INDEPENDENT SCIENTIFIC ADVISORY BOARD

NORTHWEST POWER PLANNING COUNCIL
NATIONAL MARINE FISHERIES SERVICE
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10 February 1997

William Stelle, Jr., Regional Administrator
Donna Darm, Chair, Implementation Team
National Marine Fisheries Service
Northwest Regional Office
7600 Sand Point Way NE
Seattle, WA 98115-0070

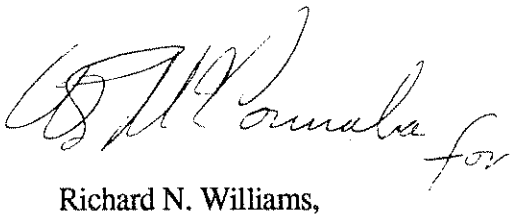
Dear Mr. Stelle and Ms. Darm:

Enclosed is the Independent Scientific Advisory Board's Report 97-3, *Ecological impacts of the flow provisions of the Biological Opinion for endangered Snake river salmon on resident fishes in the Hungry Horse and Libby systems in Montana, Idaho, and British Columbia.* This report responds to the letter of 27 March 1996 from Donna Darm, Chair of the Implementation Team, to Chip McConnaha (NWPPC), Science Coordinator for the ISAB in which Ms. Darm requested assistance from the ISAB in addressing scientific questions associated with late summer drawdown of Hungry Horse and Libby reservoirs.

In summary, the ISAB review found that the biological effects of summer drafting are not likely to drive resident fish populations to extirpation in Hungry Horse and Libby reservoirs. Nevertheless, late summer drawdown of the reservoirs adversely effect resident fishes in the reservoirs, as well as those downstream of the projects through increased flows in the streams and lakes below the two reservoirs. Finally, the question of benefits of August flow augmentation to endangered Snake River salmon is a complex one with information that is subject to more than one interpretation. In *Return to the River* (ISG 96-6), the ISG concluded that a flow-survival relationship remains to be demonstrated. The question is currently being pursued by the ISAB in other contexts.

We hope that you find our review helpful. Please do not hesitate to get in touch if there are further questions concerning this matter.

Sincerely,



Richard N. Williams,
Chair, Independent Scientific Advisory Board

cc: Mr. John Etchart, NPPC
Dr. Brian Allee, CBFWA

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Ecological impacts of the flow provisions of the Biological Opinion for endangered Snake River salmon on resident fishes in the Hungry Horse, and Libby systems in Montana, Idaho, and British Columbia

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ISAB 97- 3
March 4, 1997

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I. INTRODUCTION

Background of Assignment

Within the community of biologists in the basin, contention exists with respect to the scientific rationale for late summer flow augmentation in the mainstem Columbia River intended to assist outmigration of endangered Snake River fall chinook, as called for in the Biological Opinion (BiOp). Contention primarily exists with respect to three concerns:

1. Flow augmentation in August and September is provided by deep drafting of Hungry Horse and Libby reservoirs in the headwater reaches of the Columbia River in Montana, leading to negative effects borne by residents there (Figures 1, 2 and 3). Such drafting can also impact refill schedules, leading to negative effects with basin-wide implications.
2. Summer drafting, following on the heels of deeper flood control drafting in early spring, might cause significant negative impacts on the ecology of both reservoirs, as well as lakes and river segments downstream to the target reaches in the mainstem , and;
3. Flow augmentation in the mainstem during summer and fall (normally low flow periods) may or may not significantly benefit endangered fall chinook.

Litigation has been threatened or pursued owing to a lack of resolution of these concerns by policy makers. People in the headwater areas believe that the impacts of drawdowns on resident fisheries are substantial and not warranted on the basis of a presumed weak or non-existent flow-survival relationship for endangered fall chinook using the mainstem. On the other side, the Biological Opinion (BiOp) concluded the flows were needed because slow water movement in the lower Columbia River, and high water temperatures at that time of year negatively impact the endangered fish. Additionally, downstream constituents want the BiOp implemented as called for under the authority of the Endangered Species Act.

Statement of Assignment

In a March 27, 1996 letter from Donna Darm (National Marine Fisheries Service) to Chip McConnaha, ISAB Coordinator, the Independent Scientific Advisory Board (ISAB) was asked to address two questions.

1. Does available evidence/analysis demonstrate that resident fish populations are at risk of extinction in Libby Reservoir? In Hungry Horse Reservoir? If yes (or maybe):

2. Does available evidence/analysis demonstrate that the Biological Opinion operations increase the risk of extinction of resident fish in Libby Reservoir? In Hungry Horse Reservoir?

Rather than providing narrowly focused answers to these questions, we approached our review from an ecosystem perspective. In our proposal of September 27, 1996, we stated our objective to "Evaluate the type and extent of ecological impacts of the flow provisions of the

Biological Opinion on resident fishes in the Hungry Horse/Libby systems, including the potential of the provisions to increase the probability of their extinction". Specifics of the ISAB review process are presented in Appendix 1.

The ISAB noted that the two questions are couched in the language of the Endangered Species Act and reflect the region's ongoing policy struggles in this area. They are not forthright scientific questions, when considered in an ecosystem context. The questions focus on extinction of reservoir fishes, which undoubtedly have persisted, and in some cases likely even proliferated, in these reservoirs since they were built, rather than focusing on the negative impacts of headwater drafting on the ecology of all upstream waters affected by the drafting. Finally, these questions explicitly do not ask for an evaluation of any flow-survival relationship for fall chinook in the mainstem, the lack of which could compromise the rationale for drafting headwater reservoirs. To be most useful to policy makers, the questions should ask whether there are negative effects of the August flow augmentation that would require balancing against benefits to endangered Snake River salmon. Unfortunately, we were not able to develop information for this report on benefits to Snake River salmon, because of the limits of time and the complexity of the problem. We are continuing to pursue the question in other contexts, such as our participation in design of studies to address the NWPPCs mainstem flow hypothesis and our participation in the PATH process.

