Status Report

Work to Date on the Development of the VARQ Flood Control Operation at Libby Dam and Hungry Horse Dam

January 1999

Section 2

Kootenai River Flood Control Study
Analysis of Local Impacts of the Proposed VARQ Flood Control Plan

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Executive Summary

The current flood control plan for Libby Dam no longer satisfies the changing needs of the Pacific Northwest. Deep reservoir drafts coupled with minimum releases during the spring runoff period are not compatible with refill goals for Lake Koocanusa if downstream flow objectives established within the framework of the Endangered Species Act are to be successfully met. Failure to refill Lake Koocanusa damages the resident fishery, impacts the local tourist industry, and limits water availability for other uses. In an attempt to address this situation, the U.S. Army Corps of Engineers (Corps) has developed a new flood control plan known as VARQ (pronounced "vair Q") that can accommodate the variable flows required for endangered species, maintain current flood protection, and improve the ability to refill Lake Koocanusa. This report evaluates the risks, benefits, and costs associated with the VARQ flood control plan, and assesses the impacts of VARQ when used in conjunction with other flow augmentation proposals. The study area for this analysis includes the Kootenai (Kootenay) River Basin from the outlet of Kootenay Lake to the headwater reservoirs behind Libby and Duncan Dams. Power impacts associated with the VARQ flood control plan are not addressed.

The original Columbia River Treaty Flood Control Operating Plan for Libby Dam was developed as part of the Columbia River Treaty process in the late 1960's and early 1970's. It prescribed criteria and procedures by which the United States would operate Libby Dam to achieve flood control objectives in both the United States and Canada. The original flood control plan was modified in 1991 as described in the Columbia River and Tributaries Study , CRT-63 and is now used to guide the flood control operation of Libby Dam (BASE-CRT63).

If the sole interest is to minimize local flood damages downstream of Libby Dam with no regard for endangered species, then the dam should continue to be operated to the BASE-CRT63 flood control plan. However, the Endangered Species Act requires that reasonable and prudent measures be taken to assure the survival of various fish species downstream of Libby Dam. Since the 1994 listing of the Kootenai River white sturgeon under the Endangered Species Act, the U.S. Fish and Wildlife Service and the National Marine Fisheries Service have required the Corps to release water volumes from Libby Dam during the spring and summer months far in excess of that envisioned in the BASE-CRT63 flood control plan.

In 1997 the Corps officially adopted the Preferred Alternative from the Columbia River System Operation Review as the operating plan for Libby Dam. The Preferred Alternative (SOSPA) *operating plan* drafts Lake Koocanusa according to the BASE-CRT63 *flood control plan,* and includes endangered species flows as described in the Biological Opinions (BIOPs) of the federal fisheries agencies. The SOSPA operating plan has shortcomings when compared to other alternatives which include the VARQ flood control plan. The SOSPA operating plan will result in an average shortfall in refilling Lake Koocanusa of approximately 28 feet. SOSPA will cause significant agricultural impacts in the Kootenai River valley, and result in lower recreation benefits than alternatives featuring the VARQ flood control plan.

The logic behind the VARQ flood control plan is simple: If releases from Libby Dam during the spring runoff period are greater than those specified by the current BASE-CRT63 flood control plan, then it is not necessary to draft Lake Koocanusa as deeply to provide the same level of flood protection downstream. This allows Lake Koocanusa to be more full during the winter, and increases refill reliability.

The VARQ flood control plan requires generally higher reservoir releases from Libby Dam than the current BASE-CRT63 flood control plan during the refill period in years with average and below average runoff. Dam operators will continue to limit reservoir releases when necessary to protect public safety. There will be no increase in out-of-bank flooding downstream of Libby Dam under the VARQ flood control plan. In those years when a large amount of runoff is anticipated, the VARQ flood control plan is similar to the BASE-CRT63 flood control plan, calling for Lake Koocanusa to be drafted to the bottom of the flood control pool (elevation 2287 feet). The VARQ flood control plan can require up to 1.5 million acre-feet less flood control storage than the current BASE-CRT63 flood control plan. Lake Koocanusa will be up to 45 feet higher during the winter months depending on the water supply forecast.

Most damages downstream of Libby Dam are not the result of out-of-bank flooding, but the consequence of an elevated groundwater table most often driven by the endangered species flows, and not flood control releases. Assuming that endangered species flows will continue into the foreseeable future, a change to the VARQ flood control plan at Libby Dam will not increase downstream agricultural damages.

The VARQ flood control plan would result in maximum Kootenay Lake elevations up to one foot higher than the current BASE-CRT63 flood control plan. There would be essentially no impact at Duncan Dam.

A potentially negative impact associated with the VARQ flood control plan is that it can result in an increased risk of spilling water at Libby Dam if additional releases for fish or power beyond those specified by the flood control plan are *not* done. Spill is a function of the current limited turbine capacity at the Libby Dam powerhouse. Spill is not a flood control issue because a spill event would occur weeks after the runoff peak. Spill can be damaging to resident fish in the river below the dam. Because an important reason for pursuing the VARQ flood control plan is to provide better conditions for fish both in the reservoir and below the dam, it is likely that additional water releases will be pursued until another safe method of releasing water can be achieved .

This study looked at combining the VARQ flood control plan with the Biological Opinion flow regime (VARQ w/BIOP), and the tiered flow regime characteristic to the Integrated Rule Curves (VARQ w/IRCs). Both combinations would result in favorable agricultural and refill impacts as compared to the current SOSPA operation.

This study confirmed that the condition of the levee system along the Kootenai River from Bonners Ferry to the Canadian border has deteriorated since Libby Dam went into operation. Both toe and crest erosion have occurred due to years of neglected maintenance. Erosion is exacerbated by high summer flows for endangered species and winter power releases. Future erosion will continue regardless of the flood control plan at Libby Dam. Bringing the current levee system in Idaho back up to a condition that provides 200-year flood protection for the Kootenai River valley will cost an estimated $8.7 million. In addition, under any alternative, an estimated 707,000 cubic yards of revetment costing approximately $17.7 million will be needed to stabilize the levees from future erosion by the Kootenai River. The maximum capital cost which induced flood damages would economically justify under any alternative is only $135,900. Therefore, from an economics standpoint, it makes little sense to invest large sums of money towards improving the Kootenai River levee system.

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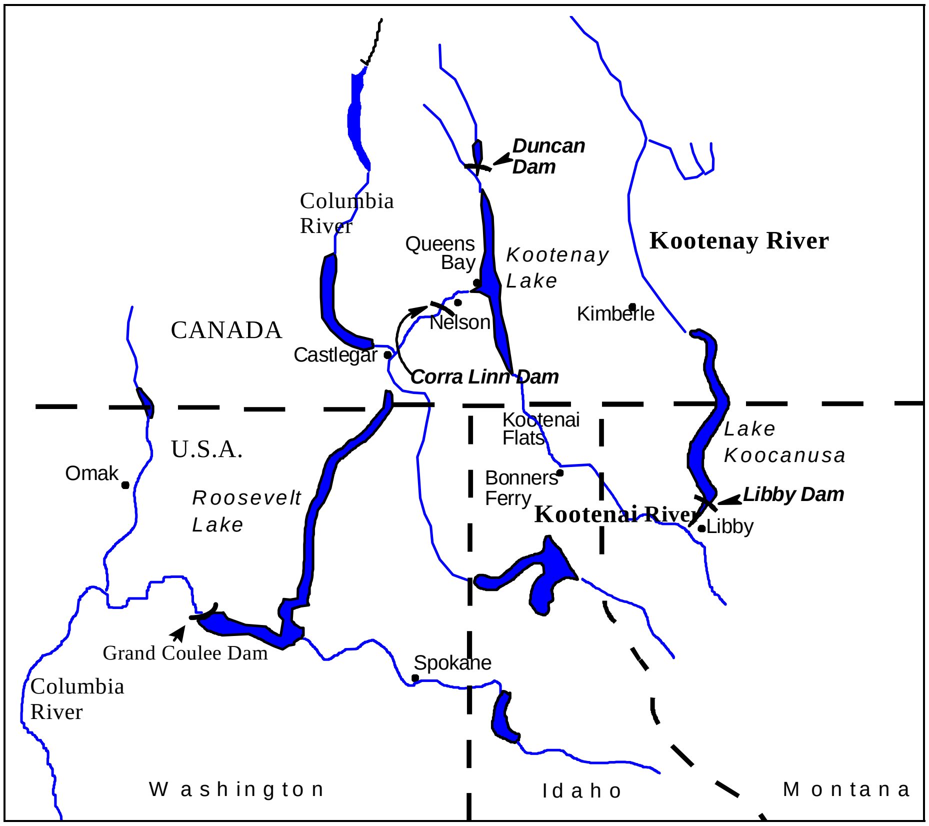
Figure 1-1. Map of the Kootenai River and Vicinity



1.0 INTRODUCTION

1.1 Need for Study

The current flood control plan for Libby Dam no longer satisfies the changing needs of the Pacific Northwest. Deep reservoir drafts coupled with minimum releases during the spring runoff period for the purpose of flood control are not compatible with refill goals for Lake Koocanusa if downstream flow objectives established within the framework of the Endangered Species Act are to be successfully met. Failure to refill Lake Koocanusa damages the resident fishery, impacts the local tourist industry, and limits water availability for other uses. In an attempt to address this situation, the U.S. Army Corps of Engineers (Corps) has developed a new flood control plan known as VARQ (pronounced "vair Q") that can accommodate the variable flows required for endangered species, maintain current flood protection, and improve the ability to refill Lake Koocanusa.

The VARQ flood control plan was originally developed by the Hydrologic Engineering Branch of the Northwestern Division of the U. S. Army Corps of Engineers in the late 1980's. VARQ was introduced in the screening analysis for the Columbia River System

Operation Review (SOR)[1], and further examined in the Columbia River Basin System Flood Control Review-Preliminary Analysis Report.[2] These studies revealed that VARQ can meet all downstream flood control objectives while improving the probability of refilling Lake Koocanusa. VARQ can be modified to satisfy the flow requirements in the U.S. Fish and Wildlife and National Marine Fisheries Services' 1995 Biological Opinions for endangered sturgeon[3] and salmon.[4] VARQ reservoir releases can also be adjusted to meet the flow targets associated with the Montana Integrated Rule Curves (IRCs), and the Draft Kootenai River White Sturgeon Recovery Plan[5]. Prompted by positive results in the both the SOR screening process and the subsequent preliminary analysis, the Corps of Engineers decided to proceed further with VARQ's development.

1.2 The Preliminary Analysis

The Columbia River Basin System Flood Control Review- Preliminary Analysis Report was completed in February 1997 in response to the U.S. Fish and Wildlife and National Marine Fisheries Services' 1995 Biological Opinions. The primary purpose of the preliminary analysis was to assess the impacts on system flood control of raising the controlled flow target in the lower Columbia River. A secondary purpose of the preliminary analysis was to provide further insight into the potential impacts of the VARQ flood control plan at Libby Dam.

The Preliminary Analysis Report:

- Confirmed that endangered species actions, not the underlying flood control operations, were responsible for most flow related impacts downstream of Libby Dam[6].
- Suggested that the sturgeon flow releases characterized in the current operating strategy for Libby Dam, SOSPA (the Preferred Alternative from the Columbia

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[1] Columbia River System Operation Review, Final Environmental Impact Statement, Appendix E, Flood Control, DOE/EIS 0170, Bonneville Power Administration, November 1995, p. 4-20.
[2] Columbia River Basin System Flood Control Review - Preliminary Analysis Report, U.S. Army Corps of Engineers, North Pacific Division, Portland, February, 1997, pp. 66-69..
[3] Dwyer, Thomas, Acting Regional Director of USFWS, Portland, in letter to General Ernest J. Harrell, Commander, North Pacific Division, US Army Corps of Engineers, March 1, 1995, pp. 9-10.
[4] Endangered Species Act - Section 7 Consultation, BIOLOGICAL OPINION, Reinitiation of Consultation of 1994-1998 Operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years, National Marine Fisheries Service, Northwest Division, Seattle, March 2, 1995, p. 104.
[5] White Sturgeon: Kootenai River Population - Draft Recovery Plan, U.S. Fish and Wildlife Service-Region 1, Portland, 1996, pp. 47-48.
[6] Columbia River Basin System Flood Control Review - Preliminary Analysis Report, U.S. Army Corps of Engineers, North Pacific Division, Portland, February, 1997, pp. 64-65.

River System Operation Review), will lead to higher river stages, increased pumping costs, and greater river bank erosion than historic reservoir operation [7].

- Found that the VARQ flood control plan would have little or no impact on the magnitude and duration of flows below Libby Dam as compared to flows associated with SOSPA[8].
- Concluded that Integrated Rule Curves (IRCs) could be implemented "if the flood control season is guided by the VARQ procedure"[9].
- Established that "VARQ operations would result in higher levels of Lake Koocanusa, allow for increased river flows for endangered species, enhanced reservoir levels and refill for recreation and resident fish"[10] .

The Preliminary Analysis Report contained a very confusing sentence that has lead some readers to incorrectly conclude that the VARQ concept was not viable. The report stated "While VARQ operations would result in higher levels of Lake Koocanusa, allow for increased river flows for endangered species, enhanced reservoir levels and refill for recreation and resident fish, mitigation of flood control impacts to levees and drainage facilities on Kootenai River below Bonners Ferry is not economically feasible."[11] This statement has proven to be quite misleading. Bringing the levees up to the condition existing when Libby Dam was constructed (200-year design level of protection) may not be economically feasible, however, this should not be attributed to VARQ. The levees have deteriorated due to years of neglected maintenance.[12] Overwhelming evidence elsewhere in the report suggests that potential impacts to levees and drainage facilities resulting from the VARQ flood control plan would be minor or non-existent when compared to the impacts of the endangered species flows currently being undertaken. The lack of negative impacts attributable to the VARQ flood control plan in the preliminary analysis prompted the Corps to proceed further in investigating VARQ.

1.3 Purpose of this Study

The purpose of this study is to assess the hydrologic, levee, and economic impacts of the VARQ flood control plan on the Kootenai River basin as compared to the current BASE-CRT63 flood control plan. BASE-CRT63 is described in the Columbia River Treaty Flood Control Operating Plan[13] and amended by the Columbia River and Tributaries Study, CRT-63 [14]. This study takes a detailed look at the two plans (BASE-CRT63 and

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[7] Columbia River Basin System Flood Control Review - Preliminary Analysis Report, U.S. Army Corps of Engineers, North Pacific Division, Portland, February, 1997, pp. 64-65.
[8] Ibid.
[9] Ibid., pp. 69.
[10] Ibid., pp. 96.
[11] Ibid.
[12] Ibid., pp. 62.
[13] Columbia River Treaty Flood Control Operating Plan, U.S. Army Corps of Engineers, North Pacific Division, Portland, October 1972, pp. 29-30
[14] Review of Flood Control Columbia River Basin, Columbia River and Tributaries Study, CRT-63, U.S. Army Corps of Engineers, North Pacific Division, Portland, June 1991, pp. 36-49.

VARQ) from the sole perspective of flood control, and then reassesses them with sturgeon flow regimes superimposed on flood control requirements. This study also examines the impacts of the Biological Opinion sturgeon flow regime on both BASE-CRT63 and VARQ, and evaluates the VARQ flood control plan with the Integrated Rule Curve (IRC) flow regime. The IRC flow regime is supported by the state of Montana, the Northwest Power Planning Council, and the White Sturgeon Recovery Team. In addition to examining impacts at Bonners Ferry and Kootenay Lake, this study determines reservoir elevations at Lake Koocanusa and discharges associated with VARQ and BASE-CRT63, and the potential of spilling water from Libby Dam.

Since the Preliminary Analysis Report established that endangered species actions, not the underlying flood control plan, were responsible for most flow related impacts downstream of Libby Dam, it was decided to examine the VARQ flood control plan in greater detail due to its positive impact on refill. Endangered species flow augmentation from Libby Dam will no doubt continue whether or not the flood control plan is updated. Implementation of VARQ would allow more consistent refill of Lake Koocanusa despite the large endangered species flow requirements.

The Preferred Alternative (SOSPA) from the Columbia River System Operation Review is also examined in detail in this report. SOSPA is the current system operation strategy for Libby Dam. SOSPA includes the BASE-CRT63 flood control plan and the 1995 Biological Opinion endangered species flows.

1.4 Operating Alternatives for Libby Dam

The primary flood control alternatives examined in this report are VARQ and BASE-CRT63 as shown in Table 1-1. To facilitate a comparison, the study was expanded to include VARQ and BASE-CRT63 modified to various sturgeon flow regimes (See Table 1-2).

Table 1-1 Primary Alternatives for Libby Dam Flood Control Operating Plan.

Primary Alternative	General Description as Modeled
BASE-CRT63	Libby Dam is regulated to meet the flood control rule curves as specified in the Columbia River Treaty Flood Operating Plan[15] as amended by CRT63[16]. No additional power drafts. No sturgeon or salmon releases.
VARQ	Releases from Libby Dam are variable during the refill period based upon runoff forecasts and available storage. Libby drafts empty by mid-March in the largest runoff years, but remains more full than BASE-CRT63 in most other years. No additional power drafts. No sturgeon or salmon releases.

[15] Columbia River Treaty Flood Control Operating Plan, U.S. Army Corps of Engineers, North Pacific Division, Portland, October 1972, pp.29-30.
[16] Review of Flood Control Columbia River Basin, Columbia River and Tributaries Study, CRT-63, U.S. Army Corps of Engineers, North Pacific Division, Portland, June 1991, pp. 36-49.

Table 1- 2 Alternatives Modified with Sturgeon Releases.

Alternative	General Description as Modeled
SOSPA (SOR Preferred Alternative)	Libby Dam is operated to the BASE-CRT63 flood control rule curves, and provides the sturgeon flows specified in the Biological Opinion (BIOP)[17]. Provides sturgeon spawning flows at Bonners Ferry, Id. of 35,000 cfs for 42 days from June 1 until July 12, and sturgeon incubation flows of 11,000 cfs for 21 days following the maximum flow period. Due to the uncertainty of salmon releases in August and the lack of flood control impacts, no August salmon releases were included in this evaluation. SOSPA is the current operating plan for Libby Dam.
VARQ w/BIOP Sturgeon Flows	Libby Dam is operated to the VARQ flood control rule curves and modifies the VARQ releases to provide the sturgeon flows specified in the Biological Opinion.
VARQ w/IRC Sturgeon Flows	Libby Dam is operated to the VARQ flood control rule curves and modifies the VARQ releases to provide for the tiered flow regime characteristic of the Integrated Rule Curves (IRCs). This tiered flow regime is outlined in <u>The USFWS Draft White Sturgeon Recovery Plan</u> [18]and features flows in June at Bonners Ferry, Idaho ranging from a low of 8,000 cfs in dry years to 50,000 cfs in the wettest years.

[17] Dwyer, Thomas, Acting Regional Director of USFWS, Portland, in letter to General Ernest J. Harrell, Commander, North Pacific Division, US Army Corps of Engineers, March 1, 1995, pp. 9-10.

[18] <u>White Sturgeon: Kootenai River Population - Draft Recovery Plan</u>, U.S. Fish and Wildlife Service-Region 1, Portland, 1996, pp. 47-48.

2.0 HYDROLOGIC ANALYSIS

2.1 Hydro-Regulations

2.1.1 Introduction

An important element of any flood control study is the accuracy of the hydro-regulations. Hydro-regulations offer a detailed look at the impacts of both VARQ and BASE-CRT63 by simulating reservoir operation on the Kootenai River system over a fixed period of record. The hydro-regulations reveal what "would have" happened if the dams on the Kootenai River system had been regulated to the various alternatives during those historic years. The Streamflow Synthesis and Reservoir Regulation computer model (SSARR) with it pre/post processor AUTOREG was used in this analysis. Reservoir release decisions were made a daily basis. Limited foresight was used in the simulations to reflect the uncertainty associated with "real-time" reservoir regulation. Historic runoff and updated runoff forecasting techniques were employed.

2.1.2 Selection of Years for Evaluation

A 31 year record (1948-1978) was used in this study. Many significant spring floods have occurred within this 31 year period; including the floods of 1948, 1956, 1972, and 1974. In addition, the 200-year flood at Libby and Bonners Ferry was reviewed and used to define the upper end of the regulated frequency curves for all scenarios modeled.[19]

2.1.3 Simulated Water Supply Forecasts

Reservoir regulators use volume runoff forecasts to determine the amount of flood control space necessary at storage reservoirs. Hydro-regulations use the volume runoff forecasts to introduce the element of forecast error into the simulations. Simulated water supply volume forecasts for the 1948-1978 period were used in development of the flood control rule curves which guide operations at Libby and Duncan Dams. Unlike most previous Corps' studies which used the standard Kuehl-Moffitt Simulated Seasonal Volume Runoff Forecasts, this study used a more accurate forecasting procedure developed by Wortman and Morrow of the Corps' North Pacific Division in 1986. The Wortman-Morrow forecasts are currently used in real-time operations for Libby Dam. The Wortman-Morrow forecasts are available on a monthly basis for water years beginning in 1948.

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[19] Merkle, Lawrence, "The 200 Year Flood (regulated) at Bonners Ferry" in file titled Libby Operation Except 1972, U.S. Army Corps of Engineers, Seattle District, H&H Files, October 12, 1971.

Table 2-1 compares the Wortman-Morrow and Kuehl-Moffitt simulated runoff forecasts done on April 1 for April through August period. The smaller standard error associated with the Wortman-Morrow method makes large forecasting errors unlikely.

Table 2-1. Comparison of the Kuehl-Moffitt forecasts and the Wortman-Morrow forecasts. Note the smaller errors associated with Wortman-Morrow (especially in 1948).

APRIL 1 (APRIL - AUGUST) VOLUME RUNOFF FORECASTS for LIBBY INFLOW
Kuehl-Moffitt data came from crdata\fcst.dss
Wortman-Morrow data from Russ Morrow 12/5/95

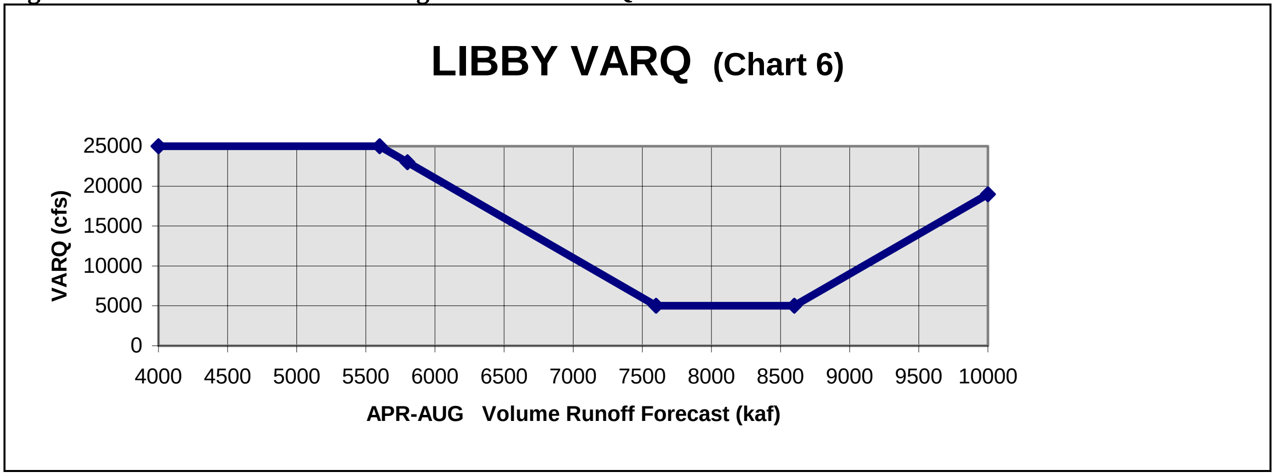
		Kuehl-Moffit		Wortman-Morrow	
Date	Actual	Forecast	Error	Forecast	Error
1948	8456	6188	2268	7538	918
1949	5043	6240	-1197	6030	-987
1950	7384	8414	-1030	7146	238
1951	8516	8119	397	8477	39
1952	6321	5990	331	6973	-652
1953	6577	6117	460	6167	410
1954	9126	7810	1316	8673	453
1955	6603	5503	1100	5809	794
1956	8718	7937	781	8468	250
1957	6013	6191	-178	6436	-423
1958	5723	5578	145	5967	-244
1959	8115	7468	647	7247	868
1960	6429	7182	-753	6946	-517
1961	7840	7408	432	7275	565
1962	5957	5425	532	6349	-392
1963	6432	5912	520	5854	578
1964	6930	6210	720	6703	227
1965	6956	7608	-652	7585	-629
1966	7177	7258	-81	7004	173
1967	8155	7973	182	8915	-760
1968	6235	5333	902	6173	62
1969	8243	6994	1249	7573	670
1970	4650	4673	-23	5009	-359
1971	7980	6679	1301	7738	242
1972	8868	7762	1106	9327	-459
1973	5025	5201	-176	5662	-637
1974	9220	8398	822	8921	299
1975	5976	7454	-1478	7021	-1045
1976	7408	6770	638	7648	-240
1977	3491	3439	52	4034	-543
1978	6288	5971	317	5859	429
Average Error=			344 kaf	Average Error=	-22 kaf
Standard Error=			692 kaf	Standard Error=	493 kaf

2.1.4 Modeling Procedure

Upper Rule Curves to guide seasonal reservoir lowering and refill were developed for Lake Koocanusa and Duncan Reservoir based on the seasonal volume runoff forecasts and the respective storage reservation diagrams (Figures 2-2 and 2-3). Kootenay Lake was drafted to its flood control rule curve as described by the International Joint Commission (IJC) Order of 1938 . When a conflict existed in meeting the 1938 Order at Kootenay Lake, Duncan Reservoir was reduced to passing no more than inflow and Libby

Reservoir was allowed to continue to draft if possible. At no time were Libby or Duncan Dams required to pass less than inflow. Libby and Duncan were operated so as not to drive Kootenay Lake above its allowable lake level during the period governed by the "lowering formula". For the purpose of system flood control for the lower Columbia River, Libby and Duncan passed inflow (or evacuated trapped storage, if possible) after April 1 until the Initial Controlled Flow was exceeded at the Dalles. At which time both reservoirs were set at a minimum discharge (4000 cfs and 100 cfs respectively) modified for both trapped storage and changing volume runoff forecasts in the BASE-CRT63 simulations. In the VARQ simulation, Libby's discharge during refill was determined by Chart 6 (Figure 2-1), and was then modified for trapped storage and changing volume runoff forecasts.

Figure 2-1. Chart 6 for determining the Initial VARQ



Libby and Duncan Reservoirs were refilled until Libby reached elevation 2429 (30 feet from full) and/or Duncan reached elevation 1852 (40 feet from full). At which time those projects completed filling using the guidance of filling transition curves (FTCs). FTCs are computer algorithms that objectively attempt to refill based on inflow and reservoir elevation. The FTCs act to limit the amount of foresight used in the hydro-regulations.

The Preferred Alternative (SOSPA) was modeled by simply adding the BIOP sturgeon flows to BASE-CRT63. In the case of VARQ w/BIOP Sturgeon Flows, a methodology was devised (and is described in the section titled **Adapting VARQ to the BIOP** in the Hydrology Appendix) which attempted to balance the volume released from Libby under VARQ during the period when Libby Dam is regulating for system flood control .

None of the scenarios modeled drafted Libby Reservoir in August to meet salmon flow targets in the lower Columbia River. There are no flood control impacts associated with the August draft.

Throughout the simulations, it was assumed that Corra Linn Dam at the outlet of Kootenay Lake was regulating to its upper rule curve except during the "lowering" period when it was releasing its hydraulic capacity.

