,140	10,904	118,088	61-62
62-63	4,893	4,177	6,628	8,098	9,726	12,063	13,092	11,020	9,281	4,391	4,246	12,344	13,521	11,920	125,402	62-63
63-64	4,927	4,081	7,449	7,130	8,946	8,890	13,730	8,209	7,817	5,573	4,450	11,961	18,066	15,578	126,807	63-64
64-65	5,608	4,446	8,087	8,777	9,393	14,073	18,708	13,492	13,387	4,736	7,306	16,161	15,455	11,080	150,709	64-65
65-66	5,623	5,176	7,901	8,621	8,624	9,637	14,466	7,459	8,524	6,830	5,149	11,199	11,603	12,834	123,646	65-66
66-67	4,974	3,787	6,800	6,753	8,631	10,069	15,781	13,240	9,325	4,775	3,646	12,084	17,826	15,107	132,797	66-67
67-68	5,527	4,128	7,498	8,411	8,983	9,972	14,637	10,572	11,811	3,573	4,176	10,955	13,730	13,005	126,977	67-68
68-69	5,031	4,756	9,322	9,467	10,727	11,226	17,754	11,517	11,817	6,907	6,980	17,863	14,391	12,147	149,907	68-69
69-70	4,531	3,497	7,047	7,872	8,744	8,839	13,384	9,974	9,490	3,672	4,322	12,700	15,114	10,164	119,350	69-70
70-71	3,805	3,500	6,523	7,021	8,889	9,650	16,901	15,428	12,891	6,832	6,589	19,235	17,108	14,348	148,723	70-71
71-72	6,102	5,289	8,077	7,897	8,824	9,892	16,563	14,226	18,289	7,798	5,338	18,741	18,679	16,057	161,773	71-72
72-73	6,454	6,063	8,446	8,403	8,667	10,249	12,487	6,934	7,759	2,933	3,073	9,903	9,406	8,781	109,558	72-73
73-74	3,819	3,506	4,795	6,558	9,319	13,070	20,329	15,074	15,280	7,438	7,739	18,296	18,870	17,341	161,432	73-74
74-75	5,990	5,723	7,757	7,280	8,637	8,897	14,256	9,677	11,387	4,181	4,684	13,559	16,034	15,876	133,938	74-75
75-76	4,871	4,992	8,191	9,508	10,791	15,664	17,930	11,262	11,382	7,436	6,442	17,764	12,583	14,895	153,711	75-76
76-77	7,017	7,430	12,156	7,876	8,490	8,430	8,003	6,273	6,147	2,910	2,969	7,501	8,914	6,605	100,723	76-77
77-78	3,605	3,248	4,836	6,352	7,519	8,875	15,399	9,919	11,399	6,429	5,192	13,496	12,000	12,179	120,446	77-78
78-79	4,758	4,354	10,284	8,325	8,605	8,462	10,660	7,777	11,131	3,181	4,853	14,918	9,364	8,621	115,292	78-79
79-80	3,824	3,503	5,628	6,344	7,956	8,890	11,466	7,877	7,732	4,188	6,813	17,073	11,593	9,652	112,538	79-80
80-81	3,870	3,535	7,249	7,263	9,040	13,378	15,419	10,054	9,755	3,264	4,498	15,599	14,589	14,475	131,990	80-81
81-82	5,638	5,423	7,113	7,813	8,793	10,685	12,461	14,932	15,627	6,416	6,004	16,560	15,607	16,323	149,394	81-82
82-83	5,688	5,231	9,194	9,078	8,725	11,104	16,599	10,711	16,107	5,561	5,755	15,017	11,872	13,910	144,552	82-83
83-84	5,670	5,071	7,892	7,706	11,400	10,838	15,596	9,975	12,739	5,911	7,130	14,578	15,224	13,683	143,412	83-84
84-85	5,340	3,933	7,773	7,944	9,221	9,522	14,098	7,518	8,955	4,828	6,286	13,295	9,244	8,600	116,557	84-85
85-86	3,811	3,501	5,700	7,590	9,441	9,400	14,256	11,351	16,873	5,677	6,214	13,187	12,419	10,743	130,162	85-86
86-87	4,366	3,489	6,675	7,562	8,850	9,258	10,117	6,982	10,011	4,141	4,509	13,020	9,402	8,646	107,029	86-87
87-88	3,813	3,502	4,830	6,394	6,635	7,962	6,834	6,032	6,081	3,874	5,351	11,513	10,308	8,645	91,773	87-88
88-89	3,813	3,502	4,928	6,395	8,204	8,839	12,594	7,662	8,851	5,716	6,742	13,600	9,366	8,888	109,100	88-89
89-90	3,948	4,049	6,542	6,481	9,928	11,790	15,510	9,871	10,633	4,788	6,765	13,132	12,768	13,575	129,782	89-90
90-91	5,213	4,290	6,329	6,843	11,521	11,314	16,165	12,724	10,232	5,036	5,703	14,076	11,629	15,247	136,322	90-91
91-92	5,885	5,371	6,875	6,305	8,191	9,013	9,534	8,749	7,562	3,475	3,275	10,525	9,406	8,462	102,627	91-92
92-93	3,785	3,169	4,795	6,332	6,314	7,777	8,291	6,070	7,932	4,230	3,723	15,593	11,392	11,125	100,529	92-93
93-94	4,324	4,040	5,259	6,369	7,310	9,022	8,877	6,795	6,982	3,663	5,385	12,056	9,609	8,645	98,336	93-94
94-95	3,813	3,502	4,829	6,394	6,636	8,991	12,832	11,028	10,882	5,620	4,419	13,492	12,347	11,668	116,454	94-95
95-96	5,007	3,962	7,024	8,600	12,439	18,390	18,165	17,607	14,182	7,488	8,069	15,732	13,800	15,704	166,171	95-96
96-97	5,508	4,745	7,230	7,561	8,997	11,185	19,354	15,012	15,387	6,958	7,852	18,604	18,379	16,428	163,199	96-97
97-98	5,574	5,215	9,580	11,472	10,241	10,772	13,001	9,234	10,263	5,208	5,797	17,608	12,780	10,638	137,382	97-98
98-99	4,494	3,491	6,512	6,323	8,571	11,076	16,250	11,178	14,868	5,768	6,868	14,504	15,226	15,405	140,532	98-99
AVE	4,916	4,319	7,223	7,834	9,112	10,550	14,179	10,465	10,950	5,446	5,670	14,555	13,973	12,418	131,611	AVE

The differences in generation among alternative and benchmark combinations for the Columbia River Basin System projects are summarized in Tables K.3-7 through K.3-13 in units of GWh. For all tables, the second alternative combination was subtracted from the first. For example, in Table K.3-7, the differences summarized in the table are "Benchmark Combination LV+HV" minus "Benchmark Combination LS+HS."

TABLE K.3-7. DIFFERENCE IN SYSTEM GENERATION FOR BENCHMARK COMBINATION LV+HV MINUS BENCHMARK COMBINATION LS+HS (GWH)

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	TOTAL	YEAR
47-48	0	0	0	0	0	0	-366	-974	5	73	82	496	31	54	-599	47-48
48-49	0	0	0	0	0	0	-952	-40	-589	233	-147	614	642	43	-196	48-49
49-50	0	0	70	17	81	-25	-469	-37	-212	90	-51	267	222	65	19	49-50
50-51	1	-16	0	0	0	13	124	-354	-49	48	-55	82	41	-50	-215	50-51
51-52	-3	5	0	0	0	0	85	-780	-256	5	-39	206	156	628	8	51-52
52-53	66	0	0	0	354	-190	-187	-644	-87	80	-241	361	392	132	36	52-53
53-54	-21	0	0	0	0	0	-838	21	229	175	-57	125	202	33	-130	53-54
54-55	23	0	3	0	0	0	-1,411	-876	32	587	234	-273	589	427	-667	54-55
55-56	-2	-80	0	0	0	0	52	-382	199	8	11	-6	22	-20	-198	55-56
56-57	41	0	0	0	0	0	-1,059	-694	-8	-30	-198	481	912	182	-374	56-57
57-58	3	0	0	-1	0	0	-857	-497	296	-17	-105	354	737	10	-76	57-58
58-59	3	0	0	0	0	0	-199	-445	-109	1	57	500	282	-62	28	58-59
59-60	14	0	0	0	0	298	-1,059	-447	61	-20	-8	574	598	2	13	59-60
60-61	0	0	0	0	0	0	-737	-644	-106	-94	-219	472	506	179	-643	60-61
61-62	0	0	0	0	77	-3	-1,391	-158	190	-196	-91	478	542	482	-69	61-62
62-63	0	0	0	0	0	0	-1,261	-161	-19	-51	-140	368	837	200	-228	62-63
63-64	120	0	0	0	0	0	-770	-286	7	-38	-297	350	437	384	-93	63-64
64-65	0	-11	0	0	0	0	-43	-588	288	135	8	216	174	-93	84	64-65
65-66	51	0	0	0	0	0	-841	-146	30	-67	-68	243	492	237	-68	65-66
66-67	1	0	0	0	0	0	-377	33	425	235	-92	-25	75	-132	142	66-67
67-68	-43	0	0	0	0	0	-870	-640	-287	182	-183	276	810	379	-377	67-68
68-69	20	0	0	0	0	179	-262	-419	50	-90	73	235	161	134	82	68-69
69-70	98	0	-1	0	0	1	-213	-49	4	-157	-238	339	76	77	-62	69-70
70-71	0	0	4	0	0	0	-920	38	40	129	37	254	317	54	-46	70-71
71-72	1	0	0	0	0	0	-443	106	137	-24	-114	331	-45	-247	-298	71-72
72-73	53	15	0	0	0	0	-1,028	-284	-167	0	0	327	54	121	-909	72-73
73-74	0	0	-1	134	633	161	6	-109	187	39	46	75	58	-65	1,164	73-74
74-75	-52	-11	0	0	0	0	-860	-580	144	13	-197	427	464	382	-270	74-75
75-76	105	0	0	0	0	26	-183	-1,101	164	118	86	237	264	246	-39	75-76
76-77	41	6	1	0	0	3	-170	1	1	0	1	41	32	-31	-74	76-77
77-78	1	0	1	-1	1,130	-1,124	-644	-831	15	172	-101	54	514	924	111	77-78
78-79	0	0	0	0	0	0	-879	-59	-280	-49	40	556	-1	0	-672	78-79
79-80	0	0	82	0	1,377	-652	-1,176	42	6	14	-220	530	402	-31	374	79-80
80-81	1	-2	0	0	0	0	-878	-219	299	-17	-228	504	314	103	-121	80-81
81-82	-4	-25	0	0	0	0	-946	-416	-251	160	-53	421	656	246	-212	81-82
82-83	-2	-16	0	0	0	0	-834	-744	11	-28	-247	348	1,079	470	37	82-83
83-84	0	0	0	0	0	0	-1,078	-270	79	116	-222	384	798	10	-184	83-84
84-85	0	0	0	0	0	0	-884	-84	-117	182	-112	103	1	0	-911	84-85
85-86	0	0	63	109	563	423	-1,670	-39	10	90	-228	136	801	679	939	85-86
86-87	0	0	0	0	0	0	-1,021	-228	-34	5	-128	734	-1	0	-671	86-87
87-88	0	0	1	-1	0	1	0	224	129	111	3	419	-45	0	841	87-88
88-89	0	0	-4	0	-93	-43	-1,161	807	-648	-792	-57	769	63	153	-1,006	88-89
89-90	59	72	96	170	324	213	-875	15	-26	-16	44	384	541	-94	906	89-90
90-91	-5	0	0	0	0	4	133	-3	-7	-50	-54	-4	92	-84	21	90-91
91-92	-42	-8	0	0	0	167	-1,106	-466	10	-1	-108	784	0	252	-519	91-92
92-93	133	96	0	0	1	0	-322	0	48	15	-1	222	151	16	358	92-93
93-94	0	0	0	0	0	0	-243	1	1	-42	-252	498	336	-1	299	93-94
94-95	0	0	-1	0	-202	33	-607	-48	-296	505	-297	507	-305	-6	-716	94-95
95-96	0	0	0	0	0	132	33	53	-224	229	-153	-150	20	-60	-119	95-96
96-97	-1	19	0	0	0	0	-240	-123	-4	112	-45	78	280	237	313	96-97
97-98	-109	0	0	0	0	0	-133	-46	-586	644	511	434	-1,166	-313	-764	97-98
98-99	0	0	0	1	0	-1	-724	-597	11	0	51	339	564	262	-93	98-99
AVE	11	1	6	8	82	-7	-630	-272	-24	52	-72	317	292	125	-112	AVE

TABLE K.3-8. DIFFERENCE IN SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LV1+HV MINUS ALTERNATIVE COMBINATION LS1+HS (GWH)

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	TOTAL	YEAR
47-48	0	0	0	0	0	0	-366	-974	5	73	82	496	21	69	-594	47-48
48-49	6	30	-5	0	0	0	-952	-40	-589	233	-147	432	305	291	-435	48-49
49-50	80	0	-1	-1	74	327	-482	-37	-213	91	-51	267	171	47	271	49-50
50-51	10	52	22	0	0	13	124	-354	-49	48	-55	82	45	-46	-109	50-51
51-52	2	7	-6	0	0	0	85	-780	-256	-3	-39	206	257	77	-450	51-52
52-53	30	26	191	1	497	-17	-187	-644	-87	80	-241	254	58	193	154	52-53
53-54	285	199	-11	0	0	0	-838	21	229	175	-57	125	153	28	309	53-54
54-55	59	25	6	0	0	0	-1,411	-876	32	587	234	-390	359	473	-903	54-55
55-56	60	396	0	0	0	0	42	-382	199	8	11	-6	102	-46	385	55-56
56-57	-20	-55	5	0	0	0	-1,059	-694	-8	-30	-198	414	322	426	-898	56-57
57-58	248	0	278	95	0	0	-857	-497	296	-17	-105	265	125	384	216	57-58
58-59	218	200	17	0	0	0	-199	-445	-109	1	57	496	217	-72	380	58-59
59-60	95	40	-11	0	0	298	-1,059	-447	61	-20	-8	574	287	60	-131	59-60
60-61	45	50	203	0	0	0	-737	-644	-106	-94	-219	472	391	256	-383	60-61
61-62	76	37	22	0	77	-3	-1,391	-158	13	-30	-91	411	120	324	-593	61-62
62-63	177	175	189	167	56	0	-1,261	-161	-19	-51	-140	240	504	235	112	62-63
63-64	485	116	0	0	0	0	-770	-286	7	-38	-297	282	49	420	-32	63-64
64-65	82	557	-6	0	0	0	-43	-588	288	135	8	212	105	-179	570	64-65
65-66	4	-5	22	233	0	0	-841	-146	30	-67	-68	243	303	238	-54	65-66
66-67	112	96	0	0	0	0	-377	33	425	235	-92	-33	28	-83	343	66-67
67-68	-28	-25	11	0	0	0	-870	-640	-287	182	-183	175	257	418	-990	67-68
68-69	411	337	5	0	0	179	-266	-419	50	-90	73	225	77	211	795	68-69
69-70	75	45	11	0	0	1	-213	-49	4	-157	-238	293	-28	91	-165	69-70
70-71	86	73	-5	0	0	0	-920	38	40	129	37	254	160	47	-60	70-71
71-72	104	113	-21	0	0	0	-443	106	137	-24	-114	322	81	-228	33	71-72
72-73	-73	-24	-151	0	0	0	-1,028	-284	-167	0	0	209	0	132	-1,386	72-73
73-74	11	0	-1	1	800	382	0	-125	173	36	32	-1	22	-10	1,320	73-74
74-75	-29	-25	-7	0	0	0	-860	-580	144	13	-197	427	279	141	-695	74-75
75-76	95	98	326	129	0	26	-183	-1,101	164	118	86	211	81	199	248	75-76
76-77	123	106	99	0	0	3	-170	1	1	0	1	41	32	22	259	76-77
77-78	19	32	0	1	1,096	-1,254	-696	-825	19	172	-101	-42	232	853	-494	77-78
78-79	265	232	15	0	0	0	-879	-59	-280	-49	40	404	0	-1	-311	78-79
79-80	1	0	-1	1	1,318	-449	-1,088	43	13	14	-219	641	292	-69	497	79-80
80-81	26	24	-11	0	0	0	-878	-219	299	-17	-228	407	111	66	-420	80-81
81-82	11	138	195	0	0	0	-946	-431	-251	160	-53	421	402	237	-117	81-82
82-83	40	262	-16	0	0	0	-834	-744	13	-28	-247	348	580	417	-208	82-83
83-84	51	352	220	9	0	0	-1,078	-270	79	116	-222	144	347	309	57	83-84
84-85	226	204	-6	0	0	0	-884	-84	-117	182	-112	45	47	-1	-499	84-85
85-86	0	0	-1	553	475	275	-1,674	-68	-103	88	-228	-125	559	771	522	85-86
86-87	261	198	-22	0	0	0	-1,021	-228	-34	5	-128	485	0	0	-483	86-87
87-88	0	0	0	0	1	0	-1	604	121	23	5	408	-19	-77	1,066	87-88
88-89	0	0	1	-1	-19	-27	-1,206	-454	155	-293	-57	656	30	362	-854	88-89
89-90	195	189	61	109	30	187	-884	15	-26	-16	44	390	127	170	593	89-90
90-91	91	80	-11	0	0	4	133	-3	-7	-50	-54	-4	36	-34	180	90-91
91-92	-15	-33	6	0	0	167	-1,106	-466	10	-1	-108	558	-1	78	-911	91-92
92-93	47	360	-1	0	0	0	144	1	32	8	-1	46	213	92	942	92-93
93-94	-25	-10	0	1	6	-1	-244	1	1	-42	-252	332	203	1	-28	93-94
94-95	-28	0	-1	-1	-5	391	-832	-48	-296	505	-297	272	-297	218	-417	94-95
95-96	9	18	6	0	0	132	33	53	-224	229	-153	-150	76	-50	-20	95-96
96-97	-8	-44	5	0	0	0	-240	-123	-4	112	-45	79	34	163	-72	96-97
97-98	103	261	16	0	0	0	-133	-46	-586	644	511	277	-1,145	-179	-278	97-98
98-99	-4	19	-6	0	0	0	-725	-597	11	0	51	339	356	204	-351	98-99
AVE	79	95	31	25	85	12	-626	-290	-15	63	-73	253	136	147	-79	AVE

TABLE K.3-9. DIFFERENCE IN SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LV2+HV MINUS ALTERNATIVE COMBINATION LS2+HS (GWH)