Our analysis in this report therefore focuses on the effects of reservoir drafting on resident fishes in the upstream areas. We are sensitive to the fact that the result of approaching the problem from this perspective is that it may lead to an impression of a one-sided point of view in our response, which is not intended.

II. ISAB CONCLUSIONS

Overall Conclusions of the ISAB Review

(A) The biological effects of the summer drafting are not likely to drive resident fish populations to extirpation in Hungry Horse and Libby reservoirs. However, the two questions posed are overly simplistic. Certain resident fishes (Kootenai River White Sturgeon and Bull Trout) in the Hungry Horse and Libby systems are at some risk of extinction.

(B) There is a complex interaction of the requirements for flow augmentation in the BiOp for endangered Snake River salmon with requirements for flood control, power production, irrigation, provision for resident fishes, including endangered Kootenai River White Sturgeon, as well as recreational pursuits and aesthetics, and associated effects on reservoir elevations and fluctuations in river flow in the Hungry Horse/Libby systems. This interaction may be described as a collision of objectives (Ripley, 1971).

(C) Drawdown of the reservoirs adversely affects resident fishes, including adfluvial populations. Flow augmentation in August leads to increased flows in the streams and lakes below the two reservoirs and adversely affects resident fish populations to the points where the streams join the Columbia River. Increased flows also make possible wider fluctuations in daily and weekly flows as the power system follows the load, and these fluctuations in turn adversely affect resident fishes.

(D) Although the primary effects of drawdown in August are different from those in late winter and spring, they can not be viewed as separate actions, because there are interactions .

(E) These adverse effects on resident fishes are among the trade-offs that must be considered by policy makers for water management in the region, as noted by Wright, (1996)

(F) Integrated Rule Curves (IRCs) offer policy makers a tool to evaluate and optimize the trade-offs associated with decisions on river reregulation that can take into account varying objectives in water management and uncertainties in supply. Model evaluations of the IRCs have been used to explore the interactions between effects of flows called for by NMFS in the BiOp for endangered Snake River salmon on resident fishes upstream, as well as on flood control, power production and other factors (Marotz, et al.., 1996). While various flow scenarios have been modeled in this way, the quantification of benefits to Snake River salmon would require use of another model.

(G) The question of benefits of August flow augmentation to endangered Snake River salmon is a complex one with information that is subject to more than one interpretation. The ISG concluded that a flow-survival relationship remains to be demonstrated (ISG 96-6). The question is being pursued by the ISAB in other contexts, such as our participation in design of studies to address the NWPPC's mainstem flow hypothesis and our participation in the PATH process.

III. FINDINGS

1. Description of the Systems and Their Operations

Hungry Horse and Libby dams are located in Montana, Figure 1. Their reservoirs are drafted in late winter or early spring to elevations usually 85 feet and 95-110 feet below full pool respectively to provide space for spring runoff as a flood control measure, as well as storage space for later power production, irrigation, and many other water uses, Figures 2 and 3. The flow augmentation provision of NMFS BiOp for endangered Snake River salmon leads to drawdown in August to elevations 20 feet below full pool, as a maximum. A more complete description of the Hungry Horse and Libby systems and their operations is found in Appendix 2.

Operations at Hungry Horse and Libby dams interact with operations of projects downstream. There are five other dams downstream of Hungry Horse Reservoir in what might be referred to as the Hungry Horse system, before it enters the Columbia River. In the Libby system, there is one dam, Corra Linn Dam, below Libby Dam. Duncan Dam impounds the Duncan River which is a side stream entering Corra Linn Reservoir (Lake Koocanusa). Further information on downstream operations is given in Appendix 3.

2. Risk of Extinction of Resident Fishes in the Reservoirs and Systems

Studies relating to the risk of extinction of resident fishes that occur in the Hungry Horse and Libby systems include one of Kootenai River white sturgeon which resulted in listing under the ESA in 1994 (USFWS, 1996), and several studies of bull trout (Thomas, 1992; Montana Bull Trout Scientific Group, 1996A, 1996B, etc.). Bull trout are thought to be at high risk of extinction throughout much of their range (Rieman and McIntyre 1993, 1995, 1996). The studies by Thomas and the Montana Bull Trout Scientific Group are specific to Montana, and include information on factors thought to affect the risk of extinction of bull trout in the waters of the Hungry Horse and Libby systems. The study by Thomas (1992) was conducted prior to implementation of the BiOp for Snake River salmon and therefore does not include information directly bearing on whether implementation might be expected to lead to an increased likelihood of extinction. The series of bull trout studies by the Montana Bull Trout Scientific Group generally point to the lack of quantitative information on historic abundance of bull trout. The Kootenai River study identified a need for further study of the effects of dam operation on bull

trout. Neither the bull trout studies nor the Kootenai River White Sturgeon study can be used as they stand to assess whether or to what extent the NMFS Biological Opinion operations might lead to an increased probability of extinction of these resident fishes.

The Kootenai River White Sturgeon Draft Recovery Plan includes provisions for maintaining minimum and stable flows during the spawning season in July, as well as other measures. The IRCs are cited in the draft Recovery Plan as the best available guidelines for operation of Libby Dam to balance requirements for white sturgeon with the needs of other species. The plan notes that the IRCs could be affected by NMFS Section 7 requirements relative to flows for listed Snake River salmon (USFWS, 1996, p.46).

Further information on both the bull trout and white sturgeon is provided in Appendix 4.