Figure 2-2. The VARQ Storage Reservation Diagram for Libby Dam

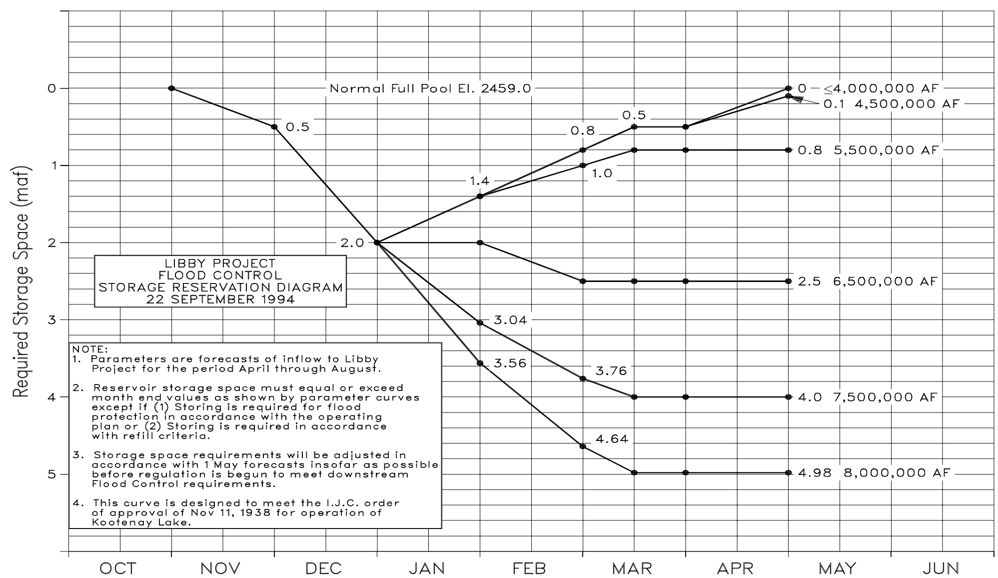
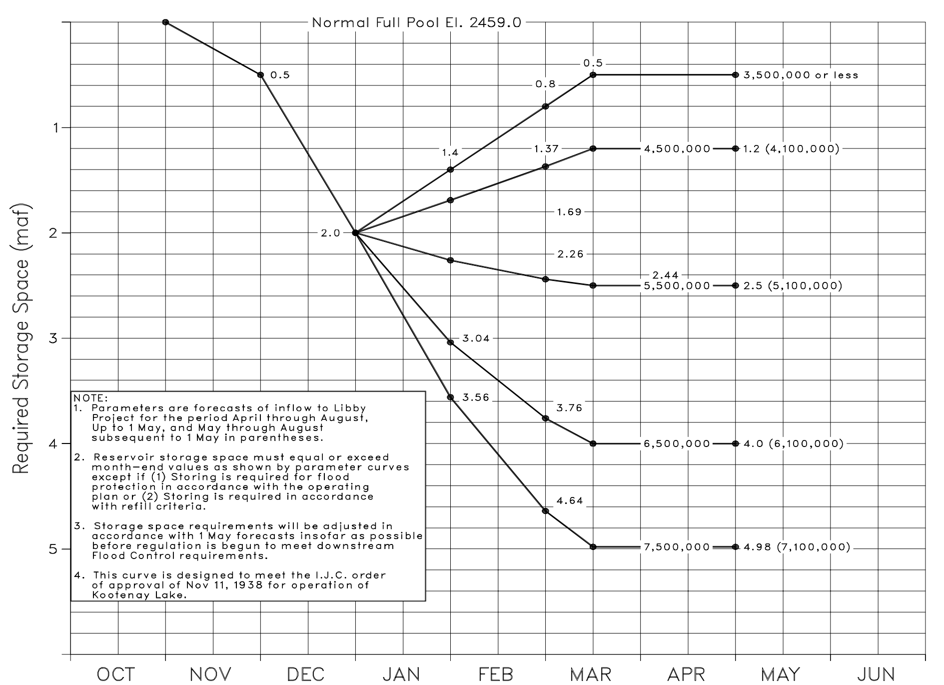


Figure 2-3. The BASE-CRT63 Storage Reservation Diagram for Libby Dam



2.2 Hydrologic Results

2.2.1 Statistical Analysis

Frequency curves at Libby Dam, Duncan Dam, Bonners Ferry, and Kootenay Lake were derived to illustrate the impacts of the various flow regimes on local flood control. Procedures for graphing regulated frequency curves are explained in the U.S. Army Corps Of Engineer's Engineering Memorandum Hydrologic Frequency Analysis, EM 1110-2-1415[20].

2.2.2 Bonners Ferry Description

The U.S.G.S. gage on the Kootenai River at Bonners Ferry, Idaho is the damage center located 69 miles downstream of Libby Dam which has been used historically as a reference point to determine the flood magnitude in the Kootenai River.

2.2.2.1 Bonners Ferry Stage

Prior documentation (NPSOM 500-1-1, 3 February 1992[21]) identified the flood stage on the Kootenai River as elevation 27.0 feet on the Bonners Ferry gage (i.e. elevation 1770 feet, mean sea level). The Columbia River System Operation Review (SOR) placed Bonners Ferry flood stage at elevation 1766.5 feet[22]. Both of these elevations were too high based on the levee evaluation field work done in 1995-1997, and the water surface profile modeling done for The Preliminary Analysis Report[23]. The flood stage for the Kootenai Flats area as measured at the Bonners Ferry gage is currently elevation 1764.0 feet. Field observations in both 1996 and 1997 confirmed this flood stage. Erosion occurred, but no levee breaches were in evidence. Flooding at elevation 1764 feet is agricultural in nature, and generally resulted from an elevated groundwater table or inflows from non-leveed tributaries.

The Corps of Engineers operates Libby Dam to minimize downstream flood impacts without compromising the overall local flood control objective of providing 200-year

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[20] U.S. Army Corps of Engineers, Hydrologic Frequency Analysis, EM 1110-2-1415, 5 March 1993, pp. 6.1-6.4.
[21] U.S. Army Corps of Engineers, Seattle District, Plans for Natural Disaster Procedures, NPSOM 500-1-1, February 1992, pp. v-3.
[22] Bonneville Power Administration, Columbia River System Operation Review Final Environmental Impact Statement Appendix E Flood Control, November 1995, pp. 3-3.
[23] Columbia River Basin System Flood Control Review - Preliminary Analysis Report, U.S. Army Corps of Engineers, North Pacific Division, Portland, February, 1997, pp. 51-52.

flood protection to the Bonners Ferry area from river stages in excess of elevation 1770 feet. [24] The best information available suggests that river stages in excess of elevation 1764 feet may eventually result in levee failure in the reach from Bonners Ferry to the Canadian border. Flood control space permitting, the Corps attempts to regulate the Kootenai River to no higher than elevation 1764 feet at the Bonners Ferry gage. The Corps may allow the Kootenai River to exceed elevation 1764 feet at Bonners Ferry if necessary to preserve flood control space in the reservoir during large runoff events. The stage target at Bonners Ferry will depend on the best information available at the time.

The VARQ and BASE-CRT63 hydro-regulations reflect operations for the sole purpose of flood control. Power drafts at Libby Reservoir have historically supplemented flood control drafts, often resulting in more flood control space being available at the beginning of the spring runoff period. With release of the National Marine Fisheries Services' 1995 Biological Opinion, which requires U.S. projects to be at flood control elevations at the beginning of the spring runoff season[25], the advantageous effects of supplemental power drafts ended. The effect of this change in reservoir operation is demonstrated by the difference in the frequency curve for BASE-CRT63 and the regulated frequency curve developed for the Libby Dam and Lake Koocanusa -Water Control Manual[26] which incorporated power drafts in the hydro-regulations and encompassed a drier period of record (1929-1958). BASE-CRT63 represents an accurate picture of the flood control capability of Libby Dam.

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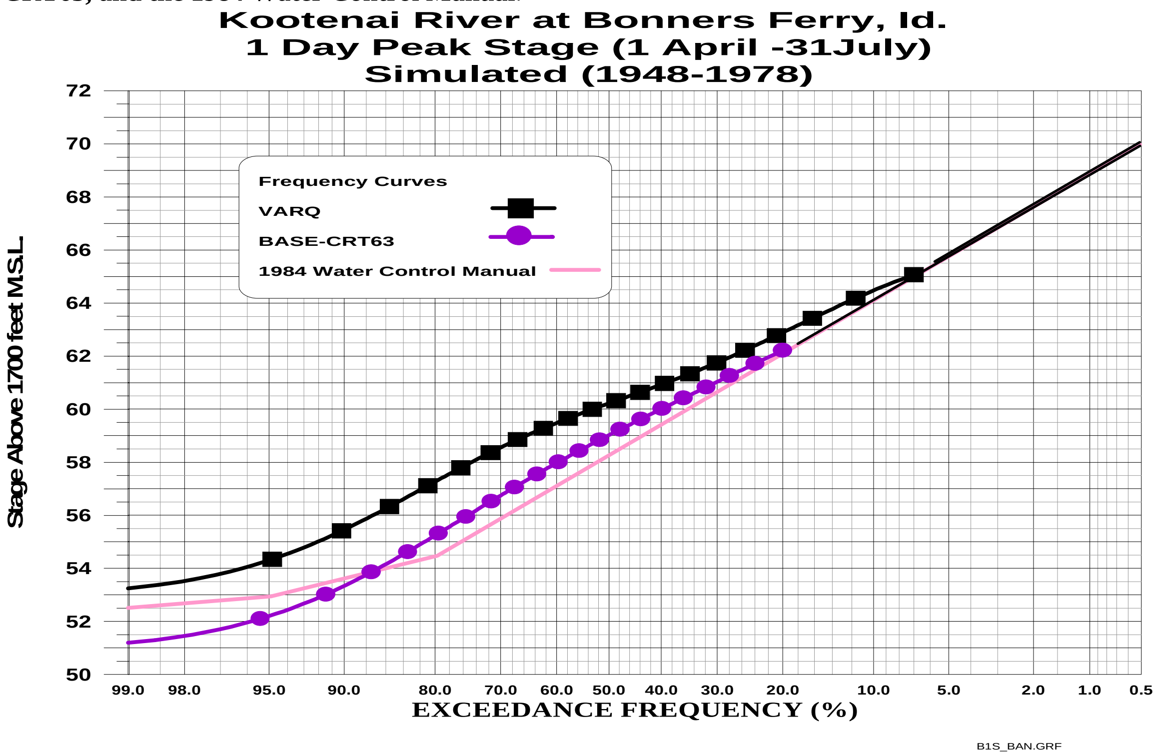
[24] McGrane, Memo for Record: Local Flood Control Objectives for Libby Dam Project, U.S. Army Corps of Engineers, Seattle District, H&H Files, July 30, 1996.

[25] Endangered Species Act - Section 7 Consultation, BIOLOGICAL OPINION, Reinitiation of Consultation of 1994-1998 Operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years, National Marine Fisheries Service, Northwest Division, Seattle, March 2, 1995, p. 95.

[26] U.S. Army Corps of Engineers, Seattle District, Libby Dam and Lake Koocanusa -Water Control Manual, July 1984, Chart 4-2.

Figure 2-4. Frequency curves, Kootenai River at Bonners Ferry, Id., 1 day maximum stage VARQ, BASE-CRT63, and the 1984 Water Control Manual.



The VARQ flood control operation results in higher stages than BASE-CRT63 for all return periods shorter than 20 years, i.e., exceedance frequencies of >5%. Figure 2-4 suggests that there is no difference in the exceedance frequency between VARQ and BASE-CRT63 at the highest stages. There is a slight increase in the frequency of exceeding the zero damage stage of 1764.0. There is no impact to the 20, 50, 100, and 200 year flood peaks. This is contrary to the Preliminary Analysis Report which found a 1 ½ foot difference in the 200 year flood stage[27]. While appropriate for a reconnaissance study, the frequency curves in the Preliminary Analysis Report were assembled from hydro-regulations performed for various other studies.[28] Statistically, the frequency curves developed in this study are more valid because the data used in creating the hydro-regulations is uniform and includes improved water supply forecasts.

[27] Columbia River Basin System Flood Control Review - Preliminary Analysis Report, U.S. Army Corps of Engineers, North Pacific Division, Portland, February, 1997, pp. 64-65.

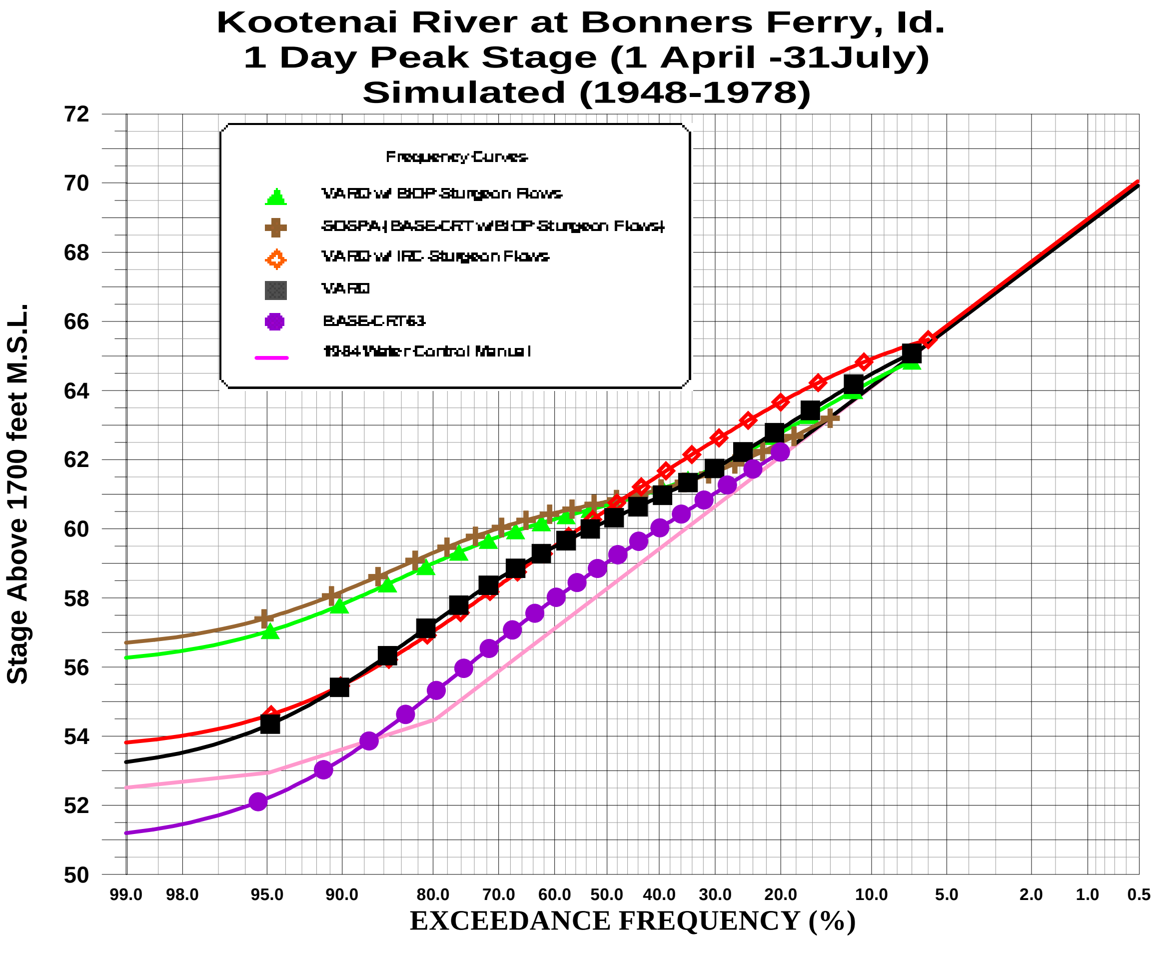
[28] Ibid., p. 53.

Table 2-2. Return periods, exceedance frequencies, and corresponding stages for the Kootenai River at Bonners Ferry, Idaho as a result the different flow alternatives.

Return Period (years)	Exceedance Frequency	Base-CRT63 (feet msl)	VARQ		SOSPA (Base-CRT63 with BIOP Sturgeon Flows)	VARQ w/BIOP Sturgeon Flows	VARQ w/IRC Sturgeon Flows
1	.99	1751.2	1753.3		1756.7	1756.3	1753.8
	.95	1752.2	1754.3		1757.4	1757.0	1754.5
	.90	1753.3	1755.5		1758.2	1757.8	1755.5
	.80	1755.3	1757.3		1759.3	1759.0	1757.0
2	.50	1759.0	1760.2		1760.7	1760.7	1760.5
5	.20	1762.0	1762.9		1762.4	1762.8	1763.6
10	.10	1764.0	1764.5		1764.0	1764.2	1764.9
20	.05	1765.8	1765.8		1765.8	1765.8	1765.8
50	.02	1767.7	1767.7		1767.7	1767.7	1767.7
100	.01	1768.9	1768.9		1768.9	1768.9	1768.9
200	.005	1770	1770		1770	1770	1770

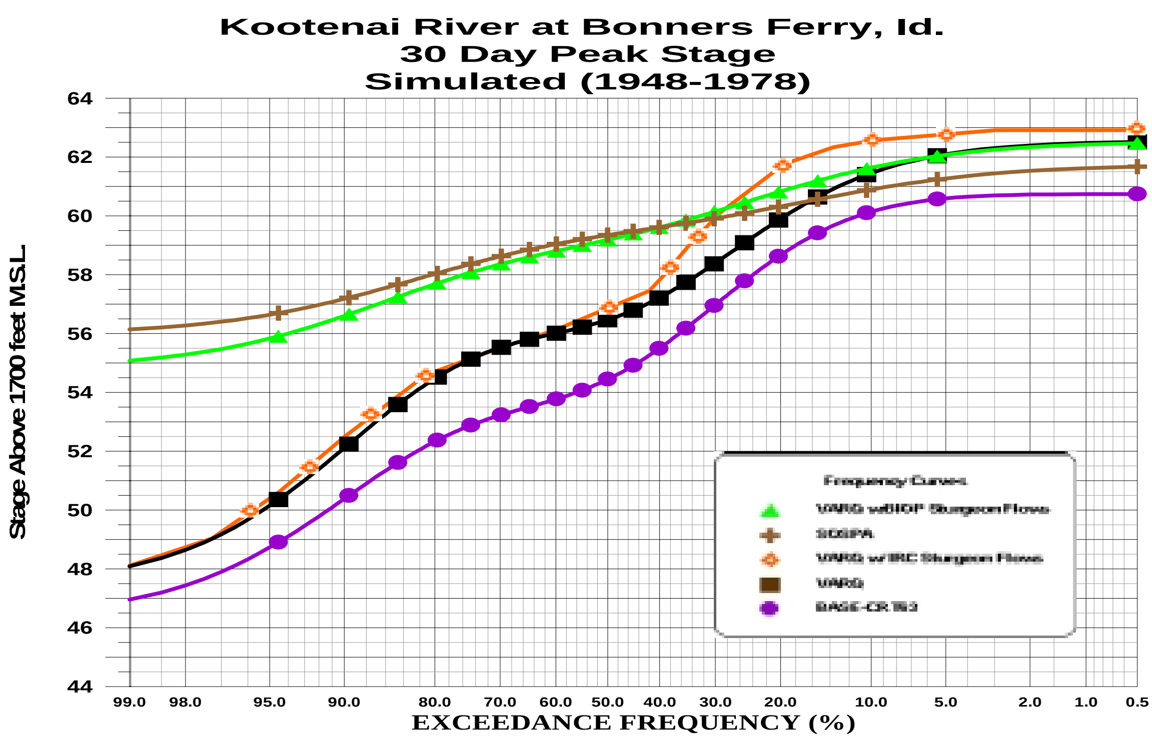
Table 2-2 represents a summary of the frequency curve information. Differences between the VARQ, and BASE-CRT63 flood control operations are illustrated in their respective frequency curves (Figure 2-4). The SOSPA and VARQ w/BIOP sturgeon flows regimes increase the peak stage relative to the BASE-CRT63 flood control operation in the low and moderate runoff years. However, there is no impact on the peak stage at Bonners for return periods greater than 20 years. Figure 2-5 shows that VARQ w/BIOP sturgeon flows and SOSPA, i.e., BASE-CRT63 w/BIOP result in essentially the same peak stage throughout the range of frequencies. VARQ w/IRC sturgeon flows results in a slightly greater probability of exceeding the flood stage of 1764 than the other alternatives due to the flow targets of 40,000 to 50,000 cfs at Bonners Ferry.

Figure 2-5. Frequency curves, Kootenai River at Bonners Ferry, Id., 1-day maximum average stage (1 April-31 July) for all scenarios modeled.



Farmers experience additional pumping costs when the Kootenai River at Bonners Ferry exceeds elevation 1755 feet. As can be seen in the frequency curve for the 30 day duration (Figure 2-6), the VARQ flood control operation results in a much greater probability of exceeding elevation 1755 feet for 30 consecutive days than the BASE-CRT63 flood control operation. When IRC sturgeon flows are added to VARQ there is no change in the frequency of high 30 day river stages in the dry years, but a dramatic increase in the frequency of prolonged high river stages in the wet years. The IRCs feature a tiered approach to reservoir releases with flow targets at Bonners Ferry ranging from of 8,000 cfs in years with less than 5.0 maf of anticipated runoff to targets of 50,000 cfs in years of greater than 9.5 maf. The Biological Opinion sturgeon flows will result in sustained 30-day river stages in excess of elevation 1755 feet in virtually every year, regardless of the flood control operation.

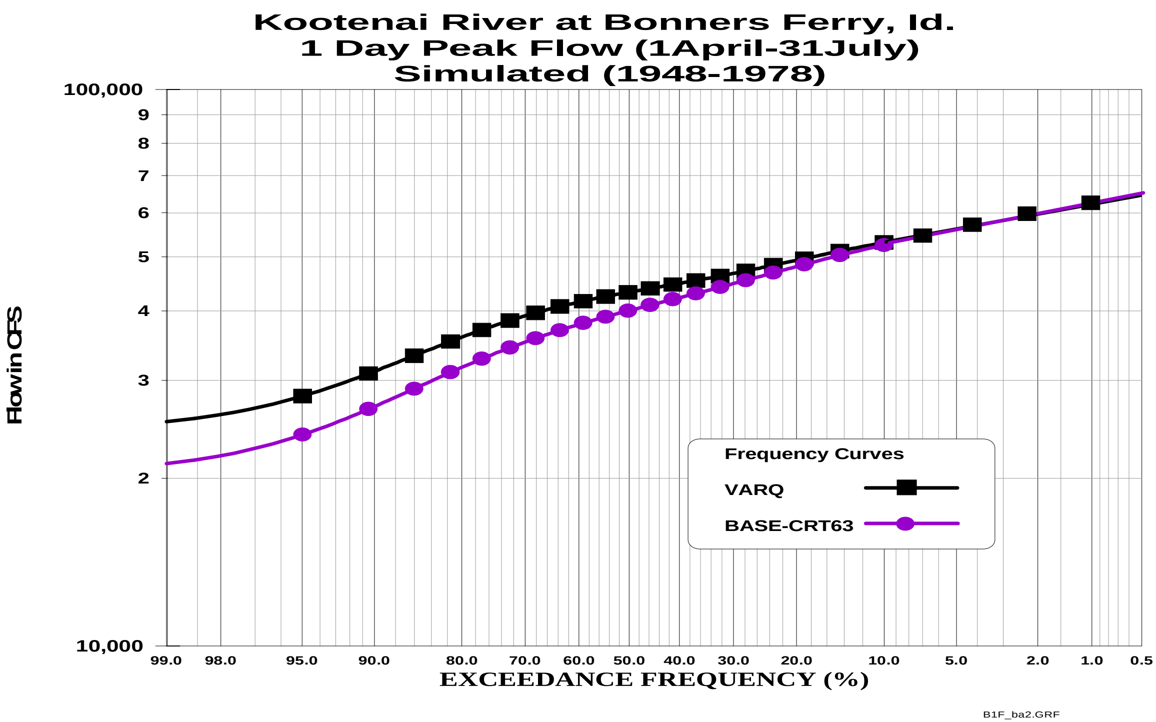
Figure 2-6. Frequency curves, Kootenai River at Bonners Ferry, Id., 30 day maximum average stage (1 April-31 July) for all scenarios modeled.



2.2.2.2 Bonners Ferry Flow

The Columbia River Treaty Flood Control Operating Plan states that "Flooding at Bonners Ferry, Idaho occurs when flows exceed 57,000 cfs." It goes on to state "It is considered that if flows at Bonners Ferry are controlled to 57,000 cfs, flood protection for Creston (B.C.) will be achieved."[29] Under all scenarios modeled, there was no increase in the frequency of flows exceeding 57,000 cfs. There is very little difference between VARQ w/BIOP and SOSPA. Frequency curves were developed for all scenarios (Figures 2-7 and 2-8).

Figure 2-7. Frequency curves, Kootenai River at Bonners Ferry, Id., 1 day maximum flow (1 April-31 July) BASE-CRT63 and VARQ



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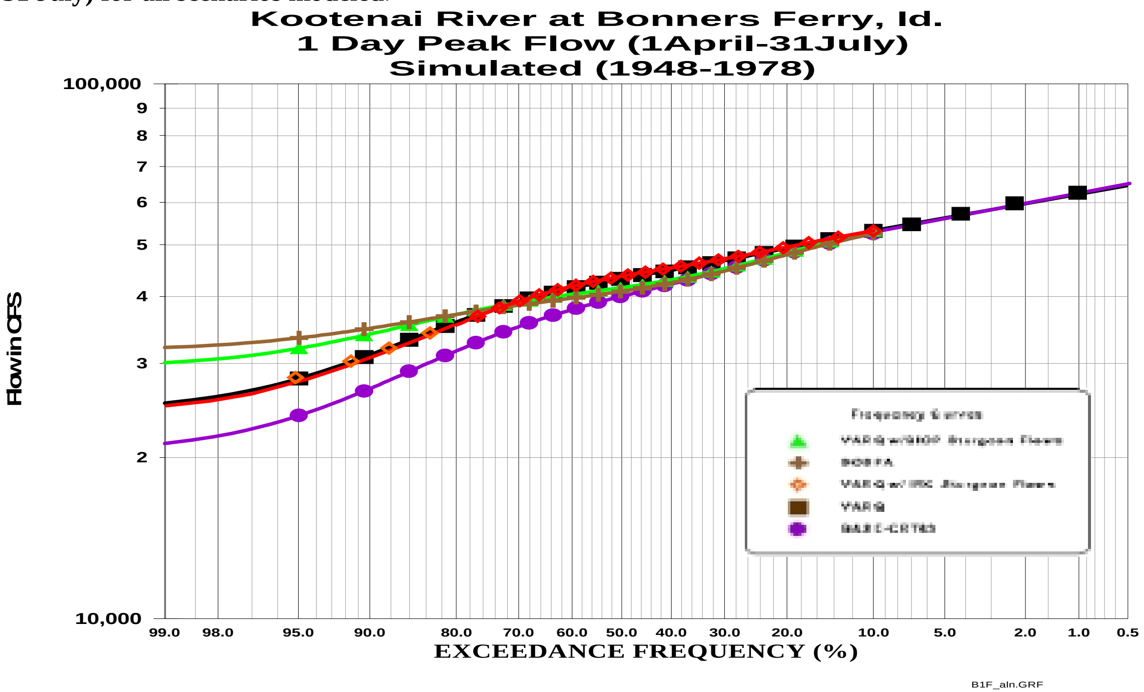
[29] Columbia River Treaty Flood Control Operating Plan, U.S. Army Corps of Engineers, North Pacific Division, Portland, October 1972, pp. 13.

Figure 2-8. Frequency curves, Kootenai River at Bonners Ferry, Id., 1 day maximum flow (1 April-31 July) for all scenarios modeled.



2.2.3 Libby Dam Description

Libby Dam is the major U.S. storage project on the Kootenai River. Lake Koocanusa, i.e., Libby Reservoir is owned by the U.S. Army Corps of Engineers and stores up to five million acre feet for hydropower production, flood control, recreation, and fisheries.