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	TOTAL	YEAR
47-48	0	0	0	0	0	0	-366	-974	5	73	82	496	22	120	-543	47-48
48-49	13	88	-148	0	0	0	-952	-40	-589	233	-147	393	341	291	-518	48-49
49-50	79	0	-1	-1	77	329	-482	-37	-213	91	-51	267	168	20	247	49-50
50-51	14	97	6	0	0	13	124	-354	-49	48	-55	82	47	-54	-81	50-51
51-52	-3	5	0	0	0	0	85	-780	-256	5	-39	206	263	58	-456	51-52
52-53	12	17	186	-1	498	32	-187	-644	-87	80	-241	280	56	158	159	52-53
53-54	297	201	-32	0	0	0	-838	21	229	175	-57	124	153	17	290	53-54
54-55	60	40	24	0	0	0	-1,411	-876	32	587	234	-378	351	488	-850	54-55
55-56	61	412	5	0	0	0	42	-382	199	8	11	-6	102	-45	407	55-56
56-57	-25	-31	-11	0	0	0	-1,059	-694	-8	-30	-198	426	307	397	-927	56-57
57-58	229	0	276	145	0	0	-857	-497	296	-17	-105	275	118	373	236	57-58
58-59	217	200	17	0	0	0	-199	-445	-109	1	57	496	215	-51	398	58-59
59-60	57	50	-5	0	0	298	-1,059	-447	61	-20	-8	574	282	30	-188	59-60
60-61	32	30	225	59	0	0	-737	-644	-106	-94	-219	472	354	280	-348	60-61
61-62	112	70	-11	0	0	267	-1,568	-158	13	-30	-91	450	84	292	-569	61-62
62-63	164	160	179	167	129	0	-1,261	-161	-19	-51	-140	237	484	243	130	62-63
63-64	453	191	-27	0	0	0	-770	-286	7	-38	-297	302	59	395	-11	63-64
64-65	80	537	0	0	0	0	-43	-588	288	135	8	212	99	-179	549	64-65
65-66	2	5	1	231	6	19	-841	-146	30	-67	-68	243	324	219	-41	65-66
66-67	98	100	5	0	0	0	-377	33	425	235	-92	-33	24	-83	334	66-67
67-68	-23	-20	-5	0	0	0	-870	-640	-287	182	-183	174	249	445	-979	67-68
68-69	427	344	0	0	0	179	-292	-419	50	-90	73	225	96	196	789	68-69
69-70	62	50	11	0	0	1	-213	-49	4	-157	-238	279	-23	97	-177	69-70
70-71	76	74	11	0	0	0	-920	38	40	129	37	254	168	67	-24	70-71
71-72	54	104	-5	0	0	0	-443	106	137	-24	-114	322	67	-228	-24	71-72
72-73	-53	-28	-130	0	0	0	-1,028	-284	-167	0	0	175	0	125	-1,389	72-73
73-74	0	0	0	1	829	391	2	-124	174	37	33	24	14	-12	1,369	73-74
74-75	-13	-29	4	0	0	0	-860	-580	144	13	-197	427	269	124	-699	74-75
75-76	86	89	333	184	0	26	-183	-1,101	164	118	86	211	91	187	290	75-76
76-77	126	111	91	0	0	3	-170	1	3	0	3	39	33	17	257	76-77
77-78	14	28	0	0	1,097	-1,251	-688	-825	19	172	-101	-11	78	822	-647	77-78
78-79	399	292	0	0	0	0	-879	-59	-280	-49	40	371	0	-1	-166	78-79
79-80	0	0	-1	0	328	16	-481	43	13	14	-219	659	253	-49	577	79-80
80-81	10	10	6	0	0	0	-878	-219	299	-17	-228	398	81	106	-432	80-81
81-82	14	149	226	0	0	0	-946	-429	-251	160	-53	421	409	234	-65	81-82
82-83	40	252	-10	0	0	0	-834	-744	12	-28	-247	348	614	387	-210	82-83
83-84	46	311	199	78	0	0	-1,078	-270	79	116	-222	79	355	402	95	83-84
84-85	206	194	-10	0	0	0	-884	-83	-119	182	-112	22	43	-1	-562	84-85
85-86	0	0	0	519	528	295	-1,674	-68	-103	88	-228	-131	549	802	577	85-86
86-87	265	215	-55	0	0	0	-1,021	-226	-36	5	-128	465	0	0	-515	86-87
87-88	0	0	-1	1	1	0	-1	613	133	29	167	392	-6	-54	1,273	87-88
88-89	0	0	0	0	-24	-25	-1,227	-454	155	-293	-57	675	37	317	-896	88-89
89-90	195	184	83	106	30	187	-884	15	-26	-16	44	390	135	163	605	89-90
90-91	79	80	0	0	0	4	133	-3	-7	-50	-54	-4	30	-38	169	90-91
91-92	-4	-22	-5	0	0	167	-1,106	-466	10	-1	-108	522	0	102	-912	91-92
92-93	61	360	-1	0	1	1	141	0	30	7	-1	45	202	103	948	92-93
93-94	-25	-20	0	0	12	4	-244	1	1	-42	-252	328	137	1	-97	93-94
94-95	-1	0	0	-1	-8	7	-422	-48	-296	505	-297	237	-341	209	-454	94-95
95-96	73	48	27	0	0	132	33	53	-224	229	-153	-150	83	-80	71	95-96
96-97	-5	-35	0	0	0	0	-240	-123	-4	112	-45	79	51	193	-18	96-97
97-98	113	223	-32	0	0	0	-133	-46	-586	644	511	280	-1,116	-196	-337	97-98
98-99	-25	5	5	0	0	0	-725	-597	11	0	51	339	359	214	-362	98-99
AVE	80	99	27	29	67	21	-611	-290	-15	63	-69	250	130	147	-72	AVE

TABLE K.3-10. DIFFERENCE IN SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LS1+HS MINUS BENCHMARK COMBINATION LS+HS (GWH)

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	TOTAL	YEAR
47-48	-7	0	-1,149	0	0	0	0	0	0	0	0	0	45	199	-913	47-48
48-49	57	523	-1,139	0	0	0	0	0	0	0	0	331	650	0	422	48-49
49-50	0	0	-462	-78	-134	-573	7	1	0	-4	1	0	361	266	-615	49-50
50-51	0	-65	-1,153	0	0	0	0	0	0	0	0	0	525	93	-600	50-51
51-52	27	209	-1,134	0	0	0	0	0	0	0	0	0	631	788	520	51-52
52-53	-28	5	-1,354	-1	-143	-173	0	0	0	0	0	210	483	-57	-1,058	52-53
53-54	-28	217	-1,142	0	0	0	0	0	0	0	0	0	330	196	-428	53-54
54-55	-58	166	-893	-9	0	0	0	0	0	0	0	165	256	-51	-424	54-55
55-56	49	322	-1,131	0	0	0	0	0	0	0	0	0	337	121	-302	55-56
56-57	84	298	-1,146	0	0	0	0	0	0	0	0	180	724	-124	16	56-57
57-58	-3	0	-1,238	-1	0	0	0	0	0	0	0	196	790	-228	-484	57-58
58-59	17	26	-1,107	1	1	0	0	0	0	0	0	4	353	115	-590	58-59
59-60	90	256	-690	-400	0	0	0	0	0	0	0	0	734	380	371	59-60
60-61	-101	44	-1,341	0	0	0	0	0	0	0	0	0	115	208	-1,075	60-61
61-62	266	316	-1,162	0	0	0	0	0	0	0	0	193	640	508	761	61-62
62-63	-106	2	-1,336	-167	-56	0	0	0	0	0	0	412	440	-124	-934	62-63
63-64	-67	238	-1,136	0	0	0	0	0	0	0	0	193	469	-57	-360	63-64
64-65	0	94	-1,122	0	0	0	0	0	0	0	0	4	635	449	59	64-65
65-66	113	119	-1,475	-233	0	0	0	0	0	0	0	0	686	32	-758	65-66
66-67	27	141	-1,150	0	0	0	0	0	0	0	0	8	417	52	-505	66-67
67-68	1	207	-1,143	0	0	0	0	0	0	0	0	348	494	-103	-196	67-68
68-69	17	90	-1,119	0	0	0	0	0	0	0	0	10	444	-79	-636	68-69
69-70	238	113	-946	0	0	0	0	0	0	0	0	433	333	-112	58	69-70
70-71	57	70	-1,025	0	1	1	0	0	0	0	0	0	454	158	-284	70-71
71-72	-73	285	-1,132	0	0	0	0	0	0	0	0	9	42	211	-658	71-72
72-73	126	184	-824	0	0	0	0	0	0	0	0	442	54	-1	-19	72-73
73-74	-1	0	1	-92	-94	-510	7	15	14	3	14	77	104	97	-365	73-74
74-75	106	479	-1,104	0	0	0	0	0	0	0	0	0	637	621	740	74-75
75-76	-3	-83	-1,472	-129	0	0	0	0	0	0	0	33	816	490	-348	75-76
76-77	-198	-201	-1,176	-14	0	0	0	0	0	0	0	0	0	386	-1,204	76-77
77-78	219	211	1	-1	0	-461	-300	-6	-4	0	0	131	429	262	480	77-78
78-79	12	46	-1,120	0	0	0	0	0	0	0	0	373	0	0	-689	78-79
79-80	-1	0	-765	-1	294	-44	20	-1	-6	0	0	-20	193	283	-48	79-80
80-81	244	250	-1,140	0	0	0	0	0	0	0	0	362	240	-222	-268	80-81
81-82	53	444	-1,099	0	0	0	0	-1	0	0	0	0	672	197	266	81-82
82-83	-22	-36	-1,112	0	0	0	0	0	0	0	0	0	726	466	22	82-83
83-84	-40	-118	-1,340	-9	0	0	0	0	0	0	0	542	281	-51	-734	83-84
84-85	-2	115	-1,138	0	0	0	0	0	0	0	0	355	0	0	-669	84-85
85-86	0	0	-855	-372	417	147	4	29	113	2	0	422	274	6	188	85-86
86-87	54	38	-1,002	1	0	0	0	0	0	0	0	423	0	0	-485	86-87
87-88	0	0	1	-1	-1	1	1	-380	-94	-3	0	-80	-29	77	-508	87-88
88-89	0	0	-102	0	218	-53	-210	0	0	0	0	205	63	341	463	88-89
89-90	14	-33	-1,092	83	294	25	9	0	0	0	0	0	714	132	146	89-90
90-91	-71	71	-1,143	0	0	0	0	0	0	0	0	4	527	193	-418	90-91
91-92	-116	227	-1,147	0	0	0	0	0	0	0	0	427	0	373	-235	91-92
92-93	118	73	1	0	0	0	-713	0	-31	-49	-2	-58	-309	48	-922	92-93
93-94	425	458	-477	1	-454	-199	0	-34	0	0	0	371	0	-1	91	93-94
94-95	126	0	0	1	-204	-376	0	-1	0	0	0	404	-46	-62	-160	94-95
95-96	275	353	-1,140	0	0	0	0	0	0	0	0	25	240	52	-195	95-96
96-97	58	500	-1,131	0	0	0	0	0	0	0	0	1	324	145	-103	96-97
97-98	27	256	-1,127	0	0	0	0	0	0	0	0	339	-224	117	-613	97-98
98-99	319	211	-994	-1	2	4	1	0	0	0	0	0	680	403	626	98-99
AVE	44	137	-968	-27	3	-43	-23	-7	0	-1	0	144	341	138	-261	AVE

TABLE K.3-11. DIFFERENCE IN SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LS2+HS MINUS BENCHMARK COMBINATION LS+HS (GWH)

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	TOTAL	YEAR
47-48	-7	0	-1,149	0	0	0	0	0	0	0	0	0	60	182	-913	47-48
48-49	50	459	-1,128	0	0	0	0	0	0	0	0	432	554	0	366	48-49
49-50	0	-1	-462	-77	-140	-592	7	1	0	-4	1	0	374	273	-620	49-50
50-51	-4	-111	-1,143	0	0	0	0	0	0	0	0	0	615	107	-535	50-51
51-52	17	84	-1,140	0	0	0	0	0	0	0	0	0	657	798	417	51-52
52-53	-24	5	-1,354	1	-144	-222	0	0	0	0	0	272	488	-102	-1,080	52-53
53-54	-44	207	-1,136	0	0	0	0	0	0	0	0	0	364	227	-382	53-54
54-55	-113	130	-930	-9	0	0	0	0	0	0	0	269	235	-124	-542	54-55
55-56	48	302	-1,136	0	0	0	0	0	0	0	0	0	374	102	-310	55-56
56-57	59	273	-1,141	0	0	0	0	0	0	0	0	237	721	-160	-11	56-57
57-58	1	0	-1,241	-51	0	0	0	0	0	0	0	262	784	-285	-528	57-58
58-59	7	17	-1,107	1	1	0	0	0	0	0	0	4	413	92	-573	58-59
59-60	65	230	-701	-400	0	0	0	0	0	0	0	0	778	405	378	59-60
60-61	-101	44	-1,373	-59	0	0	0	0	0	0	0	0	152	187	-1,150	60-61
61-62	234	286	-1,146	0	0	0	0	0	0	0	0	257	657	474	762	61-62
62-63	-103	2	-1,337	-167	-129	0	0	0	0	0	0	542	427	-164	-928	62-63
63-64	-161	228	-1,136	0	0	0	0	0	0	0	0	254	446	-97	-465	63-64
64-65	4	103	-1,138	0	0	0	0	0	0	0	0	4	678	467	118	64-65
65-66	112	114	-1,476	-294	-6	-19	0	0	0	0	0	0	739	16	-815	65-66
66-67	3	112	-1,139	0	0	0	0	0	0	0	0	8	456	10	-551	66-67
67-68	-22	183	-1,127	0	0	0	0	0	0	0	0	478	487	-214	-215	67-68
68-69	7	70	-1,124	0	0	0	0	0	0	0	0	10	516	-97	-618	68-69
69-70	202	78	-946	0	0	0	0	0	0	0	0	510	323	-175	-7	69-70
70-71	56	64	-1,036	0	1	1	0	0	0	0	0	0	523	129	-261	70-71
71-72	-90	237	-1,132	0	0	0	0	0	0	0	0	9	101	215	-660	71-72
72-73	51	170	-914	0	0	0	0	0	0	0	0	547	54	-1	-93	72-73
73-74	0	0	0	-92	-166	-541	7	14	12	2	13	51	120	151	-429	73-74
74-75	78	430	-1,138	0	0	0	0	0	0	0	0	0	669	629	667	74-75
75-76	-8	-82	-1,473	-184	0	0	0	0	0	0	0	33	874	494	-346	75-76
76-77	-230	-230	-1,184	-14	0	0	0	0	0	0	0	0	0	391	-1,267	76-77
77-78	224	215	1	0	-1	-464	-308	-6	-4	0	0	199	436	197	489	77-78
78-79	-7	32	-1,115	0	0	0	0	0	0	0	0	466	0	1	-623	78-79
79-80	-1	0	-765	-1	233	-106	20	-1	-6	0	0	38	179	230	-180	79-80
80-81	239	245	-1,140	0	0	0	0	0	0	0	0	461	215	-328	-309	80-81
81-82	51	444	-1,113	0	0	0	0	-1	0	0	0	0	703	184	268	81-82
82-83	-26	-61	-1,107	0	0	0	0	0	0	0	0	0	759	486	51	82-83
83-84	-40	-118	-1,341	-78	0	0	0	0	0	0	0	608	273	-109	-806	83-84
84-85	-6	105	-1,128	0	0	0	0	0	0	0	0	445	1	0	-583	84-85
85-86	0	0	-855	-400	339	128	4	29	113	2	0	555	255	-117	54	85-86
86-87	48	33	-1,012	1	0	0	0	0	0	0	0	509	0	-1	-422	86-87
87-88	0	0	1	-1	-1	1	1	-416	-129	-3	0	-103	-42	54	-638	87-88
88-89	0	0	-102	0	222	-49	-195	0	0	0	0	272	63	307	519	88-89
89-90	14	-33	-1,146	86	294	25	9	0	0	0	0	0	762	117	127	89-90
90-91	-93	51	-1,143	0	0	0	0	0	0	0	0	4	612	209	-359	90-91
91-92	-163	137	-1,136	0	0	0	0	0	0	0	0	504	-1	350	-309	91-92
92-93	105	72	1	0	-1	-1	-731	0	-39	-50	-2	-62	-309	36	-980	92-93
93-94	425	467	-477	1	-460	-203	0	-34	0	0	0	435	0	-1	154	93-94
94-95	105	1	-1	1	-204	-405	0	-1	0	0	0	510	-12	-114	-121	94-95
95-96	208	320	-1,166	0	0	0	0	0	0	0	0	25	330	70	-214	95-96
96-97	44	386	-1,137	0	0	0	0	0	0	0	0	1	357	148	-200	96-97
97-98	-15	233	-1,121	0	0	0	0	0	0	0	0	379	-275	117	-681	97-98
98-99	319	211	-994	-1	2	4	1	0	0	0	0	0	732	403	678	98-99
AVE	29	118	-973	-33	-3	-47	-23	-8	-1	-1	0	181	359	119	-282	AVE

TABLE K.3-12. DIFFERENCE IN SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LV1+HV MINUS BENCHMARK COMBINATION LV+HV (GWH)

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	TOTAL	YEAR
47-48	-7	0	-1,149	0	0	0	0	0	0	0	0	0	35	214	-908	47-48
48-49	63	553	-1,144	0	0	0	0	0	0	0	0	150	314	248	183	48-49
49-50	80	0	-533	-96	-141	-221	-6	1	-1	-4	1	0	310	247	-363	49-50
50-51	10	2	-1,132	0	0	0	0	0	0	0	0	0	528	97	-494	50-51
51-52	31	210	-1,140	0	0	0	0	0	0	-8	0	0	732	237	63	51-52
52-53	-64	31	-1,164	0	0	0	0	0	0	0	0	103	148	4	-940	52-53
53-54	279	415	-1,153	0	0	0	0	0	0	0	0	0	280	190	11	53-54
54-55	-22	192	-890	-9	0	0	0	0	0	0	0	48	25	-5	-660	54-55
55-56	111	798	-1,131	0	0	0	-10	0	0	0	0	0	418	94	281	55-56
56-57	22	243	-1,141	0	0	0	0	0	0	0	0	113	135	121	-508	56-57
57-58	242	0	-960	95	0	0	0	0	0	0	0	107	177	146	-192	57-58
58-59	232	226	-1,090	1	1	0	0	0	0	0	0	0	288	105	-237	58-59
59-60	171	296	-701	-400	0	0	0	0	0	0	0	0	423	438	227	59-60
60-61	-56	94	-1,138	0	0	0	0	0	0	0	0	0	0	285	-814	60-61
61-62	342	353	-1,140	0	0	0	0	0	-178	167	0	126	218	350	237	61-62
62-63	72	178	-1,147	0	0	0	0	0	0	0	0	285	107	-89	-595	62-63
63-64	298	354	-1,136	0	0	0	0	0	0	0	0	124	81	-21	-299	63-64
64-65	82	662	-1,128	0	0	0	0	0	0	0	0	0	567	362	545	64-65
65-66	65	114	-1,454	0	0	0	0	0	0	0	0	0	498	33	-744	65-66
66-67	138	237	-1,150	0	0	0	0	0	0	0	0	0	370	101	-303	66-67
67-68	16	182	-1,132	0	0	0	0	0	0	0	0	247	-59	-64	-809	67-68
68-69	409	427	-1,114	0	0	0	-4	0	0	0	0	0	359	-1	76	68-69
69-70	214	157	-934	0	0	0	0	0	0	0	0	387	230	-99	-45	69-70
70-71	143	142	-1,035	0	1	1	0	0	0	0	0	0	297	152	-298	70-71
71-72	30	398	-1,153	0	0	0	0	0	0	0	0	0	168	231	-326	71-72
72-73	0	145	-975	0	0	0	0	0	0	0	0	324	0	11	-495	72-73
73-74	10	0	1	-225	73	-289	1	-1	-1	0	0	0	68	153	-210	73-74
74-75	129	465	-1,111	0	0	0	0	0	0	0	0	0	451	380	315	74-75
75-76	-13	16	-1,146	0	0	0	0	0	0	0	0	7	633	443	-61	75-76
76-77	-116	-101	-1,079	-14	0	0	0	0	0	0	0	0	0	438	-871	76-77
77-78	237	242	-1	1	-35	-590	-353	0	-1	0	0	35	147	191	-125	77-78
78-79	277	279	-1,105	0	0	0	0	0	0	0	0	221	1	-1	-328	78-79
79-80	0	0	-848	0	235	159	109	0	1	0	0	91	82	246	75	79-80
80-81	268	275	-1,151	0	0	0	0	0	0	0	0	264	37	-260	-566	80-81
81-82	67	607	-904	0	0	0	0	-16	0	0	0	0	418	189	361	81-82
82-83	21	242	-1,128	0	0	0	0	0	1	0	0	0	228	412	-224	82-83
83-84	12	234	-1,120	0	0	0	0	0	0	0	0	303	-170	248	-492	83-84
84-85	224	319	-1,143	0	0	0	0	0	0	0	0	298	46	-1	-257	84-85
85-86	0	0	-919	71	329	0	0	0	0	0	0	161	32	97	-229	85-86
86-87	315	236	-1,023	1	0	0	0	0	0	0	0	174	1	0	-296	86-87
87-88	0	0	0	0	0	0	0	0	-101	-90	1	-91	-3	0	-283	87-88
88-89	0	0	-98	-1	292	-36	-254	-1,261	803	499	0	92	30	551	615	88-89
89-90	150	84	-1,128	22	0	0	0	0	0	0	0	6	300	397	-168	89-90
90-91	26	151	-1,154	0	0	0	0	0	0	0	0	4	471	243	-259	90-91
91-92	-88	202	-1,141	0	0	0	0	0	0	0	0	201	-1	199	-627	91-92
92-93	33	337	0	0	-1	0	-247	1	-47	-56	-2	-234	-247	124	-339	92-93
93-94	400	448	-477	1	-447	-199	-1	-33	0	0	0	205	-133	0	-236	93-94
94-95	98	0	0	0	-7	-19	-225	-1	0	0	0	169	-38	161	139	94-95
95-96	284	371	-1,134	0	0	0	0	0	0	0	0	25	296	62	-96	95-96
96-97	51	436	-1,126	0	0	0	0	0	0	0	0	2	78	71	-488	96-97
97-98	239	517	-1,111	0	0	0	0	0	0	0	0	181	-202	251	-126	97-98
98-99	315	230	-999	-1	2	5	0	0	0	0	0	0	472	344	368	98-99
AVE	112	231	-942	-11	6	-23	-19	-25	9	10	0	79	185	160	-227	AVE