3. Adverse Effects of Drawdown.

On the basis of experience elsewhere, as reported in the scientific literature, adverse effects on resident fish populations are to be expected from reservoir drawdown. A brief review of the literature is provided in Appendix 5. Drawdown is a recognized management technique for reduction of some fish populations considered to be undesirable (e.g. Bennett, 1954; Shields, 1957; EPA, 1996).

While we could find no evidence that deep summer drafting of Hungry Horse and Libby reservoirs as called for in the BiOp will lead to extirpation of resident fishes in the reservoirs, studies in the reservoirs and rivers have demonstrated that deep drawdowns adversely affect the ecological dynamics of the reservoirs and their food webs, which in turn is likely to adversely affect the resident fish populations (see Appendix 4 for detailed discussion).

Hungry Horse Reservoir contains fish populations that are of particular significance, because the full complement of species native to the headwater reaches of the upper Columbia River are present. There have been few introductions of non-native fishes upstream of Hungry Horse Dam, and the management objective is to reduce or eliminate them. (Brian Marotz, personal communication) The construction of the dam has prevented non-native fish stocked elsewhere in the basin from invading the South Fork of the Flathead River drainage. Consequently, Hungry Horse Reservoir and the South Fork of the Flathead River above it, may serve as an important reserve for both westslope cutthroat trout and bull trout. Populations of both of these species appear to be stable in the Hungry Horse and Libby systems, based on annual net surveys for cutthroat in the Hungry Horse system (Brian Marotz, pers. comm.) and redd counts of bull trout in spawning tributaries (Montana Bull Trout Scientific Group, 1996A, 1996B). Elsewhere in the northwest, both of these species are believed at risk of local and regional extinction (Rieman and McIntyre, 1996). Hungry Horse Reservoir and its main tributary, the South Fork of the Flathead River would be a likely candidate for special protection as a native salmonid reserve owing to the presence of healthy core populations of bull trout and westslope cutthroat trout. This concept is discussed in greater detail in the ISG's recent report (96-6), *Return to the River*, which discusses the role of and need for salmonid reserves in the preservation and recovery of Columbia River salmonid stocks. The fish populations in Libby Reservoir have a lower conservation profile than those in Hungry Horse, but support a valuable sport fishery, especially the kokanee and cutthroat trout.

Limnological studies were conducted in the Hungry Horse and Libby Reservoirs in the late 1970s and 1980s with Bonneville Power Administration funding in response to the NWPPC Fish and Wildlife Program. The research described seasonal productivity of the food web in relation

to drawdown and refill of the reservoirs and population dynamics and growth of the fish taken in the sport fisheries. The studies at Hungry Horse Reservoir focused on factors affecting abundance of westslope cutthroat trout, bull trout, mountain whitefish, northern squawfish, largescale suckers and longnose suckers, the most abundant fishes in the reservoir (May et al., 1988). In Libby Reservoir (Lake Koocanusa), those factors were considered in their effects on peamouth (most abundant), suckers, northern squawfish, yellow perch, kokanee, mountain whitefish, bull trout, and other salmonids, in descending order of abundance (Chisholm, 1989).

Summer and fall growth periods for these fishes were driven mainly by abundance of zooplankton and benthic midges, although terrestrial insects were of considerable importance to cutthroat in Hungry Horse. Availability of all of these forage sources were found to be influenced by temperature seasonality and interannual drawdown schedules. In summary, the reservoir environments were more productive and fish grew faster when the reservoirs filled early and were not deeply drafted in the summer (Fraley 1986). While the impetus for these studies arose from the drawdowns in late winter and early spring, their results can be applied as principles to the August drawdown. August drawdown affects a somewhat different complex of invertebrates, leading to reductions in the food supply for resident fishes at a critical time for growth. Because those invertebrates have a life cycle extending for more than one year, their reduction in the fall carries over into the spring, exacerbating the changes brought about by spring drawdown (Marotz et al, 1996). Further details are given in Appendix 5.

4. Effects Downstream of the Projects

Storage of water in the two reservoirs has resulted in reduction of spring flows and increase in flows the rest of the year, accompanied by the ability to follow power loads in the region on a daily basis, leading at times to rapid changes in flow over short time periods (Stanford and Hauer, 1992). For example in the Kootenai River, August flows from Libby Dam since 1982 have created late summer flows outside of the previously observed ranges of both maximum and minimum flows recorded in the 71 years prior to closure of Libby Dam (Figures 4 and 5). Increased flows under the BiOp might heighten this problem.

Loss of seasonality of flow (i.e., no scouring spring flows to maintain quality salmonid habitats... see *Return to the River*; ISG Report 96-6) occurs in both river systems, but is less pronounced in the Flathead system because of the confluence of the unregulated flows from the North and Middle Forks of the Flathead River with the regulated flows in the South Fork only a few miles downstream from Hungry Horse Reservoir.

Stanford and Hauer (1992) reviewed effects of altered hydrographs caused by Hungry Horse and Kerr Dams on the ecology of the Flathead River system. The main problem is that an unusually wide varial zone (i.e., that portion of the river bottom that is alternately flooded and dewatered by flow fluctuations associated with drafting and with daily variations due to load following by the power system) exists in the regulated segments of this river. Many important organisms cannot survive in this wide varial zone.