2.2.3.1 Lake Koocanusa Refill

The main purpose of changing the flood control operation of Libby Dam is to improve the likelihood of refilling Lake Koocanusa during the summer months. The Corps of Engineers has historically attempted to refill Lake Koocanusa with a high degree of certainty. This hydrologic study showed that without power or endangered species releases, it was possible to refill the reservoir to within 5 feet of full before the end of July in 94% of the years modeled, regardless of the flood control operation. Historically, power releases and a series of below normal runoff years have prevented this degree of refill success.

When Biological Opinion sturgeon releases are required from Libby Dam, a far bleaker picture emerges. SOSPA (i.e. BASE-CRT63 w/ BIOP Sturgeon flows) refilled the reservoir to within 5 feet of full in only 16% of the years modeled. SOSPA resulted in an average Lake Koocanusa elevation of 2430.6 feet (over 28 feet from full). The National Marine Fisheries Service's 1995 Biological Opinion for salmon calls for Lake Koocanusa to be drafted to elevation 2439 feet if necessary in the month of August to meet salmon flow targets in the lower Columbia River[30]. Under SOSPA, the reservoir reached a maximum elevation of 2439 feet in only 32% of years modeled. By satisfying the Biological Opinion sturgeon flows in June and July, there is little water left in Libby Reservoir to satisfy Biological Opinion salmon flows in August.

This situation is partially remedied by the VARQ flood control operating plan. VARQ w/BIOP refilled to within 5 feet of full in 42% of the years modeled and peaked out at an average elevation of 2447.6 feet (11 feet from full). VARQ w/IRCs did the best job in filling the reservoir among the sturgeon flow options, refilling Lake Koocanusa to within five feet of full before the end of July in 65% of the years modeled, and resulting in an average peak elevation of 2455.3 feet (four feet from full).

Neither the VARQ flood control operation nor the IRCs flow regime will result in refilling Lake Koocanusa every year. Refill would be possible during August in many years if the shortfall is not too great in July, and salmon releases are not required. It is possible to refill more frequently in July if the reservoir regulator is willing to risk spilling water over the spillways at Libby Dam much more frequently than has been the case historically. This is discussed further under the section 2.2.3.5 titled **Spill from Libby Dam**.

This study focuses on refill in July because of the uncertainty of reservoir releases from Libby Dam in August. In 1995, 1996, and 1997 water swaps were arranged between B.C. Hydro and the Corps of Engineers that allowed water to be taken from Arrow Reservoir in Canada instead of Lake Koocanusa to meet August salmon targets downstream. There is no guarantee that this swap can or will continue.

Figure 2-9 and Table 2-3 illustrate the differences between the maximum Lake Koocanusa elevations achieved before July 31 with Libby Dam regulated under the various scenarios.

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[30] Endangered Species Act - Section 7 Consultation, BIOLOGICAL OPINION, Reinitiation of Consultation of 1994-1998 Operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years, National Marine Fisheries Service, Northwest Division, Seattle, March 2, 1995, p. 95.

Figure 2-9. Frequency curves, Lake Koocanusa, Peak Reservoir Elevation (1 April - 31 July) for All Scenarios Modeled.

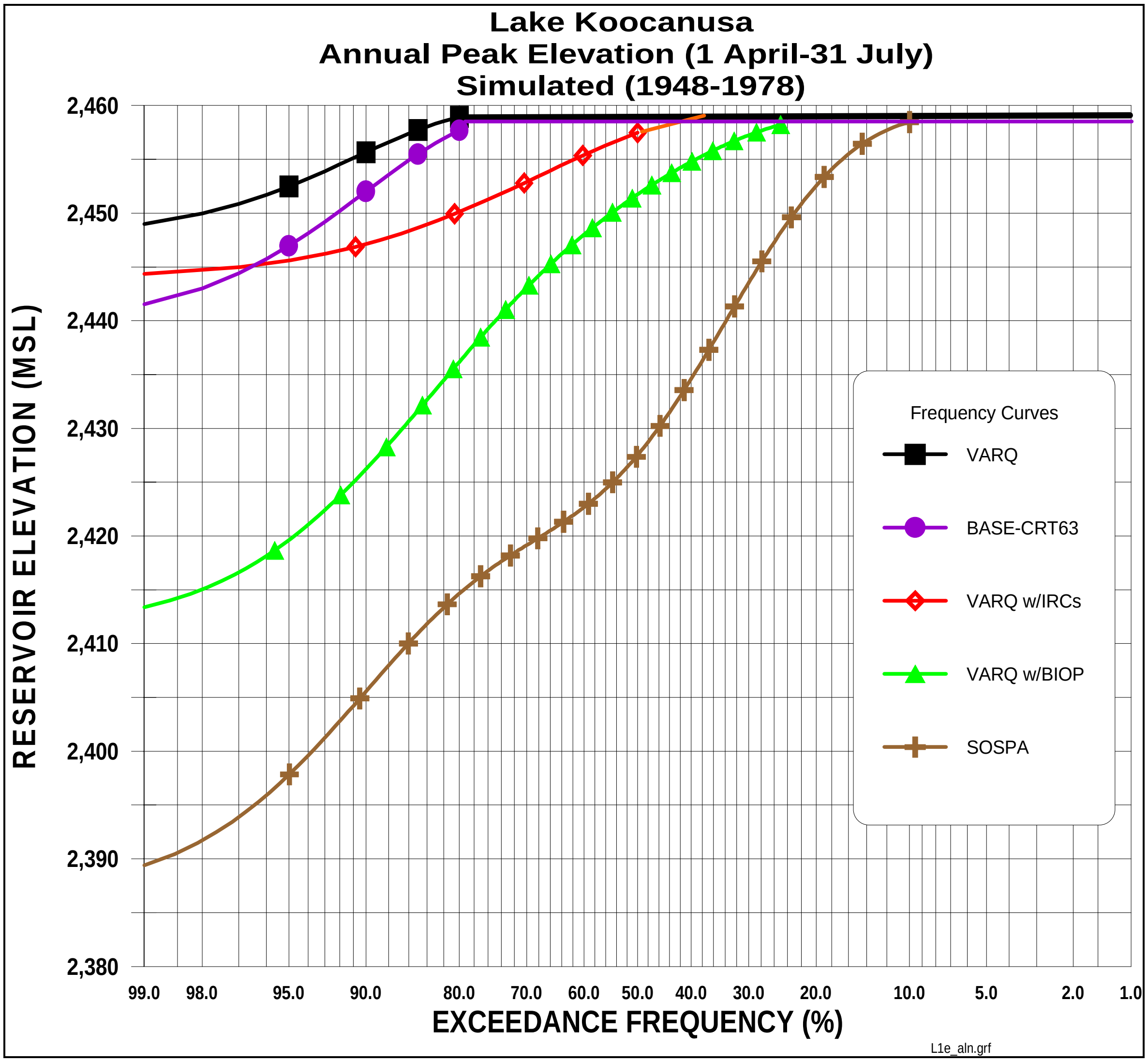


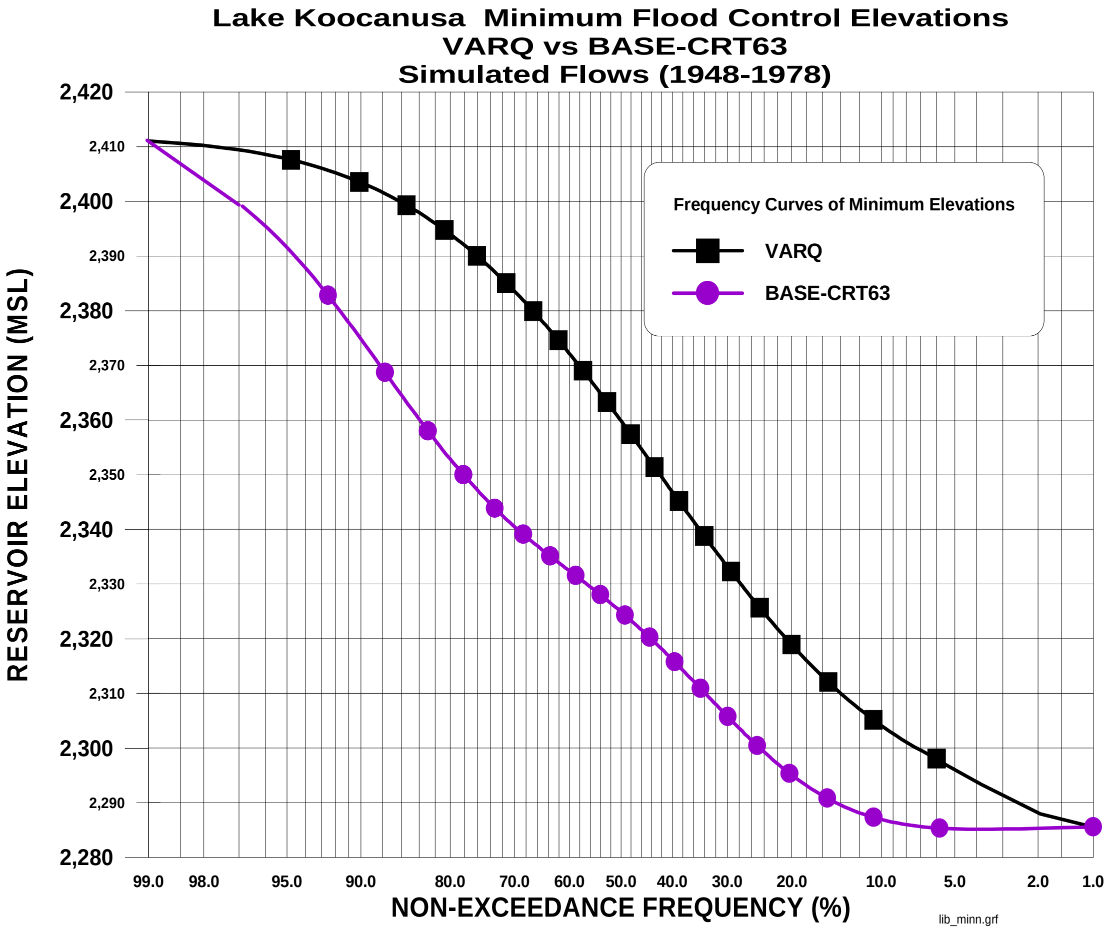
Table 2-3. Maximum Elevation of Libby Reservoir (April 1-July 31)

	VARQ-	BASE-CRT63	VARQ w/BIOP	VARQ w/IRC	SOSPA
1948	2459.0	2459.0	2459.0	2459.0	2453.3
1949	2459.0	2454.3	2447.7	2459.0	2420.8
1950	2459.0	2458.9	2447.0	2447.8	2425.3
1951	2459.0	2459.0	2450.3	2456.4	2454.4
1952	2458.6	2458.0	2414.8	2450.9	2407.5
1953	2459.0	2459.0	2459.0	2459.0	2434.0
1954	2459.0	2459.0	2459.0	2458.7	2458.3
1955	2459.0	2459.0	2459.0	2459.0	2459.0
1956	2459.0	2459.0	2449.3	2453.4	2453.6
1957	2459.0	2459.0	2455.3	2459.0	2419.1
1958	2459.0	2459.0	2457.6	2459.0	2421.4
1959	2459.0	2459.0	2457.3	2459.0	2432.3
1960	2459.0	2455.8	2429.4	2446.4	2407.3
1961	2459.0	2459.0	2459.0	2459.0	2446.3
1962	2450.4	2445.6	2434.0	2447.4	2389.5
1963	2459.0	2459.0	2458.2	2459.0	2429.1
1964	2459.0	2459.0	2459.0	2459.0	2435.4
1965	2459.0	2459.0	2433.6	2452.9	2417.4
1966	2459.0	2459.0	2449.3	2459.0	2427.2
1967	2459.0	2459.0	2449.2	2447.7	2450.7
1968	2459.0	2459.0	2458.7	2459.0	2421.7
1969	2459.0	2459.0	2447.2	2459.0	2434.9
1970	2459.0	2459.0	2439.7	2459.0	2429.0
1971	2459.0	2459.0	2451.1	2459.0	2442.2
1972	2459.0	2459.0	2450.1	2447.3	2456.5
1973	2457.3	2458.1	2445.2	2455.2	2406.0
1974	2459.0	2459.0	2459.0	2458.8	2459.0
1975	2458.5	2455.2	2429.0	2450.6	2411.6
1976	2459.0	2459.0	2425.5	2450.1	2420.8
1977	2451.4	2444.4	2426.1	2447.0	2413.9
1978	2459.0	2458.6	2456.9	2459.0	2410.3
Average Peak Elevation=	2458.4	2457.6	2447.6	2455.3	2430.6
	VARQ-	BASE-CRT63	VARQ W/BIOP	VARQ W/IRC	SOSPA
% refill to 2459=	84%	71%	23%	52%	6%
% refill in top 5 feet=	94%	94%	42%	65%	16%
% refill in top 10 feet=	100%	94%	61%	81%	26%
% refill in top 15 feet=	100%	100%	74%	100%	29%
% refill in top 20 feet=	100%	100%	77%	100%	32%

2.2.3.2 Lake Koocanusa Minimum Elevation

Minimum elevation frequency curves were developed for VARQ and BASE-CRT63 (Figure 2-10). VARQ drafts Lake Koocanusa less than BASE-CRT63 by as much as 45 feet.

Figure 2-10. Frequency curves, Lake Koocanusa, 1 day minimum elevation for BASE-CRT63 and VARQ.



2.2.3.3 Trapped Storage at Libby

It is not always possible to draft Lake Koocanusa to the flood control elevations specified by its storage reservation diagram. Any water remaining in a reservoir above the flood control rule curve is known as “trapped storage”. Trapped storage is usually caused by not drafting Libby Reservoir due to either a mechanical breakdown, in one or more of the generators, or conflicts with the 1938 IJC Order on Kootenay Lake. This study assumed no mechanical breakdowns.

The 1938 Order requires Kootenay Lake be lowered during the winter months to elevations specified by its flood control rule curve. Because the releases from Libby Dam eventually flow into Kootenay Lake, they must be done in a manner so as not to force a violation of the IJC Order. Therefore, there are times when the flood control rule curve for Libby Reservoir must be violated by reducing Libby Dam discharges to prevent Kootenay Lake from going above its flood control rule curve. Duncan Reservoir is in a similar situation. When Kootenay Lake is near or above its flood control elevation, the Columbia River Treaty Operating Committee decides on a course of action. In this study it is assumed that when a conflict occurs with the 1938 IJC Order the following sequence of events will occur:

1. Releases from Corra Linn Dam are set at the maximum possible.
2. Releases from Duncan Dam are reduced to no more than inflow, if necessary.
3. Releases from Libby Dam are reduced to no more than inflow, if necessary.

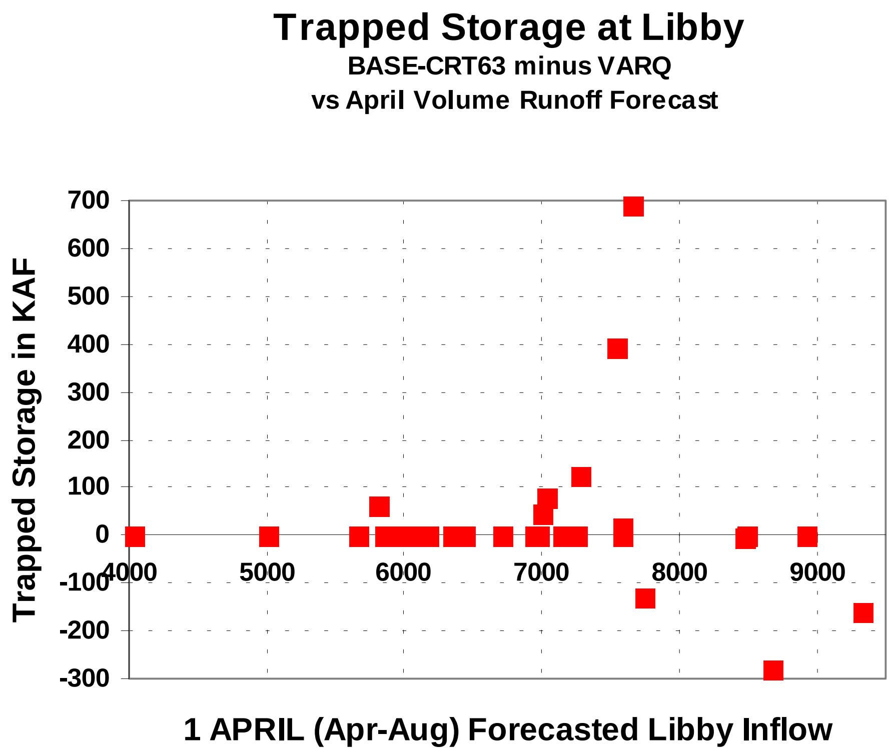
The VARQ and BASE-CRT63 storage reservation diagrams both call for Libby Reservoir to be drafted to ultimately the same elevation (2287 feet) in years when the forecasted April-August volume is equal to or greater than 8.0 maf. However, it is sometimes more difficult to draft to the March 15 flood control elevation in VARQ as compared to BASE-CRT63. In those years when a dramatic increase occurs between the January and March water supply forecasts, it can be difficult to quickly draft Libby Reservoir due to discharge limitations associated with the 1938 IJC Order on Kootenai Lake. The IJC Order makes drafting Libby Reservoir in March and February more difficult than drafting in January. For example, in 1954 the forecast for the April-August period jumped from 7.1 maf in January to 8.7 maf in March. The flood control elevation under both VARQ and BASE-CRT63 was ultimately the same on 15 March at 2287 feet. Under VARQ, it was not possible to draft Libby Reservoir deeper than elevation 2311 feet due to conflicts with the 1938 IJC Order in February. Under BASE-CRT63 it was possible to evacuate more water in January resulting in 279,000 additional acre-feet of flood storage in April as compared to VARQ.

From the Table 2-4 it is possible to compare the amount of trapped storage relative to the flood control operation. There is a tendency for more trapped storage under BASE-CRT63 in years when the April-August runoff volume is 7.7 maf or less. This is due to the simple fact that BASE-CRT63 drafts more than VARQ presenting a greater opportunity for trapped storage. As can be seen in Figure 2-11, the VARQ flood control operation results in greater trapped storage in years with greater than a 7.7 maf forecast.

Table 2-4. Trapped Storage at Libby Dam.

Date	BASE-CRT63 Draft Required (ACRE-FEET)	Flood Control Elevation (FEET)	Minimum Elevation (FEET)	**Trapped Storage (KAF)**	VARQ Draft Required (ACRE-FEET)	Flood Control Elevation (FEET)	Minimum Elevation (FEET)	**Trapped Storage (KAF)**	**Difference in Trapped Storage CRT63 minus VARQ (kaf)**
1948	4979468	2287	2323	**629**	4074440	2336	2346	**234**	**395**
1949	3295000	2368	2351	**0**	1701000	2419	2403	**0**	**0**
1950	4632736	2308	2287	**0**	3469000	2362	2336	**0**	**0**
1951	4979468	2287	2338	**945**	4979468	2287	2338	**945**	**0**
1952	4463288	2317	2305	**0**	3209500	2372	2337	**0**	**0**
1953	3500500	2361	2350	**0**	1933900	2413	2393	**0**	**0**
1954	4979468	2287	2295	**129**	4979468	2287	2311	**408**	**-279**
1955	2963500	2381	2383	**63**	1325300	2429	2404	**0**	**63**
1956	4979468	2287	2301	**226**	4979468	2287	2301	**231**	**-5**
1957	3904000	2344	2326	**0**	2391200	2400	2390	**0**	**0**
1958	3200500	2372	2353	**0**	1593900	2422	2399	**0**	**0**
1959	4731663	2302	2287	**0**	3620500	2356	2348	**0**	**0**
1960	4436843	2319	2318	**0**	3169000	2373	2360	**0**	**0**
1961	4759088	2301	2319	**329**	3662500	2354	2362	**202**	**127**
1962	3773500	2349	2325	**0**	2243300	2404	2370	**0**	**0**
1963	3031000	2378	2358	**0**	1401800	2427	2385	**0**	**0**
1964	4198832	2330	2328	**0**	2804500	2386	2374	**0**	**0**
1965	4979468	2287	2288	**19**	4166510	2332	2328	**0**	**19**
1966	4493652	2315	2318	**45**	3256000	2370	2356	**0**	**45**
1967	4979468	2287	2287	**0**	4979468	2287	2287	**0**	**0**
1968	3509500	2360	2346	**0**	1944100	2413	2392	**0**	**0**
1969	4979468	2287	2287	**1**	4143002	2333	2316	**0**	**1**
1970	1861700	2415	2392	**0**	456300	2449	2403	**0**	**0**
1971	4979468	2287	2312	**427**	4466227	2317	2343	**554**	**-127**
1972	4979468	2287	2287	**0**	4979468	2287	2297	**157**	**-157**
1973	2743000	2388	2363	**0**	1075400	2435	2402	**0**	**0**
1974	4979468	2287	2317	**519**	4979468	2287	2317	**519**	**0**
1975	4510303	2314	2319	**81**	3281500	2369	2342	**0**	**81**
1976	4979468	2287	2334	**874**	4289923	2326	2334	**184**	**690**
1977	873800	2439	2394	**0**	6800	2459	2404	**0**	**0**
1978	3038500	2378	2340	**0**	1410300	2426	2384	**0**	**0**
			Average=	138			Average=	111	

Figure 2-11. Trapped Storage at Libby Reservoir. The difference between the amount of trapped storage as a result of BASE-CRT63 vs VARQ is graphed by the 1 April (Apr-Aug) forecasted inflow volume to Libby. Positive values (+) show that BASE-CRT resulted in more trapped storage and negative values (-) show where VARQ resulted in more. Zero values reflect years where there the same amount of trapped storage in both VARQ and BASE-CRT63.



2.2.3.4 Libby Discharge

The VARQ flood control operation features higher discharges on average than BASE-CRT63. The peak discharges from the flood control plans converge at the high end of the frequency curves (Figure 2-12). The 3 sturgeon options are less likely to result in extreme releases from Libby Dam than either BASE-CRT63 or VARQ. Although sturgeon flows require generally higher discharges from Libby Dam, they actually result in fewer extreme events as suggested by Figure 2-13. As a result of the high volumes mandated by the BIOP and the IRCs, the likelihood of filling Lake Koocanusa is less and therefore the likelihood of filling and spilling is less.

Figure 2-12. Frequency curves, Kootenay Lake below Libby Dam, Mt., 1 day maximum flow for BASE-CRT63 and VARQ

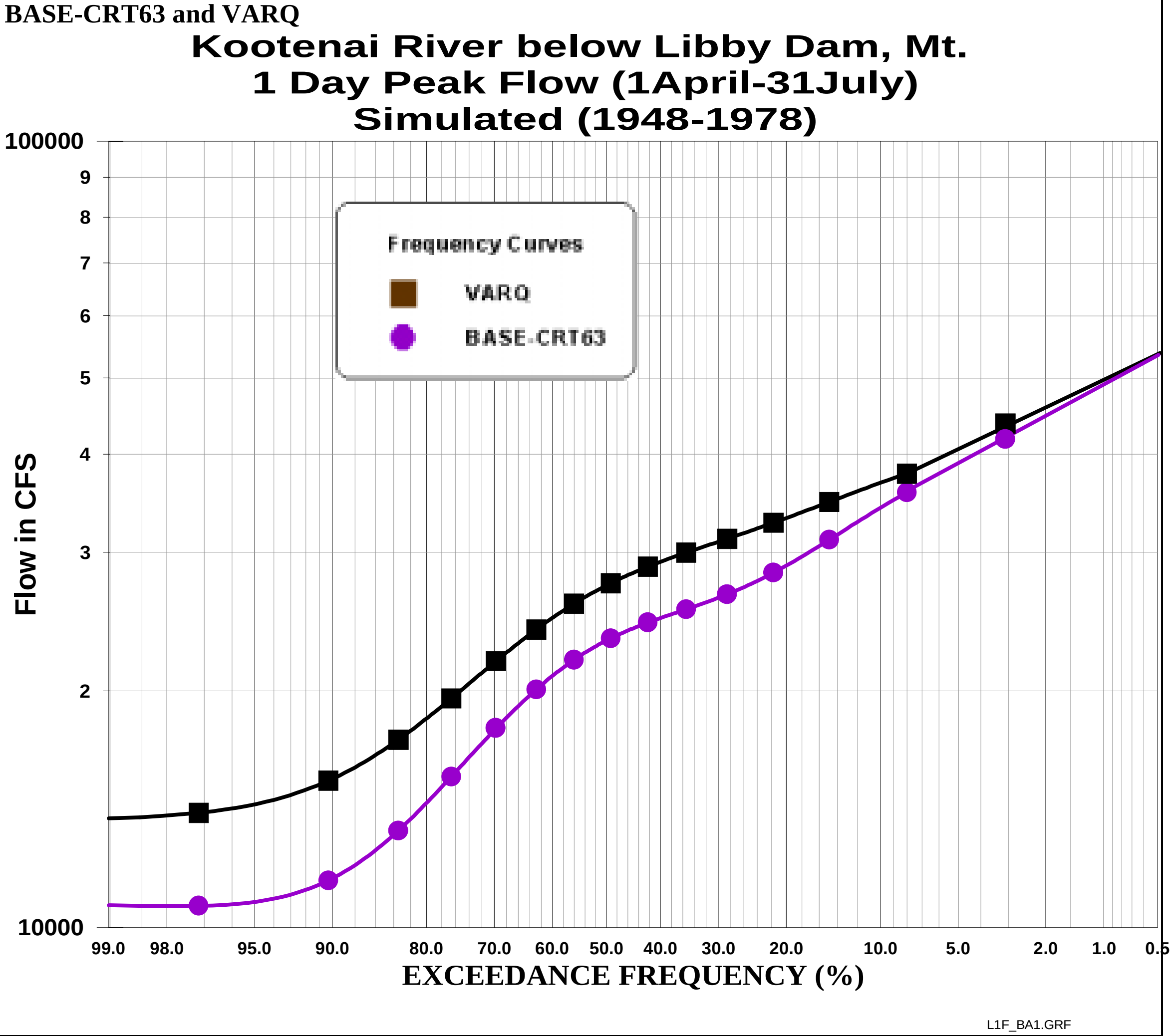
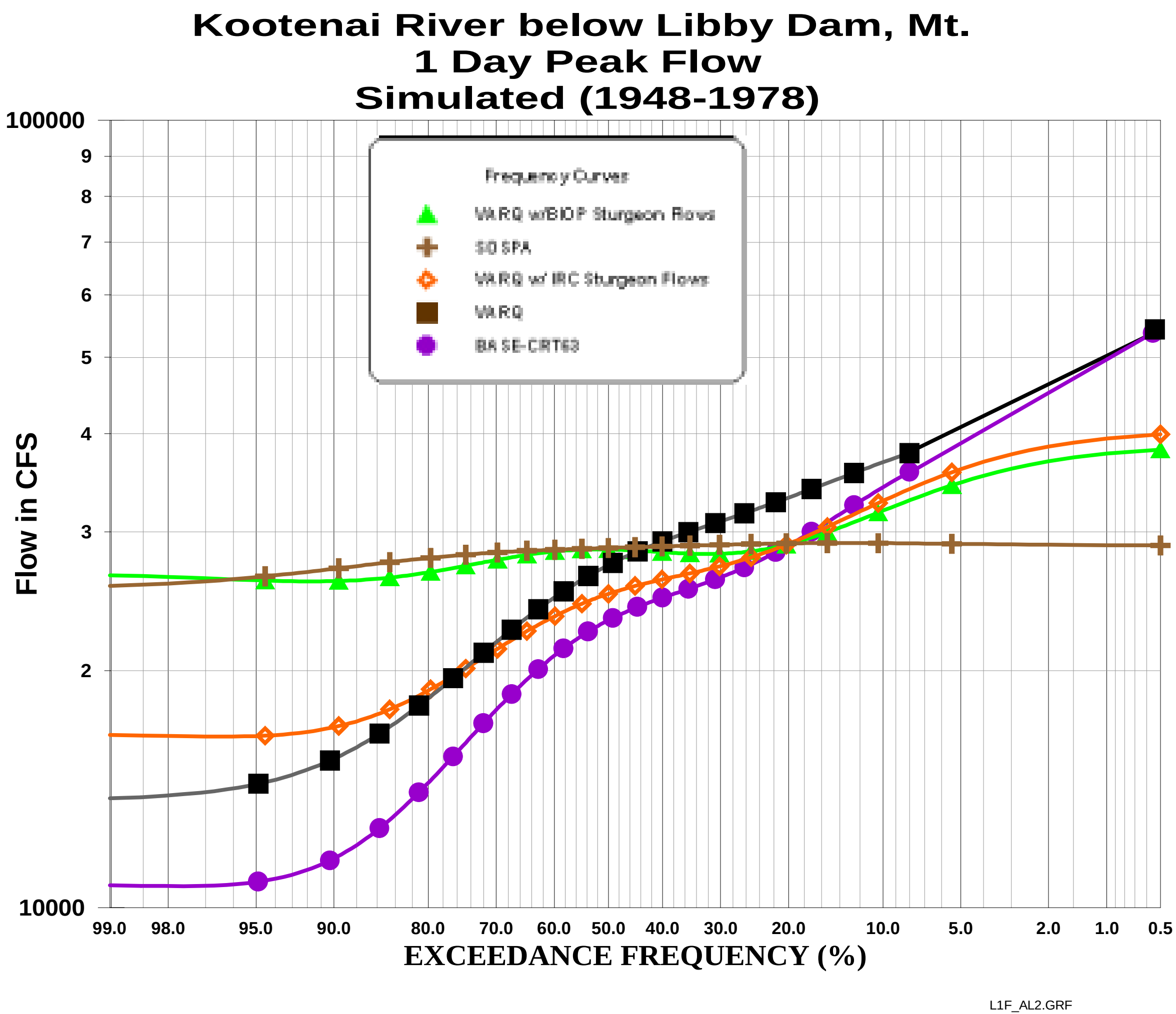


Figure 2-13. Frequency curves, Kootenay River below Libby Dam , Mt. 1 day maximum flow (1April-31July) for all scenarios modeled.