TABLE K.3-13. DIFFERENCE IN SYSTEM GENERATION FOR ALTERNATIVE COMBINATION LV2+HV MINUS BENCHMARK COMBINATION LV+HV (GWH)

YEAR	AG1	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	AP1	APR	MAY	JUN	JUL	TOTAL	YEAR
47-48	-7	0	-1,149	0	0	0	0	0	0	0	0	0	51	248	-857	47-48
48-49	63	546	-1,277	0	0	0	0	0	0	0	0	211	253	248	45	48-49
49-50	79	0	-533	-96	-144	-238	-7	1	-1	-4	1	0	320	228	-393	49-50
50-51	10	2	-1,137	0	0	0	0	0	0	0	0	0	621	103	-401	50-51
51-52	16	84	-1,140	0	0	0	0	0	0	0	0	0	764	228	-47	51-52
52-53	-78	22	-1,169	0	0	0	0	0	0	0	0	192	152	-77	-957	52-53
53-54	274	408	-1,169	0	0	0	0	0	0	0	0	-1	315	211	38	53-54
54-55	-76	170	-909	-9	0	0	0	0	0	0	0	164	-4	-62	-725	54-55
55-56	111	794	-1,131	0	0	0	-10	0	0	0	0	0	454	77	295	55-56
56-57	-7	242	-1,152	0	0	0	0	0	0	0	0	181	117	56	-564	56-57
57-58	227	0	-965	95	0	0	0	0	0	0	0	182	165	79	-217	57-58
58-59	222	217	-1,090	1	1	0	0	0	0	0	0	0	345	103	-203	58-59
59-60	108	280	-706	-400	0	0	0	0	0	0	0	0	462	432	177	59-60
60-61	-69	74	-1,148	0	0	0	0	0	0	0	0	0	0	289	-854	60-61
61-62	346	356	-1,156	0	-77	270	-178	0	-178	167	0	229	199	284	263	61-62
62-63	62	162	-1,158	0	0	0	0	0	0	0	0	411	73	-121	-571	62-63
63-64	172	419	-1,163	0	0	0	0	0	0	0	0	206	68	-86	-383	63-64
64-65	85	651	-1,138	0	0	0	0	0	0	0	0	0	603	382	583	64-65
65-66	63	119	-1,475	-63	0	0	0	0	0	0	0	0	571	-2	-787	65-66
66-67	99	212	-1,134	0	0	0	0	0	0	0	0	0	405	59	-359	66-67
67-68	-3	162	-1,132	0	0	0	0	0	0	0	0	376	-73	-148	-817	67-68
68-69	414	415	-1,124	0	0	0	-31	0	0	0	0	0	450	-36	89	68-69
69-70	166	127	-934	0	0	0	0	0	0	0	0	449	225	-155	-122	69-70
70-71	133	138	-1,030	0	1	1	0	0	0	0	0	0	375	142	-239	70-71
71-72	-37	341	-1,137	0	0	0	0	0	0	0	0	0	213	234	-385	71-72
72-73	-54	127	-1,044	0	0	0	0	0	0	0	0	394	0	4	-573	72-73
73-74	0	0	1	-225	30	-310	3	-1	-1	0	0	0	77	204	-224	73-74
74-75	117	412	-1,134	0	0	0	0	0	0	0	0	0	473	371	239	74-75
75-76	-27	7	-1,140	0	0	0	0	0	0	0	0	7	701	436	-17	75-76
76-77	-145	-124	-1,094	-14	0	0	0	0	2	0	3	-2	1	438	-937	76-77
77-78	237	242	-1	1	-34	-591	-353	0	-1	0	0	134	-1	95	-270	77-78
78-79	392	324	-1,115	0	0	0	0	0	0	0	0	281	1	0	-118	78-79
79-80	0	0	-847	-1	-816	562	716	0	1	0	0	167	30	212	23	79-80
80-81	248	256	-1,135	0	0	0	0	0	0	0	0	355	-18	-326	-620	80-81
81-82	69	619	-887	0	0	0	0	-13	0	0	0	0	456	172	415	81-82
82-83	16	207	-1,117	0	0	0	0	0	1	0	0	0	294	403	-197	82-83
83-84	6	192	-1,141	0	0	0	0	0	0	0	0	303	-170	283	-527	83-84
84-85	199	299	-1,138	0	0	0	0	1	-2	0	0	364	43	-1	-234	84-85
85-86	0	0	-919	10	305	0	0	0	0	0	0	288	2	6	-308	85-86
86-87	313	248	-1,067	1	0	0	0	1	-1	0	0	240	1	-1	-265	86-87
87-88	0	0	-1	1	0	0	-1	-28	-124	-84	163	-130	-3	0	-206	87-88
88-89	0	0	-98	0	292	-31	-260	-1,261	803	499	0	178	37	470	629	88-89
89-90	149	78	-1,160	22	0	0	0	0	0	0	0	6	355	374	-175	89-90
90-91	-8	132	-1,143	0	0	0	0	0	0	0	0	4	549	255	-211	90-91
91-92	-124	124	-1,141	0	0	0	0	0	0	0	0	241	-1	199	-702	91-92
92-93	33	336	0	0	-1	0	-268	0	-57	-58	-2	-240	-258	124	-390	92-93
93-94	400	448	-477	1	-448	-199	-1	-33	0	0	0	265	-199	1	-243	93-94
94-95	104	0	0	0	-10	-432	185	-1	0	0	0	239	-48	101	140	94-95
95-96	281	367	-1,140	0	0	0	0	0	0	0	0	25	392	49	-24	95-96
96-97	40	331	-1,137	0	0	0	0	0	0	0	0	2	128	103	-531	96-97
97-98	208	457	-1,153	0	0	0	0	0	0	0	0	225	-225	234	-254	97-98
98-99	294	217	-989	-1	2	5	0	0	0	0	0	0	526	354	408	98-99
AVE	99	216	-951	-13	-17	-18	-4	-26	8	10	3	114	197	140	-242	AVE

The same approach was taken to quantify Federal, non-Federal and individual project hydropower benefits impacts. Tables K.3-14 through K.3-29 summarize the differences in generation between alternative and benchmark combinations for these project groupings. Please note that the units in these tables are expressed in MWh.

TABLE K.3-14. 52-YEAR AVERAGE DIFFERENCE IN FEDERAL GENERATION FOR BENCHMARK COMBINATION LV+HV MINUS BENCHMARK COMBINATION LS+HS (MWH)

	LIB	HGH	GCL	CHJ	MCN	JDA	TDA	BON	TOTAL
AG1	1,440	0	1,800	1,080	0	360	360	360	5,400
AUG	768	0	-384	0	0	0	0	0	384
SEP	0	0	0	0	0	0	0	0	0
OCT	0	0	0	0	0	0	0	0	0
NOV	0	0	15,840	8,640	3,600	5,040	3,600	2,160	38,880
DEC	0	5,208	-8,184	-3,720	-1,488	-2,232	-1,488	-744	-12,648
JAN	-101,928	-23,064	-139,872	-73,656	-23,064	-48,360	-34,968	-20,088	-465,000
FEB	-30,240	-24,864	-51,072	-28,896	-10,080	-17,472	-13,440	-6,720	-182,784
MAR	3,720	4,464	-12,648	-4,464	-1,488	-2,232	-1,488	-744	-14,880
AP1	5,400	-2,160	9,360	7,920	2,880	4,320	3,600	2,160	33,480
APR	7,200	-45,360	-10,440	-1,080	-360	-360	-360	-360	-51,120
MAY	103,416	59,520	31,248	29,016	8,184	17,112	11,904	5,952	266,352
JUN	77,760	32,400	79,920	38,880	10,080	23,760	17,280	8,640	288,720
JUL	11,160	3,720	32,736	15,624	2,976	8,928	5,208	5,208	85,560
TOTAL	78,696	9,864	-51,696	-10,656	-8,760	-11,136	-9,792	-4,176	

TABLE K.3-15. 52-YEAR AVERAGE DIFFERENCE IN FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LV1+HV MINUS ALTERNATIVE COMBINATION LS1+HS

	LIB	HGH	GCL	CHJ	MCN	JDA	TDA	BON	TOTAL
AG1	23,760	0	19,440	10,080	4,320	4,320	2,880	3,600	68,400
AUG	20,736	0	25,344	13,440	5,376	5,760	3,840	3,456	77,952
SEP	6,480	0	4,320	2,160	720	1,440	720	720	16,560
OCT	2,976	0	2,976	1,488	744	744	744	0	9,672
NOV	1,440	0	18,720	10,800	4,320	5,760	4,320	2,880	48,240
DEC	3,720	5,208	-2,232	0	0	0	0	0	6,696
JAN	-100,440	-23,064	-139,872	-72,912	-23,808	-48,360	-34,968	-20,088	-463,512
FEB	-30,240	-24,864	-56,448	-31,584	-11,424	-19,488	-14,784	-8,064	-196,896
MAR	3,720	4,464	-8,928	-2,232	-744	-1,488	-744	0	-5,952
AP1	5,400	-2,160	12,960	9,720	3,600	5,040	4,320	2,520	41,400
APR	7,200	-45,360	-10,440	-1,080	-360	-360	-360	-360	-51,120
MAY	85,560	59,520	17,856	21,576	5,208	13,392	9,672	3,720	216,504
JUN	18,720	32,400	36,000	15,120	3,600	10,080	7,920	2,880	126,720
JUL	52,080	3,720	31,248	14,136	3,720	8,184	5,208	5,208	123,504
TOTAL	101,112	9,864	-49,056	-9,288	-4,728	-14,976	-11,232	-3,528	

(MWH)

TABLE K.3-16. 52-YEAR AVERAGE DIFFERENCE IN FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LV2+HV MINUS ALTERNATIVE COMBINATION LS2+HS(MWH)

	LIB	HGH	GCL	CHJ	MCN	JDA	TDA	BON	TOTAL
AG1	23,400	0	19,800	10,080	4,320	4,320	2,880	3,600	68,400
AUG	21,120	0	26,112	13,824	5,760	5,760	3,840	3,840	80,256
SEP	5,760	0	3,600	2,160	720	720	720	0	13,680
OCT	3,720	0	4,464	2,232	744	744	744	0	12,648
NOV	1,440	0	13,680	7,920	2,880	4,320	2,880	1,440	34,560
DEC	3,720	5,208	0	0	0	0	0	0	8,928
JAN	-100,440	-23,064	-134,664	-70,680	-22,320	-47,616	-34,224	-19,344	-452,352
FEB	-30,240	-24,864	-56,448	-32,256	-11,424	-19,488	-14,784	-8,064	-197,568
MAR	3,720	4,464	-8,928	-2,232	-744	-1,488	-744	0	-5,952
AP1	5,400	-2,160	12,960	9,720	3,600	5,400	4,320	2,520	41,760
APR	7,200	-45,360	-10,440	-1,080	-360	0	0	-360	-50,400
MAY	84,816	59,520	17,112	20,832	5,208	13,392	9,672	3,720	214,272
JUN	18,720	32,400	35,280	15,120	3,600	10,080	8,640	2,880	126,720
JUL	52,080	3,720	31,248	14,136	3,720	8,184	5,208	5,208	123,504
TOTAL	100,416	9,864	-46,224	-10,224	-4,296	-15,672	-10,848	-4,560	

TABLE K.3-17. 52-YEAR AVERAGE DIFFERENCE IN FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LS1+HS MINUS BENCHMARK COMBINATION LS+HS (MWH)

	LIB	HGH	GCL	CHJ	MCN	JDA	TDA	BON	TOTAL
AG1	19,800	0	9,000	5,040	2,160	1,800	1,080	1,440	40,320
AUG	36,864	0	38,016	19,968	8,832	8,448	5,760	5,376	123,264
SEP	-243,360	0	-213,120	-116,640	-48,240	-68,400	-53,280	-34,560	-777,600
OCT	-9,672	0	-9,672	-4,464	-1,488	-2,232	-2,232	-744	-30,504
NOV	-5,040	0	-5,040	-2,160	-720	-1,440	-720	-720	-15,840
DEC	-12,648	0	-13,392	-6,696	-2,976	-4,464	-2,976	-1,488	-44,640
JAN	-2,232	0	-5,208	-2,232	-744	-1,488	-744	-744	-13,392
FEB	0	0	-672	0	0	0	0	0	-672
MAR	0	0	0	0	0	0	0	0	0
AP1	0	0	0	0	0	0	0	0	0
APR	0	0	0	0	0	0	0	0	0
MAY	47,616	0	29,016	16,368	5,208	8,928	5,952	3,720	116,808
JUN	118,080	0	95,040	47,520	12,960	28,080	20,880	10,800	333,360
JUL	-27,528	0	58,032	29,016	4,464	16,368	10,416	8,184	98,952
TOTAL	-78,120	0	-18,000	-14,280	-20,544	-14,400	-15,864	-8,736	

TABLE K.3-18. 52-YEAR AVERAGE DIFFERENCE IN FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LS2+HS MINUS BENCHMARK COMBINATION LS+HS (MWH)

	LIB	HGH	GCL	CHJ	MCN	JDA	TDA	BON	TOTAL
AG1	15,840	0	5,400	3,240	1,440	1,080	720	1,080	28,800
AUG	33,024	0	33,024	17,280	7,680	7,296	4,992	4,224	107,520
SEP	-244,080	0	-214,560	-116,640	-48,960	-68,400	-53,280	-34,560	-780,480
OCT	-10,416	0	-10,416	-5,208	-2,232	-2,976	-2,232	-1,488	-34,968
NOV	-5,040	0	-5,760	-2,880	-720	-1,440	-1,440	-720	-18,000
DEC	-13,392	0	-14,880	-7,440	-2,976	-4,464	-2,976	-1,488	-47,616
JAN	-2,232	0	-5,208	-2,232	-744	-1,488	-744	0	-12,648
FEB	0	0	-672	0	0	0	0	0	-672
MAR	0	0	-744	0	0	0	0	0	-744
AP1	0	0	0	0	0	0	0	0	0
APR	0	0	0	0	0	0	0	0	0
MAY	61,008	0	37,200	20,832	6,696	11,160	7,440	5,208	149,544
JUN	113,040	0	101,520	49,680	13,680	29,520	21,600	11,520	340,560
JUL	-35,712	0	54,312	26,784	3,720	15,624	10,416	7,440	82,584
TOTAL	-87,960	0	-20,784	-16,584	-22,416	-14,088	-15,504	-8,784	

TABLE K.3-19. 52-YEAR AVERAGE DIFFERENCE IN FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LV1+HV MINUS BENCHMARK COMBINATION LV+HV (MWH)

	LIB	HGH	GCL	CHJ	MCN	JDA	TDA	BON	TOTAL
AG1	41,760	0	26,640	14,040	6,120	5,760	3,960	5,040	103,320
AUG	56,832	0	64,128	34,176	14,592	14,592	9,984	9,216	203,520
SEP	-236,880	0	-208,800	-113,760	-47,520	-66,960	-52,560	-33,840	-760,320
OCT	-6,696	0	-5,952	-2,976	-744	-1,488	-744	-744	-19,344
NOV	-2,880	0	-1,440	-720	0	-720	0	0	-5,760
DEC	-9,672	0	-7,440	-3,720	-1,488	-2,232	-1,488	-744	-26,784
JAN	-1,488	0	-4,464	-2,232	-744	-1,488	-744	0	-11,160
FEB	0	0	-5,376	-3,360	-1,344	-2,016	-1,344	-672	-14,112
MAR	0	0	2,976	744	0	744	0	0	4,464
AP1	0	0	3,240	1,800	360	720	360	360	6,840
APR	0	0	0	0	0	0	0	0	0
MAY	29,760	0	15,624	8,928	2,232	5,208	2,976	2,232	66,960
JUN	59,040	0	51,120	23,760	6,480	14,400	10,800	5,040	170,640
JUL	12,648	0	56,544	28,272	5,208	15,624	10,416	8,184	136,896
TOTAL	-57,576	0	-13,200	-15,048	-16,848	-17,856	-18,384	-5,928	

TABLE K.3-20. 52-YEAR AVERAGE DIFFERENCE IN FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LV2+HV MINUS BENCHMARK COMBINATION LV+HV (MWH)

	LIB	HGH	GCL	CHJ	MCN	JDA	TDA	BON	TOTAL
AG1	37,800	0	23,400	12,600	5,400	5,040	3,600	4,320	92,160
AUG	53,760	0	59,904	31,872	13,824	13,440	9,216	8,448	190,464
SEP	-238,320	0	-210,960	-114,480	-47,520	-66,960	-52,560	-34,560	-765,360
OCT	-6,696	0	-6,696	-2,976	-744	-1,488	-1,488	-744	-20,832
NOV	-2,880	0	-7,200	-3,600	-1,440	-2,160	-1,440	-720	-19,440
DEC	-10,416	0	-5,208	-2,976	-1,488	-1,488	-1,488	-744	-23,808
JAN	-1,488	0	0	0	0	0	0	0	-1,488
FEB	0	0	-5,376	-3,360	-1,344	-2,016	-1,344	-672	-14,112
MAR	0	0	2,976	744	0	744	0	0	4,464
AP1	0	0	3,240	1,800	360	720	720	360	7,200
APR	0	0	0	0	0	360	360	0	720
MAY	42,408	0	22,320	12,648	4,464	7,440	5,208	2,976	97,464
JUN	53,280	0	56,160	25,920	6,480	15,840	12,960	5,040	175,680
JUL	4,464	0	52,824	26,040	4,464	14,880	9,672	7,440	119,784
TOTAL	-68,088	0	-14,616	-15,768	-17,544	-15,648	-16,584	-8,856	

The differences in generation for the non-Federal projects grouping are shown in Tables K.3-21 through K.3-27. Please note that the units for these tables are expressed in MWh.