In the 1980s the effects of regulation on river ecology in the Kootenai were studied extensively (Perry 1984; Perry and Perry 1986; Perry et al., 1986; Perry and Perry 1991). As a result of the changes in river conditions, benthic communities survive to some extent in the Kootenai River only in the deepest parts of the channel (thalweg). Recent studies show that the area of the varial zone is increasing and the diversity and productivity of the benthic food web has declined in relation to the studies in the mid-1980s (F.R. Hauer, Flathead Lake Biological Station,

personal communication). Loss of habitat and food web integrity extends all the way to Kootenay Lake and is correlated with the decline of the Kootenai River white sturgeon. No recruitment of white sturgeon has been observed in the river since Libby Dam was closed, leading to the listing of the species under the Endangered Species Act (USFWS, 1996). Species that need resting and feeding habitats in the near shore area, like young-of-the-year fishes, either are left high and dry or washed downstream, as a result of the rapid daily fluctuations in flow.

For many years, summer drafting from the bottom of Hungry Horse Reservoir also caused rapid and extreme (> 10°C in a few seconds of time) temperature changes. That problem was solved by the retrofitting of the dam in 1996 with a depth-selective release structure. Temperature in the tailwaters in 1996 was designed to follow seasonal norms that occurred in the unregulated Flathead River. While this thermal regulation can be expected to produce positive results with respect to the thermal energetics of river biota, the fluctuating flows remain a problem.

The recent summer drafting associated with the BiOp flows has produced summer high water conditions in the rivers downstream that previously were not experienced by resident fishes. Summer drafting of the reservoirs causes high and variable flows in the tailwaters and river reaches downstream through Flathead and Kootenay lakes at a time of year when this is not normal. Adverse effects are likely to occur. These river reaches contain important resident fishes, including the endangered white sturgeon in the Kootenai River and rapidly declining Flathead Lake bull trout. Several detailed studies have demonstrated the adverse effects that hydropower operations have had on the food webs of these rivers (Perry and Perry 1986; Spencer et al.. 1991; Stanford and Hauer 1992).

When the flows pass through Flathead Lake, they affect the operations of Kerr Dam on the outlet of the lake. The operators of Kerr Dam are required by the terms of their FERC license to hold Flathead Lake at full pool from mid June until October. Hence, summer drafting at Hungry Horse has to be accommodated by high discharges from Kerr Dam. This introduces a problem, because the operators of Kerr Dam are facing implementation of a recent FERC order to baseload the powerhouse, rather than follow power loads. The problem is that if the operators at Hungry Horse Dam follow the load during the August flow augmentation period, operators at Kerr Dam may be forced to do likewise.

Flathead Lake is also of concern with respect to summer drafting of Hungry Horse. Long term limnological studies on Flathead Lake have related declining water quality to anthropogenic loading of nitrogen and phosphorus. Because mass flux of plant growth nutrients through Flathead Lake is controlled by the rate of exchange of water, water quality in the lake is directly influenced by both Hungry Horse and Kerr Dam operations (Stanford and Hauer 1992; Stanford et al.. 1994). The State of Montana has initiated an aggressive nutrient control strategy for Flathead Lake (Flathead Basin Commission 1994) and the US Environmental Protection Agency currently is in the process of implementing a Total Maximum Daily Load allocation under authority of the Federal Clean Water Act. These control strategies are affected by summer drafting of Hungry Horse Dam for BiOp flows. The specific effects of those operations are unknown at this time.

The Integrated Rule Curves (IRCs) for Hungry Horse Reservoir, described below, provide rational guidance for minimizing this problem (Marotz et al., 1996).

5. Models of Effects of Dam Operation on Resident Fishes

From the limnological studies in Hungry Horse and Libby reservoirs and their immediate environs, mathematical models were developed for use in describing the biological systems in the reservoirs (Fraley et al., 1989; Marotz et al., 1996). The models can be used to illustrate the probable extent to which drawdowns, failure to refill, and other water management options are harmful or beneficial to aquatic life in the reservoirs and downstream within the boundaries covered. Resident fishes incorporated in the models were cutthroat trout in Hungry Horse Reservoir and kokanee in Libby Reservoir. Further information on the models is provided in Appendix 5. The models have been reviewed in their particulars by Andersen, (1991), and Swartzman, (1995). The ISAB itself has not reviewed the mathematical basis of the models. While the models may not provide precise quantitative results, we believe they produce reasonable results in agreement with studies on effects of drawdown elsewhere.

6. Balancing Downstream Flow Needs With Resident Fish Needs: Development of the Integrated Rule Curves

The biological models were used as a basis for developing Integrated Rule Curves (IRCs) (Fraley et al., 1989; Marotz et al., 1996; Marotz in prep., and briefing to ISAB). The IRCs are a family of operational rules for dam operation that incorporate incremental adjustments to allow for uncertainties in water availability. Their use is similar to the use of flood control and power rule curves. The IRCs are themselves FORTRAN models that simulate the physical operation of the dams including the water budget and downstream flood concerns, and predict the resulting thermal structure of the reservoir and tailwater operation, which in turn predict biological responses (Marotz et al., 1996). The IRCs can be used to specify flows and to examine their effects on the interrelated requirements for water uses, such as those called for by NMFS in the Biological Opinion for endangered Snake River salmon and resident fish upstream, as well as the requirements for flood control, power production and irrigation. The IRCs have the flexibility to incorporate new information as it becomes available. Consequently, they offer a tool for use by policy makers in balancing the needs of salmon downstream against the need to maintain high pool elevations to enhance reservoir productivity for the benefit of resident fishes, as well as the needs of other water users. A recent study conducted for NMFS included a set of findings of a Steering Committee which reported that "There are legitimate biological trade-offs relating to flow augmentation for migrating salmon vs. protection for resident fish populations in reservoirs" (Wright, 1996).

Iterations of the IRCs are currently being exchanged between affected parties including the State of Montana, the Confederated Salish and Kootenai Tribes of Montana, and Bonneville Power Administration. Communications are taking place with the Corps of Engineers with respect to flood control rule curves in the two systems.