2.2.3.5 Spill from Libby Dam

Due to the height of Libby Dam and the geometry of its stilling basin, spilling from either the spillways or sluiceways entrains gases into the water which can be toxic to resident fish. The stilling basin below the dam is the home to numerous species of fish including bull trout and some of the largest rainbow trout in the world. In addition, the Montana state water quality standard of 110% for total dissolved gases may be exceeded in the tailrace at Libby Dam when water is spilled.

Spilling has occurred at Libby Dam numerous times since 1972 for a combination of reasons. In the 1970's, spill was the only option for reservoir releases before all the units in the powerhouse came on line. Spill occurred in winter of 1981 to evacuate water so that the flood control elevation could be attained. There were large test spills in 1985 to test the emergency spillway gate closure system. "Fill-and-spill" events, caused by prematurely refilling the reservoir, occurred in 1980 and 1981. The historic incidence of fill-and-spill at magnitudes greater than 5,000 cfs is roughly one event in every 10 years of dam operation (i.e. 10%). The current philosophy among Corps reservoir regulators is that spill from Libby Dam should be avoided.

Spill is a function of the limited generating capacity of Libby Dam. The dam was authorized to have eight generating units with a hydraulic capacity of over 40,000 cfs. Due to legal and economic constraints, only five generating units have been installed. In this hydrologic study it was assumed that whenever Libby Dam was forced to release more than 28,000 cfs, the release would be in the form of spill. It was assumed that spill was unnecessary to achieved target flood control elevations during the winter drawdown period. It was also assumed that all five generating units were in service throughout the study period.

Increased spill is the tradeoff with increased reservoir refill reliability. As described in the **Appendix** under **Adapting VARQ to the BIOP**, VARQ releases during the refill period are adjusted to take into account trapped storage, changing forecasts, and fish flows. The fish flow adjustment (see **Appendix, Development of Chart 7**) was developed specifically to limit the occurrence of fill-and-spill to the historic level of one event in 10 years. It would have been very easy to allow spilling more often, with the result of refilling Lake Koocanusa with greater reliability. The probability of spill could be minimized further by drafting Lake Koocanusa deeper than the VARQ flood control curves, releasing more water than specified by VARQ, or installing additional generating units at Libby Dam. The Table 2-5 summarizes the incidents of spill in the various scenarios tested.

Table 2-5. Summary of spill from the various scenarios tested.

	VARQ MAX SPILL (cfs)	DUR-ATION (days)	BASE-CRT63 MAX SPILL (cfs)	DUR-ATION (days)	VARQ w/BIOP MAX SPILL (cfs)	DUR-ATION (days)	VARQ w/IRCs MAX SPILL (cfs)	DUR-ATION (days)	SOSPA MAX SPILL (cfs)	DUR-ATION (days)
1948	911	12	0	0	1000	11	911	12	0	0
1949	0	0	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0	0	0
1951	4920	4	7023	9	0	0	0	0	0	0
1952	0	0	0	0	0	0	0	0	0	0
1953	5337	7	1409	5	0	0	0	0	0	0
1954	12818	17	12818	13	0	0	0	0	0	0
1955	5684	15	5729	14	7660	23	5684	15	0	0
1956	1382	3	1640	3	0	0	0	0	0	0
1957	0	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	0	0	0	0
1959	1674	4	0	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	0	0	0	0
1961	10798	11	0	0	7157	11	10798	11	0	0
1962	0	0	0	0	0	0	0	0	0	0
1963	5623	8	0	0	0	0	2965	4	0	0
1964	1892	4	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0
1966	3023	11	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	0	0	0	0
1968	4363	5	0	0	0	0	0	0	0	0
1969	1882	8	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0	0	0
1972	0	0	2477	5	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0
# of spill events in 31 yrs=	13		6		3		4		0	
# of spill events >5000cfs=	4		3		2		2		0	
# of spill days=		109		49		45		42	0	0

The VARQ flood control operation produces far more instances of spill than the BASE-CRT63 flood control operation. In the 31 years modeled, Libby was forced to spill in 13 of them under VARQ. Nine of these spill events were less than 5,000 cfs and thought to be relatively benign; however, four spill events exceeded 5,000 cfs.

When VARQ is combined with sturgeon releases, the incidence of spill drops. VARQ w/BIOP produced only three spill events with two over 5,000 cfs. VARQ w/ IRCs produced four spill events with two over 5,000 cfs. BASE-CRT63 produced six spill events with three over 5,000.

2.2.3.6 The 1948 Flood

The magnitude of the regulated 1948 flood has historically been a limiting factor for changing the storage reservation diagrams for Libby Dam. The Kuehl-Moffitt forecasts underestimated the April-August Libby inflow volume by 2.3 maf. Any previous flood control study that used the Kuehl-Moffitt forecasts did not draft Libby Reservoir adequately in 1948. In the preliminary analysis of VARQ, Libby Reservoir prematurely filled, and subsequently was forced to release 74,900 cfs due to the large Kuehl-Moffitt forecast error.[31] This study used the more realistic Wortman-Morrow forecasts which underestimated the 1948 inflow volume by 0.9 maf. The VARQ simulation resulted in a maximum release from Libby Dam of 29,900 cfs and no downstream flooding in 1948.

2.2.4 Kootenay Lake Description

Corra Linn Dam controls the level of Kootenay Lake during the majority of the year when low runoff and base flow conditions exist. During periods of high flow, the lake level is governed by the outlet geometry of the Grohman Narrows (upstream of Corra Linn Dam), a natural constriction in the west arm of Kootenay Lake. Originally completed in 1932, the dam was operated as a run-of-river hydropower plant until the 1938 International Joint Commission (IJC) Order on Kootenay Lake was negotiated. The 1938 Order called for the excavation of the Grohman Narrows, after which the dam’s owner, West Kootenay Power, was allowed to seasonally raise Kootenay Lake an additional six feet for hydropower generation during the winter months.

There are two hydropower plants at the outlet of Kootenay Lake, Corra Linn Dam and the Kootenay Canal Plant and several other hydroelectric dams immediately downstream. This study modeled them as one dam. During the winter months the dam released whatever was necessary to keep Kootenay Lake below its allowable lake level. After April 1, Corra Linn Dam was put on free flow until spring runoff forced the lake elevation to its annual high point and then receded back to elevation 1743.32 feet.

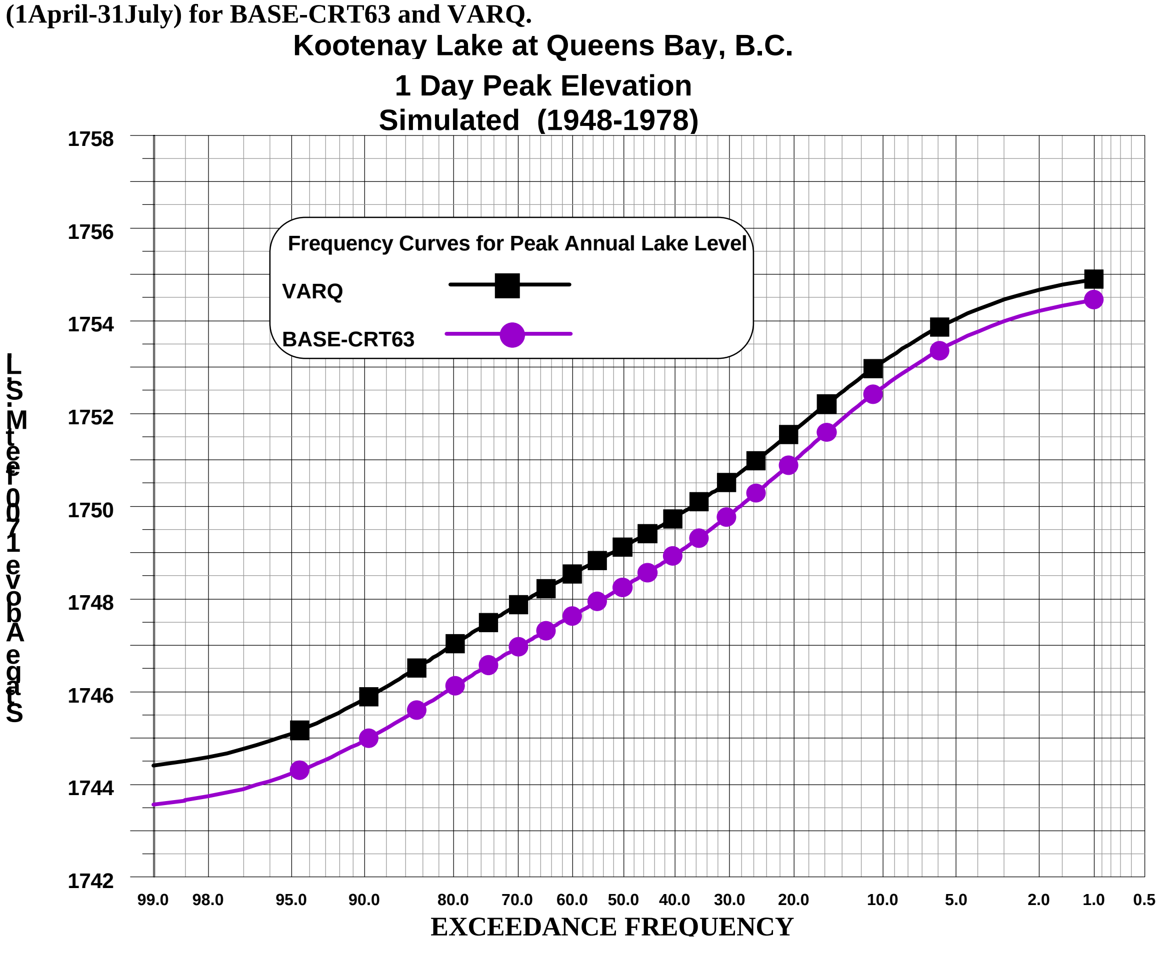
[31] Columbia River Basin System Flood Control Review - Preliminary Analysis Report, U.S. Army Corps of Engineers, North Pacific Division, Portland, February, 1997, pp. 53.

2.2.4.1 Kootenay Lake Elevation

The 1972 Columbia River Treaty Flood Control Operating Plan states that "damage commences at Nelson when Kootenay Lake reaches elevation 1755 feet and major damage stage is elevation 1,759 feet".[32] This is no longer true. Since 1972, a considerable amount of development has taken place along the shores of Kootenay Lake. Problems experienced during high water in 1995, 1996, and 1997 suggest that damage occurs at lake elevations of approximately 1,750 feet as measured at Queens Bay, B.C.

VARQ results in an approximately one foot stage increase at Queens Bay relative to BASE-CRT63 at all frequencies up to 100 years (Figure 2-14).

Figure 2-14. Frequency curves, Kootenay Lake at Queens Bay, B.C., 1 day maximum elevation (1April-31July) for BASE-CRT63 and VARQ.



[32] U.S. Army Corps of Engineers, North Pacific Division, Columbia River Treaty Flood Control Operating Plan , Portland , October 1972, pp. 13.

When sturgeon flows are added to the flood control releases, the elevation of Kootenay Lake increases. Figure 2-15 shows the maximum 1-day elevation frequency curves for Kootenay Lake for the five different scenarios modeled. Both VARQ w/BIOP sturgeon flows and SOSPA produce stages one to two feet high than VARQ most years, and three feet higher than BASE-CRT63. VARQ w/BIOP converges to the same elevation as VARQ during events with greater than a 20 year return period, and SOSPA converges to the same as BASE-CRT63. The BIOP flow regimes are generally two to three feet higher than BASE-CRT63 in most years. VARQ w/IRC sturgeon flows produces the highest lake elevations at Queens Bay. The frequency curve for VARQ w/IRC sturgeon flows converges to VARQ during the 1-day extreme events, but remains higher for the 30-day duration due to the high flow target in June (Figure 2-16) . There is very little difference between VARQ w/BIOP and SOSPA.

Figure 2-15. Frequency curves, Kootenay Lake at Queens Bay, B.C., 1 day maximum elevation (1April-31July) for all the scenarios modeled.

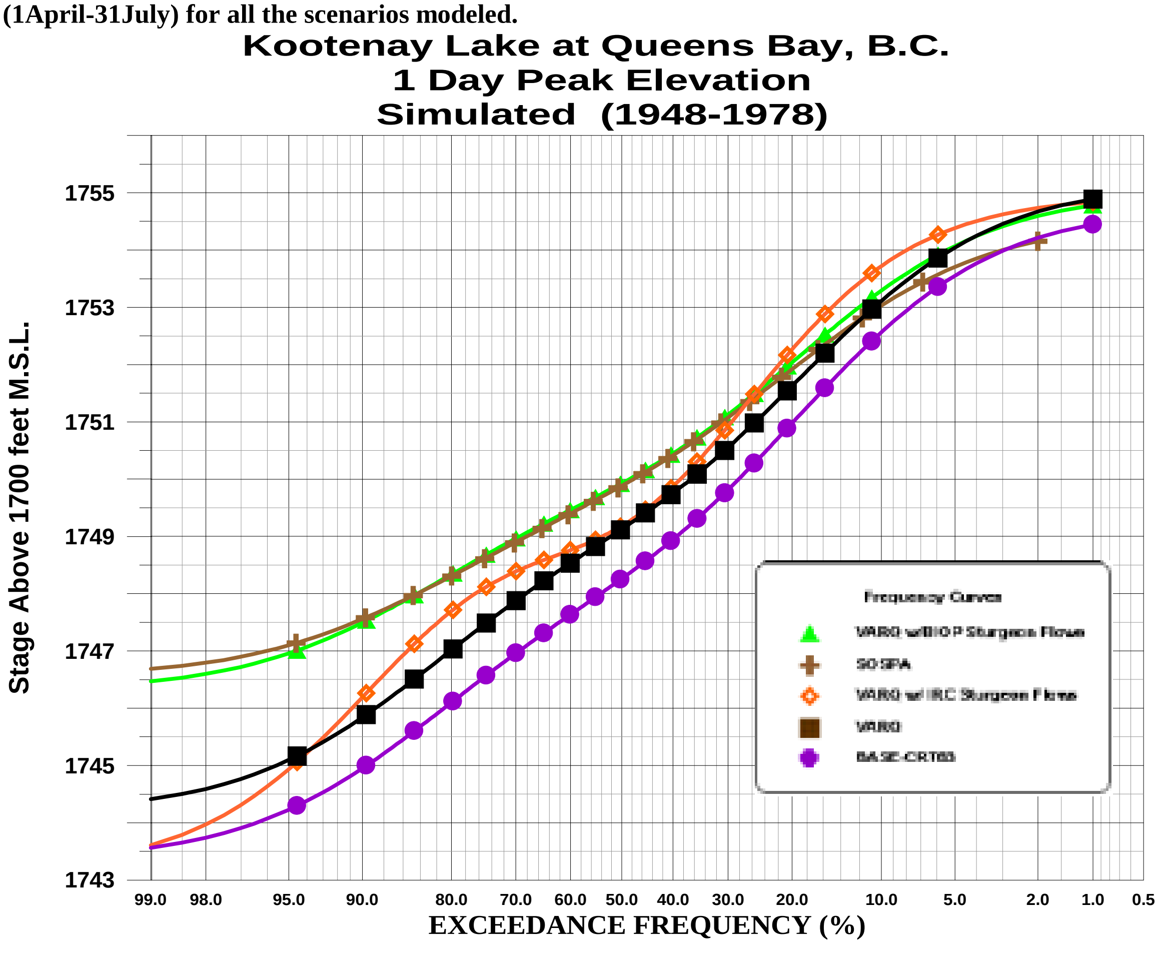
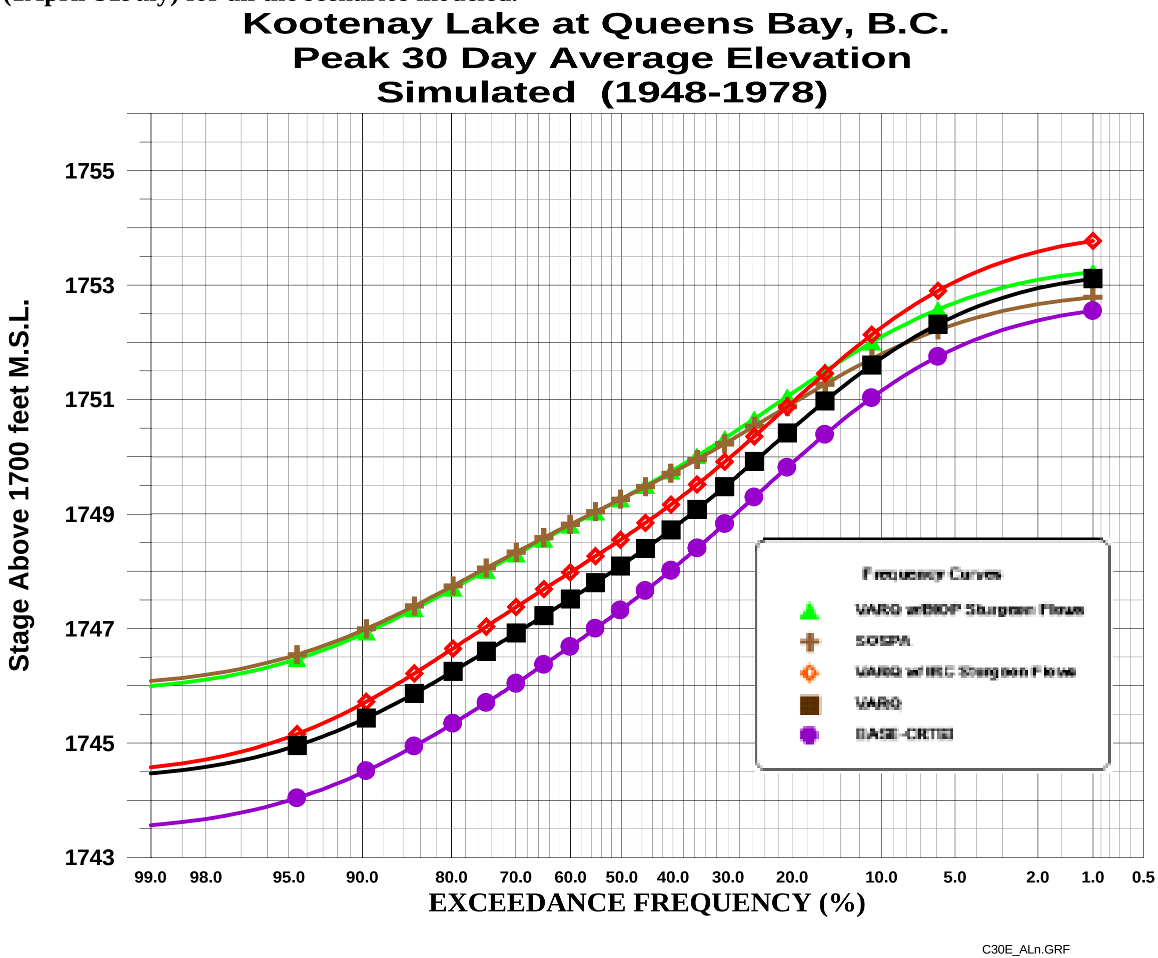


Figure 2-16. Frequency curves, Kootenay Lake at Queens Bay, B.C., peak 30 day average elevation (1April-31July) for all the scenarios modeled.



2.2.4.2 Kootenay Lake Discharge

The frequency curves in Figure 2-17 show flow increases in the Kootenay River (Canadian spelling) associated with VARQ as compared to BASE-CRT63. Peak daily discharges from Kootenay Lake are approximately 5,000 cfs higher during 1 April-31 July as a result of VARQ regardless of the return period. The sturgeon options result in peak flows of up to 25,000 cfs more than the flood control operations in low to moderate years, and converge to the same level in more extreme events as illustrated in Figure 2-18. There is very little difference between VARQ w/BIOP and SOSPA.

Figure 2-17. Frequency curves, Kootenay Lake Discharge below Nelson, B.C., 1 day peak daily average (1April-31July) flow for VARQ and BASE-CRT63.

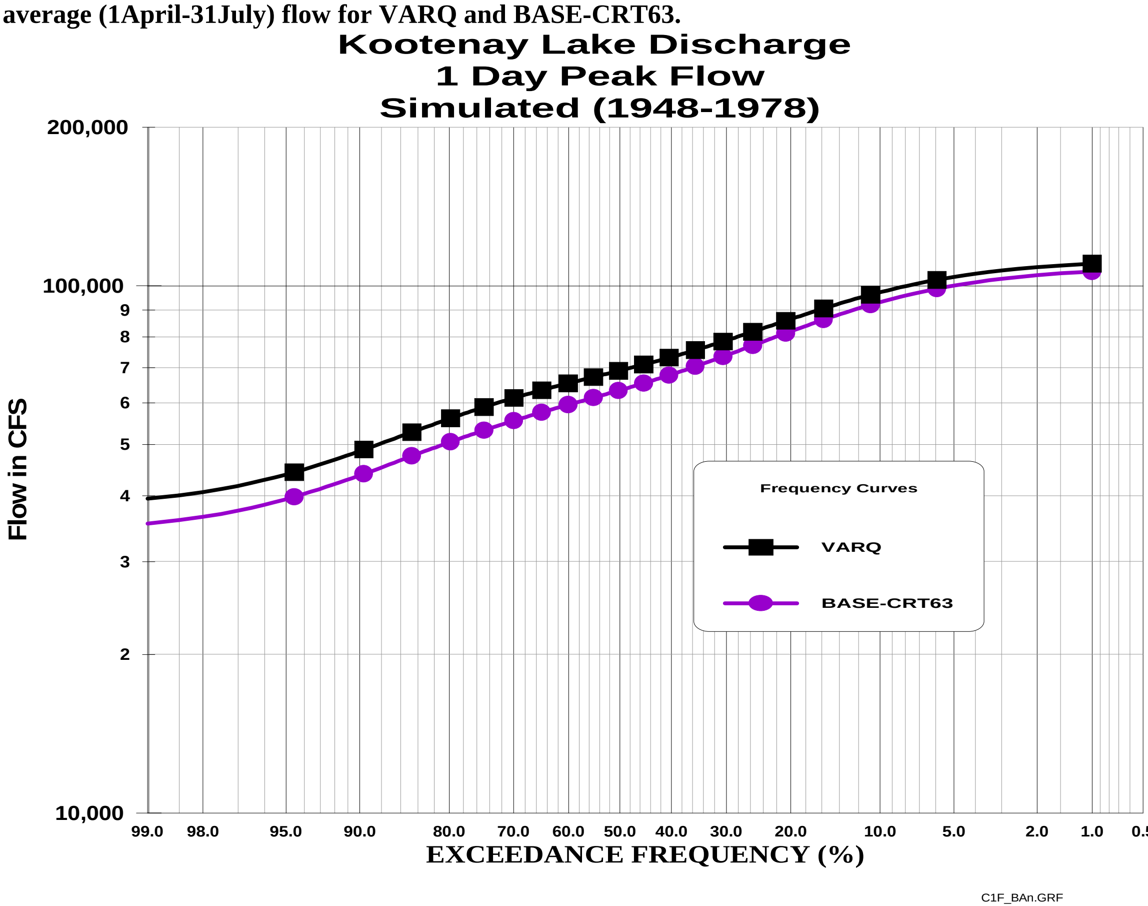
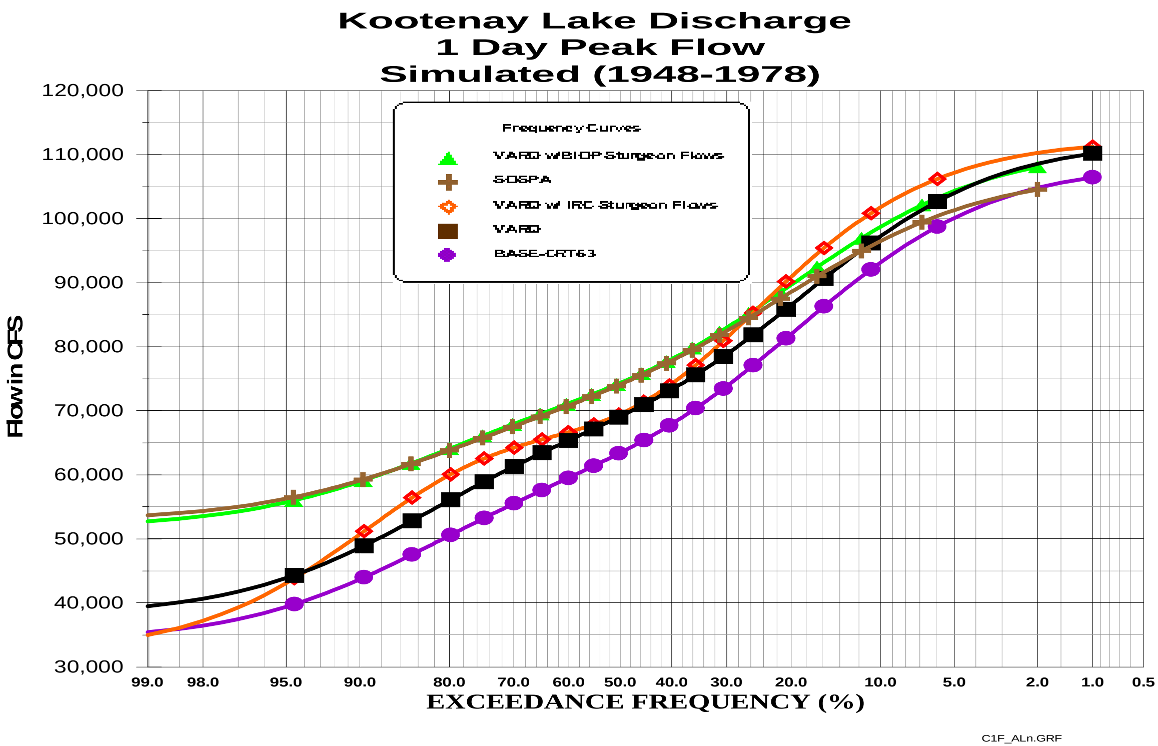


Figure 2-18. Frequency curves, Kootenay Lake Discharge below Nelson, B.C., 1 day peak daily average (1April-31July) flow for all the scenarios modeled.