TABLE K.3-21. 52-YEAR AVERAGE DIFFERENCE IN NON-FEDERAL GENERATION FOR BENCHMARK COMBINATION LV+HV MINUS BENCHMARK COMBINATION LS+HS (MWH)

	KER	TOM	NOX	CAB	BOX	BND	PRD	WAN	RIS	RRH	WEL	TOTAL
AG1	0	0	0	0	0	-360	0	0	0	0	0	-360
AUG	0	0	0	0	0	0	0	0	0	0	0	0
SEP	0	0	0	0	0	0	0	0	0	0	0	0
OCT	744	0	744	0	0	1,488	3,720	3,720	1,488	4,464	2,976	19,344
NOV	720	0	1,440	720	0	2,160	-1,440	-1,440	-720	-1,440	-1,440	-1,440
DEC	-8,184	-2,232	-7,440	-4,464	-1,488	-12,648	-21,576	-26,784	-14,136	-35,712	-23,064	-157,728
JAN	-5,952	-2,232	-8,184	-5,208	-1,488	-14,136	-12,648	-14,136	-6,696	-15,624	-11,160	-97,464
FEB	0	0	0	0	0	-672	-1,344	-1,344	-672	-1,344	-1,344	-6,720
MAR	744	0	744	0	0	1,488	5,952	6,696	2,976	7,440	5,952	31,992
AP1	-4,320	-720	-3,960	-2,160	-360	-5,040	0	-360	0	-360	-360	-17,640
APR	0	0	720	0	0	720	2,520	3,960	2,160	5,400	3,600	19,080
MAY	0	0	5,208	0	0	3,720	10,416	11,904	5,952	15,624	10,416	63,240
JUN	0	0	0	0	0	1,440	3,600	3,600	2,160	5,760	4,320	20,880
JUL	-1,488	-744	-744	-744	0	-1,488	-744	-744	-744	-1,488	-744	-9,672
TOTAL	-17,736	-5,928	-11,472	-11,856	-3,336	-23,328	-11,544	-14,928	-8,232	-17,280	-10,848	

TABLE K.3-22. 52-YEAR AVERAGE DIFFERENCE IN NON-FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LV1+HV MINUS ALTERNATIVE COMBINATION LS1+HS (MWH)

	KER	TOM	NOX	CAB	BOX	BND	PRD	WAN	RIS	RRH	WEL	TOTAL
AG1	-360	0	-360	-360	0	-720	2,520	2,520	1,440	4,320	3,240	12,240
AUG	0	0	0	0	0	-384	3,456	3,072	2,688	6,528	4,608	19,968
SEP	0	0	0	0	0	0	720	720	0	720	720	2,880
OCT	0	0	0	0	0	0	744	744	0	744	0	2,232
NOV	1,440	0	1,440	720	0	2,880	4,320	4,320	2,160	5,040	3,600	25,920
DEC	744	0	1,488	744	0	2,232	0	0	0	0	0	5,208
JAN	-8,928	-2,976	-8,184	-5,208	-1,488	-12,648	-21,576	-27,528	-14,136	-35,712	-22,320	-160,704
FEB	-5,376	-2,016	-6,720	-4,032	-1,344	-12,096	-12,768	-14,112	-6,720	-15,456	-11,424	-92,064
MAR	0	0	0	0	0	-744	-744	-744	0	-744	-744	-3,720
AP1	360	0	0	0	0	720	3,960	4,320	1,800	4,680	3,240	19,080
APR	-4,320	-720	-3,960	-2,160	-360	-5,040	0	-360	0	-360	-360	-17,640
MAY	0	0	1,488	0	0	1,488	4,464	5,952	2,976	8,184	4,464	29,016
JUN	0	0	5,040	0	0	3,600	5,040	5,760	2,160	5,760	3,600	30,960
JUL	-744	0	0	0	0	0	3,720	3,720	2,232	5,952	4,464	19,344
TOTAL	-17,184	-5,712	-9,768	-10,296	-3,192	-20,712	-6,144	-11,616	-5,400	-10,344	-6,912	

TABLE K.3-23. 52-YEAR AVERAGE DIFFERENCE IN NON-FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LV2+HV MINUS ALTERNATIVE COMBINATION LS2+HS (MWH)

	KER	TOM	NOX	CAB	BOX	BND	PRD	WAN	RIS	RRH	WEL	TOTAL
AG1	-360	0	-360	0	0	-720	2,520	2,520	1,800	4,320	3,240	12,960
AUG	0	0	0	0	0	-384	3,456	3,072	2,688	6,528	4,608	19,968
SEP	0	0	0	0	0	0	720	720	0	720	720	2,880
OCT	0	0	0	0	0	0	744	744	0	744	744	2,976
NOV	2,160	0	1,440	720	0	2,880	2,880	2,880	1,440	3,600	2,880	20,880
DEC	744	0	1,488	744	0	2,232	0	0	0	0	0	5,208
JAN	-8,928	-2,976	-8,184	-5,208	-1,488	-12,648	-20,832	-26,040	-13,392	-34,224	-21,576	-155,496
FEB	-5,376	-2,016	-6,720	-4,032	-1,344	-12,096	-12,768	-14,112	-6,720	-16,128	-11,424	-92,736
MAR	-744	0	0	0	0	-744	-744	-744	0	-744	-744	-4,464
AP1	360	0	0	0	0	360	3,960	4,320	1,800	4,680	3,240	18,720
APR	-4,320	-720	-3,960	-2,160	-360	-5,040	360	0	0	-360	-360	-16,920
MAY	0	0	1,488	0	0	744	3,720	5,952	2,976	8,184	4,464	27,528
JUN	0	0	5,040	0	0	3,600	5,040	5,760	2,160	5,760	3,600	30,960
JUL	-744	0	0	0	0	0	3,720	3,720	2,232	5,952	4,464	19,344
TOTAL	-17,208	-5,712	-9,768	-9,936	-3,192	-21,816	-7,224	-11,208	-5,016	-10,968	-6,144	

TABLE K.3-24. 52-YEAR AVERAGE DIFFERENCE IN NON-FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LS1+HS MINUS BENCHMARK COMBINATION LS+HS (MWH)

	KER	TOM	NOX	CAB	BOX	BND	PRD	WAN	RIS	RRH	WEL	TOTAL
AG1	-720	0	-720	-360	0	-1,440	1,080	1,080	720	2,160	1,440	3,240
AUG	-1,920	-384	-1,536	-1,152	-384	-3,072	5,376	4,608	3,840	9,600	7,296	22,272
SEP	720	0	720	720	0	1,440	-47,520	-51,840	-25,200	-58,320	-43,920	-223,200
OCT	0	0	0	0	0	744	-1,488	-1,488	-744	-2,232	-1,488	-6,696
NOV	720	0	720	720	0	1,440	-720	-720	0	-720	-720	720
DEC	0	0	0	0	0	744	-2,976	-2,976	-1,488	-3,720	-2,232	-12,648
JAN	0	0	0	0	0	0	-744	-744	0	-744	-744	-2,976
FEB	0	0	0	0	0	-672	0	0	0	0	0	-672
MAR	0	0	0	0	0	0	0	0	0	0	0	0
AP1	0	0	0	0	0	0	0	0	0	0	0	0
APR	0	0	0	0	0	0	0	0	0	0	0	0
MAY	0	0	0	0	0	0	2,976	4,464	2,232	5,952	5,208	20,832
JUN	0	0	0	0	0	0	11,520	12,960	7,200	18,000	12,960	62,640
JUL	0	0	0	0	0	0	7,440	7,440	4,464	11,904	8,184	39,432
TOTAL	-1,200	-384	-816	-72	-384	-816	-25,056	-27,216	-8,976	-18,120	-14,016	

TABLE K.3-25. 52-YEAR AVERAGE DIFFERENCE IN NON-FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LS2+HS MINUS BENCHMARK COMBINATION LS+HS (MWH)

	KER	TOM	NOX	CAB	BOX	BND	PRD	WAN	RIS	RRH	WEL	TOTAL
AG1	-720	0	-720	-360	0	-1,440	720	720	360	1,080	1,080	720
AUG	-1,920	-384	-1,536	-1,152	-384	-3,072	4,608	4,224	3,456	8,448	6,144	18,432
SEP	720	0	720	720	0	1,440	-47,520	-51,840	-25,200	-59,040	-43,920	-223,920
OCT	0	0	0	0	0	744	-1,488	-2,232	-744	-2,232	-1,488	-7,440
NOV	720	0	720	0	0	1,440	-720	-720	0	-1,440	-720	-720
DEC	0	0	0	0	0	0	-2,976	-2,976	-1,488	-3,720	-2,232	-13,392
JAN	0	0	0	0	0	0	-744	-744	0	-744	-744	-2,976
FEB	0	0	0	0	0	-672	0	0	0	0	0	-672
MAR	0	0	0	0	0	0	0	0	0	0	0	0
AP1	0	0	0	0	0	0	0	0	0	0	0	0
APR	0	0	0	0	0	0	0	0	0	0	0	0
MAY	0	0	0	0	0	0	3,720	5,208	2,976	8,184	6,696	26,784
JUN	0	0	0	0	0	0	12,240	13,680	7,920	18,720	12,960	65,520
JUL	0	0	0	0	0	0	7,440	6,696	4,464	11,160	7,440	37,200
TOTAL	-1,200	-384	-816	-792	-384	-1,560	-24,720	-27,984	-8,256	-19,584	-14,784	

TABLE K.3-26. 52-YEAR AVERAGE DIFFERENCE IN NON-FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LV1+HV MINUS BENCHMARK COMBINATION LV+HV (MWH)

	KER	TOM	NOX	CAB	BOX	BND	PRD	WAN	RIS	RRH	WEL	TOTAL
AG1	-1,440	-360	-1,080	-720	0	-2,160	3,600	3,240	2,160	5,760	4,680	13,680
AUG	-1,920	-384	-1,920	-1,152	-384	-3,072	8,832	8,064	6,912	16,512	11,904	43,392
SEP	1,440	0	720	720	0	2,160	-46,800	-51,120	-24,480	-57,600	-42,480	-217,440
OCT	744	0	0	0	0	744	-744	-744	0	-1,488	-744	-2,232
NOV	2,160	720	1,440	720	0	2,880	0	0	0	0	0	7,920
DEC	0	0	0	0	0	744	-1,488	-1,488	-744	-1,488	-1,488	-5,952
JAN	0	0	0	0	0	0	-744	-744	0	-744	-744	-2,976
FEB	0	0	0	0	0	0	-1,344	-1,344	-672	-1,344	-1,344	-6,048
MAR	0	0	0	0	0	0	0	0	0	744	0	744
AP1	0	0	0	0	0	0	360	720	0	720	360	2,160
APR	0	0	0	0	0	0	0	0	0	0	0	0
MAY	0	0	0	0	0	0	1,488	2,232	1,488	2,976	2,232	10,416
JUN	0	0	0	0	0	0	5,760	7,200	3,600	8,640	6,480	31,680
JUL	-744	0	-744	0	0	-1,488	7,440	7,440	4,464	11,904	7,440	35,712
TOTAL	240	-24	-1,584	-432	-384	-192	-23,640	-26,544	-7,272	-15,408	-13,704	

TABLE K.3-27. 52-YEAR AVERAGE DIFFERENCE IN NON-FEDERAL GENERATION FOR ALTERNATIVE COMBINATION LV2+HV MINUS BENCHMARK COMBINATION LV+HV (MWH)

	KER	TOM	NOX	CAB	BOX	BND	PRD	WAN	RIS	RRH	WEL	TOTAL
AG1	-1,080	-360	-1,080	-720	0	-2,160	3,240	2,880	2,160	5,040	3,960	11,880
AUG	-1,920	-384	-1,920	-1,152	-384	-3,072	8,448	7,680	6,528	15,360	11,136	40,320
SEP	720	0	720	720	0	1,440	-46,800	-51,120	-25,200	-58,320	-43,200	-221,040
OCT	0	0	0	0	0	744	-744	-744	0	-1,488	-744	-2,976
NOV	2,160	720	1,440	720	0	2,880	-1,440	-1,440	-720	-2,160	-1,440	720
DEC	0	0	0	0	0	744	-744	-1,488	-744	-1,488	-744	-4,464
JAN	0	0	0	0	0	0	0	0	0	0	0	0
FEB	0	0	0	0	0	0	-1,344	-1,344	-672	-2,016	-1,344	-6,720
MAR	0	0	0	0	0	0	0	0	0	0	0	0
AP1	0	0	0	0	0	0	360	720	0	720	360	2,160
APR	0	0	0	0	0	0	720	360	0	0	0	1,080
MAY	0	0	0	0	0	0	2,232	2,976	1,488	5,208	3,720	15,624
JUN	0	0	0	0	0	0	6,480	7,920	3,600	9,360	6,480	33,840
JUL	-744	0	-744	0	0	-1,488	6,696	6,696	4,464	11,160	6,696	32,736

The 52-year average difference in generation at Libby and Hungry Horse for each comparison of alternative and benchmark combinations is shown in Tables K.3-28 and 3-29.

TABLE K.3-28. 52-YEAR AVERAGE GENERATION DIFFERENCE AT LIBBY (MWH)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	1,440	19,800	15,840	41,760	23,760	23,400	37,800
AUG	768	36,864	33,024	56,832	20,736	21,120	53,760
SEP	0	-243,360	-244,080	-236,880	6,480	5,760	-238,320
OCT	0	-9,672	-10,416	-6,696	2,976	3,720	-6,696
NOV	0	-5,040	-5,040	-2,880	1,440	1,440	-2,880
DEC	0	-12,648	-13,392	-9,672	3,720	3,720	-10,416
JAN	-101,928	-2,232	-2,232	-1,488	-100,440	-100,440	-1,488
FEB	-30,240	0	0	0	-30,240	-30,240	0
MAR	3,720	0	0	0	3,720	3,720	0
AP1	5,400	0	0	0	5,400	5,400	0
APR	7,200	0	0	0	7,200	7,200	0
MAY	103,416	47,616	61,008	29,760	85,560	84,816	42,408
JUN	77,760	118,080	113,040	59,040	18,720	18,720	53,280
JUL	11,160	-27,528	-35,712	12,648	52,080	52,080	4,464
TOTAL	**78,696**	**-78,120**	**-87,960**	**-57,576**	**101,112**	**100,416**	**-68,088**

TABLE K.3-29. 52-YEAR AVERAGE GENERATION DIFFERENCE AT HUNGRY HORSE (MWH)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	0	0	0	0	0	0	0
AUG	0	0	0	0	0	0	0
SEP	0	0	0	0	0	0	0
OCT	0	0	0	0	0	0	0
NOV	0	0	0	0	0	0	0
DEC	5,208	0	0	0	5,208	5,208	0
JAN	-23,064	0	0	0	-23,064	-23,064	0
FEB	-24,864	0	0	0	-24,864	-24,864	0
MAR	4,464	0	0	0	4,464	4,464	0
AP1	-2,160	0	0	0	-2,160	-2,160	0
APR	-45,360	0	0	0	-45,360	-45,360	0
MAY	59,520	0	0	0	59,520	59,520	0
JUN	32,400	0	0	0	32,400	32,400	0
JUL	3,720	0	0	0	3,720	3,720	0
TOTAL	**9,864**	**0**	**0**	**0**	**9,864**	**9,864**	**0**

K.3.3 Heavy Load and Light Load Hours Distribution

The value of energy varies hourly, daily, weekly and seasonally. Hydropower systems such as the Columbia River hydropower system are typically operated to maximize generation during higher value (on-peak) periods and minimize generation during lower value (off-peak) periods. For this evaluation, capturing the value of changes to weekly “on-peak” and “off-peak” energy generation should represent impacts to hydropower benefits for Columbia River basin projects. Heavy load hours (HLH) hours are what are traditionally considered "on-peak" hours. There are 96 HLH in a typical week, Monday through Saturday, 6am to 10pm. Light load hours, (LLH) are traditionally considered "off-peak" hours and are the remaining 72 hours in the week.

Average monthly generation must be determined for HLH and LLH periods. Since HYSSR determines average monthly generation, this generation must be distributed to the various HLH and LLH periods to apply the appropriate energy values. This was accomplished by multiplying the average monthly generation by distribution factors for each period. These factors were computed using an hourly system power production cost model that matched resources against load and accounted for installed powerplant capacity. A distribution factor greater than 1 for HLH meant that during that period average generation was greater than the average monthly generation. A distribution factor less than 1 for LLH meant that, during that period, average generation was less than the average monthly generation. These factors vary by powerplant and hydrologic period. Please note that these factors are derived from average megawatts and to be applied to energy expressed in GWh or MWh they must be weighted by the hours in each period. The monthly generation by period for each month is then multiplied by the unit energy value for each period to come up with the average value for each month and these are then summed to determine the average annual value.

Since the impacts in this study are primarily distributed over the entire system and not limited to one hydro powerplant, weighted distribution factors for the system were determined and applied to the change in generation. The average for the 52-year hydrologic period simulated in HYSSR was used to distribute the average generation changes for the VARQ study. Table K.3-30 summarizes the monthly distribution factors used to determine HLH and LLH generation.

TABLE K.3-30. MONTHLY LIGHT AND HEAVY LOAD HOURS DISTRIBUTION FACTORS

Month	Light Load Hours	Heavy Load Hours
Aug 1-15	0.72	1.21
Aug 16-31	0.73	1.20
Sep	0.71	1.22
Oct	0.69	1.23
Nov	0.71	1.22
Dec	0.67	1.25
Jan	0.74	1.20
Feb	0.73	1.20
Mar	0.72	1.21
Apr 1-15	0.81	1.14
Apr 16-30	0.78	1.16
May	0.80	1.15
Jun	0.76	1.18
Jul	0.73	1.20

These distribution factors were applied to the change in long-term monthly average generation to determine the energy difference by period. The change in monthly generation by period is then multiplied by the unit energy value for each period to compute the average value for each month and then summed to determine the total change in generation for that period. This methodology is illustrated below.

The units for energy values are in $/MWh. Average megawatt values from HYSSR were multiplied by the hours in each period to convert to the MWh units. For example, assume generation for an alternative changed by 5,400 MWh for the AG1 period. As discussed previously, for a typical week, there are 72 LLH, and 96 HLH. Using the distribution factors shown in Table K.3-14 and adjusting for the number of HLH and LLH hours, the generation for HLH and LLH time periods is computed as follows:

For HLH: change in generation = 1.21*5,400*(96/168) = 3,734 MWh

For LLH: change in generation = 0.72*5,400*(72/168) = 1,666 MWh

Total = 5,400 MWh

For this example, the average change in hydropower benefits is the difference in energy generation for the period times the energy value for that period. For the AG1 period, the change in hydropower benefits would be:

For HLH, 3,734 MWh * 48.48 $/MWh = $ 181,024

For LLH, 1,666 MWh * 38.21 $/MWh = $ 63,658

The energy value used here was taken from Table K.3-47 of this report. A discussion on the derivation of monthly energy values follows in the next section.

K.3.4 Heavy Load and Light Load Hours Generation

As described in Section K.3.3, on-peak and off-peak distribution factors were used to determine the generation during heavy load hours and light load hours for each of the monthly period simulated in HYSSR.

Tables K.3-31 through K.3-36 show the total HLH and LLH generation during each period of the year for each of the alternative and benchmark combinations and project groupings. Although calculations were done in MWh, the total generation in these tables is shown in GWh due to its magnitude. Tables K.3-37 through K.3-46 show HLH and LLH generation differences during each period of the year for each of the alternative and benchmark combinations and project groupings as well as for Libby and Hungry Horse individually. Data in the generation difference tables are reported in units of MWh to prevent a zero result caused by rounding for differences that are less than one GWh, and for consistency with the unit energy values.