Similar analyses of water release schedules are occurring elsewhere in the basin. Geist et al.. (1996) developed a spreadsheet simulation model to examine drawdown alternatives and their respective tradeoffs in benefits and costs among river uses/resource groups, among species, and among reservoirs..

The Northwest Power Planning Council adopted the IRCs in the 1994 Fish and Wildlife Program, but the concept was not implemented in 1995 or 1996 because operators began to

implement the NMFS BiOp for endangered Snake River salmon (Marotz, *in prep.*). The differences in operations would be substantial during the summer after July. Under both alternatives refill is normally achieved by August 1. The BiOp requires drafting the reservoirs, usually 20 feet, during August, while the IRCs would maintain reservoir elevations near full pool through September (Marotz et al., 1996).

7. Recommendation

Identification and assessment of the effects of water allocation actions associated with the Biological Opinion are among the region's central management and research questions. NMFS and BPA employed a facilitator in 1995 to attempt to arrive at an agreement among federal, state and tribal parties on modifications to the operations called for in the BiOp (Wright, 1996). We agree with the Steering Committee Findings in that report that, "The need for and level of August flow requirements should be one of the region's top salmon monitoring and evaluation priorities."

We recommend that NMFS undertake an assessment of the tradeoffs between the benefits of spring and summer flow augmentation for Snake River and other salmon, and the accompanying effects on other water uses, including resident fishes. In the meantime, decisions by policy makers will have to be based on the best information currently available. The ISAB can assist in identifying that information, and in identifying studies needed to improve the information..

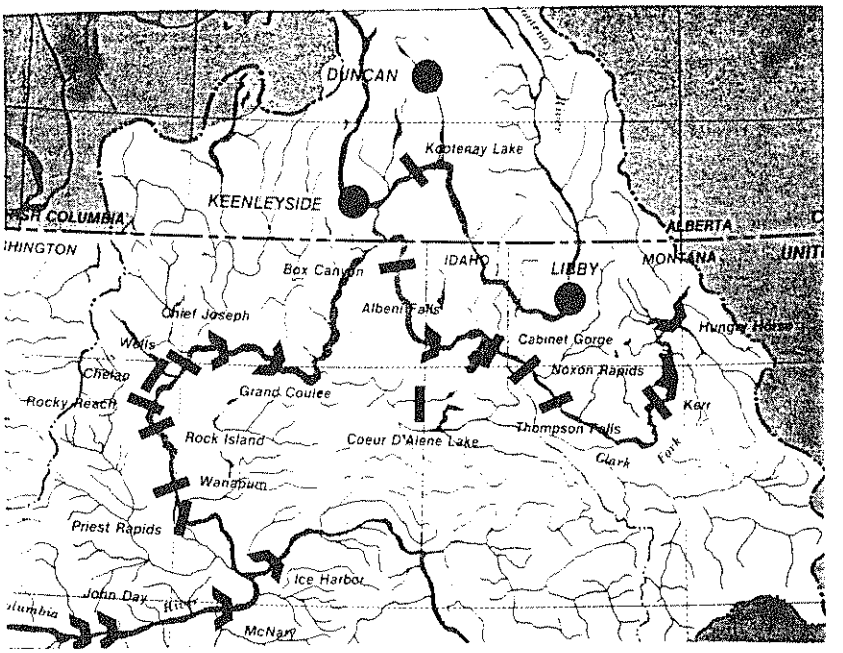

Figure 1. Map of Hungry Horse and Libby systems. (Adapted from BPA, 1980)

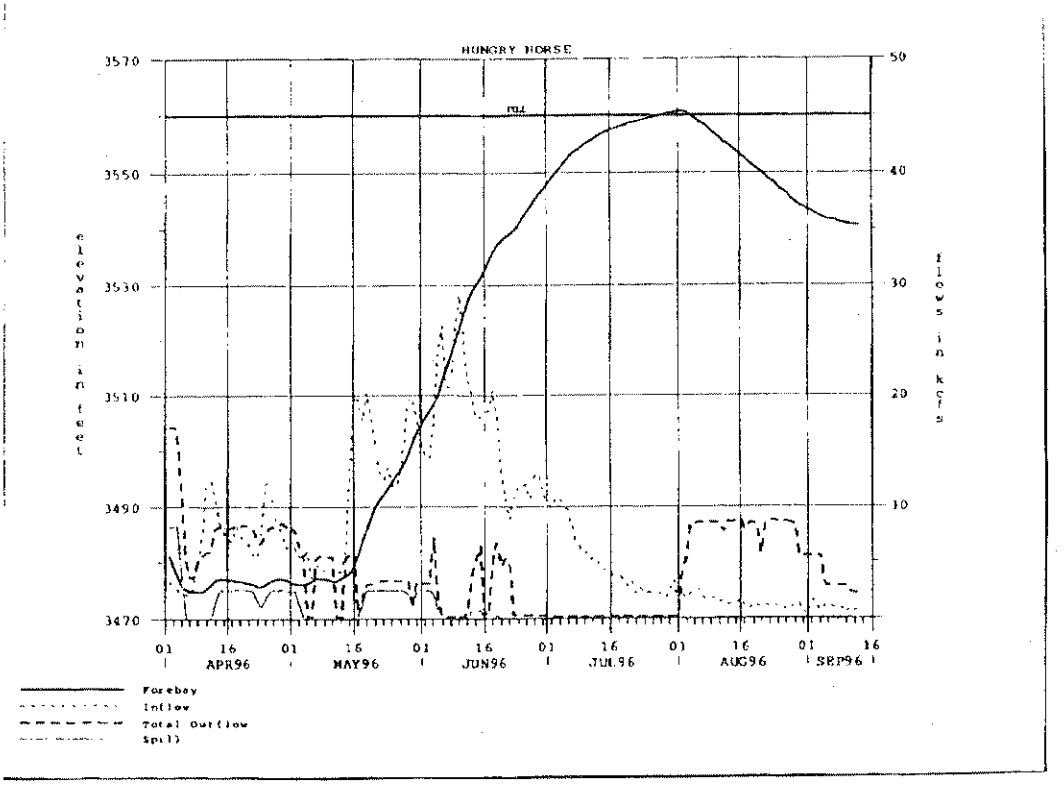

Figure 2. Hungry Horse Reservoir elevations in 1996 (Provided by Mark Reller)