2.2.4.3 Compliance with the 1938 IJC Order on Kootenay Lake

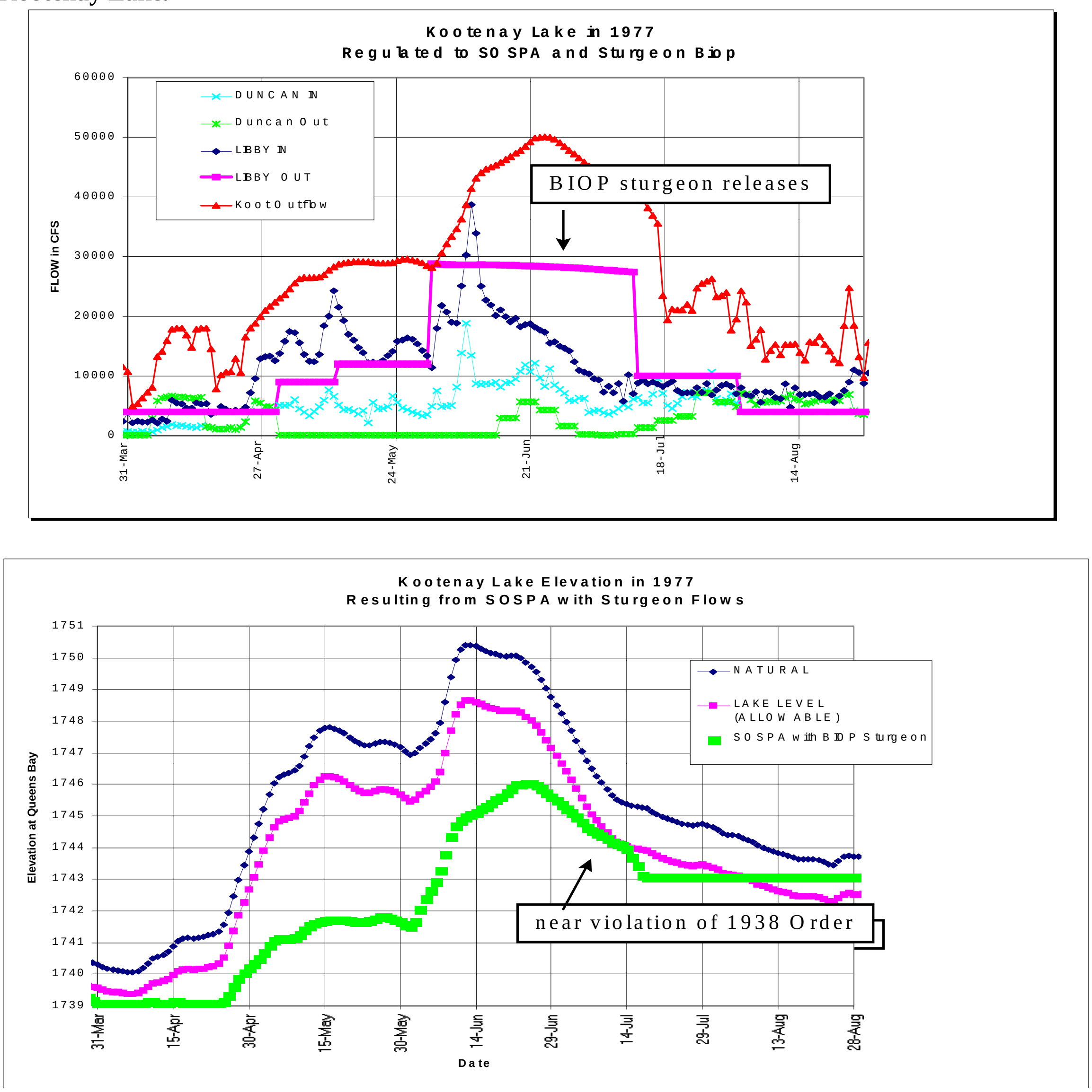
The 1938 International Joint Commission (IJC) Order on Kootenay Lake governs the lakes maximum allowable level. All hydro-regulations for this study met the requirements of the 1938 Order. Kootenay Lake was drafted to its flood control rule curve as required. When a conflict existed in meeting the 1938 Order at Kootenay Lake, Duncan Reservoir was reduced to passing no more than inflow and Libby was allowed to continue to draft if allowable. At no time were the headwater reservoirs required to pass less than inflow. The headwater projects were operated so as not to drive Kootenay Lake above its allowable lake level in the period of the "lowering formula".

Only the 1977 simulation featuring BIOP sturgeon releases came close to violating the 1938 Order. When the BIOP sturgeon flows were combined with either the BASE-

CRT63 and VARQ flood control operations, there was a period when Libby Dam was releasing almost 20,000 cfs above inflow. The 1938 Order was not violated in 1977, but the level of Kootenay Lake came very close to the allowable level as calculated with natural flows (Figure 2-19).

This study did not draft Lake Koocanusa in August to meet salmon flow targets in the lower Columbia River. Therefore, the impacts of the August draft as related to the IJC Order were not ascertained.

Figure 2-19. How 1977 with BIOP sturgeon flows comes close to violating the 1938 Order on Kootenay Lake.



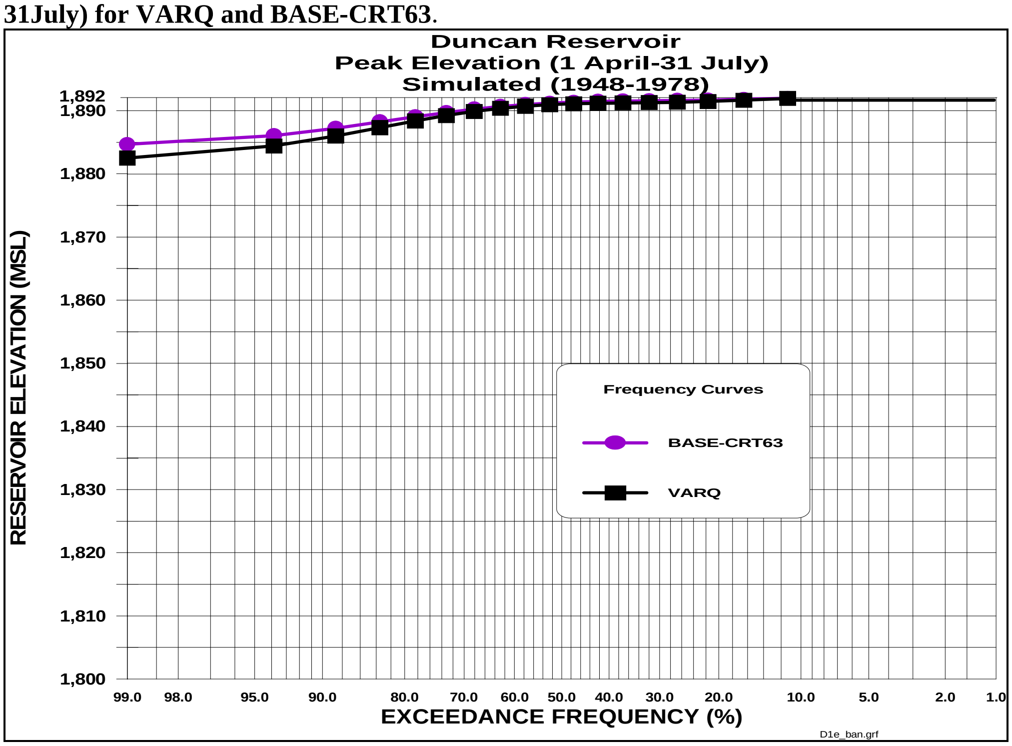
2.2.5 Duncan Dam Description

Duncan Dam is a hydropower, flood control, and irrigation dam upstream of Kootenay Lake on the Duncan River in southern British Columbia. Duncan Dam was built by British Columbia Hydro and Power Authority (BC Hydro) and has no generating units. It provides 1.4 million acre-feet of storage that, when released, supplies downstream hydro-power dams in both Canada and the U. S. As part of the Columbia River Treaty Flood Control Operating Plan, Duncan provides up to 1.27 maf of flood control space that varies depending on the forecasted volume runoff.[33] This study assumed that Libby Reservoir was given priority to draft before Duncan Reservoir when conflicts developed with the 1938 IJC Order on Kootenay Lake during the winter drawdown period.

2.2.5.1 Duncan Reservoir Elevation

There is essentially no difference between VARQ and BASE-CRT63 flood control operations in the frequency curves for the maximum elevation at Duncan Reservoir (Figure 2-20). Both flood control operations result in a very high likelihood of Duncan Reservoir refill. The sturgeon flow alternatives have no effect on Duncan's maximum elevation. The sturgeon flow regimes have no further effect on the elevation of Duncan.

Figure 2-20. Frequency curves, Duncan Reservoir Elevation, 1 day peak daily elevation (1April-31July) for VARQ and BASE-CRT63.



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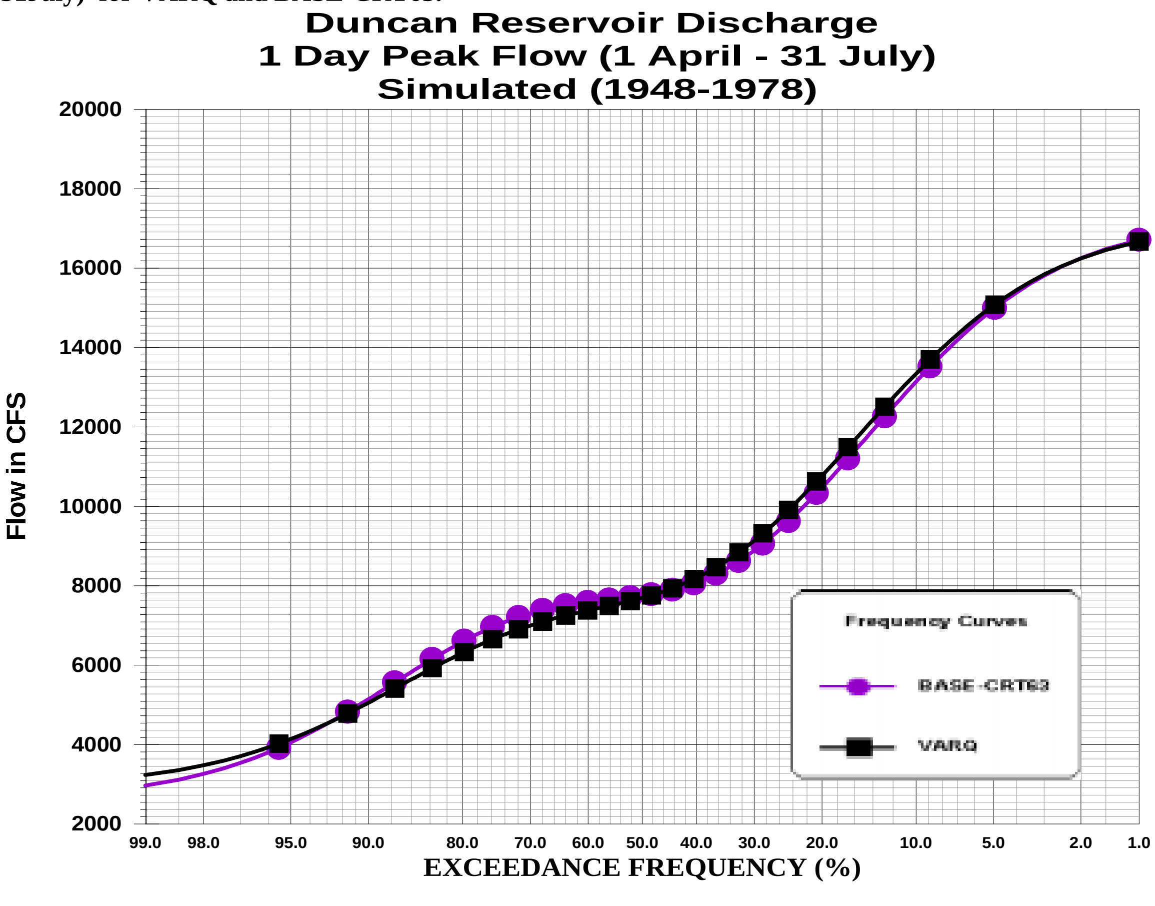
[33] U.S. Army Corps of Engineers, North Pacific Division, Columbia River Treaty Flood Control Operating Plan , Portland , October 1972, pp. 18.

2.2.5.2 Duncan Dam Discharge

The channel capacity below Duncan Dam is 20,000 cfs. Whenever possible, B.C. Hydro attempts to limit discharges from Duncan Dam to 10,000 cfs to minimize erosion damage.[34] During the computer simulations, Duncan Dam was set on a minimum flow that was adjusted for trapped storage during the refill period. When the reservoir reached elevation 1,852 feet, 40 feet from full, filling transition curves were used to simulate the uncertainty of refilling the reservoir based on inflow and reservoir elevation.

The simulations showed that there is essentially no difference in the maximum daily discharge from Duncan Reservoir resulting from the VARQ and BASE-CRT63 flood control plans (Figure 2-21). Both flood control operations result in essentially the same peak dam releases. The sturgeon flow alternatives have no effect on Duncan Dam's maximum discharge.

Figure 2-21. Frequency curves, Duncan Dam Discharge, 1 day peak daily average flow (1April-31July) for VARQ and BASE-CRT63.



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[34] Ketchum, Kelvin, BC Hydro, personal conversation on 3/14/97.

2.3 Risk

VARQ by design provides less storage space at the beginning of spring runoff and increases average discharges in spring and summer in all but the largest years of runoff. Under-forecasting the seasonal water supply volume could lead to higher than desired outflows from Libby Dam. Less storage space in the reservoir reduces operating flexibility to control excessive spill during refill.[35] This risk should not be overstated. The 1991 CRT-63 study found that changes in the initial flood storage amount at Libby will often result in little or no change in the eventual peak stage at Bonners Ferry. This is due to the fact that the operation of Libby Dam between 15 March and the initiation of the peak flood period will often compensate for the decrease in flood storage assumed at the start of the refill period.[36]

With less storage space available in the reservoir under the VARQ flood control operation, higher releases need to be timed so as not to impact flooding downstream. Modeling suggests that there can be more trapped storage in Libby Reservoir during some years as a result of VARQ. When a dramatic increase occurs between the monthly inflow forecasts for Libby Dam, the 1938 International Joint Commission Order on Kootenay Lake makes it more difficult to achieve the March 15 flood control elevation at Libby under VARQ as compared to BASE-CRT63.

The risks associated with VARQ can be minimized. It is essential that every effort be made to draft Lake Koocanusa to flood control elevations specified by the VARQ storage reservation diagrams. Although better forecasting procedures make large runoff forecasting errors less likely today than in the past, every effort should be made to improve long range runoff forecasting procedures.

Risk is illustrated by the confidence intervals associated with the frequency curves for damage centers below a project being studied. For Libby Dam, the historic damage center is the USGS gage on the Kootenai River at Bonners Ferry, Idaho. When one hears the expression "the 200-year flood stage at Bonners Ferry is elevation 1770 feet", what is really being said is "there is a 50/50 chance that the return period associated with a river stage of elevation 1770 feet at Bonners Ferry is 200 years". There is a 50% chance that the river stage with a 200-year return period is greater than elevation 1770 feet, and a 50% chance that it is less than elevation 1770 feet.. The 95% upper and lower confidence limits specify the interval where there is a 95% chance that the 200-year flood will occur.

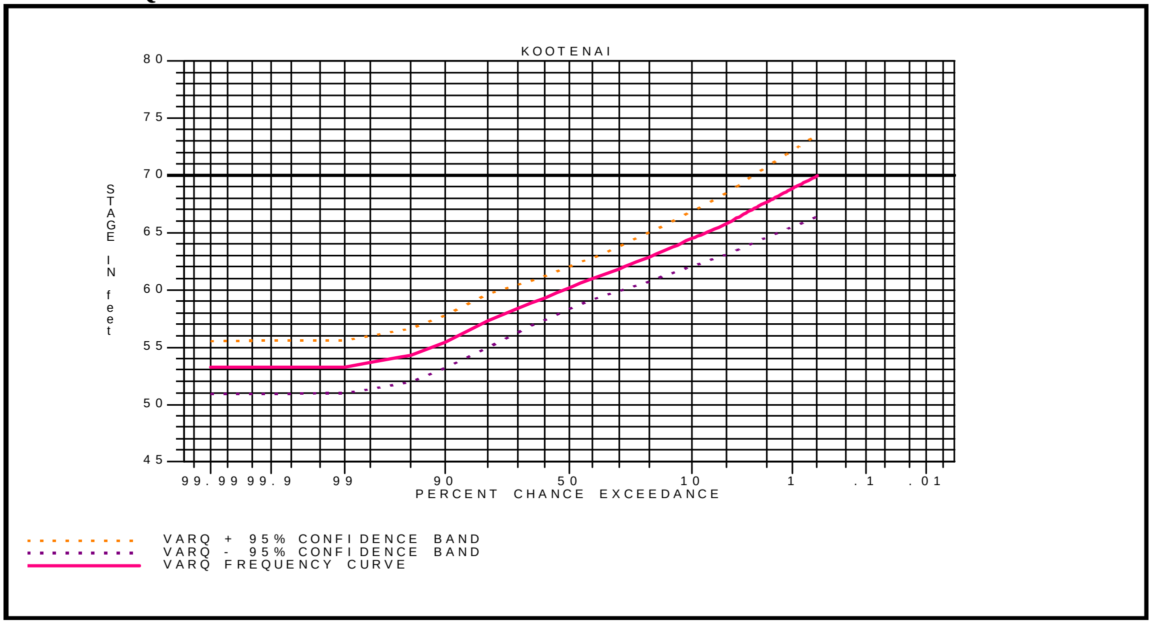
[35] Columbia River Basin System Flood Control Review - Preliminary Analysis Report, U.S. Army Corps of Engineers, North Pacific Division, Portland, February, 1997, pp. 69.
[36] Review of Flood Control Columbia River Basin, Columbia River and Tributaries Study, CRT-63, U.S. Army Corps of Engineers, North Pacific Division, Portland, June 1991, pp. 44..

There are many issues that determine the confidence intervals associated with the VARQ frequency curve for Bonners Ferry, Idaho. There is uncertainty associated with:

- future weather trends
- the accuracy to the runoff forecasts
- the availability of 5 generating units at Libby Dam
- the magnitude and shape of future sturgeon and salmon flow requests
- operational changes at Kootenay Lake

The frequency curves in Figures 2-22 through 2-26 for the Kootenai River at Bonners Ferry, Idaho were calculated as described by the U.S. Army Corps of Engineer's Engineering Memorandum Hydrologic Frequency Analysis, EM 1110-2-1415[37]. The computer program LIMIT was used in the analysis.[38] For all scenarios modeled, the 95% confidence intervals were plus or minus approximately three feet of the frequency curves for a 100-year return period.

Figure 2-22. Frequency curve for Daily Peak Stage at Bonners Ferry with 95% Confidence Limits under VARQ.



[37] U.S. Army Corps of Engineers, Hydrologic Frequency Analysis, EM 1110-2-1415, 5 March 1993, pp. 6.1-6.4.

[38] U.S. Army Corps of Engineers, Draft Report: Uncertainty Estimates for Non-Analytic Frequency Curves, ETL 1110-2-XXXX, November 1993, pp.13-20.

Figure 2-23. Frequency curve for Daily Peak Stage at Bonners Ferry with 95% Confidence Limits under BASE-CRT63.

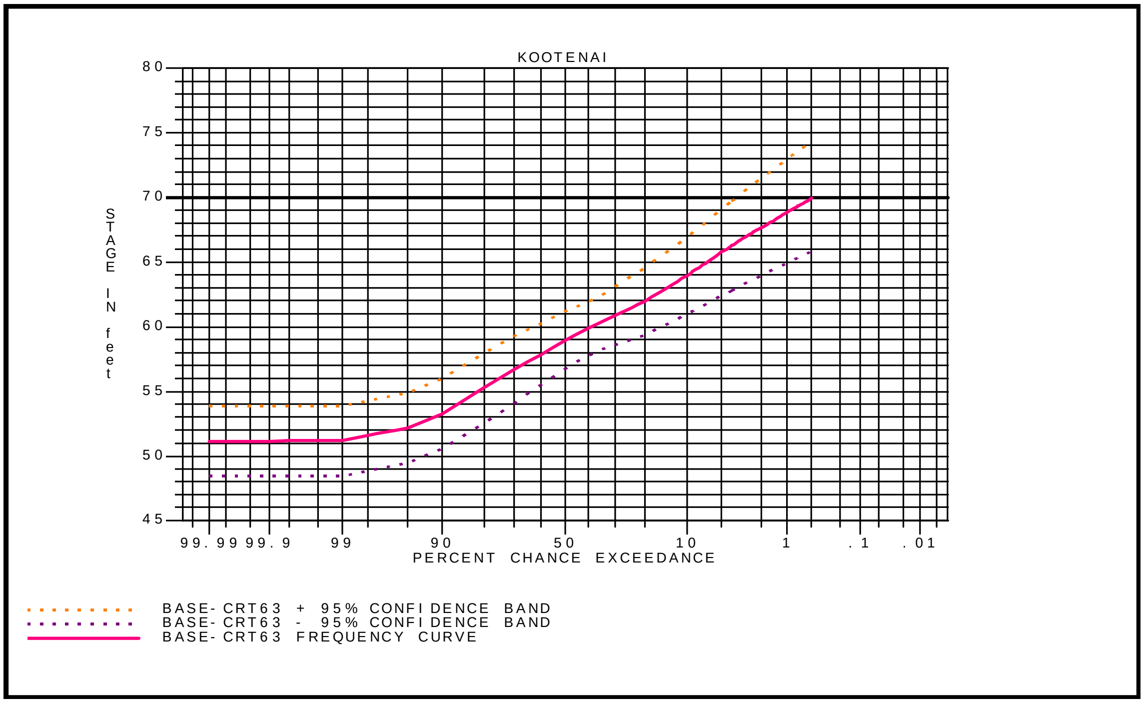


Figure 2-24. Frequency curve for Daily Peak Stage at Bonners Ferry with 95% Confidence Limits under VARQ with BIOP Sturgeon Flows.

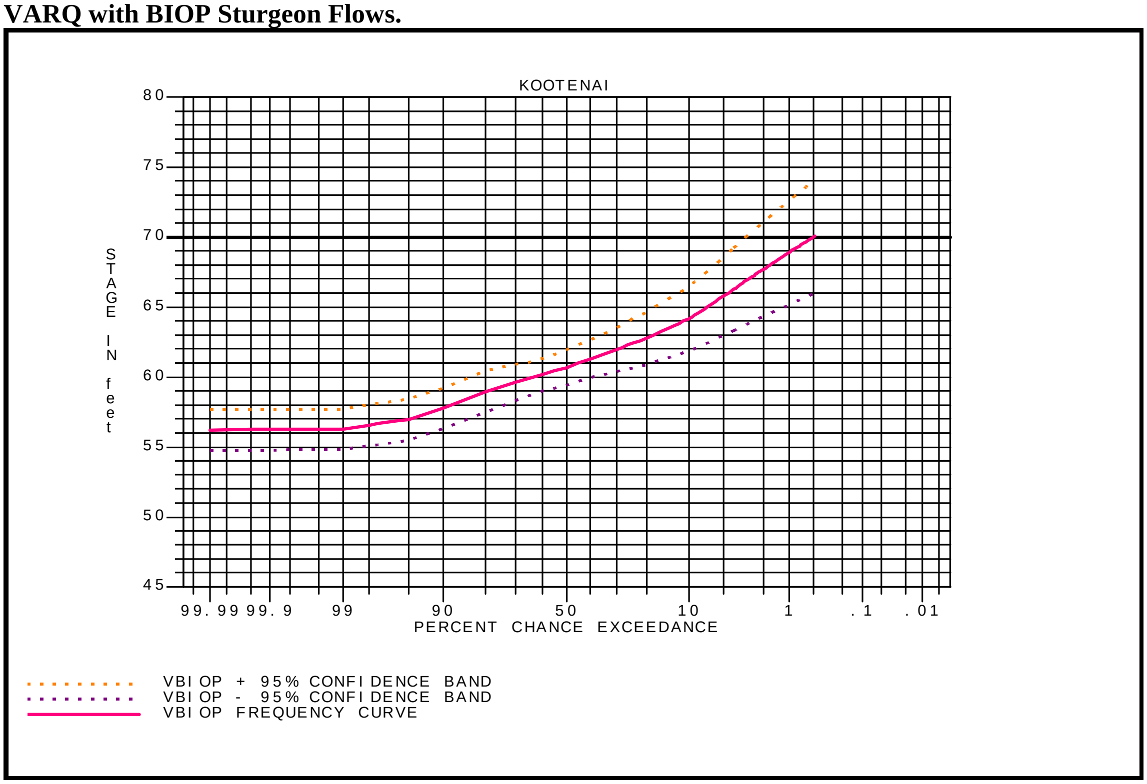


Figure 2-25. Frequency curve for Daily Peak Stage at Bonners Ferry with 95% Confidence Limits under SOSPA.

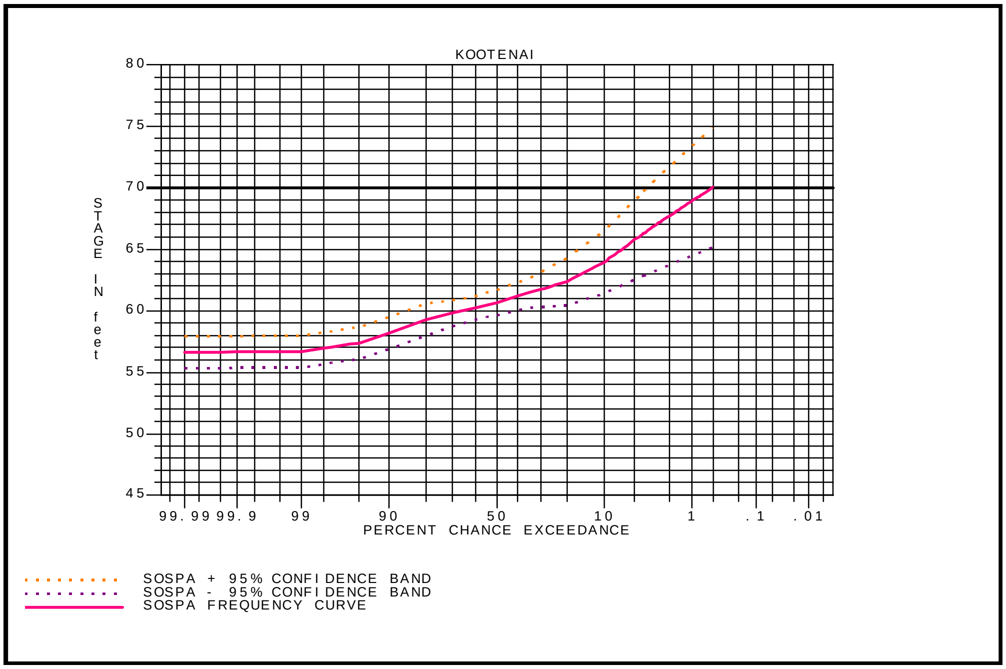
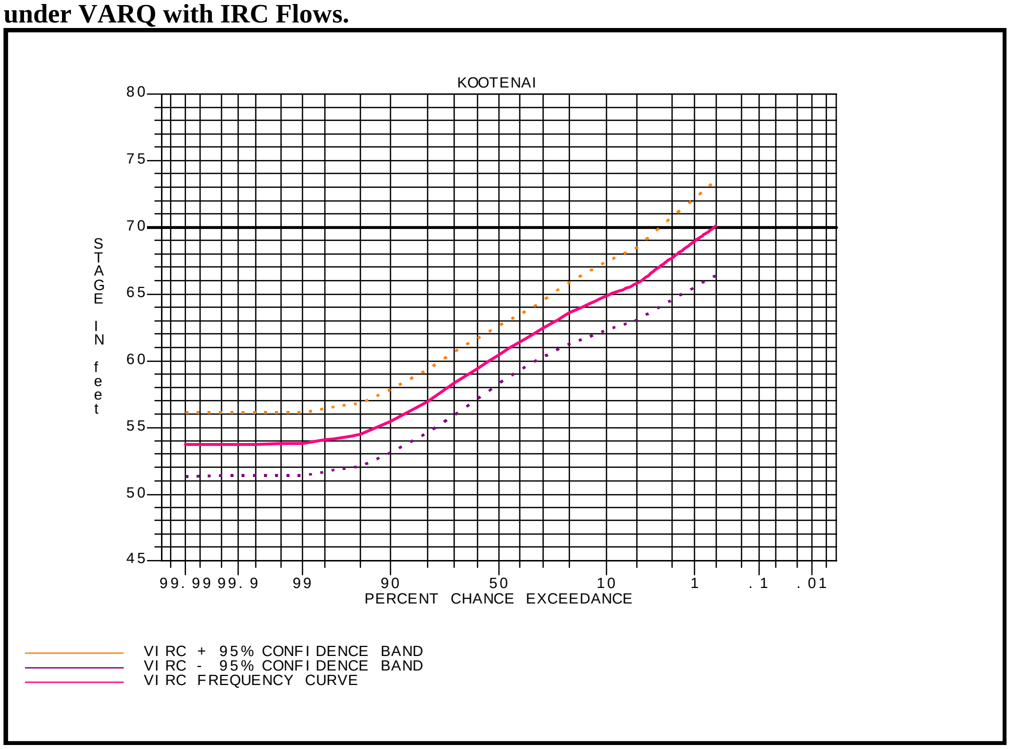


Figure 2-26. Frequency curve for Daily Peak Stage at Bonners Ferry with 95% Confidence Limits under VARQ with IRC Flows.