TABLE K.3-31. SYSTEM HEAVY LOAD HOURS GENERATION BY ALTERNATIVE COMBINATION AND BENCHMARK COMBINATION (GWH)

	Alternative Combinations					Benchmark Combinations	
	LS1+HS	LV1+HV	LS2+HS	LV2+HV		LS+HS	LV+HV
AG1	3,420	3,474	3,410	3,465		3,389	3,397
AUG	3,055	3,120	3,042	3,110		2,961	2,961
SEP	4,347	4,369	4,344	4,363		5,020	5,024
OCT	5,499	5,517	5,495	5,515		5,519	5,524
NOV	6,297	6,356	6,293	6,340		6,295	6,352
DEC	7,504	7,513	7,501	7,516		7,535	7,529
JAN	10,101	9,674	10,101	9,684		10,117	9,687
FEB	7,353	7,154	7,353	7,154		7,358	7,172
MAR	7,588	7,577	7,587	7,577		7,588	7,571
AP1	3,515	3,556	3,515	3,557		3,516	3,550
APR	3,812	3,764	3,812	3,766		3,812	3,764
MAY	9,461	9,627	9,486	9,650		9,366	9,575
JUN	9,460	9,552	9,472	9,560		9,230	9,427
JUL	8,538	8,639	8,525	8,626		8,443	8,530
TOTAL	**89,951**	**89,892**	**89,935**	**89,881**		**90,149**	**90,062**

TABLE K.3-32. FEDERAL HEAVY LOAD HOURS GENERATION BY ALTERNATIVE COMBINATION AND BENCHMARK COMBINATION (GWH)

	Alternative Combinations					Benchmark Combinations	
	LS1+HS	LV1+HV	LS2+HS	LV2+HV		LS+HS	LV+HV
AG1	1,900	1,947	1,892	1,940		1,871	1,875
AUG	1,634	1,688	1,623	1,680		1,549	1,548
SEP	2,234	2,247	2,231	2,243		2,776	2,777
OCT	2,779	2,787	2,777	2,787		2,802	2,802
NOV	3,005	3,040	3,003	3,030		3,017	3,046
DEC	3,803	3,808	3,801	3,809		3,837	3,828
JAN	5,476	5,157	5,476	5,164		5,487	5,167
FEB	3,417	3,280	3,417	3,280		3,418	3,292
MAR	3,605	3,598	3,604	3,598		3,606	3,594
AP1	1,672	1,699	1,672	1,699		1,672	1,694
APR	1,932	1,897	1,932	1,898		1,932	1,897
MAY	4,914	5,058	4,934	5,077		4,834	5,012
JUN	4,904	4,992	4,909	4,995		4,678	4,875
JUL	4,608	4,694	4,596	4,683		4,537	4,598
TOTAL	**45,880**	**45,892**	**45,867**	**45,882**		**46,015**	**46,007**

TABLE K.3-33. NON-FEDERAL HEAVY LOAD HOURS GENERATION BY ALTERNATIVE COMBINATION AND BENCHMARK COMBINATION (GWH)

	Alternative Combinations					Benchmark Combinations	
	LS1+HS	LV1+HV	LS2+HS	LV2+HV		LS+HS	LV+HV
AG1	723	736	708	734		708	707
AUG	563	565	644	564		644	644
SEP	1,327	1,329	1,331	1,329		1,331	1,331
OCT	1,655	1,675	1,654	1,670		1,654	1,670
NOV	1,663	1,667	1,672	1,668		1,672	1,671
DEC	2,454	2,337	2,456	2,340		2,456	2,340
JAN	1,799	1,727	1,800	1,727		1,800	1,732
FEB	1,496	1,492	1,497	1,492		1,497	1,490
MAR	1,891	1,921	1,891	1,921		1,891	1,918
AP1	890	876	890	877		890	876
APR	1,146	1,156	1,139	1,158		1,139	1,152
MAY	2,434	2,454	2,391	2,456		2,391	2,432
JUN	2,077	2,091	2,051	2,089		2,051	2,068
JUL	1,857	1,850	1,863	1,850		1,863	1,856
TOTAL	**21,975**	**21,878**	**21,986**	**21,876**		**21,986**	**21,887**

TABLE K.3-34. SYSTEM LIGHT LOAD HOURS GENERATION BY ALTERNATIVE COMBINATION AND BENCHMARK COMBINATION (GWH)

	Alternative Combinations					Benchmark Combinations	
	LS1+HS	LV1+HV	LS2+HS	LV2+HV		LS+HS	LV+HV
AG1	1,530	1,554	1,525	1,550		1,516	1,520
AUG	1,400	1,430	1,395	1,426		1,357	1,358
SEP	1,903	1,912	1,901	1,909		2,197	2,199
OCT	2,299	2,306	2,297	2,305		2,307	2,309
NOV	2,736	2,762	2,735	2,755		2,735	2,760
DEC	3,011	3,014	3,009	3,015		3,023	3,021
JAN	4,685	4,487	4,685	4,491		4,692	4,493
FEB	3,377	3,286	3,377	3,285		3,379	3,293
MAR	3,386	3,382	3,386	3,382		3,386	3,379
AP1	1,878	1,900	1,878	1,900		1,878	1,896
APR	1,931	1,907	1,931	1,908		1,931	1,907
MAY	4,921	5,008	4,934	5,020		4,872	4,980
JUN	4,562	4,606	4,568	4,610		4,451	4,546
JUL	3,892	3,938	3,886	3,932		3,849	3,888
TOTAL	**41,512**	**41,492**	**41,507**	**41,489**		**41,575**	**41,549**

TABLE K.3-35. FEDERAL LIGHT LOAD HOURS GENERATION BY ALTERNATIVE COMBINATION AND BENCHMARK COMBINATION (GWH)

	Alternative Combinations				Benchmark Combinations	
	LS1+HS	LV1+HV	LS2+HS	LV2+HV	LS+HS	LV+HV
AG1	850	871	846	868	837	839
AUG	749	774	744	770	710	710
SEP	978	984	976	982	1,215	1,215
OCT	1,162	1,165	1,161	1,165	1,171	1,171
NOV	1,306	1,321	1,305	1,317	1,311	1,324
DEC	1,526	1,528	1,525	1,528	1,539	1,536
JAN	2,540	2,392	2,540	2,395	2,545	2,396
FEB	1,569	1,506	1,569	1,506	1,570	1,512
MAR	1,609	1,606	1,608	1,606	1,609	1,604
AP1	893	908	893	908	893	905
APR	979	961	979	962	979	961
MAY	2,556	2,631	2,567	2,641	2,514	2,607
JUN	2,365	2,407	2,368	2,409	2,256	2,351
JUL	2,100	2,140	2,095	2,135	2,068	2,096
TOTAL	**21,180**	**21,193**	**21,176**	**21,190**	**21,218**	**21,228**

TABLE K.3-36. NON-FEDERAL LIGHT LOAD HOURS GENERATION BY ALTERNATIVE COMBINATION AND BENCHMARK COMBINATION (GWH)

	Alternative Combinations				Benchmark Combinations	
	LS1+HS	LV1+HV	LS2+HS	LV2+HV	LS+HS	LV+HV
AG1	323	329	322	328	317	316
AUG	258	259	258	259	295	295
SEP	581	582	580	582	583	583
OCT	692	700	691	698	691	698
NOV	723	725	723	725	726	726
DEC	985	938	985	939	985	939
JAN	835	801	834	801	835	803
FEB	687	685	687	685	687	684
MAR	844	858	844	858	844	856
AP1	475	468	475	469	475	468
APR	581	586	582	587	577	584
MAY	1,266	1,277	1,267	1,278	1,244	1,265
JUN	1,002	1,008	1,001	1,007	989	997
JUL	847	844	847	844	849	846
TOTAL	**10,097**	**10,058**	**10,096**	**10,058**	**10,098**	**10,061**

TABLE K.3-37. SYSTEM HEAVY LOAD HOURS GENERATION DIFFERENCES (MWH)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	7,271	30,479	20,204	77,623	54,414	55,132	68,066
AUG	608	93,914	81,063	158,253	64,947	67,777	148,232
SEP	4,228	-673,139	-676,625	-655,524	21,843	19,118	-661,736
OCT	5,812	-19,262	-23,540	-7,497	17,577	20,170	-9,182
NOV	56,908	1,911	-2,114	4,063	59,060	46,976	-12,046
DEC	-5,269	-30,337	-33,544	-16,317	8,751	15,072	-13,203
JAN	-430,306	-15,424	-15,571	-13,000	-427,882	-417,403	-2,668
FEB	-186,685	-4,959	-5,455	-17,260	-198,986	-198,791	-17,562
MAR	-16,728	-109	-712	6,341	-10,278	-10,160	5,856
AP1	34,161	-645	-668	6,372	41,178	41,345	6,516
APR	-48,008	152	138	9	-48,150	-46,037	2,109
MAY	208,485	94,572	119,269	52,218	166,131	164,437	75,221
JUN	196,876	230,365	242,284	125,117	91,628	87,826	133,234
JUL	86,052	94,976	81,463	109,953	101,030	100,705	96,116
TOTAL	**-86,596**	**-197,508**	**-213,808**	**-169,650**	**-58,737**	**-53,833**	**-181,046**

TABLE K.3-38. FEDERAL HEAVY LOAD HOURS GENERATION DIFFERENCES (MWH)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	3,731	27,858	19,898	71,385	47,259	47,259	63,675
AUG	263	84,516	73,721	139,544	53,448	55,028	130,592
SEP	0	-540,876	-542,880	-528,857	11,519	9,515	-532,363
OCT	0	-21,512	-24,660	-13,642	6,821	8,920	-14,691
NOV	27,103	-11,042	-12,548	-4,015	33,627	24,091	-13,551
DEC	-9,027	-31,859	-33,983	-19,115	4,779	6,372	-16,991
JAN	-317,666	-9,149	-8,641	-7,624	-316,650	-309,026	-1,017
FEB	-125,260	-461	-461	-9,671	-134,931	-135,391	-9,671
MAR	-10,288	0	-514	3,086	-4,115	-4,115	3,086
AP1	21,823	0	0	4,459	26,986	27,220	4,693
APR	-33,929	0	0	0	-33,929	-33,451	478
MAY	175,214	76,840	98,374	44,048	142,422	140,954	64,115
JUN	194,784	224,900	229,758	115,122	85,491	85,491	118,522
JUL	58,770	67,969	56,726	94,032	84,834	84,834	82,278
TOTAL	**-14,482**	**-132,816**	**-145,208**	**-111,248**	**7,561**	**7,700**	**-120,845**

TABLE K.3-39. NON-FEDERAL HEAVY LOAD HOURS GENERATION DIFFERENCES (MWH)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	-249	2,239	497	9,452	8,457	8,954	8,208
AUG	0	15,271	12,638	29,752	13,691	13,691	27,645
SEP	0	-155,252	-155,752	-151,245	2,003	2,003	-153,749
OCT	13,642	-4,722	-5,247	-1,574	1,574	2,099	-2,099
NOV	-1,004	502	-502	5,521	18,068	14,555	502
DEC	-112,568	-9,027	-9,558	-4,248	3,717	3,717	-3,186
JAN	-66,583	-2,033	-2,033	-2,033	-109,785	-106,228	0
FEB	-4,605	-461	-461	-4,145	-63,090	-63,551	-4,605
MAR	22,120	0	0	514	-2,572	-3,086	0
AP1	-11,498	0	0	1,408	12,437	12,202	1,408
APR	12,664	0	0	0	-11,708	-11,230	717
MAY	41,601	13,704	17,619	6,852	19,088	18,109	10,278
JUN	14,087	42,260	44,203	21,373	20,887	20,887	22,830
JUL	-6,644	27,085	25,552	24,530	13,287	13,287	22,486
TOTAL	**-99,038**	**-70,434**	**-73,043**	**-63,843**	**-73,947**	**-74,590**	**-69,565**

TABLE K.3-40. LIBBY HEAVY LOAD HOURS GENERATION DIFFERENCES (MWH)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	995	13,680	10,944	28,853	16,416	16,167	26,117
AUG	527	25,276	22,643	38,967	14,218	14,481	36,861
SEP	0	-169,274	-169,775	-164,767	4,507	4,006	-165,769
OCT	0	-6,821	-7,346	-4,722	2,099	2,623	-4,722
NOV	0	-3,513	-3,513	-2,008	1,004	1,004	-2,008
DEC	0	-9,027	-9,558	-6,903	2,655	2,655	-7,434
JAN	-69,632	-1,525	-1,525	-1,017	-68,616	-68,616	-1,017
FEB	-20,723	0	0	0	-20,723	-20,723	0
MAR	2,572	0	0	0	2,572	2,572	0
AP1	3,520	0	0	0	3,520	3,520	0
APR	4,779	0	0	0	4,779	4,779	0
MAY	68,030	31,323	40,133	19,577	56,284	55,794	27,897
JUN	52,460	79,662	76,262	39,831	12,629	12,629	35,945
JUL	7,666	-18,909	-24,530	8,688	35,773	35,773	3,066
TOTAL	**50,193**	**-59,127**	**-66,265**	**-43,501**	**67,117**	**66,666**	**-51,063**

TABLE K.3-41. HUNGRY HORSE HEAVY LOAD HOURS GENERATION DIFFERENCES (MWH)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	0	0	0	0	0	0	0
AUG	0	0	0	0	0	0	0
SEP	0	0	0	0	0	0	0
OCT	0	0	0	0	0	0	0
NOV	0	0	0	0	0	0	0
DEC	3,717	0	0	0	3,717	3,717	0
JAN	-15,756	0	0	0	-15,756	-15,756	0
FEB	-17,039	0	0	0	-17,039	-17,039	0
MAR	3,086	0	0	0	3,086	3,086	0
AP1	-1,408	0	0	0	-1,408	-1,408	0
APR	-30,106	0	0	0	-30,106	-30,106	0
MAY	39,154	0	0	0	39,154	39,154	0
JUN	21,859	0	0	0	21,859	21,859	0
JUL	2,555	0	0	0	2,555	2,555	0
TOTAL	**6,062**	**0**	**0**	**0**	**6,062**	**6,062**	**0**

TABLE K.3-42. SYSTEM LIGHT LOAD HOURS GENERATION DIFFERENCES (MWH)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	3,253	13,635	9,039	34,725	24,343	24,664	30,450
AUG	279	43,056	37,165	72,554	29,776	31,074	67,960
SEP	1,850	-294,611	-296,137	-286,901	9,560	8,367	-289,620
OCT	2,429	-8,052	-9,840	-3,134	7,347	8,431	-3,838
NOV	24,729	830	-919	1,766	25,664	20,413	-5,234
DEC	-2,114	-12,171	-13,457	-6,546	3,511	6,046	-5,297
JAN	-199,577	-7,154	-7,222	-6,029	-198,452	-193,593	-1,238
FEB	-85,733	-2,278	-2,505	-7,927	-91,383	-91,293	-8,065
MAR	-7,466	-49	-318	2,830	-4,587	-4,534	2,614
AP1	18,247	-345	-357	3,404	21,995	22,084	3,481
APR	-24,325	77	70	5	-24,397	-23,326	1,069
MAY	108,445	49,192	62,038	27,161	86,414	85,533	39,126
JUN	94,945	111,095	116,844	60,339	44,189	42,355	64,253
JUL	39,226	43,294	37,134	50,121	46,053	45,906	43,813
TOTAL	**-25,811**	**-63,478**	**-68,465**	**-57,633**	**-19,967**	**-17,873**	**-60,526**

TABLE K.3-43. FEDERAL LIGHT LOAD HOURS GENERATION DIFFERENCES (MWH)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	1,669	12,462	8,902	31,935	21,142	21,142	28,485
AUG	121	38,748	33,799	63,976	24,504	25,228	59,872
SEP	0	-236,724	-237,601	-231,464	5,041	4,165	-232,998
OCT	0	-8,992	-10,308	-5,702	2,851	3,728	-6,141
NOV	11,777	-4,798	-5,452	-1,745	14,613	10,469	-5,889
DEC	-3,621	-12,781	-13,633	-7,669	1,917	2,556	-6,817
JAN	-147,334	-4,243	-4,007	-3,536	-146,863	-143,327	-471
FEB	-57,524	-211	-211	-4,441	-61,966	-62,177	-4,441
MAR	-4,592	0	-230	1,378	-1,837	-1,837	1,378
AP1	11,657	0	0	2,381	14,414	14,540	2,507
APR	-17,191	0	0	0	-17,191	-16,949	242
MAY	91,138	39,969	51,170	22,912	74,082	73,318	33,350
JUN	93,936	108,460	110,803	55,518	41,229	41,229	57,158
JUL	26,790	30,983	25,858	42,864	38,671	38,671	37,506
TOTAL	**6,826**	**-37,128**	**-40,912**	**-33,592**	**10,607**	**10,756**	**-36,259**

TABLE K.3-44. NON-FEDERAL LIGHT LOAD HOURS GENERATION DIFFERENCES (MWH)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	-111	1,001	223	4,228	3,783	4,006	3,672
AUG	0	7,001	5,794	13,640	6,277	6,277	12,675
SEP	0	-67,949	-68,168	-66,195	877	877	-67,291
OCT	5,702	-1,974	-2,193	-658	658	877	-877
NOV	-436	218	-218	2,399	7,852	6,325	218
DEC	-45,160	-3,621	-3,834	-1,704	1,491	1,491	-1,278
JAN	-30,881	-943	-943	-943	-50,919	-49,269	0
FEB	-2,115	-211	-211	-1,903	-28,974	-29,185	-2,115
MAR	9,872	0	0	230	-1,148	-1,378	0
AP1	-6,142	0	0	752	6,643	6,518	752
APR	6,416	0	0	0	-5,932	-5,690	363
MAY	21,639	7,128	9,165	3,564	9,928	9,419	5,346
JUN	6,793	20,380	21,317	10,307	10,073	10,073	11,010
JUL	-3,028	12,347	11,648	11,182	6,057	6,057	10,250
TOTAL	**-37,451**	**-26,623**	**-27,421**	**-25,101**	**-33,333**	**-33,602**	**-27,275**

TABLE K.3-45. LIBBY LIGHT LOAD HOURS GENERATION DIFFERENCES (MWH)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	445	6,120	4,896	12,907	7,344	7,233	11,683
AUG	241	11,588	10,381	17,865	6,518	6,639	16,899
SEP	0	-74,086	-74,305	-72,113	1,973	1,754	-72,552
OCT	0	-2,851	-3,070	-1,974	877	1,097	-1,974
NOV	0	-1,527	-1,527	-872	436	436	-872
DEC	0	-3,621	-3,834	-2,769	1,065	1,065	-2,982
JAN	-32,296	-707	-707	-471	-31,824	-31,824	-471
FEB	-9,517	0	0	0	-9,517	-9,517	0
MAR	1,148	0	0	0	1,148	1,148	0
AP1	1,880	0	0	0	1,880	1,880	0
APR	2,421	0	0	0	2,421	2,421	0
MAY	35,386	16,293	20,875	10,183	29,276	29,022	14,511
JUN	25,300	38,418	36,778	19,209	6,091	6,091	17,335
JUL	3,494	-8,619	-11,182	3,960	16,307	16,307	1,398
TOTAL	**28,503**	**-18,993**	**-21,695**	**-14,075**	**33,996**	**33,751**	**-17,025**

TABLE K.3-46. HUNGRY HORSE LIGHT LOAD HOURS GENERATION DIFFERENCES (MWH)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	0	0	0	0	0	0	0
AUG	0	0	0	0	0	0	0
SEP	0	0	0	0	0	0	0
OCT	0	0	0	0	0	0	0
NOV	0	0	0	0	0	0	0
DEC	1,491	0	0	0	1,491	1,491	0
JAN	-7,308	0	0	0	-7,308	-7,308	0
FEB	-7,825	0	0	0	-7,825	-7,825	0
MAR	1,378	0	0	0	1,378	1,378	0
AP1	-752	0	0	0	-752	-752	0
APR	-15,254	0	0	0	-15,254	-15,254	0
MAY	20,366	0	0	0	20,366	20,366	0
JUN	10,541	0	0	0	10,541	10,541	0
JUL	1,165	0	0	0	1,165	1,165	0
TOTAL	**3,802**	**0**	**0**	**0**	**3,802**	**3,802**	**0**

K.3.5 Derivation of Monthly Energy Values

Monthly energy values used to estimate the impact on annual energy benefits of the various alternative and benchmark combinations are based on hourly marginal costs that were developed by the Bonneville Power Administration (BPA). BPA utilized two models in the process of developing these hourly marginal costs, HYDSIM and AURORA.

HYDSIM is a hydro-regulation model whose operation is very similar to the Corps' HYSSR model. That is, HYDSIM simulates the power generating and non-power characteristics of the Columbia River Basin system of water control projects for given power loads and varying flow conditions. Like HYSSR, HYDSIM utilizes a monthly time step when regulating the system of hydropower projects. One difference that exists between HYDSIM and HYSSR is that HYDSIM simulates a 50-year water record (August 1928 through July 1978) instead of the 60-year water record (August 1928 through July 1988) capability of HYSSR. As mention previously, only 52 years were used in simulations by HYSSR for this study. Output from HYDSIM that served as input to the AURORA model consisted of the system monthly generation over the 50-year period of record.

AURORA is a chronological hourly production-cost model that economically simulate the operation of an electric power system. AURORA dispatches system generating resources hour-by-hour in order to meet hourly system loads, with the resources having the least variable costs (primarily the cost of fuel) being dispatched first. Other user-defined constraints on a generating resource can affect when the resource is dispatched, also.