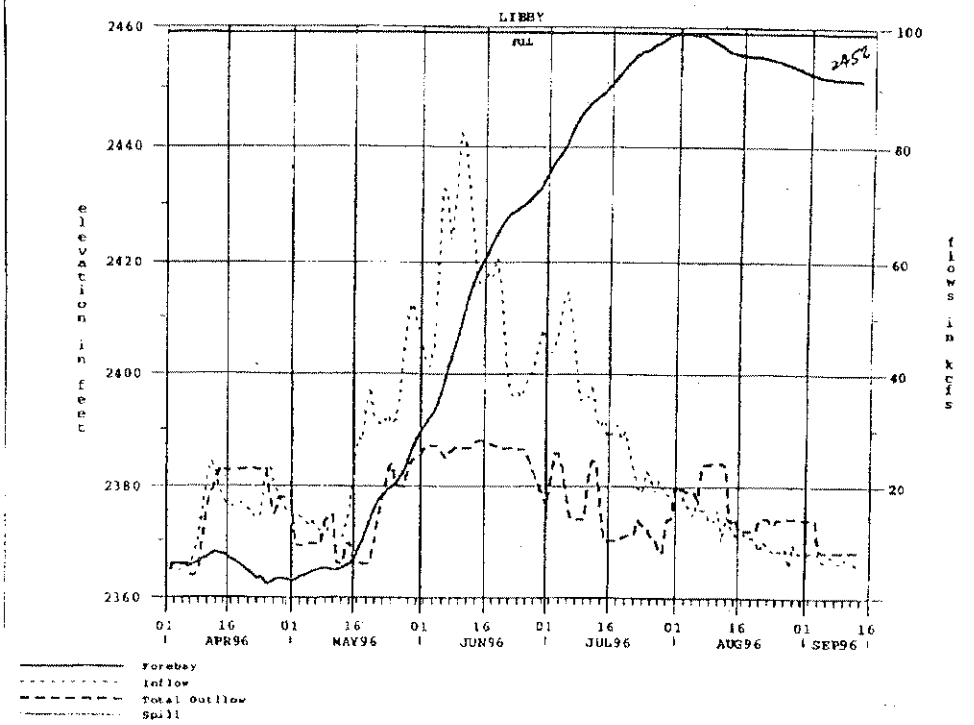

Figure 3. Libby Reservoir elevations in 1996 (Provided by Mark Reller)

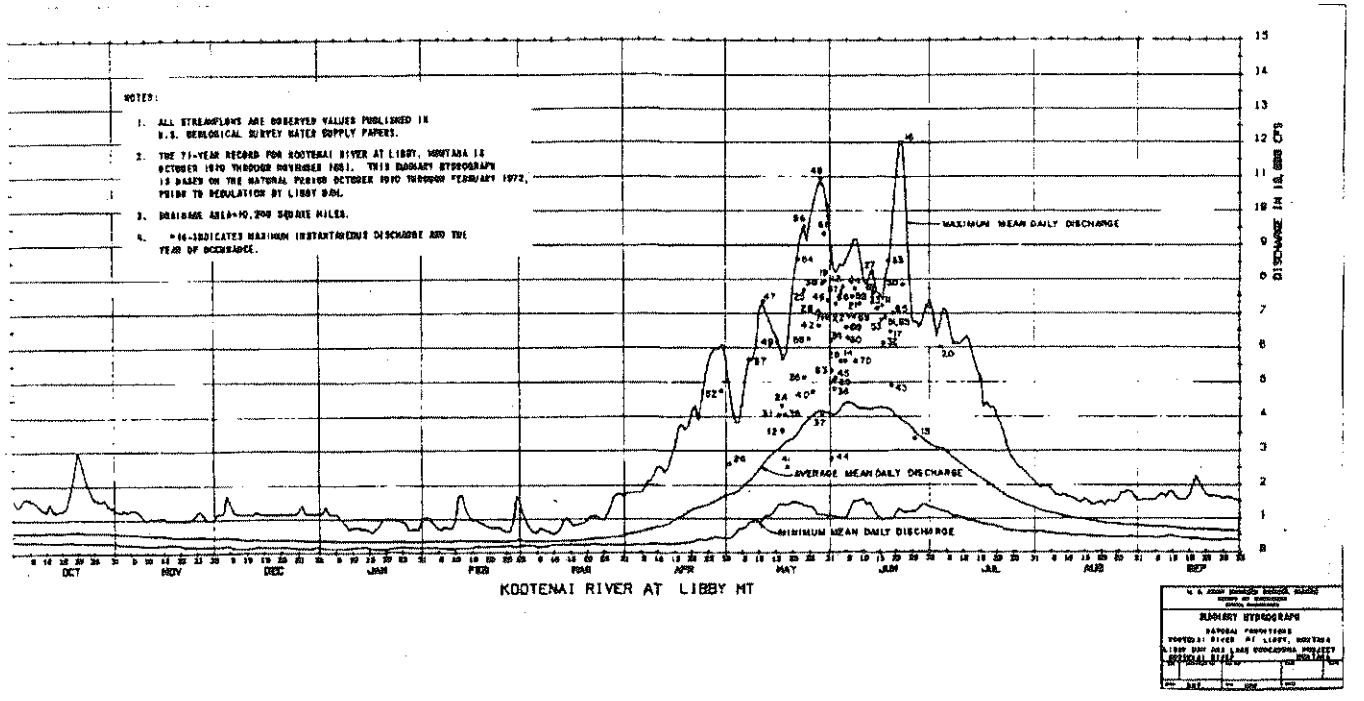

Figure 4. Kootenai River flow before closure of Libby Dam (Provided by Mark Reller)