3.0 LEVEE ANALYSIS

3.1 Background

The Kootenai River is bordered by a combination of natural and manmade levees from upstream of Bonners Ferry, Idaho to Kootenay Lake. Centuries of floods have scoured and lifted excess sediment up and over the river banks forming natural levees. These natural levees were supplemented by manmade ones when farmers began cultivating the valley floor. Much of this activity took place in the 1920's. The maintenance, repair, and modification of the levee system was largely performed by local interests before 1948. Between 1948 and 1974 much of this activity was done by the Corps of Engineers under its flood fighting authorities.[39] The manmade levee system today extends on both sides of the Kootenai River for 75 miles from Bonners Ferry to Kootenay Lake with few natural stretches. With the completion of Libby Dam in 1974, the threat of overbank flooding has become minimal, and bank protection efforts have been for the most part abandoned.

A congressional appropriation of $1.5 million was granted in 1974 to compensate land owners in the Kootenai Flats for pumping costs and erosion below Libby Dam. The appropriation was distributed on a first come - first serve basis, and terms of the authority were limited to the appropriated funds. There was not enough money available to satisfy all claims. The listing of the Kootenai River white sturgeon as an endangered species in 1994 prompted the Corps of Engineers to perform a series of field evaluations of the U.S. levee system in an attempt to assess their condition, and ability to safely handle the higher flows required to meet the Biological Opinion.

3.2 Levee Evaluation

An evaluation of the safe capacity of the Kootenai River levees from Bonners Ferry to the Canadian border was based on six field inspections during 1995, 1996, and 1997. Boat surveys and cross-sections of the river were analyzed. Conditions of the levees and river banks were summarized into three categories; 1) locations where erosion has progressed to the point of endangering the integrity of the levees, 2) locations where erosion has occurred, and if allowed to progress will endanger the integrity of the levees, and 3) locations where erosion has occurred, but is not expected to affect the integrity of the levees. (See Figure 3-1). Erosion sites ranged from 20 feet in length to several hundred feet. Using cross-sections for each river reach, the worst case per reach was used to determine the level of protection. Probable Nonfailure Point (PNP) and Probable Failure Point (PFP) values were assigned as shown in Table 3-1 for the river miles assumed to be the most susceptible to failure or most likely to sustain costly damages in a flood.

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[39] "Kootenai Flats Erosion Study", US Army Corps of Engineers, Seattle District, Hydrology and Hydraulics Branch Files, 25 August 1983, p. 3.

Results of the October 1997 erosion survey identified that 12 sites which had previously been categorized as potential threats in 1995 and 1996 had become imminent threats. In at least one case, the levee had been essentially breached with only the landward shoulder and slope remaining intact. The October 1997 survey suggested that the rate of erosion occurring along the river in Kootenai flats area had not slowed, and may have accelerated. The continuing deterioration of the river banks, and subsequent erosion of the existing levees may eventually result in another revision of the safe capacity of this system to protect property from flood waters.

Exposed materials on the eroded areas permitted evaluation of the levee and bank structure, and composition. Sampling, or excavating of the levee or banks was not required. The levees and banks consist mostly of fine grained sands and silts for the majority of the reach from Bonners Ferry to the Canadian border. The levees were built on top of silt and sediment materials naturally deposited prior to any human flood control activities. These materials are highly susceptible to erosion. Numerous sites throughout the study area show that erosion of the river banks has progressed into the levee section.

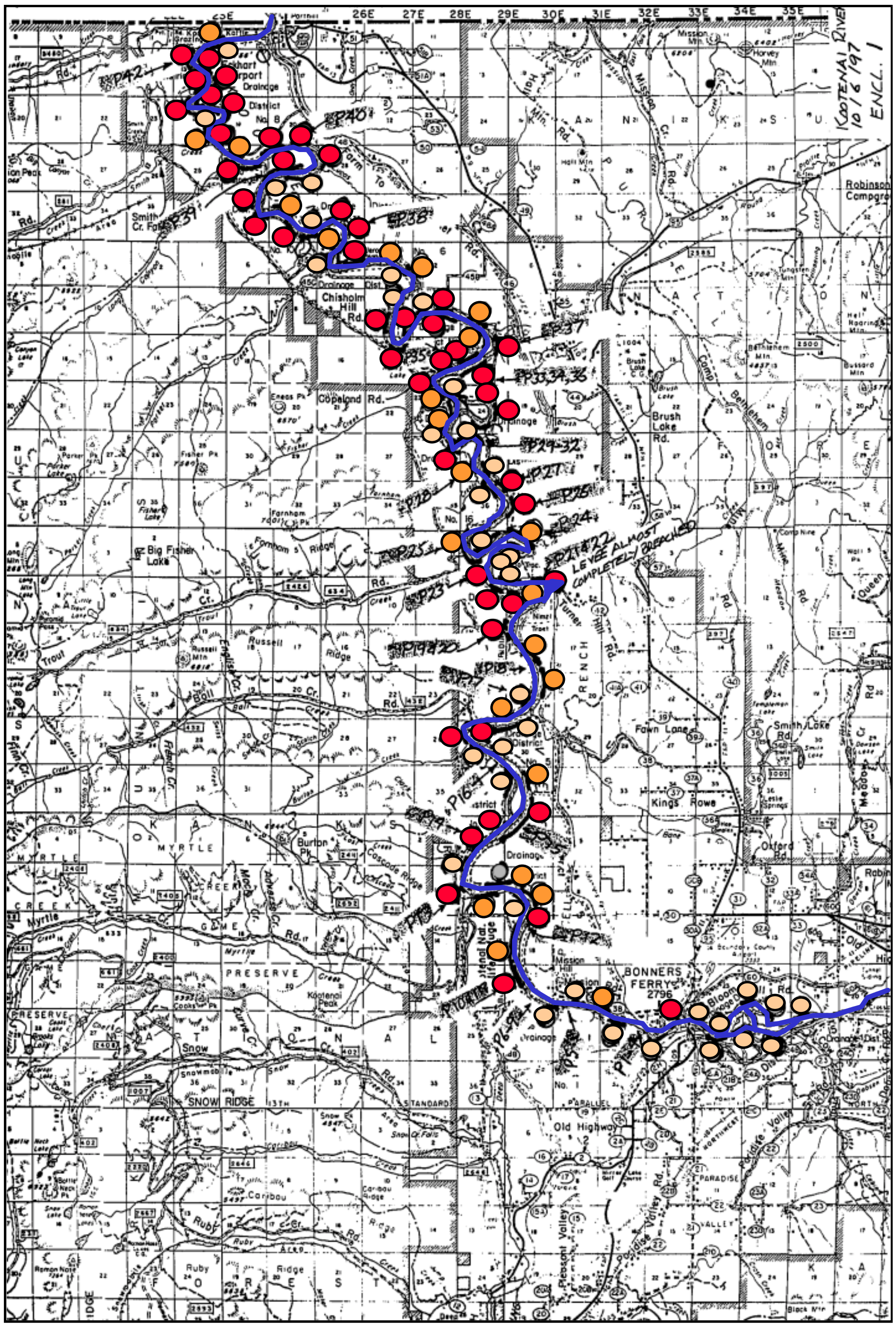
Table 3-1. Levee Evaluation, Worst Locations

River Mile	PNP (Elev, ft)	PFP (Elev, ft)	Δ, ft
124.2	1755	1760	5
125.8	1762	1765	3
127.0	1762	1763	1
128.6	1762	1765	3
130.8	1760	1763	3
131.5	1760	1762	2
133.5	1763	1763	0
134.0	1750	1760	10
135.7	1763	1766	3
137.5	1760	1763	3
138.0	1764	1765	1
142.0	1765	1768	3
143.5	1765	1768	3
145.5	1758	1765	7
146.8	1765	1769	4
149.0	1764	1767	3
149.5	1765	1770	5
151.0[1/]	1764	1768	4

PNP - Probable Non-Failure Point; PFP - Probable Failure Point
[1/] The Bonners Ferry gage on Kootenai River is located at river mile 152.8 (measured from the confluence with the Columbia River).

Figure 3-1. Erosion Study Area, Kootenai River 10/6/97

- **Imminent threat** (red)
- **Potential threat** (orange)
- **Eroding but currently no**



3.3 Revised Flood Stage, Kootenai River at Bonners Ferry

Prior documentation had identified the flood stage on the Kootenai River as elevation 27.0 feet at the Bonners Ferry gage (1770 feet, mean sea level, MSL).[40] The levee evaluation field work done in 1995 and 1996, and water surface profiles generated for Preliminary Analysis Report concluded that elevation 1770 feet was too high.[41] A new flood stage for the Kootenai River valley as measured at the Bonners Ferry gage was determined to be elevation 1764.0 feet (MSL).[42] The new flood stage is based on the premise that prolonged river stages in excess of elevation 1764 feet will eventually result in levee failure, and subsequent overland flow. The river level reached 1763.4 feet in 1996, and 1764.7 feet during 1997. Crop damage occurred in 1996 and 1997 as the result of a high groundwater table caused by high stages in the river, and inflows from non-leveed tributaries. Erosion occurred in both years, but overbank flooding from the Kootenai River did not.

3.4 Levee Deferred Maintenance

The condition of the levees has deteriorated since Libby Dam went into operation as reflected by the 1996 downward revision of Bonners Ferry flood stage from elevation 1770 feet to elevation 1764 feet (MSL). Both toe and crest erosion have occurred. An estimated 1.5 million cubic yards of material at an estimated cost of $8.7 million is currently needed to bring the levees up to the regulated 200-year design level of protection. Levee deterioration has resulted from years of locally neglected maintenance, and it should be considered as deferred maintenance.

Erosion has always been a problem in the Bonners Ferry and Kootenai Flats area. Operation of Libby Dam may have caused some minor erosion problems, however, any such damage would be insignificant compared to what would have occurred without flood control provided by Libby Dam. If the levee system is to be protected from continuing future erosion by the Kootenai River, *under any alternative*, an estimated 707,000 cubic yards of revetment costing approximately $17.7 million would be needed to stabilize the levees.[43]

The real question is whether or not the potential flood damage prevented by repairing the levees outweighs the potential costs of such work. The economic analysis in this report, as well as the Preliminary Analysis Report suggests that it does not. The maximum

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[40] Plans for Natural Disaster Procedures, NPSOM 500-1-1, U.S. Army Corps of Engineers, Seattle District, February 1992,p. V-3.
[41] Columbia River Basin System Flood Control Review - Preliminary Analysis Report, U.S. Army Corps of Engineers, North Pacific Division, Portland, February, 1997, pp. 51-53.
[42] Merkle, Lawrence O., "New Zero Damage Stage for Kootenai River at Bonners Ferry", Seattle District, USACE, Hydrology and Hydraulics Branch files, June 4, 1996
[43] Columbia River Basin System Flood Control Review - Preliminary Analysis Report, U.S. Army Corps of Engineers, North Pacific Division, Portland, February, 1997, pp. 62.

capital cost which induced flood damages would economically justify was determined to be $869,000 in the Preliminary Analysis Report.[44] Further analysis done for this study (see **Mitigation for Flood Damage** section) suggests that expenditures exceeding $135,900 would not be economically justifiable.

3.5 Canadian Levee Impacts

In general, the Canadian levees on the Kootenay River are not as high or extensive as those in Idaho. No detailed analysis of the safe capacity of the Canadian levee system has been done. The Water Management Branch of the B.C. Ministry of Environment at Nelson commissioned a small monitoring study in 1995 assessing impacts of the Biological Opinion flows on six levee cross-sections from the Canada/USA border to Kootenay Lake.[45] Only one of the six levee cross-sections experienced a measurable loss of material during the 1995 summer season.

3.6 VARQ vs. BASE-CRT63

Without maintenance, the already weakened levee system along the Kootenai River will continue to deteriorate regardless of whether the VARQ flood control operation is implemented at Libby Dam. For the foreseeable future, endangered species flow requirements and local runoff below Libby Dam will dictate the river stage during the summer months regardless of the flood control operation.

The impacts to levees resulting from higher summer river stages and velocities required by endangered species may be partially offset by the VARQ flood control operation during the winter time because VARQ requires less flood control draft, and therefore less opportunities for hydropower operations that often fluctuate the river level. The current Libby Dam project operating limits allow a maximum tailwater fluctuation of 4 feet per 24 hours from May 1 to September 30, and six feet per 24 hours from October 1 to April 30. These tailwater fluctuations can be felt downstream in the Bonners Ferry area 12 to 18 hours later with little attenuation. Although the daily operating limits are rarely achieved, load following (power peaking) does take place throughout much of the fall and winter. In approximately one half of all years under VARQ there will be no further flood control drafting required at Lake Koocanusa after January 1. If the Corps continues to

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[44] Columbia River Basin System Flood Control Review - Preliminary Analysis Report, U.S. Army Corps of Engineers, North Pacific Division, Portland, February, 1997, pp. 64.

[45] Klassen, Dave, "Kootenay River Banks and Dyke Systems 1995 Monitoring Contract, Canada-USA Border to Kootenay Lake", B.C. Ministry of the Environment, Water Management Branch, Nelson. B.C., 1995.

draft Lake Koocanusa only to the flood control rule curves, opportunities for load following below Libby Dam may be limited with VARQ.

4.0 ECONOMIC ANALYSIS

4.1 Purpose and Scope

The purpose of this Economic Analysis is to quantify the economic impacts of the two flood control plans, BASE-CRT63 and VARQ, as well as their endangered species refinements, SOSPA, VARQ w/BIOP and VARQ w/IRCs. This economic analysis looked specifically at flood impacts, mitigation of flood impacts, groundwater agricultural impacts, agricultural pumping power costs, and Lake Koocanusa recreation impacts. Downstream impacts are summarized. No attempt was made to summarize total economic impacts because a power analysis was not done as part of this study. A power analysis will be done at a future date by the Power Branch of the Northwest Division of the Corps of Engineers. It is anticipated that power impacts will dwarf all others.

In order to validly compare the two flood control plans it is necessary to examine the current operation of Libby Dam, SOSPA, which combines the BASE-CRT63 flood control plan with the Biological Opinion sturgeon operation, and compare it to the VARQ flood control plan with the same sturgeon operation (VARQ w/BIOP). The VARQ flood control operation with IRC flows was also examined purely to see its impacts (VARQ w/IRCs).

The scope of the various studies that comprise the economic analysis varied considerably. The hydrologic analyses, for instance, was done at a feasibility level of detail, while the analyses on flood damages, levees, agricultural pumping costs, groundwater impacts, and Lake Koocanusa recreational impacts were done at a lower level of detail.

4.2 Study Area

The study area for this economic analysis was limited to the United States portion of Lake Koocanusa, extending downstream of Libby Dam along the Kootenai River to the international boundary. Canadian economic impacts were not analyzed. Along the Kootenai River downstream of Libby Dam are the towns of Libby (population 2,532) and Troy (pop. 953) in Montana, and Bonners Ferry in Idaho (pop. 2,193). In addition to Libby Dam, flood protection is provided in the United States portion of the flood plain by levees downstream of Bonners Ferry that protect about 35,000 acres of agricultural lands used to grow wheat, barley, hops, clover seed, timothy seed, and hay. About 190 acres within the town of Bonners Ferry are also in the Kootenai river flood plain. This area consists of 106 homes, 66 commercial establishments, and 12 public facilities.

4.3 Flood Damages

Data on damageable property, including residential structures and contents, commercial/industrial, public, agricultural crops and emergency aid, was obtained from a detailed 1987 study.[46] This information was updated to July 1996 conditions for price level and an assumed rate of growth, using field observations, interviews, maps, aerial photographs, and property tax assessment data. Damage by river stage as a consequence of over-bank flooding, for all categories is summarized on Table 4-1. The zero dollar damage point for the river reach from Bonners Ferry, Idaho to the US/Canada border was revised downward to elevation 1764.0 feet in 1996. Damages associated with high groundwater and poor drainage are not included as flood damage, but are addressed in Section 4.4, Groundwater Agricultural Damages.

Table 4-1 Stage vs. Flood Damage (July 1996 Prices and Conditions) ($1,000)

Stage*	Residential	Commercial/ Industrial	Public	Agri- cultural	Emergency Aid	Other	Total Flood Damages
1764	-	-	-	-	-	-	-
1766	7	98	50	113	61	25	354
1768	15	197	99	226	121	49	707
1770	30	428	215	488	262	106	1,529
1772	52	725	361	828	444	181	2,591
1776	184	2,566	1,284	2,934	1,573	642	9,183
1777	263	3,686	1,844	4,212	2,258	922	13,185
1778	447	6,253	3,127	7,146	3,831	1,564	22,368
1780	1,048	14,680	7,339	16,775	8,991	3,669	52,502
1781	1,129	15,798	7,898	18,054	9,677	3,949	56,505

*Elevation in MSL Datum

Stage-frequency relationships were developed for the Bonners Ferry gage for each of the alternatives, and analyzed to derive average annual flood damages. Average annual flood damages were computed using the Corps of Engineers Hydrologic Engineering Center computer program "Expected Annual Flood Damage Computation".[47] This program integrates exceedence frequency with associated damages to determine annual damages for a given frequency interval. Table 4-2 presents a summary of expected average annual flood damages for each operating scenario.

[46] "Damages Prevented by Libby Dam, Bonners Ferry, Idaho", Economics Report Number DP-315, in files of Planning Branch, U.S. Army Corps of Engineers, Seattle District, 1987.
[47] Expected Annual Flood Damage Computation, Users Manual, CPD-30, U.S. Army Corps of Engineers, Hydrologic Engineering Center, Davis, CA., March 1989.

TABLE 4-2 SUMMARY OF AVERAGE ANNUAL FLOOD DAMAGES
(JULY 1996 Prices & Conditions)

Scenario	Flood Damages
BASE-CRT63	$43,000
VARQ	$47,000
SOSPA	$43,000
VARQ w/BIOP	$44,000
VARQ w/IRC	$53,000

Table 4-3 presents a summary of expected average annual flood damages for each operating scenario when compared to SOSPA. SOSPA is the current operating plan for Libby Dam as per the Corps of Engineers' Record of Decision dated February 20, 1997.[48] Table 4-3 suggests that there is little difference in average annual flood impacts between SOSPA and VARQ w/BIOP. VARQ w/IRCs produces slightly more flood damage than the BIOP alternatives due to its 50,000 cfs flow targets in large runoff years.

TABLE 4-3 SUMMARY OF AVERAGE ANNUAL FLOOD IMPACTS
(Change from SOSPA, JULY 1996 Prices & Conditions)

Scenario	Average Annual Flood Damages (Change from SOSPA)
SOSPA	n.a.
VARQ w/BIOP	$1,000
VARQ w/IRC	$10,000

4.4 Groundwater Agricultural Damage

The Kootenai River is leveed along both sides between Bonners Ferry and the U.S./Canada border, a distance of about 50 miles. Land use in this area is mostly agricultural, separated into 14 drainage districts totaling approximately 35,000 acres. Each drainage district is separated by cross levees. Gravity drains and pumping facilities are used to transport surface and ground water back into the river. Higher river stages result in higher pumping costs to keep the land arable. If the river stage gets too high, the existing interior drainage facilities may not be adequate to keep the land dry enough to farm.

Agricultural impacts occur from standing water and high groundwater, beginning when the Kootenai River is well below flood stage. For river stages greater than elevation 1755 feet, gravity drainage of some fields is no longer possible, and pumps need to be

[48] Griffin, Robert H., "Record of Decision -Columbia River System Operation Review -Selection of a System Operation Strategy", U.S. Army Corps of Engineers, North Pacific Division, Portland, February 20, 1997, pp. 1-12.

employed. Adverse impacts due to high groundwater include the inability to seed land, delayed seeding and resultant reduction in crop yield, and crops that drown before harvest. Table 4-4 gives a history of recent agricultural impacts due to groundwater as determined by Dave Wattenbarger, Idaho State University Agriculture Extension Agent in Bonners Ferry.

Table 4-4. Agricultural Damage in the Kootenai River Valley of Idaho since 1994. [49]
1994 - The maximum river stage at Bonners Ferry was 1753.4. No agricultural damage was reported.
1995 - The river reached a maximum level of 1758.5 feet at Bonners Ferry. High groundwater caused an estimated $120,000 in crop damage to approximately 600 acres in the valley. The river was above elevation 1755.0 at Bonners Ferry for 42 days.
1996 - The river reached 1763.4 at Bonners Ferry, and an estimated 7,000 acres were either inundated or damaged by groundwater. Crop damage was estimated to be $1.3 million. The stage was at or above 1755.0 for 23 days from 10 April to 2 May, and again for 60 days between 15 May and 14 July, for a total of 83 days.
1997 - The maximum river stage was 1764.7. The river was at or above 1755.0 for 69 days. 2000 acres had reduced yields, 5000 acres of crops were drowned, and 1000 acres were not seeded. The total agricultural damage was estimated at $1.44 million.

Maximum 30-day average stage-frequency relationships were developed for the Kootenai River at Bonners Ferry for each of the 5 alternatives. Table 4-5, the Maximum 30-Day Average Stage vs Crop Damage, relationship was developed based on observed water levels in 1994-1997. This relationship assumes that crop damage from groundwater is dependent on the highest 30-day average river elevation experienced during the summer months (usually May-June).

Table 4-5 Maximum 30 Day Average Stage vs.Agricultural Damage

Max 30 Day Ave Pk Stage	Crop Damage
1755	$0
1756.89	$120,000
1761.08	$1,300,000
1762.57	$1,440,000
1763.0	$1,500,000

Expected average annual agricultural damages were computed using the Corps of Engineers' Hydrologic Engineering Center computer program, Expected Annual Flood Damage Computation. Table 4-6 presents a summary of average annual groundwater agricultural damages for each operating scenario. The groundwater agricultural damage estimates assume no increases in pumping capacity, and no change in the current cropping pattern.

[49] Dave Wattenbarger, Idaho State University, Agricultural Extension Office, personal conversation, 11/5/97.

Table 4-6 30 Day Maximum Average Stage for All Alternatives with Average Annual Groundwater Agricultural Damage

Return Period (years)	Exceedance Frequency	Base-CRT63 (feet msl)	VARQ		SOSPA (Base-CRT63 with BIOP Sturgeon Flows)	VARQ w/BIOP Sturgeon Flows	VARQ w/IRC Sturgeon Flows
1	.99	1747.0	1748.1		1756.2	1755.1	1748.1
	.95	1748.7	1750.2		1756.6	1755.8	1750.4
	.90	1750.3	1752.1		1757.2	1756.6	1752.5
	.80	1752.3	1754.5		1758.0	1757.6	1754.7
2	.50	1754.4	1756.4		1759.3	1759.2	1756.9
5	.20	1758.6	1759.8		1760.3	1760.7	1761.7
10	.10	1760.2	1761.3		1761.0	1761.6	1762.5
20	.05	1760.6	1762.1		1761.3	1762.1	1762.7
50	.02	1760.7	1762.4		1761.5	1762.4	1763.0
100	.01	1760.7	1762.5		1761.6	1762.5	1763.0
200	.005	1760.7	1762.6		1761.7	1762.6	1763.0
Average Annual Agricultural Damage		**$243,000**	**$390,000**		**$758,000**	**$749,000**	**$529,000**

SOSPA reflects the current operation of Libby Dam. Table 4-7 summarizes the differences between SOSPA (which includes the BASE-CRT63 flood control curves) with the endangered species alternatives which feature the VARQ flood control operation. Table E-7 suggests that there is little difference in expected average annual agricultural damage between SOSPA and VARQ w/BIOP. VARQ w/IRCs produces far less average annual agricultural damage than either SOSPA and VARQ w/BIOP because the IRC flow regime is tiered so that in average years the IRC flow targets are much lower than the Biological Opinion flow objectives.

TABLE 4-7 SUMMARY OF AVERAGE ANNUAL GROUNDWATER AGRICULTURAL DAMAGE

(Change from SOSPA, JULY 1996 Prices & Conditions)

Scenario	Groundwater Agricultural Damages (Change from SOSPA)
SOSPA	n.a.
VARQ w/BIOP	($9,000)
VARQ w/IRC	($229,000)

( ) means less damages than SOSPA

4.5 Pumping Power Costs

Interpolation of available data from the Preliminary Analysis Report [50] and miscellaneous monthly electric bills suggests the annual pumping power costs reflected in Table 4-8 for the Kootenai River valley in Idaho.

Table 4-8 Estimated Average Annual Pumping Power Costs for Alternatives

BASE-CRT63	$ 25,000
VARQ	$ 26,500
SOSPA	$ 31,000
VARQ w/BIOP	$ 30,700
VARQ w/IRCs	$ 26,500

Table 4-8 suggests that the two endangered species alternatives (SOSPA and VARQ w/BIOP) which feature the Biological Opinion flows of 35,000 cfs at Bonners Ferry for 42 days will result in higher average pumping power costs than the flood control operations without BIOP sturgeon flows.

TABLE 4-9 SUMMARY OF AVERAGE ANNUAL PUMPING POWER COSTS
(Change from SOSPA, JULY 1996 Prices & Conditions)

Scenario	Pumping Power Costs (Change from SOSPA)
SOSPA	n.a.
VARQ w/BIOP	($300)
VARQ w/IRC	($4,500)

( ) means less pumping power costs than SOSPA

Table 4-9 suggests that there is little difference in the expected annual average annual pumping power costs between SOSPA and VARQ w/BIOP.

This assessment did not consider the potential capital costs associated with modifying individual drainage district pumping facilities to increase pumping capacity sufficiently to mitigate for the increased water levels associated with the various operational alternatives. Detailed studies would be required to more accurately define the annual power costs and power cost increases, and the need, liability, extent, and cost of additional drainage and pumping facilities, if any, associated with a change in the flood control operation of Libby Dam. Given the magnitude of the pumping power costs determined in the analysis, a more detailed study does not appear warranted.