Using the AURORA model, BPA was able to develop hourly marginal costs for the load year being modeled, with the hourly marginal cost being equal to the variable cost of the last-added resource used to meet the hourly system load. Hourly values are grouped into two blocks, light load and heavy load. The values assigned to these blocks integrate the capacity component into the $/MWh energy price. Generally, for any given day, the value during the heavy load hours will be higher than the light load hours. The values in each block are generated in the AURORA model and reflect the market-clearing price for each hour.

BPA typically models the loads and resources of the electric power system contained within the Western Electricity Coordinating Council (WECC), a region that consists of the western portions of the United States and Canada. The main input to the AURORA model consists of the operating costs and operating characteristics of the

system generating resources and major transmission lines contained within the WECC, projected WECC loads for the load year being modeled, and historical-based factors that are used to shape the HYDSIM system monthly generation to meet the hourly loads.

In developing the hourly marginal costs that served as the basis for the monthly energy values utilized in this study, BPA elected to model the load year extending from October 2009 through September 2010. AURORA dispatched hydropower and thermal generating resources of the WECC hour-by-hour in order to meet the WECC hourly loads for this year. Since the 50 water years of Columbia River Basin system monthly generation obtained from HYDSIM served as input to AURORA, this process was carried out a total of 50 times, once for each water year. The output from AURORA consisted of, for each of the 50 water years, an hourly marginal cost for each hour of the yearly period from October 2009 through September 2010. The output from the AURORA simulations was consolidated into a single file containing 8,760 hourly marginal cost values for each of the 50 water years.

These are the assumptions used in AURORA for determining energy values for this analysis:

- Load year Oct. 2009 - Sept. 2010 was modeled using AURORA.
- 50 water years of Columbia River Basin system monthly generation obtained from HYDSIM served as input to AURORA.
- Each of the 50 water years/monthly generation was run for the modeled load year.
- An hourly marginal cost for each hour of the yearly period Oct. 2009 to Sept. 2010 was determined
- BPA provided a file containing 8,760 hourly marginal costs values for each of the 50 water years.
- These values represent the Mid-Columbia trading hub prices.
- Initial values were at the 2009-10 price level. They were de-escalated at a rate of 2.5% to 2004 price level to remove inflation.

The VARQ HYSSR study results include 14 periods per year (12 monthly values with April and August split into 2 periods each). The hourly AURORA results were used to calculate average hourly values for these 14 periods. Since it is recognized that the Federal Columbia River hydropower system is operated primarily as a peaking resource and energy prices varies throughout a typical day, average values were broken into two sub-periods for each of the 14 periods: Light Load Hours (LLH) and Heavy Load Hours (HLH).

The input data for the AURORA simulations included the simulated hydrologic period 1928-29 to 1977-78 (50 years). The VARQ HYSSR simulations use the 52-year hydrologic period 1947-48 to 1998-99. Since the hydrologic periods for the AURORA data and this study are different, it was decided to use the 50-year average value for each of the 14 periods and to apply this to the average energy change for each period in this study. Unit power values used to quantify hydropower benefits are shown below in Table K.3-47.

TABLE K.3-47. AVERAGE MONTHLY ENERGY VALUES ($/MWH)

Month	Light Load Hours	Heavy Load Hours
Aug 1-15	38.21	48.48
Aug 16-31	33.78	39.37
Sep	37.54	42.38
Oct	32.53	38.59
Nov	36.07	50.11
Dec	37.67	57.84
Jan	34.59	47.82
Feb	37.01	55.21
Mar	32.56	37.58
Apr 1-15	29.18	32.98
Apr 16-30	28.78	33.10
May	25.05	26.28
Jun	19.23	24.31
Jul	28.56	37.85

K.4 COMPUTATION OF HYDROPOWER BENEFITS IMPACTS

The average monthly energy values computed in Table K.3-48 for HLH and LLH were applied to the generation difference between the compared alternative combinations for each of the 14 periods. Average annual hydropower benefits impacts for the System, Federal, and non-Federal project groupings due to VARQ operations were computed and are summarized in Sections 4.1 through K.4.3. At-site hydropower benefits impact at Libby and Hungry Horse are shown in Section K.4.4.

K.4.1 Computation of System Hydropower Benefits Impacts

For each of the project groupings, the difference in generation (MWh) was multiplied by the average monthly energy value ($/MWh) to derive hydropower benefits impacts during HLH and LLH periods for each alternative combination and comparison of alternative combinations. Tables K.4-1 through K.4-12 summarize the economic impacts on the three project groupings, System, Federal, and non-Federal. Note that federal and nonfederal values do not necessarily add up to system values because the system includes projects which did not need to be evaluated for this effort.

During HLH and LLH periods for the System projects, VARQ alternative combinations (LV1+HV, LV2+HV) and benchmark combination (LV+HV) produced lower benefits than did Standard FC alternative combinations (LS1+HS, LS2+HS) and benchmark combination (LS+HS). Alternative combinations (LS1+HS, LV1+HV, LS2+HS, LV2+HV) did likewise compared to their benchmark combination counterparts without Libby fish flows (LS+HS, LV+HV). Average annual benefit differences during the HLH generation period are approximately three times as great compared to the LLH period.

The months of December, January, and February are considered critical generation periods in the Columbia River basin due to a high demand for power and low flows to produce hydropower. Tables K.4-1 to 4-4 summarize the results for System hydropower benefits for each alternative and benchmark combination, and comparisons of alternative and benchmark combinations.

TABLE K.4-1. SYSTEM HLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000)

	Alternative Combinations					Benchmark Combinations	
	LS1+HS	LV1+HV	LS2+HS	LV2+HV		LS+HS	LV+HV
AG1	165,852	168,491	165,353	168,027		164,374	164,726
AUG	120,291	122,848	119,785	122,454		116,592	116,616
SEP	184,297	185,223	184,149	184,960		212,835	213,014
OCT	212,301	212,980	212,136	212,915		213,045	213,269
NOV	315,685	318,645	315,483	317,838		315,589	318,442
DEC	434,232	434,738	434,046	434,919		435,987	435,683
JAN	483,267	462,796	483,260	463,291		484,005	463,418
FEB	406,135	395,144	406,107	395,128		406,409	396,097
MAR	285,217	284,830	285,194	284,812		285,221	284,592
AP1	115,973	117,331	115,972	117,336		115,994	117,121
APR	126,214	124,619	126,213	124,689		126,209	124,619
MAY	248,742	253,110	249,392	253,715		246,256	251,737
JUN	230,100	232,329	230,390	232,526		224,497	229,285
JUL	323,288	327,113	322,776	326,589		319,692	322,950
TOTAL	**3,651,591**	**3,640,198**	**3,650,256**	**3,639,196**		**3,666,703**	**3,651,570**

TABLE K.4-2. SYSTEM LLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000)

	Alternative Combinations					Benchmark Combinations	
	LS1+HS	LV1+HV	LS2+HS	LV2+HV		LS+HS	LV+HV
AG1	58,476	59,407	58,301	59,243		57,955	58,080
AUG	47,326	48,332	47,127	48,177		45,871	45,880
SEP	71,456	71,815	71,399	71,713		82,521	82,590
OCT	74,805	75,044	74,747	75,022		75,067	75,146
NOV	98,747	99,673	98,684	99,421		98,717	99,609
DEC	113,463	113,595	113,414	113,642		113,921	113,842
JAN	162,127	155,260	162,125	155,425		162,375	155,468
FEB	125,027	121,644	125,019	121,639		125,112	121,937
MAR	110,299	110,150	110,290	110,142		110,301	110,057
AP1	54,809	55,451	54,809	55,454		54,820	55,352
APR	55,612	54,909	55,612	54,940		55,610	54,909
MAY	123,323	125,488	123,645	125,788		122,090	124,808
JUN	87,746	88,596	87,857	88,671		85,610	87,436
JUL	111,184	112,500	111,008	112,319		109,947	111,068
TOTAL	**1,294,401**	**1,291,864**	**1,294,035**	**1,291,597**		**1,299,915**	**1,296,183**

TABLE K.4-3. SYSTEM HLH COMPARISON OF ALTERNATIVE AND BENCHMARK COMBINATIONS HYDROPOWER BENEFITS ($1,000)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	353	1,478	980	3,764	2,639	2,674	3,301
AUG	24	3,698	3,192	6,232	2,558	2,669	5,837
SEP	179	-28,538	-28,686	-27,791	926	810	-28,055
OCT	224	-744	-909	-289	679	779	-354
NOV	2,853	96	-106	204	2,961	2,355	-604
DEC	-305	-1,755	-1,941	-944	506	872	-764
JAN	-20,586	-738	-745	-622	-20,470	-19,969	-128
FEB	-10,311	-274	-301	-953	-10,990	-10,980	-970
MAR	-629	-4	-27	238	-386	-382	220
AP1	1,127	-21	-22	210	1,358	1,364	215
APR	-1,590	5	5	0	-1,594	-1,524	70
MAY	5,481	2,486	3,136	1,373	4,368	4,323	1,978
JUN	4,789	5,603	5,893	3,043	2,229	2,136	3,241
JUL	3,258	3,596	3,084	4,163	3,825	3,813	3,639
TOTAL	**-15,132**	**-15,111**	**-16,447**	**-11,372**	**-11,393**	**-11,059**	**-12,374**

TABLE K.4-4. SYSTEM LLH COMPARISON OF ALTERNATIVE AND BENCHMARK COMBINATIONS HYDROPOWER BENEFITS ($1,000)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	124	521	345	1,327	930	943	1,164
AUG	9	1,455	1,256	2,452	1,006	1,050	2,297
SEP	69	-11,065	-11,122	-10,775	359	314	-10,877
OCT	79	-262	-320	-102	239	274	-125
NOV	892	30	-33	64	926	737	-189
DEC	-80	-459	-507	-247	132	228	-200
JAN	-6,906	-248	-250	-209	-6,867	-6,699	-43
FEB	-3,174	-84	-93	-293	-3,383	-3,380	-299
MAR	-243	-2	-10	92	-149	-148	85
AP1	533	-10	-10	99	642	645	102
APR	-700	2	2	0	-702	-672	31
MAY	2,718	1,233	1,555	681	2,166	2,143	981
JUN	1,826	2,137	2,247	1,161	850	815	1,236
JUL	1,121	1,237	1,061	1,432	1,316	1,311	1,252
TOTAL	**-3,732**	**-5,515**	**-5,880**	**-4,319**	**-2,536**	**-2,439**	**-4,586**

K.5 COMPUTATION OF FEDERAL HYDROPOWER BENEFITS IMPACTS

Tables K.4-5 to 4-8 summarize each alternative and benchmark combination and comparison of average change in hydropower benefits among alternative and benchmark combinations for the Federal hydropower projects. Each of the alternative and benchmark combinations for VARQ results in lower hydropower benefits than counterpart Standard FC alternative and benchmark combinations during HLH and LLH periods. The alternative combinations (with Libby fish flows) resulted in lower hydropower benefits than did the benchmark combinations (without Libby fish flows).

TABLE K.5-1. FEDERAL HLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000)

	Alternative Combinations				Benchmark Combinations	
	LS1+HS	LV1+HV	LS2+HS	LV2+HV	LS+HS	LV+HV
AG1	92,120	94,436	91,746	94,062	90,733	90,950
AUG	64,347	66,483	63,922	66,141	60,987	60,977
SEP	94,696	95,269	94,589	95,078	117,711	117,732
OCT	107,272	107,597	107,191	107,576	108,184	108,184
NOV	150,643	152,380	150,568	151,901	151,247	152,707
DEC	220,050	220,326	219,957	220,388	222,016	221,494
JAN	261,957	246,711	261,957	247,051	262,492	247,173
FEB	188,703	181,149	188,703	181,149	188,780	181,810
MAR	135,493	135,261	135,473	135,261	135,531	135,106
AP1	55,151	56,057	55,151	56,064	55,151	55,886
APR	63,966	62,826	63,966	62,842	63,966	62,826
MAY	129,205	132,975	129,733	133,490	127,095	131,779
JUN	119,282	121,409	119,412	121,492	113,777	118,585
JUL	174,455	177,744	174,029	177,319	171,785	174,107
TOTAL	**1,857,339**	**1,850,621**	**1,856,398**	**1,849,813**	**1,869,454**	**1,859,315**

TABLE K.5-2. FEDERAL LLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000)

	Alternative Combinations				Benchmark Combinations	
	LS1+HS	LV1+HV	LS2+HS	LV2+HV	LS+HS	LV+HV
AG1	32,480	33,296	32,348	33,165	31,991	32,067
AUG	25,316	26,156	25,149	26,022	23,994	23,990
SEP	36,716	36,938	36,674	36,864	45,639	45,648
OCT	37,798	37,912	37,769	37,905	38,119	38,119
NOV	47,122	47,665	47,098	47,515	47,311	47,767
DEC	57,498	57,570	57,474	57,586	58,012	57,875
JAN	87,882	82,767	87,882	82,881	88,061	82,922
FEB	58,092	55,766	58,092	55,766	58,115	55,970
MAR	52,398	52,308	52,390	52,308	52,413	52,248
AP1	26,065	26,493	26,065	26,496	26,065	26,412
APR	28,184	27,682	28,184	27,689	28,184	27,682
MAY	64,058	65,927	64,320	66,182	63,012	65,334
JUN	45,487	46,298	45,537	46,330	43,388	45,221
JUL	59,998	61,129	59,852	60,983	59,080	59,878
TOTAL	**659,092**	**657,908**	**658,833**	**657,692**	**663,382**	**661,134**

TABLE K.5-3. FEDERAL HLH COMPARISON OF ALTERNATIVE AND BENCHMARK COMBINATIONS HYDROPOWER BENEFITS ($1,000)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	181	1,351	965	3,462	2,292	2,292	3,088
AUG	10	3,328	2,903	5,495	2,105	2,167	5,143
SEP	0	-22,931	-23,016	-22,421	488	403	-22,570
OCT	0	-830	-952	-527	263	344	-567
NOV	1,359	-554	-629	-201	1,686	1,208	-679
DEC	-522	-1,843	-1,966	-1,106	277	369	-983
JAN	-15,198	-438	-413	-365	-15,149	-14,784	-49
FEB	-6,918	-25	-25	-534	-7,452	-7,478	-534
MAR	-387	0	-19	116	-155	-155	116
AP1	720	0	0	147	890	898	155
APR	-1,123	0	0	0	-1,123	-1,108	16
MAY	4,607	2,020	2,586	1,158	3,745	3,706	1,686
JUN	4,738	5,470	5,588	2,800	2,079	2,079	2,883
JUL	2,225	2,573	2,148	3,560	3,212	3,212	3,115
TOTAL	**-10,309**	**-11,878**	**-12,830**	**-8,415**	**-6,843**	**-6,846**	**-9,181**

TABLE K.5-4. FEDERAL LLH COMPARISON OF ALTERNATIVE AND BENCHMARK COMBINATIONS HYDROPOWER BENEFITS ($1,000)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	64	476	340	1,221	808	808	1,089
AUG	4	1,309	1,142	2,162	828	853	2,023
SEP	0	-8,891	-8,924	-8,693	189	156	-8,751
OCT	0	-293	-335	-186	93	121	-200
NOV	425	-173	-197	-63	527	378	-213
DEC	-136	-482	-514	-289	72	96	-257
JAN	-5,098	-147	-139	-122	-5,082	-4,960	-16
FEB	-2,130	-8	-8	-164	-2,294	-2,302	-164
MAR	-150	0	-7	45	-60	-60	45
AP1	340	0	0	70	421	424	73
APR	-495	0	0	0	-495	-488	7
MAY	2,284	1,002	1,282	574	1,856	1,837	836
JUN	1,807	2,086	2,131	1,068	793	793	1,099
JUL	765	885	739	1,224	1,105	1,105	1,071
TOTAL	**-2,320**	**-4,234**	**-4,489**	**-3,154**	**-1,239**	**-1,238**	**-3,357**

K.5.1 Computation of Non-Federal Hydropower Benefits Impacts

Tables K.4-9 to 4-12 summarize each alternative and benchmark combination and comparison of alternative and benchmark combinations for the non-Federal hydropower system. VARQ alternative and benchmark combinations resulted in lower hydropower benefits than did Standard flood control alternative and benchmark combinations. Alternative combinations (with fish flows at Libby) resulted in lower benefits than did the benchmark combinations (without Libby fish flows).

TABLE K.5-5. NON-FEDERAL HLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000)

	Alternative Combinations					Benchmark Combinations	
	LS1+HS	LV1+HV	LS2+HS	LV2+HV		LS+HS	LV+HV
AG1	35,053	35,680	34,341	35,584		34,341	34,293
AUG	22,157	22,240	25,361	22,209		25,361	25,361
SEP	56,244	56,350	56,435	56,350		56,435	56,435
OCT	63,885	64,675	63,845	64,473		63,845	64,453
NOV	83,386	83,587	83,814	83,638		83,814	83,789
DEC	142,009	135,250	142,101	135,403		142,101	135,403
JAN	86,079	82,602	86,127	82,602		86,127	82,869
FEB	82,639	82,384	82,664	82,384		82,664	82,283
MAR	71,082	72,223	71,082	72,223		71,082	72,087
AP1	29,348	28,907	29,348	28,946		29,348	28,907
APR	37,944	38,292	37,699	38,340		37,699	38,150
MAY	64,004	64,532	62,859	64,583		62,859	63,953
JUN	50,520	50,863	49,894	50,804		49,894	50,296
JUL	70,316	70,064	70,529	70,064		70,529	70,258
TOTAL	**894,667**	**887,650**	**896,100**	**887,603**		**896,100**	**888,536**

TABLE K.5-6. NON-FEDERAL LLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000)

	Alternative Combinations					Benchmark Combinations	
	LS1+HS	LV1+HV	LS2+HS	LV2+HV		LS+HS	LV+HV
AG1	12,359	12,580	12,321	12,546		12,108	12,091
AUG	8,717	8,750	8,713	8,738		9,978	9,978
SEP	21,807	21,848	21,791	21,848		21,881	21,881
OCT	22,510	22,789	22,489	22,717		22,496	22,710
NOV	26,083	26,146	26,083	26,162		26,217	26,209
DEC	37,106	35,340	37,106	35,380		37,130	35,380
JAN	28,878	27,711	28,870	27,711		28,894	27,801
FEB	25,440	25,362	25,440	25,362		25,448	25,330
MAR	27,489	27,930	27,489	27,930		27,489	27,878
AP1	13,870	13,662	13,870	13,680		13,870	13,662
APR	16,719	16,872	16,750	16,893		16,611	16,810
MAY	31,732	31,994	31,758	32,019		31,165	31,707
JUN	19,265	19,396	19,261	19,373		19,027	19,180
JUL	24,183	24,096	24,183	24,096		24,256	24,163
TOTAL	**316,160**	**314,477**	**316,124**	**314,457**		**316,570**	**314,780**

TABLE K.5-7. NON-FEDERAL HLH COMPARISON OF ALTERNATIVE AND BENCHMARK COMBINATIONS HYDROPOWER BENEFITS ($1,000)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	-12	109	24	458	410	434	398
AUG	0	601	498	1,172	539	539	1,089
SEP	0	-6,582	-6,603	-6,412	85	85	-6,518
OCT	527	-182	-203	-61	61	81	-81
NOV	-50	25	-25	277	906	730	25
DEC	-6,514	-522	-553	-246	215	215	-184
JAN	-3,185	-97	-97	-97	-5,252	-5,082	0
FEB	-254	-25	-25	-229	-3,485	-3,510	-254
MAR	831	0	0	19	-97	-116	0
AP1	-379	0	0	46	410	403	46
APR	419	0	0	0	-388	-372	24
MAY	1,094	360	463	180	502	476	270
JUN	343	1,028	1,075	520	508	508	555
JUL	-252	1,026	967	929	503	503	851
TOTAL	**-7,433**	**-4,260**	**-4,479**	**-3,444**	**-5,082**	**-5,106**	**-3,779**

TABLE K.5-8. NON-FEDERAL LLH COMPARISON OF ALTERNATIVE AND BENCHMARK COMBINATIONS HYDROPOWER BENEFITS ($1,000)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	-4	38	9	162	145	153	140
AUG	0	237	196	461	212	212	428
SEP	0	-2,552	-2,560	-2,486	33	33	-2,527
OCT	186	-64	-71	-21	21	29	-29
NOV	-16	8	-8	87	283	228	8
DEC	-1,702	-136	-145	-64	56	56	-48
JAN	-1,069	-33	-33	-33	-1,762	-1,705	0
FEB	-78	-8	-8	-70	-1,073	-1,081	-78
MAR	322	0	0	7	-37	-45	0
AP1	-179	0	0	22	194	190	22
APR	185	0	0	0	-171	-164	10
MAY	542	179	230	89	249	236	134
JUN	131	392	410	198	194	194	212
JUL	-87	353	333	319	173	173	293
TOTAL	**-1,770**	**-1,587**	**-1,648**	**-1,329**	**-1,483**	**-1,490**	**-1,435**

K.5.2 Hydropower Benefits Impacts at Libby and Hungry Horse

Tables K.4-13 through K.4-16 summarize hydropower benefits for each alternative and benchmark combination and the average change in at-site hydropower benefits at the Libby project during HLH and LLH periods for each comparison of alternative and benchmark combinations. As shown in Table K.4-15, the alternative combinations with VARQ FC resulted in greater benefits than did alternative combinations with Standard FC. Otherwise, compared to benchmark combinations (without Libby fish flows), both Standard FC and VARQ FC alternative combinations resulted in lower benefits. The range of hydropower benefits impacts during the HLH period is from $4.9 million lower annual benefit for alternative combination LS2+HS compared to benchmark combination LS+HS, to a higher annual benefit of $917,000 for alternative combination LV1+HV compared to benchmark combination LV+HV.