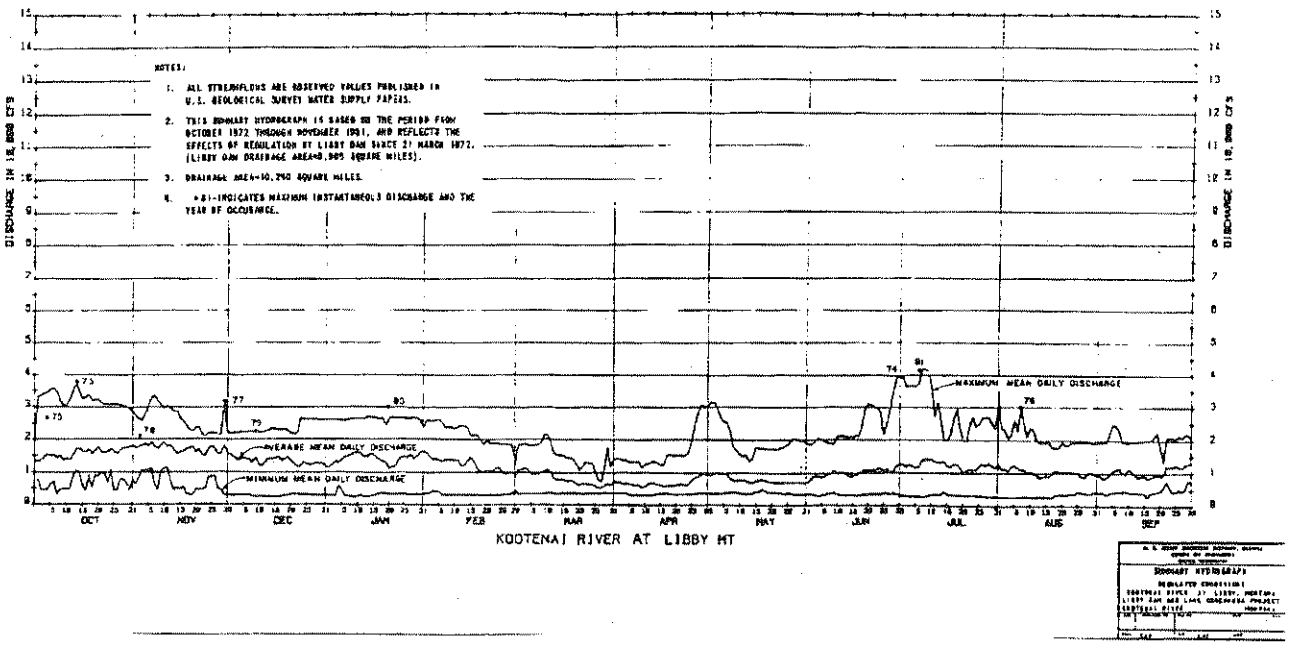

Figure 5. Kootenai River flow after closure of Libby Dam (Provided by Mark Reller)

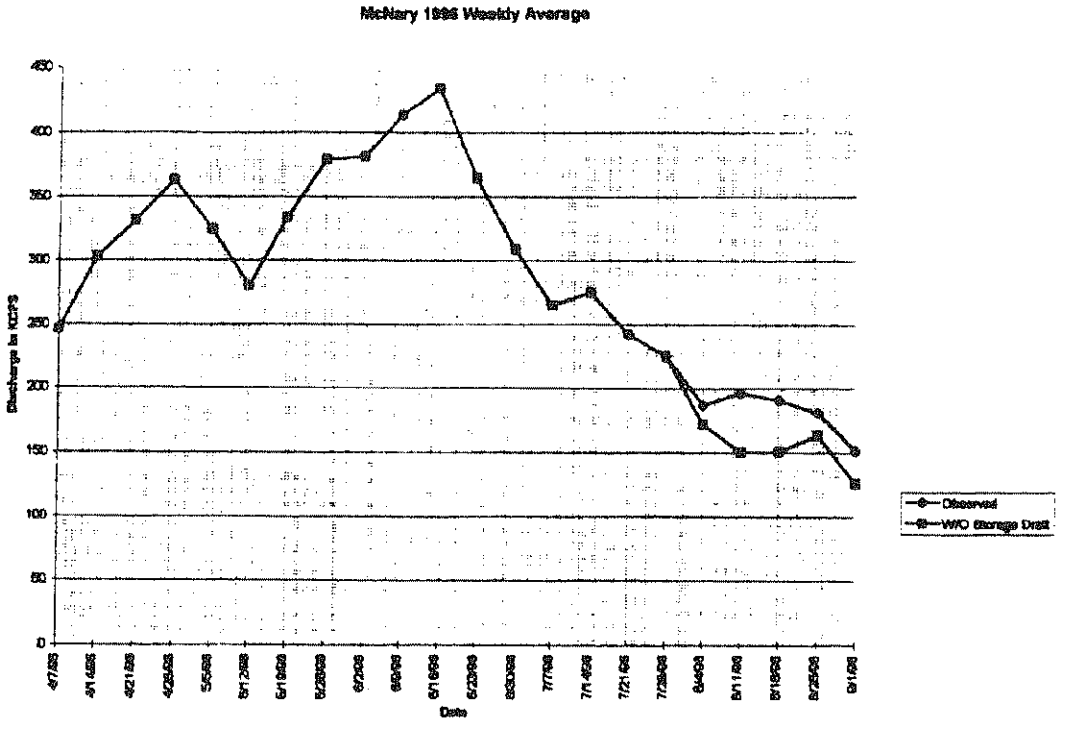

Figure 6. Columbia River flow at McNary Dam in 1996 (Provided by Mark Reller)