4.6 Summary of Downstream Impacts

[50] Columbia River Basin System Flood Control Review - Preliminary Analysis Report, U.S. Army Corps of Engineers, North Pacific Division, Portland, February, 1997, pp. 60-62.

The downstream impacts associated with the overbank flooding, groundwater agricultural damage, and pumping power costs are summarized in Table 4-10.

TABLE 4-10 SUMMARY OF AVERAGE ANNUAL DOWNSTREAM IMPACTS
(JULY 1996 Prices & Conditions)

Scenario	Flood Damages	Groundwater Agricultural Damages	Pumping Power Costs	Total Downstream Costs
BASE-CRT63	$43,000	$243,000	$25,000	$311,000
VARQ	$47,000	$390,000	$26,500	$463,500
SOSPA	$43,000	$758,000	$31,000	$832,000
VARQ w/BIOP	$44,000	$749,000	$30,700	$823,700
VARQ w/IRC	$53,000	$529,000	$26,500	$608,500

The total downstream costs identified in Table 4-10 are considerably higher than those identified in the Preliminary Analysis Report because this study considered groundwater agricultural damage, and not simply overbank flooding.[51] It is revealing that overbank flood damages and increased pumping power costs are small when compared to groundwater agricultural damage.

The lowest total downstream costs are associated with the current flood control plan with no endangered species releases, BASE-CRT63. However, it is unrealistic to imagine that endangered species releases will be terminated in the foreseeable future. SOSPA has highest total downstream costs of the endangered species alternatives. When endangered species flows are required, the alternatives featuring the VARQ flood control plan result in lower downstream costs than SOSPA, as shown in Table 4-11.

TABLE 4-11 SUMMARY OF AVERAGE ANNUAL DOWNSTREAM IMPACTS
(Change from SOSPA, JULY 1996 Prices & Conditions)

Scenario	Flood Damages	Groundwater Agricultural Damages	Pumping Power Costs	Total Downstream Costs
SOSPA	n.a.	n.a.	n.a.	n.a
VARQ w/BIOP	$ 1,000	($ 9,000)	($ 300)	($ 8,300)
VARQ w/IRC	$10,000	($229,000)	($4,500)	($223,500)

( ) means less costs than SOSPA

[51] Columbia River Basin System Flood Control Review - Preliminary Analysis Report, U.S. Army Corps of Engineers, North Pacific Division, Portland, February, 1997, pp. 63.

4.7 Mitigation for Flood Damage

BASE-CRT63 and SOSPA have the same average annual flood damages of $43,000. The increase in average annual flood damages resulting from the implementation of VARQ, VARQ w/BIOP, or VARQ w/IRC could be reduced or eliminated with extensive improvements on the Kootenai River levee system. As a basis to determine the maximum dollar amount that could be expended to raise and strengthen the levee system, from an economic perspective, the increase in average annual flood damages were calculated for all operating scenarios as shown in Table 4-12. Capitalizing these values over a 50-year analysis period at the current water resources interest rate of 7 1/8 percent indicates the amount that could be expended to mitigate for increased flood damages resulting from the implementation of each operating scenario.

TABLE 4-12 Maximum Levee Costs Which Induced Damages Would Support (July 1996 Prices & Conditions)

SCENARIO	AVERAGE ANNUAL FLOOD DAMAGES	INCREASE FROM BASE-CRT63/SOSPA	MAXIMUM LEVEE IMPROV. COST
BASE-CRT63	$43,000	n.a.	n.a.
SOSPA	$43,000	n.a.	n.a.
VARQ	$47,000	$4,000	$54,300
VARQ w/BIOP	$44,000	$1,000	$13,600
VARQ w/IRC	$53,000	$10,000	$135,900

Table 4-12 suggests that based on annual peak river stages at Bonners Ferry, the maximum capital cost which induced flood damages would economically justify is $135,900 under the VARQ w/IRC alternative. This is even less than the $869,000 determined in the Preliminary Analysis Report.[52] It has been determined that $8.7 million will be required to bring the current levees back into condition to provide 200 year flood protection to elevation 1770 feet.[53] In addition, under any alternative, an estimated 707,000 cubic yards of revetment costing approximately $17.7 million will be needed to stabilize the levees from future erosion by the Kootenai River. From an economics

[52] Columbia River Basin System Flood Control Review - Preliminary Analysis Report, U.S. Army Corps of Engineers, North Pacific Division, Portland, February, 1997, pp. 64.
[53] Columbia River Basin System Flood Control Review - Preliminary Analysis Report, U.S. Army Corps of Engineers, North Pacific Division, Portland, February, 1997, pp. 62.

standpoint, it makes little sense to improve the Kootenai River levee system based on the slight increase in overbank flood potential associated with VARQ or any of the endangered species alternatives.

4.8 Lake Koocanusa Recreation Impacts

A compelling argument for pursuing the VARQ flood control operation is its positive impact on refill at Lake Koocanusa. The low winter reservoir elevations required by the current flood control operation in combination with the sturgeon flow releases mandated by the Endangered Species Act have combined to seriously undermine the ability of the Corps of Engineers to refill Lake Koocanusa under SOSPA.

The Corps of Engineers facilities at Libby Dam project attracted 253,000 visits in 1996, the most recent year when Lake Koocanusa reached full pool.[54] It is estimated that total visitation to all facilities around the Lake is approximately 600,000 per year.[55] Expected recreation use at Lake Koocanusa based on shortfalls in reservoir refill are summarized in Table 4-13.

Visits associated with the Corps of Engineers' lands at Lake Koocanusa were calculated for each of the years modeled in this study based on the 1996 visitation rate and the percent use from Table 4-13. Visits were then converted into annual trip spending using factors developed by the Corps of Engineers' Waterways Experiment Station (see Table 4-14).[56] This analysis assumed that 25% of all visits were for camping during the summer season at a rate of $82.57 per visit, and 75% of all visits were for either sightseeing or other activities at $21.50 per visit.

Table 4-13 Recreation Use Relative to Lake Koocanusa Maximum Elevation

Max. Elevation	% of Use	Max. Elevation	% of Use
2459.0	100.0%	2434.0	73.8%
2456.5	99.3%	2429.0	71.7%
2454.0	96.2%	2419.0	69.0%
2451.5	92.9%	2409.0	67.3%
2449.0	88.1%	2399.0	65.6%
2444.0	82.4%	2389.0	63.9%
2439.0	75.6%		

[54] Libby Dam - Lake Koocanusa Project Master Plan, Design Memorandum No. 52, US Army Corps of Engineers, Seattle District, September 1997, Table 3-A.
[55] Bonneville Power Administration, "Columbia River System Operation Review Final Environmental Impact Statement - Appendix J - Recreation", November 1995, Table 4-5.
[56] Jackson, R. Scott; Stynes, Daniel; Probst, Dennis; Carlson, Bruce; "A Summary of the National and State Economic Effects of the 1994 U.S. Army Corps of Engineers Recreation Research Program", Technical Report R-96-1, Headquarters, US Army Corps of Engineers, February 1996.

Table 4-14 summarizes the average annual trip spending as a result of the various alternatives. Trip spending represents recreation spending that takes place over an entire trip (and not just in the Libby area). These numbers do not reflect durable spending benefits or benefits in Canada, or benefits associated with other lands around Lake Koocanusa.

Table 4-14 Average Annual Trip Spending
These benefits result from visitation to COE lands only.
Durable benefits are not included in this analysis.

Alternatives	Ave Annual COE Visits	Ave Annual TRIP SPENDING	Trip spending (Change from SOSPA)
BASE-CRT63	249,237	$ 9,164,000	$ 2,026,000
VARQ	251,157	$ 9,234,000	$ 2,096,000
SOSPA	194,130	$ 7,138,000	n/a
VARQ w/BIOP	222,284	$ 8,173,000	$ 1,035,000
VARQ w/IRCs	239,833	$ 8,818,000	$ 1,680,000

Table 4-14 suggests that if Libby Dam was regulated strictly to the flood control rule curves with no additional reservoir draft for power or endangered species, then trip spending would be maximized. However, at the present time endangered species releases are required. The endangered species alternatives featuring the VARQ flood control operation result in over $1 million in increased trip spending as compared to the current operation, SOSPA.

Detailed studies which may more accurately define the recreation benefits associated with a change in the flood control operation of Libby Dam were beyond the scope and budget of this flood control analysis. However, the analysis described in this report suggests that Lake Koocanusa recreation benefits of VARQ are considerable.

5.0 COORDINATION WITH CANADA

This flood control analysis encompasses the Kootenai River from Lake Koocanusa at the Montana/British Columbia (B.C.) border to the outlet of Kootenay Lake in southern B.C. Hydraulic modeling was done using river cross sections in Canada provided by the B.C. Ministry of the Environment. Computer model data input and output files from this study were supplied to the Canadian Department of Fisheries and Oceans for further analysis.

The Canadian Section of the International Joint Commission (IJC) Kootenay Lake Board of Control supplied the Corps with a copy of a 1995 report on river bank erosion from the border to Kootenay Lake.[57] A joint tour of Canadian levees involving the U.S. and Canadian International Joint Commission (IJC), Environment Canada, and the U.S. Army Corps of Engineers took place in October 1997.

A preliminary draft of this report was supplied to B.C. Hydro.

[57] Klassen, Dave, "Kootenay River Banks and Dyke Systems 1995 Monitoring Contract, Canada-USA Border to Kootenay Lake", B.C. Ministry of the Environment, Water Management Branch, Nelson. B.C., 1995.

6.0 CONCLUSIONS

6.1 Hydrology

The results of the hydrologic study generally support the findings of the Columbia River Basin System Flood Control Review - Preliminary Analysis Report. This study found that there would be little change in the frequency and magnitude of flooding downstream of Libby Dam as a result of changing to a Variable Discharge (VARQ) flood control operation. The magnitude and shape of endangered species flows below Libby Dam have a far greater influence on water levels in the Kootenai River than the underlying flood control operating plan. VARQ will increase the probability of refilling Lake Koocanusa, especially when taking into account sturgeon releases. Any differences between the results from Preliminary Analysis Report and this hydrologic study can be attributed to the far greater detail in the hydro-regulations for this study. The hydro-regulations for this hydrologic study were more realistic in every aspect.

In February 1997, the U.S. Army Corps of Engineers adopted the Preferred Alternative (SOSPA) from the Columbia River System Operation Review as the future operating strategy for Libby Dam. SOSPA commits large volumes of water from Lake Koocanusa, i.e., Libby Reservoir for the recovery of endangered Kootenai River white sturgeon. SOSPA follows the Columbia River Treaty Flood Control Operating Plan in determining the amount of winter lowering of Lake Koocanusa. Based on computer modeling of the Kootenai River system for the 31 year record from 1948 to 1978, and assuming that future weather patterns will mimic the past, it was found that the large summer releases from Libby Dam for the benefit of white sturgeon combined with the deep winter reservoir drafts under the SOSPA will result in failure to refill Lake Koocanusa in over 80% of future years. The average refill shortfall under SOSPA will be approximately 28 feet. Failure to refill Lake Koocanusa will not well serve local fisheries, the recreation community, or salmon advocates who wish to use Lake Koocanusa for flow augmentation to the Columbia River.

The variable discharge flood control operating plan (VARQ) has been proposed as a substitute for the Columbia River Treaty Flood Control Operating Plan (BASE-CRT63). When compared to BASE-CRT63 on *strictly a flood control basis*, VARQ results in peak river stages during average and below average years zero to two feet higher at Bonners Ferry, Idaho. There would be no increase to the 20, 50, 100, and 200 year flood stages. The VARQ flood control operation features peak discharges from Libby Dam up to 5,000 cfs higher than BASE-CRT63. The peak discharges resulting from the two flood control plans converge to the same magnitude at the high end of the frequency curves. VARQ results in higher winter lake levels (0-45 feet) at Lake Koocanusa, and a slightly increased probability of reservoir refill by the end of July. The VARQ and BASE-CRT63 flood control operations could result in refilling Lake Koocanusa with greater than 90% reliability *if no endangered species flows or supplemental power drafts were done.*

It is not realistic to contrast the two flood control operations without taking into consideration the additional flow requirements mandated by the Endangered Species Act. While VARQ is comparable to BASE-CRT63 on strictly a flood control basis, it compares much more favorably when endangered species flows are considered. Three scenarios were modeled that illustrate the practical impact of the VARQ and BASE-CRT63 flood control operations given the current reality of endangered species flows. The VARQ flood control operation in combination with the USFWS Biological Opinion for sturgeon recovery (VARQ w/BIOP) was compared directly to SOSPA. SOSPA includes the same Biological Opinion flows and the BASE-CRT63 flood control operation. VARQ also was modeled with the Integrated Rule Curve's (IRCs) tiered flow regime. The IRC flow regime features target flows at Bonners Ferry ranging from 8,000 cfs in years of low runoff to 50,000 cfs in extremely wet years. The IRCs have been endorsed by the state of Montana, the Northwest Power Planning Counsel, and the USFWS White Sturgeon Recovery Team. VARQ w/BIOP, and VARQ w/IRCs represent likely future operative strategies for Libby Dam.

Under all scenarios modeled, there was no increase in the frequency of a peak 1-day river stage at Bonners Ferry exceeding elevation 1765.8 feet (a 20-year event). There was a slight increase in the river stage at Bonners Ferry associated with a 10-year return period. Based on the modeling, the "10-year flood" stage at Bonners Ferry was found to be elevation 1764.0 feet under SOSPA, 1764.2 under VARQ w/BIOP, and 1764.9 under VARQ w/IRCs. These river stages are approximately 1.5 feet lower than the Preliminary Analysis Report.

Farmers in the Kootenai Flats area below Bonners Ferry experience additional pumping costs and agricultural damages when the Kootenai River at Bonners Ferry exceeds elevation 1755 feet. The Biological Opinion sturgeon flows will result in river stages in excess of elevation 1755 in virtually every year, *regardless of the flood control operation*. VARQ w/IRCs results in higher 30-day sustained river stages during years of high runoff, but lower river stages in average and below average runoff years. The 30-day average river stage did not exceed the flood stage of elevation 1764 feet in any of the strategies modeled.

Flows at Bonners Ferry in excess of 57,000 cfs have been identified in the Columbia River Treaty Flood Control Operating Plan as the threshold at which flood protection at Bonners Ferry and Creston, B.C. is achieved. Under all scenarios modeled, there was no difference in the frequency of flows in the Kootenai River at Bonners Ferry exceeding 57,000 cfs.

Although sturgeon flow targets at Bonners Ferry require generally higher discharges from Libby Dam, they actually result in fewer extreme dam releases because sturgeon flows delay Lake Koocanusa from refilling. The sturgeon releases have no impact on floods with a return period of over 20 years at Bonners Ferry and decrease the likelihood of large spill events at Libby Dam which may damage downstream fisheries.

When endangered species flows are pursued, VARQ will produce a dramatic increase in the refill probability of Lake Koocanusa when compared to the current BASE-CRT63 flood control plan. The current Libby Dam operation, SOSPA, refilled the reservoir to within five feet of full by the end of July in only 16% of the years modeled, and peaked at an average elevation of 2430.6 feet (over 28 feet from full). VARQ filled the reservoir in July more than twice as often as SOSPA when supplying the same BIOP flows. VARQ w/BIOP sturgeon flows refilled by the end of July to within five feet of full in 42% of the years modeled, and peaked at an average elevation of 2447.6 feet (11 feet from full). VARQ w/IRC sturgeon flows did the best job in filling the reservoir amongst the sturgeon flow options. Lake Koocanusa refilled to within five feet of full before the end of July in 65% of the years modeled, and peaks at an average elevation of 2455.3 feet (four feet from full).

There is a conflict between meeting the USFWS Biological Opinion *sturgeon* flow targets and the National Marine Fisheries Services (NMFS) Biological Opinion *salmon* flow objectives. The sturgeon require large releases from Libby Dam that can prevent refill. Failure to refill Lake Koocanusa limits the Corps' ability to provide salmon flow augmentation in August. The NMFS' Biological Opinion states that Lake Koocanusa be drafted, if necessary, to elevation 2439 in August to meet salmon targets in the Columbia River. Under SOSPA, Lake Koocanusa reached a *maximum* of elevation 2439 feet in only 32% of years modeled. The VARQ flood control operating plan increases the likelihood of refill and hence lessens the conflict.

The VARQ flood control operation can result in an unacceptable level of spill from Libby Dam which may damage downstream fisheries if endangered species flows are *not* pursued. Increased spill is the tradeoff with increased reservoir refill reliability. The higher lake levels associated with VARQ have a downside in that spill in excess of the current turbine capacity at Libby Dam could be expected in roughly 2 out of 5 years if no endangered species flows are done. The VARQ flood control operation resulted in 13 spill events in the 31 years modeled. Four of these spill events were greater than 5,000 cfs. This is more than double the frequency and magnitude of spill under BASE-CRT63.

The large releases associated with sturgeon recovery act to minimize the spill potential associated with the VARQ flood control operation. VARQ w/ BIOP resulted in three spill events with two of them exceeding 5,000 cfs, and VARQ w/IRCs resulted in four instances of spill with two over 5,000 cfs. This is consistent with Libby Dam's historic frequency of "fill and spill". The probability of spill can be minimized further by drafting Lake Koocanusa deeper than the VARQ flood control curves, releasing more water than specified by VARQ, or installing additional generating units at Libby Dam.

At Kootenay Lake, damages occur at lake elevations near 1750 feet. Elevation 1750 feet would be exceeded roughly every two years under the two scenarios that operated to the sturgeon Biological Opinion, VARQ w/BIOP and SOSPA. It will occur roughly one year in three under VARQ w/IRCs. With no sturgeon flows, a lake elevation of 1750 feet will occur in one of three years under VARQ and one in four years under BASE-CRT63.

The 100-year lake level will be approximately one half foot higher with VARQ, VARQ w/BIOP and VARQ w/IRCs as compared to BASE-CRT63 and SOSPA.

Duncan Reservoir in Canada is not significantly impacted by the flood control operation of Libby Dam.

There is a risk associated with reducing the amount of flood control storage space at Libby Dam. This risk appears to be minimal. VARQ was designed to draft Lake Koocanusa to the same minimum elevation as the current BASE-CRT63 flood control operation in those years of extreme runoff (8.0 maf or more). However, in most years less storage space will be available under the VARQ flood control operation, therefore higher releases need to be carefully timed so as not to impact flooding downstream. Modeling suggests that there may be more trapped storage in Lake Koocanusa in high runoff years as a result of VARQ. The operation of Libby Dam after the winter drawdown period and before the start of the peak flood period will often compensate for any decrease in flood storage. Every effort should be made to be at or below flood control elevations specified by the VARQ storage reservation diagrams to minimize impacts. Although better forecasting procedures make large runoff forecasting errors less likely today than in the past, every effort should be made to improve long range runoff forecasting procedures.

6.2 Levees

The condition of the levees below Bonners Ferry, Idaho has deteriorated markedly since the construction of Libby Dam. Changing the flood control operating plan at Libby Dam will have no significant impact to the rate of levee deterioration.

6.3 Economics

Agricultural damages from groundwater, flood damage, and increased pumping power costs combine to make up the total downstream impacts associated with high water below Libby Dam. If one is solely interested in minimizing total damages downstream of Libby Dam with no regard for endangered species, then the dam should be operated to the BASE-CRT63 flood control rule curves. However, the Endangered Species Act requires that reasonable and prudent measures be taken to assure the survival of various fish species downstream of Libby Dam. To that end, the Corps of Engineers has adopted the Preferred Alternative from the Columbia River System Operation Review as the current operating plan for Libby Dam. The Preferred Alternative (SOSPA) features the BASE-CRT63 flood control curves and endangered species flow regimes as described in the Biological Opinions (BIOPs) of the federal fisheries agencies. This study shows that the Preferred Alternative (SOSPA) results in the greatest downstream damages/costs of all alternatives investigated.

Given that endangered species flow are a reality and will probably not go away in the near future, a change in the flood control operation of Libby Dam to the proposed VARQ flood control operating plan is prudent from a flood control standpoint. There will not be an increase in the total amount of downstream damages. Downstream impacts are dominated by groundwater agricultural damages generally driven by the endangered species flows, and not flood control releases.

The recreation analysis suggests that the endangered species alternatives featuring the VARQ flood control operation will result in over $1 million in increased trip spending as compared to the current operation, SOSPA due to the increased probability of Lake Koocanusa refill.

The levee analysis suggests that the levee system along the Kootenai River is in a serious state of decay. It has been determined that $8.7 million will be required to bring the current levee system in Idaho back into condition to provide 200 year flood protection for the Kootenai River valley. In addition, under any alternative, an estimated 707,000 cubic yards of revetment costing approximately $17.7 million will be needed to stabilize the levees from future erosion by the Kootenai River. The maximum capital cost which induced flood damages would economically justify is $135,900 under the VARQ w/IRC alternative. From an economics standpoint, there are insufficient benefits to justify Federal expenditures for improving the Kootenai River levee system.

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Hydrology Appendix

A-1 Adjusting VARQ to the BIOP

VARQ was designed to minimize impacts to both system and local flood control, particularly in high runoff years. VARQ provides a process to modify Libby outflows during real-time operations, if necessary, to minimize the possibility of spill.

Figure A-1. Chart 6 for determining the Initial VARQ

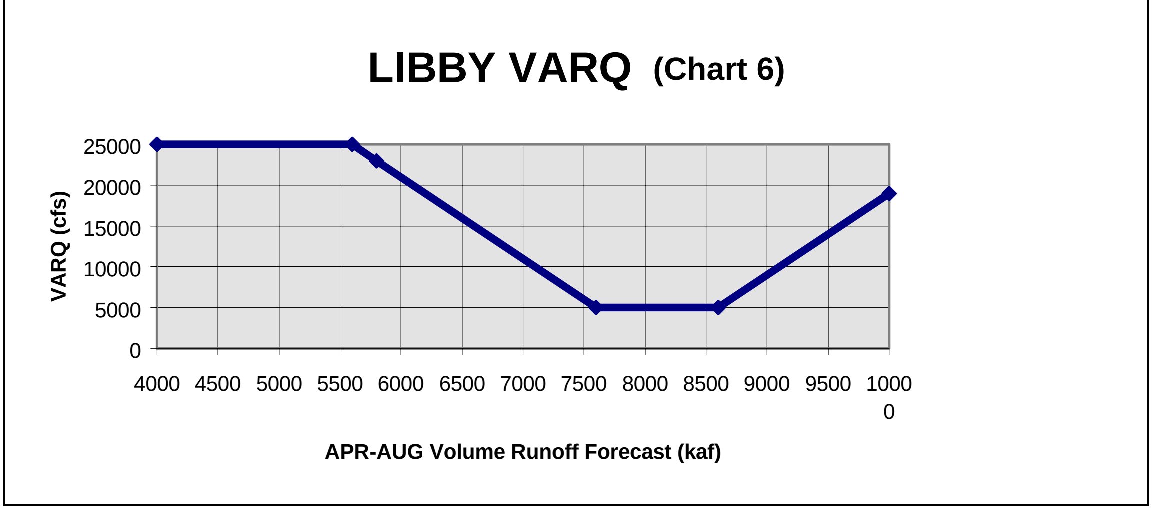
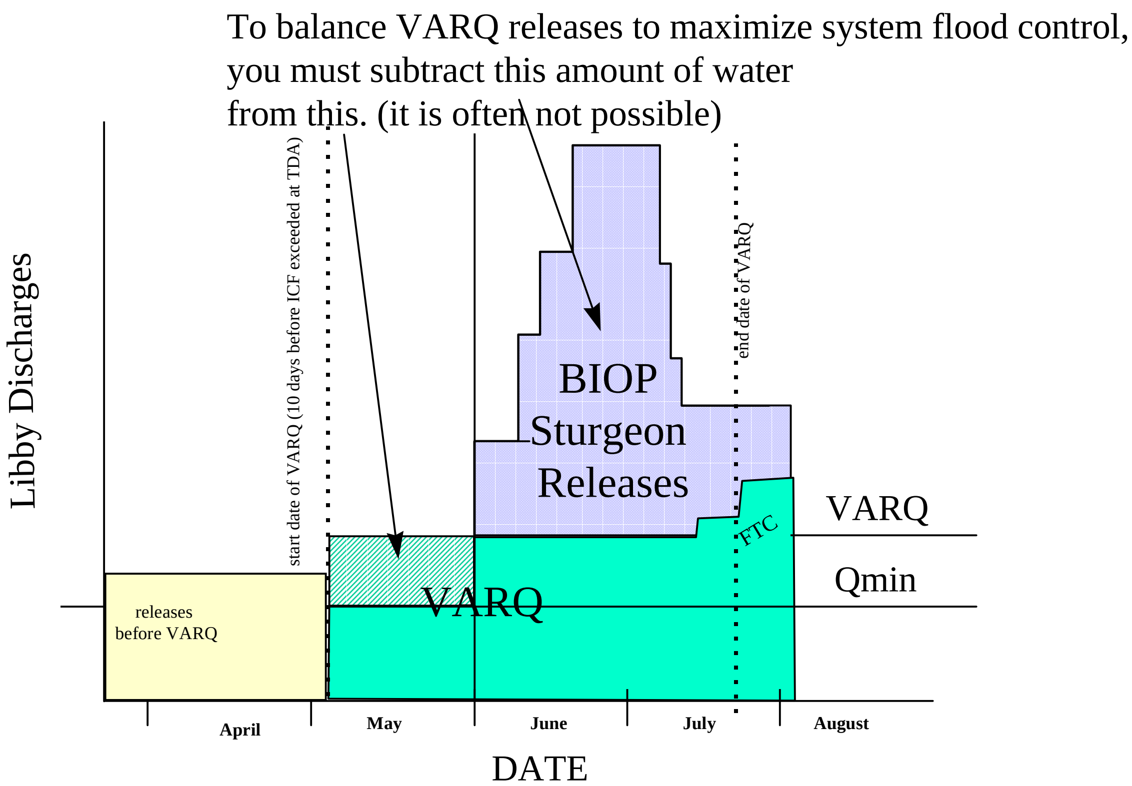


Chart 6 (Figure A-1) suggests that flows will be near minimum during the refill period in the biggest runoff years. This is in conflict with sturgeon flow requirements (especially those in the IRCs) that require high flows at Bonners Ferry in the June-July time frame. In order to meet sturgeon flow requirements, it is necessary to increase flows beyond those specified by Chart 6 during the refill period. In order to minimize the impacts on system flood control, the increased volume necessary for sturgeon should be subtracted from the VARQ flows that occur before sturgeon flows begin. This principle is illustrated in Figure A-2. This would appear to be a straight forward calculation; however, other project priorities may come into play. For example, VARQ may produce an unacceptable level of spill from Libby Dam which may damage downstream fisheries. Spill can occur as a result of VARQ in many years of only moderate runoff. It is unreasonable to adjust VARQ downward to balance the fish volume if that adjustment would only serve to further increase the incidence of spill.