During the LLH period, of the seven comparisons, three resulted in greater benefits at Libby for VARQ FC vs. Standard FC. Otherwise alternative combinations (with fish flows at Libby) resulted in lower benefits than did their benchmark combination counterparts (without Libby fish flows), The range of benefits impacts was from a higher annual benefit of $677,000 for alternative combination LV2+HV vs. alternative combination LS2+HS, to a lower annual benefit of $1.7 million for alternative combination LS2+HS vs. benchmark combination LS+HS.

TABLE K.5-9. LIBBY HLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000)

	Alternative Combinations					Benchmark Combinations	
	LS1+HS	LV1+HV	LS2+HS	LV2+HV		LS+HS	LV+HV
AG1	3,896	4,692	3,775	4,560		3,233	3,293
AUG	3,131	3,691	3,028	3,608		2,136	2,157
SEP	4,140	4,353	4,119	4,310		11,338	11,338
OCT	3,119	3,221	3,099	3,200		3,403	3,403
NOV	3,598	3,648	3,573	3,648		3,774	3,774
DEC	11,337	11,522	11,307	11,491		11,890	11,921
JAN	9,191	5,884	9,191	5,884		9,289	5,933
FEB	5,570	4,400	5,570	4,400		5,570	4,400
MAR	2,108	2,224	2,108	2,224		2,108	2,224
AP1	596	720	596	720		596	720
APR	775	941	775	941		775	941
MAY	2,226	3,706	2,458	3,925		1,390	3,178
JUN	4,253	4,561	4,171	4,466		2,304	3,592
JUL	6,114	7,469	5,902	7,275		6,830	7,140
TOTAL	**60,057**	**61,032**	**59,672**	**60,654**		**64,636**	**64,015**

TABLE K.5-10. LIBBY LLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000)

	Alternative Combinations					Benchmark Combinations	
	LS1+HS	LV1+HV	LS2+HS	LV2+HV		LS+HS	LV+HV
AG1	1,374	1,654	1,331	1,608		1,140	1,161
AUG	1,232	1,452	1,191	1,420		840	848
SEP	1,605	1,688	1,597	1,671		4,396	4,396
OCT	1,099	1,135	1,092	1,128		1,199	1,199
NOV	1,126	1,141	1,118	1,141		1,181	1,181
DEC	2,962	3,011	2,954	3,003		3,107	3,115
JAN	3,084	1,974	3,084	1,974		3,116	1,990
FEB	1,715	1,355	1,715	1,355		1,715	1,355
MAR	815	860	815	860		815	860
AP1	282	340	282	340		282	340
APR	342	415	342	415		342	415
MAY	1,104	1,837	1,219	1,946		689	1,576
JUN	1,622	1,739	1,590	1,703		879	1,370
JUL	2,103	2,569	2,030	2,502		2,349	2,456
TOTAL	**20,463**	**21,170**	**20,359**	**21,065**		**22,049**	**22,261**

TABLE K.5-11. LIBBY HLH COMPARISON OF ALTERNATIVE AND BENCHMARK COMBINATIONS HYDROPOWER BENEFITS ($1,000)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	48	663	531	1,399	796	784	1,267
AUG	21	995	892	1,535	560	570	1,452
SEP	0	-7,176	-7,198	-6,985	191	170	-7,028
OCT	0	-263	-284	-182	81	101	-182
NOV	0	-176	-176	-101	50	50	-101
DEC	0	-522	-553	-399	154	154	-430
JAN	-3,331	-73	-73	-49	-3,283	-3,283	-49
FEB	-1,145	0	0	0	-1,145	-1,145	0
MAR	97	0	0	0	97	97	0
AP1	116	0	0	0	116	116	0
APR	158	0	0	0	158	158	0
MAY	1,789	824	1,055	515	1,480	1,467	733
JUN	1,276	1,938	1,855	969	307	307	874
JUL	290	-716	-929	329	1,354	1,354	116
TOTAL	**-681**	**-4,507**	**-4,880**	**-2,970**	**917**	**902**	**-3,348**

TABLE K.5-12. LIBBY LLH COMPARISON OF ALTERNATIVE AND BENCHMARK COMBINATIONS HYDROPOWER BENEFITS ($1,000)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	17	234	187	493	281	276	447
AUG	8	392	351	604	220	224	571
SEP	0	-2,782	-2,791	-2,708	74	66	-2,725
OCT	0	-93	-100	-64	29	36	-64
NOV	0	-55	-55	-31	16	16	-31
DEC	0	-136	-145	-104	40	40	-112
JAN	-1,118	-24	-24	-16	-1,101	-1,101	-16
FEB	-352	0	0	0	-352	-352	0
MAR	37	0	0	0	37	37	0
AP1	55	0	0	0	55	55	0
APR	70	0	0	0	70	70	0
MAY	887	408	523	255	734	727	364
JUN	487	739	707	369	117	117	333
JUL	100	-246	-319	113	466	466	40
TOTAL	**190**	**-1,565**	**-1,666**	**-1,090**	**684**	**677**	**-1,195**

Tables K.4-17 through K.4-20 summarize the alternative combinations and comparisons of alternative combinations for at-site hydropower benefits at the Hungry Horse project during HLH and LLH periods. At Hungry Horse, each of the alternative and benchmark combinations for VARQ results in either lower hydropower benefits or zero difference compared to Standard FC alternative and benchmark combinations during HLH and LLH periods. There is no difference for alternative combinations compared to benchmark combinations (without Libby fish flows). The zero differences are due primarily because each of the alternative and benchmark combinations operated to the same target elevation in the HYSSR simulations. The range of hydropower benefits impacts during the HLH period was from zero to a lower value of $749,000 annually. In the LLH period, the range was from zero to an average lower value of $208,000 for VARQ FC vs Standard FC.

TABLE K.5-13. HUNGRY HORSE HLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000)

	Alternative Combinations					Benchmark Combinations	
	LS1+HS	LV1+HV	LS2+HS	LV2+HV		LS+HS	LV+HV
AG1	2,473	2,473	2,473	2,473		2,473	2,473
AUG	1,939	1,939	1,939	1,939		1,939	1,939
SEP	1,104	1,104	1,104	1,104		1,104	1,104
OCT	1,033	1,033	1,033	1,033		1,033	1,033
NOV	1,334	1,334	1,334	1,334		1,334	1,334
DEC	1,936	2,181	1,936	2,181		1,936	2,181
JAN	4,328	3,574	4,328	3,574		4,328	3,574
FEB	4,248	3,307	4,248	3,307		4,248	3,307
MAR	1,760	1,876	1,760	1,876		1,760	1,876
AP1	929	875	929	875		929	875
APR	1,899	902	1,899	902		1,899	902
MAY	1,338	2,381	1,338	2,381		1,338	2,381
JUN	1,158	1,690	1,158	1,690		1,158	1,690
JUL	3,696	3,792	3,696	3,792		3,696	3,792
TOTAL	**29,173**	**28,460**	**29,173**	**28,460**		**29,173**	**28,460**

TABLE K.5-14. HUNGRY HORSE LLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000)

	Alternative Combinations					Benchmark Combinations	
	LS1+HS	LV1+HV	LS2+HS	LV2+HV		LS+HS	LV+HV
AG1	872	872	872	872		872	872
AUG	763	763	763	763		763	763
SEP	428	428	428	428		428	428
OCT	364	364	364	364		364	364
NOV	417	417	417	417		417	417
DEC	506	570	506	570		506	570
JAN	1,452	1,199	1,452	1,199		1,452	1,199
FEB	1,308	1,018	1,308	1,018		1,308	1,018
MAR	680	725	680	725		680	725
AP1	439	413	439	413		439	413
APR	837	397	837	397		837	397
MAY	663	1,180	663	1,180		663	1,180
JUN	442	644	442	644		442	644
JUL	1,271	1,304	1,271	1,304		1,271	1,304
TOTAL	**10,442**	**10,296**	**10,442**	**10,296**		**10,442**	**10,296**

TABLE K.5-15. HUNGRY HORSE HLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	0	0	0	0	0	0	0
AUG	0	0	0	0	0	0	0
SEP	0	0	0	0	0	0	0
OCT	0	0	0	0	0	0	0
NOV	0	0	0	0	0	0	0
DEC	215	0	0	0	215	215	0
JAN	-754	0	0	0	-754	-754	0
FEB	-941	0	0	0	-941	-941	0
MAR	116	0	0	0	116	116	0
AP1	-46	0	0	0	-46	-46	0
APR	-997	0	0	0	-997	-997	0
MAY	1,029	0	0	0	1,029	1,029	0
JUN	532	0	0	0	532	532	0
JUL	97	0	0	0	97	97	0
TOTAL	**-749**	**0**	**0**	**0**	**-749**	**-749**	**0**

TABLE K.5-16. HUNGRY HORSE LLH HYDROPOWER BENEFITS FOR ALTERNATIVE AND BENCHMARK COMBINATIONS ($1,000)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
AG1	0	0	0	0	0	0	0
AUG	0	0	0	0	0	0	0
SEP	0	0	0	0	0	0	0
OCT	0	0	0	0	0	0	0
NOV	0	0	0	0	0	0	0
DEC	75	0	0	0	75	75	0
JAN	-337	0	0	0	-337	-337	0
FEB	-386	0	0	0	-386	-386	0
MAR	60	0	0	0	60	60	0
AP1	-29	0	0	0	-29	-29	0
APR	-586	0	0	0	-586	-586	0
MAY	680	0	0	0	680	680	0
JUN	270	0	0	0	270	270	0
JUL	44	0	0	0	44	44	0
TOTAL	**-208**	**0**	**0**	**0**	**-208**	**-208**	**0**

K.6 SUMMARY OF HYDROPOWER BENEFITS IMPACTS

Impacts to Columbia River basin system hydropower benefits caused by all alternative and benchmark combinations were evaluated in this study. Impacts were quantified during “on-peak” and “off-peak” generation periods designated as heavy load hours (HLH) and light load hours (LLH), respectively. Six alternatives were considered: four at the Libby project and two at Hungry Horse. These alternatives were combined into six alternative combinations which included Libby fish flows. In addition, two benchmark combinations were derived from two alternatives at Libby with out fish flows, and the two alternatives at Hungry Horse. Alternative combinations and benchmark combinations were paired in seven comparisons. Comparisons were made among alternative and benchmark combinations for three grouping of projects: Columbia River System hydropower projects, Federal hydropower projects, and non-Federal hydropower projects. Hydropower benefits impacts for each grouping are summarized in Sections 5-1 through K.5-3.

Additionally, hydropower benefits impacts were summarized at-site for two individual Federal projects. These projects were Libby and Hungry Horse. Hydropower benefits impacts for each of these projects are summarized in Section K.5-4.

K.6.1 System Hydropower Benefits Impacts

Total average annual hydropower benefits impacts on the Columbia River system projects due to various alternative and benchmark combinations are summarized below. Total hydropower benefits were computed by summing the HLH and LLH impacts. When making comparisons among alternative and benchmark combinations, the greatest average annual difference (approximately -$22.3 million in 2004 dollars) in hydropower benefits occurs when comparing alternative combination LS2+HS minus benchmark combination LS+HS in the System project grouping. The least average annual hydropower benefits difference (approximately -$13.5 million) occurs when comparing alternative combination LV2+HV minus benchmark combination LS2+HS.

Tables K.5-1 and 5-2 summarize the system hydropower benefits for each of the alternative and benchmark combinations and comparisons of alternative and benchmark combinations evaluated.

TABLE K.6-1. SUMMARY OF SYSTEM ANNUAL HYDROPOWER BENEFITS BY ALTERNATIVE AND BENCHMARK COMBINATION ($1,000)

	Alternative Combinations					Benchmark Combinations	
	LS1+HS	LV1+HV	LS2+HS	LV2+HV		LS+HS	LV+HV
HLH	3,651,591	3,640,198	3,650,256	3,639,196		3,666,703	3,651,570
LLH	1,294,401	1,291,864	1,294,035	1,291,597		1,299,915	1,296,183
TOTAL	**4,945,992**	**4,932,063**	**4,944,291**	**4,930,793**		**4,966,618**	**4,947,753**

TABLE K.6-2. SUMMARY OF COMPARISONS OF SYSTEM ALTERNATIVE AND BENCHMARK COMBINATIONS ANNUAL HYDROPOWER BENEFITS IMPACTS ($1,000)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
HLH	-15,132	-15,111	-16,447	-11,372	-11,393	-11,059	-12,374
LLH	-3,732	-5,515	-5,880	-4,319	-2,536	-2,439	-4,586
TOTAL	**-18,865**	**-20,626**	**-22,327**	**-15,691**	**-13,929**	**-13,498**	**-16,960**

K.6.2 Federal Hydropower Benefits Impacts

Total average annual hydropower benefits differences on the Federal projects due to various alternative and benchmark combinations are summarized below. Total hydropower benefits were computed by summing HLH and LLH impacts. The greatest difference in hydropower benefits for the Federal projects results from comparing alternative combination LS2+HS minus benchmark combination LS+HS, while alternative combination LV1+HV minus alternative combination LS1+HS and alternative combination LV2+HV minus alternative combination LS2+HS are comparable in producing the least benefits differences. The differences are -$17.3 million and -$8.1 million, respectively.

Tables K.5.3 and 5-4 summarize the Federal projects' hydropower benefits for each of the alternative and benchmark combinations and comparisons of alternative and benchmark combinations evaluated.

TABLE K.6-3. SUMMARY OF FEDERAL ANNUAL HYDROPOWER BENEFITS BY ALTERNATIVE AND BENCHMARK COMBINATION ($1,000)

	Alternative Combinations					Benchmark Combinations	
	LS1+HS	LV1+HV	LS2+HS	LV2+HV		LS+HS	LV+HV
HLH	1,857,339	1,850,621	1,856,398	1,849,813		1,869,454	1,859,315
LLH	659,092	657,908	658,833	657,692		663,382	661,134
TOTAL	**2,516,431**	**2,508,529**	**2,515,230**	**2,507,505**		**2,532,836**	**2,520,449**

TABLE K.6-4. SUMMARY OF COMPARISONS OF FEDERAL ALTERNATIVE AND BENCHMARK COMBINATIONS ANNUAL HYDROPOWER BENEFITS IMPACTS ($1,000)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
HLH	-10,309	-11,878	-12,830	-8,415	-6,843	-6,846	-9,181
LLH	-2,320	-4,234	-4,489	-3,154	-1,239	-1,238	-3,357
TOTAL	**-12,629**	**-16,113**	**-17,320**	**-11,569**	**-8,081**	**-8,084**	**-12,538**

K.6.3 Non-Federal Hydropower Benefits Impacts

Average annual hydropower benefits differences on the non-Federal Columbia River basin hydropower project downstream of Libby and Hungry Horse are summarized below. Total hydropower benefits were computed by summing the HLH and LLH impacts. For the non-Federal projects, subtracting benchmark combination LV+HV minus benchmark combination LS+HS produces the greatest average annual difference in hydropower benefits, approximately -$9.2 million, while alternative combination LV1+HV minus benchmark combination LV+HV produces the least difference in hydropower benefits, approximately -$4.8 million.

Table K.5.5 and Table K.5-6 summarize the non-Federal hydropower benefits for each of the alternative benchmark combinations and comparisons of alternative and benchmark combinations evaluated.

TABLE K.6-5. SUMMARY OF NON-FEDERAL ALTERNATIVE AND BENCHMARK COMBINATIONS ANNUAL HYDROPOWER BENEFITS ($1,000)

	Alternative Combinations					Benchmark Combinations	
	LS1+HS	LV1+HV	LS2+HS	LV2+HV		LS+HS	LV+HV
HLH	894,667	887,650	896,100	887,603		896,100	888,536
LLH	316,160	314,477	316,124	314,457		316,570	314,780
TOTAL	**1,210,827**	**1,202,127**	**1,212,224**	**1,202,060**		**1,212,670**	**1,203,316**

TABLE K.6-6. SUMMARY OF COMPARISONS OF NON-FEDERAL ALTERNATIVE AND BENCHMARK COMBINATIONS ANNUAL HYDROPOWER BENEFITS IMPACTS ($1,000)

	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
HLH	-7,433	-4,260	-4,479	-3,444	-5,082	-5,106	-3,779
LLH	-1,770	-1,587	-1,648	-1,329	-1,483	-1,490	-1,435
TOTAL	**-9,203**	**-5,848**	**-6,127**	**-4,773**	**-6,565**	**-6,596**	**-5,214**

K.6.4 Libby and Hungry Horse Hydropower Benefits Impacts

Total at-site average annual hydropower benefits impacts were evaluated at Libby and Hungry Horse due to the various alternative and benchmark combinations. Total hydropower benefits were computed by summing the HLH and LLH numbers.

Average annual hydropower benefits impacts at Libby range from a difference of -$6.5 million to a difference of $1.6 million when subtracting alternative combination LS2+HS minus benchmark combination LS+HS and alternative combination LV1+HV minus alternative combination LS1+HS, respectively.

At Hungry Horse, average annual differences range from zero for four of the comparisons to a difference of -$958,000 for the remaining three comparisons (VARQ alternative and benchmark combinations minus Standard FC alternative and benchmark combinations).

Table K.5.7 summarizes the Libby and Hungry Horse hydropower benefits impacts for each of the comparisons of alternative combinations evaluated.

TABLE K.6-7. SUMMARY OF COMPARISONS OF LIBBY & HUNGRY HORSE AVERAGE ANNUAL HYDROPOWER BENEFITS IMPACTS ($1,000)

Libby	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
HLH	-681	-4,507	-4,880	-2,970	917	902	-3,348
LLH	190	-1,565	-1,666	-1,090	684	677	-1,195
TOTAL	**-491**	**-6,072**	**-6,545**	**-4,060**	**1,602**	**1,579**	**-4,542**

Hungry Horse	LV+HV minus LS+HS	LS1+HS minus LS+HS	LS2+HS minus LS+HS	LV1+HV minus LV+HV	LV1+HV minus LS1+HS	LV2+HV minus LS2+HS	LV2+HV minus LV+HV
HLH	-749	0	0	0	-749	-749	0
LLH	-208	0	0	0	-208	-208	0
TOTAL	**-958**	**0**	**0**	**0**	**-958**	**-958**	**0**

APPENDIX L

Transmission Restriction Between Libby and Hungry Horse Dams

Appendix L TRANSMISSION RESTRICTION BETWEEN LIBBY AND HUNGRY HORSE DAMS

L.1 Issue

Although Libby and Hungry Horse dams are located on two different rivers and are operated independently for hydrologic purposes, they share a common transmission grid that provides power primarily for the Flathead Valley. Power in excess of that needed within the valley must be transmitted out of the valley over the transmission grid. Because power can not be stored, the two dams can not generate more power than that which can be used in the Flathead Valley or carried out of the valley over the transmission grid.