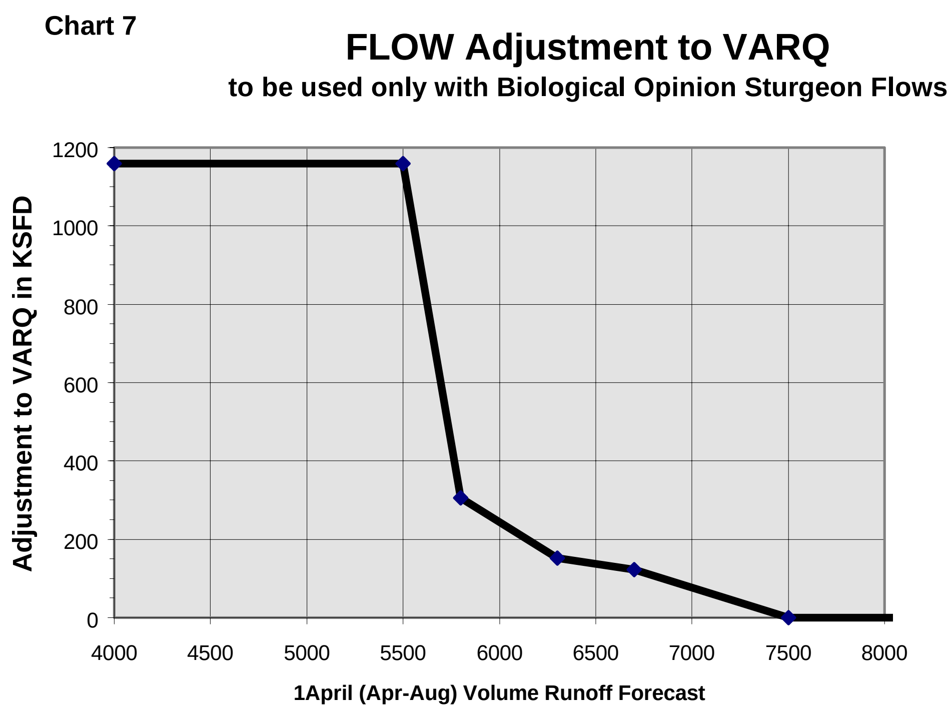
Figure A-2. This figure illustrates how fish releases should be subtracted from VARQ releases during the period of system flood control to maintain the same volume discharged from Libby Dam.



In order to meet the current operating philosophy of no more than one spill event in excess of 5,000 cfs in every 10 years, Chart 7 was devised (Figure A-3). Chart 7 is specific to the current (1997) situation at Libby Dam, i.e., no more than 10% probability of a spill event greater than 5,000 cfs, 5 generating units in operation, and USFWS Sturgeon BIOP flow regime. The methodology used to create Chart 7 could be used to develop a different chart to modify VARQ to any flow regime being requested. Chart 7 can be modified to accommodate changing spill priorities or installation of additional generating units at Libby Dam.

There is no "Chart" specific to the IRC flow regime because the IRC flows already meet the spill criteria of 10%. Any downward adjustment to the VARQ flows before June to accommodate IRC flows would only increase the possibility of spill beyond acceptable limits. Therefore, no adjustment to the initial VARQ is necessary to accommodate the IRC flow regime.

Figure A-3. Chart 7 for Adjusting VARQ to Accommodate BIOP Sturgeon Flows while Limiting Spill.



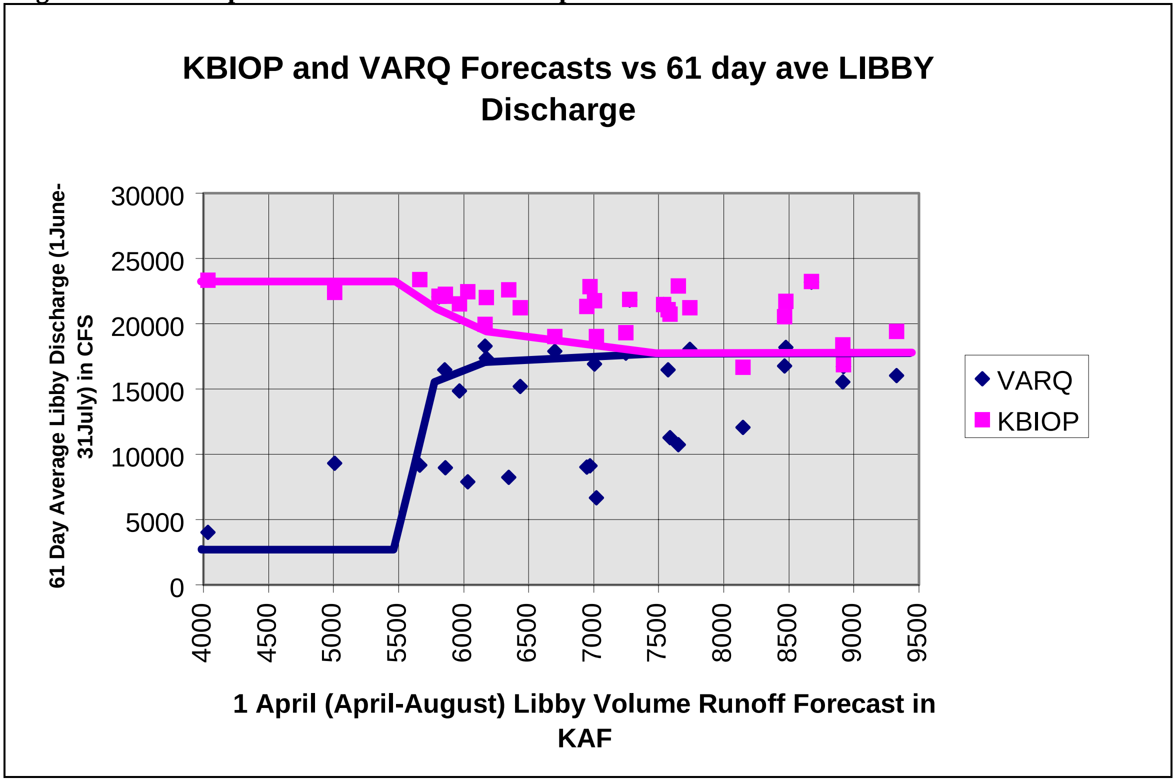
A-2 Development of Chart 7

The Kootenai River system was first regulated to VARQ with no sturgeon flows and the Wortman-Morrow forecasts (VARQ-NEW). The VARQ-NEW run was reregulated to meet the BIOP sturgeon flows with no adjustments to VARQ_NEW before June 1. This was the KBIOP simulation. KBIOP resulted in an acceptable level of spill, unlike VARQ-NEW. Then the VARQ-NEW discharges were subtracted from KBIOP discharges during the months of June and July to get the residual volume to be subtracted from the initial VARQ-NEW discharges from the time period from initial date of VARQ-NEW until the start of the BIOP sturgeon flows (June 1). The spreadsheet VARQSEMI.XLS was created to facilitate this work.

The average ICF duration for system flood control is 57 days for the 31 years modeled, but in the simulations it was only possible to store at Libby for 25 days on average before reaching elevation 2429 feet and going to Filling Transition Curves. This means that even though in theory one should attempt to hold VARQ-NEW flows for the entire system flood control period, in reality it is only possible to hold the VARQ-NEW flows for approximately one half that time.

The KBIOP flows in June and July (61 days) were graphed and compared to VARQ-NEW. Envelope curves were developed relating the 61 day average discharge necessary to meet VARQ-NEW and KBIOP vs the April-August volume runoff forecast. Remember, the fish adjustment to VARQ must be made before VARQ is initiated which is sometime in April or May. Therefore, the adjustment must be based on a forecast.

Figure A-4. Envelope curves which led to development of Chart 7.



The difference between the KBIOP curve and the VARQ curve formed the basis for CHART 7 as illustrated in Figure A-4. For example, if April-August forecast is 4,000 kaf then the adjustment from Figure A-4 would be (23000-4000)cfs *61days= 1,159 ksfd. (Look up a 4,000 kaf forecast in CHART 7 and you will get the same 1,159 ksfd adjustment.)

After the fish adjustment is looked up from Chart 7, it is necessary to reduce VARQ flows between the Initial Date of VARQ and the start of the BIOP sturgeon flows by the fish adjustment amount. In many cases this will not be possible and VARQ will be lowered to minimum flow of 4,000 cfs. There is no fish adjustment to VARQ at forecasts greater than 7.5 maf. If greater fish adjustments were made, there would be an unacceptable increase in spill from Libby project.

The VARQ w/BIOP computer simulation was the result of modifying the VARQ-NEW run to meet the BIOP with Chart 7 used to modify VARQ before June 1.

A-3 VARQ Modeling Procedure Used in Regulating Libby Dam

January 1- March 31:
Draft LIB, DCDB, and CORB to Upper Rule Curves as determined from the Wortman-Morrow (April-August) volume runoff forecast.

If there is a conflict with the 1938 IJC Order before 1 April cut back discharges at DCDB first to a minimum of inflow. If necessary, reduced discharges at LIB to inflow (but not below 4000 cfs).

Beginning April 1:
Lookup or calculate actual starting date that the Initial Controlled Flow at The Dalles is forecasted to be exceeded. (ICF_DATE). VARQ starts 10 days before the starting date of ICF. (ICF10_DATE)

Lookup duration of ICF from Charts 3,4, or 5. (ICF_DUR) See figures A-5 through A-7.

Figure A-5. Chart 3 for determining duration of the Initial Controlled Flow at TDA for ICF>350 kcfs and <400 kcfs.

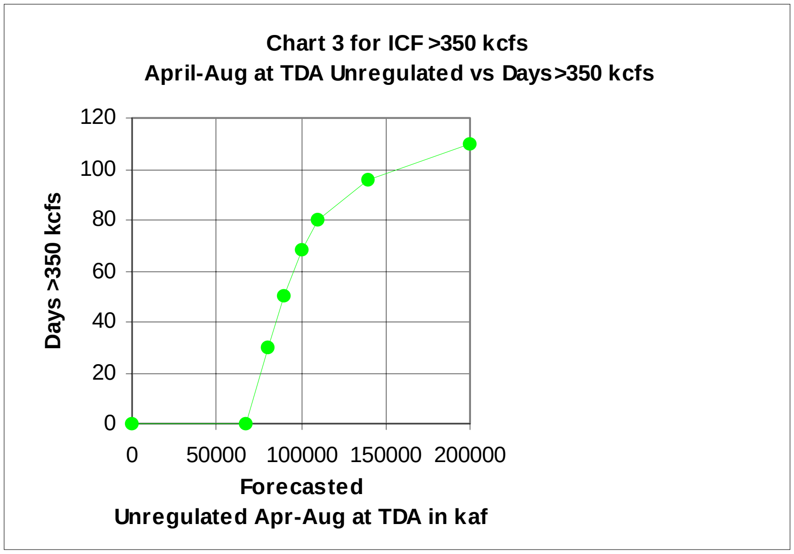


Figure A-6. Chart 4 for determining duration of the Initial Controlled Flow at TDA for ICF>400 kcfs and <450 kcfs.

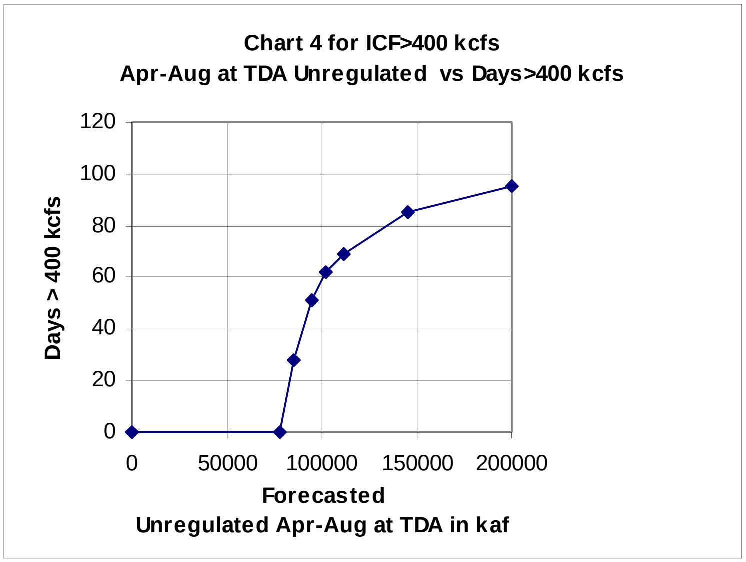
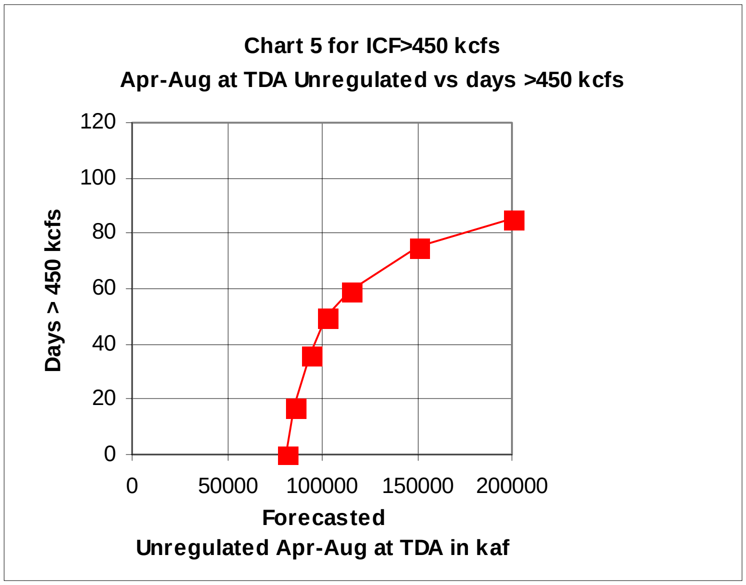
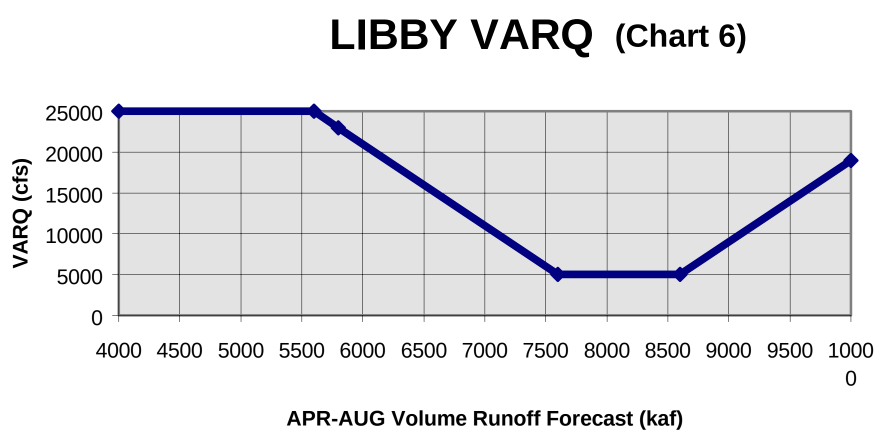


Figure A-7. Chart 5 for determining duration of the Initial Controlled Flow at TDA for ICF>450 kcfs.



Determine initial VARQ from Chart 6. (INITIAL_VARQ)

Figure A-7 Chart 6 for determining the Initial VARQ



Determine Fish Flow Adjustment. If BIOP Sturgeon flows are requested look up Fish Flow Adjustment from CHART 7. If another fish flow regime requested a new "CHART" must be developed. The IRC sturgeon flows have already been tested and they require no adjustment to VARQ.

Determine date when Kootenay Lake unregulated inflow exceed is forecasted to exceed 20,000 cfs. (IJC _DATE). Pass inflow at LIB and DCDB from 1 April until this date.

Determine date when Kootenay Lake unregulated inflow is forecasted to exceed and stay above 25,000 cfs. (Out_of_Woods_ DATE). After Out_of_Woods_ DATE, Libby and Duncan have, for modeling purposes, no IJC restriction on discharges.

Pass no more than a total of 5,000 cfs above inflow from LIB and/or DCDB between IJC_DATE and Out_of_Woods_ DATE. Pass more than inflow if there is trapped storage. Otherwise, pass inflow or less depending on whether or not (ICF10_DATE) is passed. Draft LIB before DCDB.

When ICF10_DATE is reached, pass VARQ as modified for trapped storage, URC lookback, and fish flow adjustment. These adjustments are described later in this section.

On May 9, modify INITIAL_VARQ based on Chart 6 and May final Volume Runoff forecast (Apr-Aug). Add Trapped Storage and URC Lookback Adjustments if applicable. Continue to use same Fish Flow Adjustment, if applicable.

On June 9, modify INITIAL_VARQ based on Chart 6 and June final Volume Runoff forecast (Apr-Aug). Add Trapped Storage, URC Lookback, and Fish Flow Adjustments if applicable.

On July 9, modify INITIAL_VARQ based on Chart 6 and July final Volume Runoff forecast (Apr-Aug). Add Trapped Storage and URC Lookback Adjustments if applicable.

When Libby elevation exceeds 2429, use Filling Transition Curves. (FTC)

How did I calculate VARQ?

VARQ=INITIAL_VARQ + Trapped Storage Adjustment + URC Lookback Adjustment +Fish Flow Adjustment

1. INITIAL_VARQ comes from Chart 6.
2. Trapped Storage Adjustment and URC Lookback Adjustment are described below, and can be either positive or negative.
3. The Fish Flow Adjustment has been determined for BIOP sturgeon flows (i.e. 42 days at 35,000 cfs at BFEI) and the IRC flows (i.e. the tiered approach 8,000 to 50,000 cfs at BFEI for 1 month) using a procedure described in this appendix. If BIOP Sturgeon flows requested look up Fish Flow Adjustment from CHART 7. If another fish flow regime requested a new "CHART" must be developed. The IRC sturgeon flows have already been tested and they require no adjustment to VARQ.

How did I compute Trapped Storage Adjustment?

If ICF10_DATE occurs between April 1 and April 30:

$$\text{Trapped Storage Adjustment} = \frac{(\text{URC on ICF10\_DATE} - \text{Actual storage on ICF10\_DATE}) * 504.17}{\text{ICF\_DUR}}$$

If ICF10_DATE occurs between May 1-8:

$$\text{Trapped Storage Adjustment} = \frac{(\text{April 30 URC (based on April final)} - \text{Actual storage on April 30}) * 504.17}{\text{ICF\_DUR}}$$

If ICF10_DATE occurs on May 9 or after:

$$\text{Trapped Storage Adjustment} = \frac{(\text{April 30 URC (based on May final)} - \text{Actual storage on April 30}) * 504.17}{\text{ICF\_DUR}}$$

How did I compute URC Lookback Adjustment?

URC lookback is applied to the May 9, June 9, and July 9 VARQ only if the ICF10_DATE occurs before May 9. It reflects the change between the April and May volume runoff forecasts for (Apr-Aug). There is no URC lookback calculated if ICF10_DATE is after May 9 since the change in forecast is reflected in the Trapped Storage Adjustment.

If ICF10_DATE occurs between April 1 and May 8 :

$$\text{URC Lookback} = \frac{(\text{April 30 URC}_{\text{(based on May final)}} - \text{April 30 URC}_{\text{(based on April final)}})*504.17}{(\text{ICF\_DUR} - \text{\# days already passed between ICF10\_DATE and May 9})}$$

Special Low Runoff Situations:

In low runoff years where either the volume runoff forecast for (Apr-Aug) at TDA was less than 85 maf, or LIB volume runoff forecast for (Apr-Aug) was less that 5.8 maf, I assumed that INITIAL_VARQ = 25,000 cfs and ICF_DUR=50 days.

A-4 VARQ Sample Regulation for Modeling 1948

Libby Regulation:

The April final Wortman-Morrow forecast for April-August was 7.5 maf. The May final increased to 7.7 maf. Actual April-August runoff turned out to be 8.4 maf. Therefore, 1948 was a large runoff year that was seriously underforecasted. There was no trapped storage in mid-April based on the April final forecast, therefore Libby did not draft further even though it could have passed 5,000 cfs above inflow after the Out_of_Woods_ DATE of April 16. The trapped storage was not recognized until May 9 when the May final forecast was available. Therefore, Libby Dam passed inflow from April 1 - May 9.

ICF_DATE =20 May, date uncontrolled flow exceeded ICF of 442 kcfs at TDA.

ICF10_DATE =10 May (10 days before ICF_DATE).

ICF_DUR = 63 days (Lookup duration of ICF from Chart 4). The May 1 (April-August) forecast for TDA was 103.3 maf, ICF was 442 kcfs.

IJC _DATE = April 15 (Kootenay Lake unregulated inflow exceeds 20,000 cfs) signaling the start of the "lowering formula" as outline in 1938 IJC Order. Rather than calculate the allowable lake level, it is conservatively assumed that Libby can pass 5,000 cfs more than inflow to account for the approximate 2.5 feet of space in Kootenay Lake that immediately becomes available when the "lowering formula" goes into effect.

Out_of_Woods_ DATE = April 16 (Kootenay Lake unregulated inflow forecasted to exceed 25,000 cfs and spring runoff has clearly begun in earnest). When unregulated inflow to CORB exceeds 25,000 cfs, it increases very quickly. Inflow to Libby is increasing very quickly also. It is assumed at this point that Libby can release up to powerhouse capacity.

<u>On May 10, 1948</u>:
VARQ=INITIAL_VARQ + Trapped Storage Adjustment + URC Lookback Adjustment (+Fish Flow Adjustment, if applicable)

INITIAL_VARQ = 5,000 cfs (from Chart 6 based on 7.7 maf).

$$\text{Trapped Storage Adjustment} = \frac{(\text{April 30 URC}_{\text{(based on May final)}} - \text{Actual storage on May 1}) * 504.17}{\text{ICF\_DUR}}$$

$$= \frac{(4464\ \text{kaf} - 3847\ \text{kaf}) * 504.17\ (\text{days*cfs/kaf})}{63\ \text{days}} = 4938\ \text{cfs}$$

URC Lookback Adjustment = 0 cfs. Since ICF10_DATE is after May 9, the 200 kaf increase in the volume runoff forecast is already reflected in the Trapped Storage Adjustment.

Fish Flow Adjustment = 0 cfs. If BIOP sturgeon flows had been requested, look up the April-August volume runoff forecast in CHART 7. Since the forecast was for 7.7 maf, there is no fish flow adjustment to VARQ. If IRC sturgeon flows had been requested there would also be no fish flow adjustment to VARQ.

Therefore on May 10, 1948 VARQ=5,000 cfs + 4,938 cfs + 0 cfs + 0 cfs= 9,938 cfs.

<u>On June 9, 1948</u>

INITIAL_VARQ = 5,000 cfs (from Chart 6 based on 8.0 maf)

Trapped Storage Adjustment and URC Lookback are the same as on May 10. Therefore on June 9:

VARQ=5,000 cfs + 4,938 cfs + 0 = 9,938 cfs.

However, Libby elevation reached 2439 on June 5, therefore LIB went to Filling Transition Curves on that day. Libby fills by the end of June.

1948 Regulation of Duncan:

There is no trapped storage at DCDB. DCDB passes inflow from April 1 to May 9. On May 10, DCDB is set at a minimum discharge of 100 cfs. DCDB reaches elevation 1852 on June 6 and goes to Filling Transition Curves. DCDB fills nicely and passes a maximum of 7,000 cfs downstream.

Result of VARQ Operation (no fish flow augmentation) in 1948:

LIB fills on July 5. LIB releases 29,600 cfs for the week before refill date to delay filling. LIB spills ~ 2,000 cfs for eight days. DCDB fills on August 7 and passes a maximum of 7,000 cfs. BFEI stage reaches 1763.9 on June 12, CORB reaches 1752.5 on June 16.

A-5 The Wortman-Morrow Forecasts (the "New" Forecasts)

NEW FORECAST

The Wortman-Morrow Forecasts for Libby Reservoir Inflow (April-August)

	1-Jan	1-Feb	1-Mar	1-Apr	1-May	1-Jun	1-Jul
1948	7989	7184	7462	7538	7740	8035	8261
1949	6401	5787	6241	6030	5850	5676	5331
1950	7245	7657	7529	7146	8051	7496	7304
1951	8139	8264	8629	8477	8271	8614	8348
1952	7864	7645	7365	6973	6808	6528	7029
1953	4824	6648	6446	6167	6341	6100	6227
1954	7099	7924	8655	8673	8808	8699	8716
1955	6109	5660	5456	5809	6122	6133	6118
1956	8652	8160	8187	8468	8349	8172	8199
1957	6717	6453	6614	6436	6225	6022	6146
1958	6641	6406	6211	5967	6233	5937	6178
1959	7301	7462	7224	7247	7369	8205	8138
1960	8194	7226	6957	6946	6897	7157	6711
1961	6929	6618	7197	7275	7533	8417	8111
1962	7241	7034	6334	6349	6248	6418	5979
1963	7279	6317	6103	5854	5824	5716	6358
1964	6864	6935	6616	6703	6688	6838	6901
1965	7676	7528	7888	7585	7534	7400	7306
1966	7198	7626	7169	7004	6921	6751	7096
1967	7721	8400	8453	8915	8675	8638	8500
1968	6901	6565	6226	6173	5980	6387	6471
1969	7542	7882	7683	7573	7611	7716	8446
1970	5552	5565	5142	5009	4989	4802	4832
1971	6708	7529	7279	7738	7817	7748	7801
1972	7600	8356	9231	9327	9416	9162	9149
1973	6540	6223	5859	5662	5481	5308	5004
1974	8009	8574	8710	8921	9184	9067	8777
1975	6591	6565	6912	7021	6836	6483	6144
1976	7843	7205	7594	7648	7564	7655	7544
1977	5416	4458	3841	4034	3648	3690	3327
1978	6932	6781	6265	5859	6059	6478	6237

A-6 The Kuehl-Moffit Forecasts (the "Old" Forecasts)

The Kuehl-Moffit Forecasts (the old forecasts)

//LIB/FLOW-IN/01JAN1920/IR-DECADE/APR-AUG 80L/

	1-Jan	1-Feb	1-Mar	1-Apr	1-May	1-Jun	1-Jul
1929	5407	4806	4245	4346	4245	4232	4421
1930	5739	5185	5282	4942	5034	5708	5774
1931	4417	4303	3928	3935	3745	3451	3444
1932	6453	6478	6711	6868	7262	7079	6772
1933	7172	7877	7723	8292	7861	7565	7279
1934	8923	9412	8667	9238	9029	8832	8467
1935	6646	8348	7583	7607	7207	6814	6673
1936	4551	4611	4735	5078	4917	4391	4267
1937	5069	4966	5702	5156	5835	5570	5603
1938	7228	7375	7543	7780	7732	7517	7048
1939	5619	5864	5502	5270	4735	4401	4883
1940	5911	5262	5541	5604	5630	5368	4756
1941	5617	5447	4949	4548	4082	4470	4332
1942	6945	6282	5705	5388	5169	6728	7112
1943	6532	6859	6588	6979	7187	6875	6784
1944	4548	4101	3623	3292	3168	3107	2967
1945	4644	4382	4284	4689	5018	5004	4893
1946	6291	6508	6630	6843	7081	7007	7164
1947	6893	7156	7058	6749	6673	6200	6447
1948	6192	6000	6410	6188	6656	7108	7424
1949	6298	5676	6407	6240	6080	6029	5608
1950	6710	7615	7777	8414	8409	7727	7442
1951	6934	7655	8137	8119	7838	8218	7919
1952	6583	6860	6328	5990	5891	5543	6321
1953	4685	6486	6299	6117	6524	6229	6395
1954	5973	7574	7930	7810	8430	8274	8300
1955	5853	5487	5388	5503	6265	6477	6296
1956	7581	7664	7619	7937	7874	7492	7369
1957	5714	5657	6285	6191	5810	5591	5874
1958	5405	5473	5664	5578	6067	5696	5775
1959	6818	7646	7447	7468	7984	8795	8736
1960	7456	7156	6844	7182	7315	7701	7065
1961	6486	6731	7450	7408	7844	8751	8308
1962	6314	5857	5360	5425	5363	5614	5063
1963	6454	6100	5889	5912	5971	5968	6776
1964	5820	6610	5995	6210	6375	6514	6434
1965	7649	7849	8136	7608	7602	7703	7638
1966	6761	7465	6938	7258	7200	7344	7483
1967	6845	7735	7472	7973	7760	7703	7596
1968	5241	5523	5248	5333	5239	5721	5890
1969	6851	7575	7228	6994	7608	7872	8710
1970	4869	5411	4928	4673	4865	4644	4672
1971	6041	6784	6369	6679	6946	6805	6830
1972	6588	7271	7784	7762	8108	7849	8015
1973	5871	5801	5417	5201	5075	4898	4662
1974	7341	8173	8120	8398	8941	8982	8784
1975	6444	6825	7416	7454	7321	7062	6870
1976	6503	6562	6779	6770	6630	6957	6798
1977	4412	3898	3507	3439	3079	3178	2925
1978	6435	6614	6148	5971	6362	7238	6973