The full combined generating capacity of both dams is about 1,028 MW (600 MW at Libby and 428 MW at Hungry Horse). Prior to 2001, the Columbia Falls Aluminum plant, the largest power user in the Flathead Valley, consumed up to 400 MW of power, or almost all of the power generated by Hungry Horse Dam. In 2001, the aluminum plant reduced production by about 80 percent. This decrease in power demand in the valley has led to corresponding increases in the potential amount of excess power that must be transmitted out of the valley. The current 944 MW transmission capacity (to be raised to 950 by April 2006) out of the valley, which is less than the combined generating capacity of both dams, was designed with the consideration that most of the power was being used locally.

In analyzing the local hydrologic impacts, the Corps performed daily hydrologic modeling of Libby Dam operations and Reclamation performed daily hydrologic modeling of Hungry Horse Dam operations.

As both dam operations were modeled independently, there are times when model results show that the combined generation of both dams would exceed the transmission limit of 944 MW. There are 133 days in the 52 year period between 1949 and 2001 where models indicate that the combined generation of Libby and Hungry Horse would be higher than the transmission capacity of 944 MW. In these cases, one or both projects would have to either (1) reduce releases which would impact flood control operations (2) pre-draft the reservoirs, or (3) bypass the turbines and release water either over the spillway or through the outlet works, which would increase the total dissolved gas (TDG)

in the river below the dams and would possibly exceed the state of Montana maximum water quality standard of 110 percent.

In 7 out of 19 years, model simulations showed generation in excess of the 944 MW transmission capacity occurred in January during flood control draft. During January, Hungry Horse was operated according to Variable Draft Limits; see Appendix H for details on the Hungry Horse modeling) and the period of time that combined generation exceeded transmission capacity typically lasted from one to five days. Reclamation is able to relax the Hungry Horse operation as they are below the URC, so this overlap can be resolved through coordinating operations between the two dams.

In the remaining 12 out of 19 years, generation in excess of the 944 MW transmission capacity occurs during refill of the projects (May, June and July). For these 12 years, this study looked only at impacts to spilling past the dams, when transmission limitations are exceeded. Even with considerable planning, it would be difficult to predict when both projects would be at full power plant capacity during flood control operations and pre-drafting; although it could potentially eliminate the spill concerns, it would likely increase the risk of refill failures.

If the combined generation of Hungry Horse and Libby dams were to exceed 944 MW during actual operations, flows in excess of that needed to generate 944 MW would be spilled past the dams. Spill would be increased at Hungry Horse Dam first up to a maximum of about 15 percent of total flow, at which point Libby would begin spilling up to a maximum of about 880 cfs or about 21 MW. Analysis of the model results indicates that limiting spills to the above levels would prevent TDG from exceeding the Montana State TDG limits of 110 percent in 107 of the 133 days (16 of 19 years). There are 26 days (spread over three different years) where both dams are at their generating capacity, and one or both are spilling enough to generate TDG in excess of 110 percent. For simulation purposes, Libby would spill up to 110 percent TDG and, if necessary, Hungry Horse would spill in excess of the 110 percent TDG. Hungry Horse typically does not gas the river to the extent that Libby would under similar spill amounts. Libby is on the mainstem of the Kootenai and Hungry Horse is on the South Fork of the Flathead, 5 miles upstream of the confluence with the mainstem. Gas generated from Hungry Horse dam tends to dissipate and mix more easily than gas generated from Libby dam.

Table L-1 shows the magnitude and duration by which the TDG exceeds the Montana State maximum dissolved standards in the South Fork Flathead River below Hungry Horse Dam.

Table L-1. Magnitude and duration of TDG levels above Montana State Maximum, Hungry Horse Dam.

Years	No. of days	Spill as Percent of total discharge	Percent TDG levels
1948	1	22 ≤x≤ 30	110 - 113
	8	30 ≤x≤ 45	113 - 115.5
1961	4	32≤ x ≤ 36	113 - 114
	10	23 ≤x≤ 24	110-111
1986	3	22	110 - 110.5
Total	26		

APPENDIX M

Variable December Draft at Libby

Implementation of the 31 December Variable Flood Control Draft for Libby Dam and Impacts to Franklin D. Roosevelt Lake, Salmon Flow Augmentation, Winter Flows in the Kootenai River

Background

The Corps of Engineers recently implemented a 31 December variable flood control draft for Libby Dam. Previously Libby Dam had a fixed draft to an elevation of 2,411 feet by 31 December, which provides 2.0 million acre-feet (maf) of flood control space. This fixed draft adversely affected Libby's ability to refill in some dry years.

Flood control draft requirements for Libby Dam are based on the forecasted runoff volume for the April-August period. Historically, forecasts were issued at the beginning of each month from January 1 through June 1. There was no reliable way to issue a Libby volume runoff forecast earlier than January, so Libby reservoir was drafted to the same point each year on 31 December.

In 2003, the Corps developed a methodology to forecast runoff volume for Libby based on principal components regression. This new procedure incorporates climatic variables such as the ocean-temperature-based El Niño Southern Oscillation Index (SOI), and computes early-season forecasts in November and December. From the December forecast, the Corps could then calculate a variable draft for 31 December, which would allow Libby to be drafted less (i.e. holds the reservoir higher) than the fixed 2.0 maf.

The relaxation of the December draft requirement would be permissible only with VARQ FC because it does not compromise the ability to meet flood control targets in subsequent months. It would not be permissible with Standard FC. This is because the Standard FC procedure typically specifies deeper drafts in January, February, and March, and allowing a relaxed December draft could compromise the ability to meet flood control targets in these later months.

The Corps developed the following criteria for determining the 31 December flood control draft at Libby (Corps 2004):

- If the December 1 forecast is greater than 5900 kaf, draft to 2.0 maf (i.e. reservoir elevation of 2,411 feet)
- If December 1 forecast is less than 5500 kaf, draft to 1.4 maf (i.e. reservoir elevation of 2,426.7 feet)
- For December 1 forecasts between 5500 kaf and 5900 kaf, draft by interpolating between 1.4 maf and 2.0 maf (i.e. reservoir elevation between 2,411 and 2,426.7 feet).

In years when Libby is drafted the fixed 2.0 maf on 31 December, minimum outflow requirements will keep Lake Koocanusa below its flood control rule curve if forecasts

issued in January and later months predict a low runoff volume. These are the years that would benefit from a relaxed 31 December draft point. By allowing a lesser draft on 31 December, Lake Koocanusa would have a higher elevation in subsequent months and would be closer to (or on) the rule curve. This improves the probability of refilling Lake Koocanusa.

In practical terms, a higher rule curve can be achieved under VARQ FC compared to Standard FC generally in years with runoff forecasts between 80% and 120% of average. In higher-runoff years, VARQ FC and Standard FC are the same. In lower-runoff years, minimum flow maintenance in winter makes it difficult to bring the reservoir level up to the VARQ FC rule curve. Being at a higher draft point on 31 December may assist the reservoir to be closer to the VARQ FC rule curve at some point during the winter during the lower-runoff years. Thus, with less draft on 31 December, an observable effect of VARQ FC on reservoir levels may extend to years with less than 80% of average runoff.

Impacts to Libby and resulting impacts to Franklin D. Roosevelt Lake

As Grand Coulee flood control draft requirements are dependent on available space at other flood control reservoirs, a reduction in the flood control space available at Libby could require additional space requirements for Coulee in some years.

Based on the above criteria, Libby is able to relax the draft point in 14 of 54 years of the period of record as shown by computer modeling.

Of those 14 years, 4 years (1953, 1973, 1983, 1957) have forecast increases in January and/or February and/or March, causing the elevation of Lake Koocanusa on March 15 to be back where it would have been without the relaxed December draft. In these years there is no additional flood control requirement at Grand Coulee on April 30.

In 4 years (1988, 1977, 1994, 2001), Libby receives full benefit of the reduced draft (600 kaf more full on March 1), but the flood control requirements for Grand Coulee are not changed. These were typically dry years where Grand Coulee was at its absolute minimum space requirements. There was more space than necessary available in upstream reservoirs.

Two years (1992, 1993) Libby receives partial benefit from the variable end-of-December draft with no additional draft requirement at Grand Coulee.

The remaining 4 years (1980, 1970, 1979, 1955), Libby received either partial or full benefits from the variable draft. With Libby more full on April 30, the Grand Coulee draft requirement has increased. In three of the four years, the increased draft requirement is 9 inches or less. The fourth year, Grand Coulee would need to draft about 2 ½ feet deeper on April 30 due to implementation of the 31 December variable draft at Libby.

The following table shows estimates of Grand Coulee (GCL) impacts due to a 31 December variable draft at Libby and cumulative impacts due to implementation of VARQ FC.

Years	When affected	Maximum Increase in GCL Draft Requirement (Feet)	Maximum Increase in GCL Draft due to VARQ FC (feet)	Total Cumulative Increase in GCL Draft (feet)
1980	April 30	0.3	3.9	4.2
1970	April 30	2.6	2.8	5.3
1979	April 30	0.4	5.8	6.2
1955	April 30	0.75	2.5	3.25

Impacts to Salmon Flow Augmentation

In years where variable December draft results in a higher peak elevation at Libby after refill, flows in the mainstem Columbia River are affected during the spring and summer. The following table shows the effects on flows at Priest Rapids and McNary Dams for the April-August spring and summer salmon outmigration period when there are seasonal flow objectives at these two projects.

Effects of Variable December Draft on Mainstem Flows @ Priest Rapids and McNary Dams						
		Apr 15-Apr 30	May	June	July	August
Priest Rapids	# of years w/ lower flows w/ var. draft	4	5	6	n/a	n/a
	# of years w/ higher flows w/ var. draft	1	6	6	n/a	n/a
	Avg. flow difference (cfs) in years with a difference	74	722	831	n/a	n/a
	Maximum Increase	1805	5149	6940	n/a	n/a
	Maximum Decrease	1004	1027	2506	n/a	n/a
McNary	# of years w/ lower flows w/ var. draft	4	5	6	5	0
	# of years w/ higher flows w/ var. draft	1	6	6	5	10
	Avg. flow difference (cfs) in years with a difference	74	722	831	305	957
	Maximum Increase	1805	5149	6940	7258	2515
	Maximum Decrease	1004	1027	2506	4205	5

In general, years where the variable December draft increase the peak elevation at Libby tend to result in increased flows in the mainstem Columbia. Flows can be as much as about 7,000 cfs higher in rare years, but, on average, increases are small in relation to the flow objectives of 135 kcfs at Priest Rapids Dam, and 200 to 260 kcfs at McNary Dam.

Impacts to Winter Flows on the Kootenai River during Burbot Migration and Spawning

Studies indicate that lower flows in December and January may benefit burbot by providing better conditions for burbot migration into Idaho from Kootenay Lake. In December, implementation of variable December draft would not change Libby operations in about 75 percent of years, but in the 25 percent of years with a higher Lake Koocanusa elevation on 31 December, it would result in an average decrease in dam discharge of almost 6,000 cfs. Accordingly, variable December draft would tend to benefit burbot in December by facilitating lower average dam discharges and river flows.

In January, variable December draft would not change dam discharges in almost 90 percent of years, but, for the 10 percent of years where there would be a higher Lake Koocanusa elevation on 31 December , it would result in an average increase in dam discharge of about 4,000 cfs. Higher flows in January would likely occur in about half of the years with reduced December flows. Accordingly, benefits to burbot in winters with lower December flows due to variable December draft may be offset in some years by higher January flows that could hinder burbot migration and spawning in January.

References:

(Corps) U.S. Army Corps of Engineers. 2004. Summary Report: 31 December Variable Flood Control Draft for Libby Reservoir. Northwestern Division, Portland, Oregon.

(Corps) U.S. Army Corps of Engineers. 2005. Hydropower Impacts Analysis of Libby Variable End of December Elevations, Preliminary Report. Northwestern Division, Portland, Oregon.

APPENDIX N

Use of Additional Flow Capacity to Achieve Benefits Other Than Sturgeon Spawning and Incubation Flows

Appendix N USE OF ADDITIONAL FLOW CAPACITY TO ACHIEVE BENEFITS OTHER THAN STURGEON SPAWNING AND INCUBATION FLOWS

The USFWS Biological Opinion of 2000 (Reasonable and Prudent Alternative 8.2) requested implementation of additional flow capacity from Libby Dam to provide higher base flows for sturgeon spawning and incubation in the Kootenai River. It also mentioned the benefit of greater flexibility in refilling of Lake Koocanusa. If in fact the reservoir can fill sooner in the season, then benefits to recreation, and to reservoir fish and other organisms, may result from the longer period at full pool.

The perceived mechanism by which this flexibility would work is that earlier refill could occur while reservoir inflows are still dropping between 34,500 cfs (assumed augmented outflow capability) and 24,500 cfs (roughly current powerhouse capacity) instead of only after inflows have dropped below current powerhouse capacity. If refill happens sooner than inflows drop below outflow capacity, then forced spill results, with potential adverse consequences related to high dissolved gas levels, and/or reduced capability to control flooding.

The mechanism and benefits associated with earlier refill flexibility were expressed further in an email from Robert Hallock, U.S. Fish and Wildlife Service (USFWS), to Jeff Laufle, U.S. Army Corps of Engineers (Corps), 24 Feb 2005. Items from Mr. Hallock's e-mail are individually summarized below (*in italics*), with each item followed by the Corps' assessment.

1. *Earlier reservoir refill should be possible given the flexibility to release larger amounts of water. This would have recreational and biological benefits for the reservoir.*

Actually, most of the time, a greater powerhouse capacity would make no difference in terms of peak reservoir elevation or timing of refill. When Libby Dam provides fish flows, operations for fish govern the regulation decisions and Libby does not refill in most years, so having additional flow capacity as the reservoir is refilling becomes moot. Analysis of the hydroregulation modeling that forms the basis for Kootenai River evaluations in this EIS reveals only six years within the 52-year period of record when the reservoir would be regulated differently due to additional outflow capacity. Those years were: 1955, 1977, 1988, 1993, 1995, and 1998.

In tier 1 years when no sturgeon flow is provided, there is a refill improvement when the "fill and spill" threshold is assumed to be 34,500 cfs instead of 24,500 cfs. In computer modeling for 1988 and 1993, Libby got to full pool about a week earlier. In 1977, Libby model results showed Libby reaching its highest elevation on the same day either way, but the maximum elevation was 1.3 feet higher.

In a few years (1955, 1995, 1998) Libby could reach full pool earlier (about 2 weeks earlier), but in the modeling it came at the expense of a very unnatural regulation, where there was a dramatic increase in outflow as the reservoir reached full pool.

Thus, while the Corps can take advantage of whatever flexibility is available in real-time operations, early refill is not something that can be counted on as a "normal" benefit of additional flow capacity.

2. *With additional outflow capacity, the likelihood of refill should be increased, giving better assurance of meeting flow needs for fish downstream.*

There might be a slight chance of improved refill probability in some years (see response to comment 1), and downstream fish would benefit, though the benefit to salmon would vary with the amount of refill. Modification of the storage reservation diagrams, however, would entail totally revamping flood control based on the 35,000 cfs capacity, which would be outside the scope of this EIS.

3. *"With improved water supply conditions for fish habitat, increased recreational opportunities and associated commercialization opportunities would occur in both the U.S. and Canada."*

Depending on the actual shape of the downstream flow, river recreation might benefit, but there are limits—see the recreation analysis in this EIS. If reservoir recreation is the focus of this comment, then earlier refill as described in the response to comment 1 might improve economic opportunities in relatively rare years. However, drawdown for salmon would probably not allow the reservoir to stay full for long, especially if we are attempting to avoid a "double peak" in river flows.

4. *Greater release capacity should provide better flood control.*

There was only one year to consider for this comment, because with the current powerhouse capacity, simulations showed only one year when the river at Bonners Ferry got above flood stage. When this year was simulated again assuming an increased powerhouse capacity, it made no difference (the river stage at Bonners Ferry was still the same). It happens that 1961 is a year where runoff conditions below the dam are very high at the same time water managers would like to be preserving flood control space in the reservoir. Therefore, it is difficult to draw a solid conclusion about whether increased flow capacity would provide flood control benefits. In theory, a higher powerhouse capacity could afford greater flexibility in maintaining flood control space in the final stages of refill, depending on runoff conditions below the dam. However, the project is already equipped with spillways and sluice gates to provide additional release capacity beyond powerhouse capacity.

5. *Greater release capacity could mitigate against uncontrolled spill and associated adverse consequences, especially if installation of more generators, or other improvements to address dissolved gas generation, were employed.*

The purpose and need for the EIS is to address the change in flood control operations and the effects associated with additional downstream flows. We have arrived at no mechanism to provide 10,000 cfs above current powerhouse capacity at Libby within Montana dissolved gas standards, so this is premature for this EIS.

6. *Adding generators would require new transformers, providing redundancy in case of equipment failure, which in turn might reduce risk of large spill events and help ensure needed fish flows.*

Again, we have not determined a mechanism to provide the additional 10,000 cfs out of Libby consistent with the State of Montana's water quality standard. It is outside the scope of this EIS to speculate on that mechanism. Also, refill was missed by only 2 feet in the 2002 spill event, if that event is part of the logic regarding spill and refill failure in the comment.

7. *Greater spring flows could help scour gravel clean downstream, providing biological benefits.*

(See response to #8) Recent information from the USGS indicates that the ability to scour sediment in the Kootenai/y River below Bonners Ferry may be very limited if it exists at all. Because of the Kootenay Lake backwater effect, the ability to increase velocities to levels that would mobilize and clear fine sediments is questionable, and possibly even more so in British Columbia than in Idaho.

8. *Scour might help to restore channel capacity that has been reduced by sediment accumulation.*

Analysis indicates that suspended sediment transport with additional flow capacity would be about 15% higher than that without increased release capacity. This equates to less than 0.1 foot per year of riverbed erosion if the erosion is limited to a 10 mile reach of the river (Kootenai River Sand Transport, Corps 2004).

9. *Revisiting VARQ and the variable December 31 reservoir draft level in the context of the additional release capacity could aid in reservoir refill in low-runoff years.*

We have evaluated VARQ and fish flows using 10,000 cfs above Libby powerhouse capacity. However, reformulating VARQ and the December 31 variable draft limit to 10,000 cfs above powerhouse capacity would entail totally revamping flood control, which is outside the scope of this EIS. This effort may be appropriate in the future as we get closer to a mechanism to achieve the additional outflow capacity.

10. *VARQ could increase average annual power revenues by $5 million (according to Bonneville Power Administration), which could offset costs of installing additional generator installation and transmission improvements to achieve the additional 10,000-cfs capacity.*

We are investigating the possible costs and benefits for a variety of mechanisms to achieve additional outflow capacity, but have reached no conclusions. In addition, the Corps' power analysis shows a small net average loss in system generation from VARQ versus Standard Flood Control.

11. *"Higher flows that help scour the channel in the braided reach [at Bonners Ferry] are important to maintaining a channel with sufficient depth to encourage white sturgeon to migrate into this reach where substrate and higher velocities are more appropriate for spawning and recruitment."*

It is not clear that depth in the braided reach presents a barrier to sturgeon migration under the current flow regime. Existing channel depths in the braided reach appear to be sufficient for sturgeon migration, but, for unknown reasons, sturgeon don't appear to move upstream of Bonners Ferry. Also, hydraulic conditions in the braided reach are different than they were in the 19th century. While Libby Dam did reduce sediment transport capacity in the braided reach, it also reduced the inflowing sediment load. It may be that operations for flood control will necessarily limit discharges such that scouring will not occur in the braided reach. The investigations necessary to define the magnitude of hydraulic and sediment transport changes, or to determine the discharges required to induce scour in the braided reach, have not been conducted.