APPENDICES 1-5 :
TECHNICAL BACKGROUND, ANALYSIS, AND SUPPLEMENTARY INFORMATION

Appendix 1: Process used by the ISAB to conduct the review

As a preliminary step in responding to the questions received from NMFS, a subcommittee of the ISAB met with the Implementation Team on 9 November 1996 to attempt to clarify the issues involved. Subsequently, the ISAB Chair appointed a subcommittee, consisting of Richard Whitney, Chair, James Lichatowich, William Liss and Lyman McDonald to pursue the matter. Two ISAB members, Daniel Goodman and Jack Stanford, were consulted by the subcommittee during preparation of the draft of the report because of their special knowledge in the areas of interest. They were not included as members of the subcommittee because of their previous involvement in matters relating to resident fishes in those systems, and the concern of the chair as to a potential appearance of bias or a conflict of interest. The subcommittee kept the full committee informed at every step and distributed a copy of the draft response to the full committee for their review. This response therefore represents a full committee report.

Discussions with interested parties produced a list of experts knowledgeable on the subject. Written material on the subject was provided by them to Chip McConnaha of the NWPPC and copies were distributed to the subcommittee. The following were invited to make presentations to the ISAB at our November 20 meeting, Joseph DosSantos, Salish/Kootenai Tribes, Robert Hallock, U.S. Fish and Wildlife Service, Mark Reller, Montana staff of NWPPC, and Roger Schiewe, Bonneville Power Administration Dittmer Center. At a December 17, 1996 meeting of the subcommittee, Brian Marotz of the Montana Department of Fish Wildlife and Parks made a presentation. Each of these speakers provided additional written information in support of the presentations. We have attempted to assemble all reports that might have a bearing on the question. The subcommittee has examined all of the information provided and given it full consideration in drafting a response to the questions.

In the process, the subcommittee heard testimony from knowledgeable individuals and examined reports describing large field studies and complicated models. For purpose of this review, this testimony and these reports were largely accepted at face value: the logic of the modeling and field studies impressed the subcommittee as sensible, and the results seemed reasonable. The subcommittee did not attempt to duplicate the statistical analyses, and did not subject the models to detailed critical dissection. We noted that they had been subjected to peer review by Andersen 1991 (an early version) and Swartzman, 1995)

Under the circumstances, this degree of depth in the review seemed appropriate. No quantitative analyses or models came to light that purported to address directly the specific questions about extinction of resident fish populations in Hungry Horse or Libby

reservoirs as a result of the BiOp drawdowns; and we did not encounter expressed concerns about the validity of the models or statistical analyses that were considered. Given this absence of direct evidence bearing on the questions, and lack of controversy concerning the material examined, it was the judgment of the ISAB that a deeper analysis of the available reports and models would not have altered the conclusion of this review. "

Appendix 2: Physical features and operations of Hungry Horse and Libby dams

The basic features of Hungry Horse Reservoir and its operational relationship to downstream waters including Flathead Lake and Kerr Dam are detailed in Stanford and Hauer (1992). Similar descriptions for Libby Reservoir and its relation to downstream waters including Kootenay Lake in British Columbia are given in Perry and Perry (1986) and Perry et al. (1986). Both dams were built on running river segments. The Hungry Horse and Libby systems together provide about 20% of the available storage for water in the Columbia River hydropower system (Marotz et al, 1996). The location of the projects is shown in Figure 1.

1. Physical Features of Libby Dam.

Libby Dam, located in Montana, was completed in 1972 as part of the Columbia River Treaty between the United States and Canada that inaugurated a dam construction program in Canada "...to harness the upper reaches of the Columbia and its tributaries and develop their potential to the mutual advantage of both countries" (BPA 1980B, p. 1). Libby Dam, operated by the U.S. Army Corps of Engineers, produces power and stores water from the Kootenay River in a reservoir (Lake Koocanusa) that extends into Canada with a drainage basin that covers 8,985 square miles. The dam is 370 feet high and backs up a reservoir 90 miles in length with an area of 46,500 acres at full pool. Average depth is 146 feet. Storage capacity is 4.934 million acre feet. Maximum and minimum recorded inflows were 121,000 cfs and 895 cfs respectively, and the average 11,970 cfs. Downstream of Libby Dam in the United States, the Kootenai River in Montana, Idaho and Washington becomes the Kootenay River in Canada where it enters Kootenay Lake, which was formed by construction of the Corra Linn Dam (B.C. Hydro.). Duncan River, dammed in 1967 by Duncan Dam (130 feet high, owned by B.C. Hydro.) at the outlet of Duncan Lake also empties into Kootenay Lake. The drainage area of that basin is 930 square miles. Storage capacity of the reservoir is 1.4 million acre feet. These three projects in the Libby system, along with inflow from tributaries between Libby Dam and Bonners Ferry, Idaho, are included in the model analysis used for development of the Integrated Rule Curves. Below Corra Linn Dam, the Kootenay River continues without interruption to its confluence with the Columbia River below Keenleyside Dam (B.C. Hydro.) in the reservoir above Grand Coulee Dam. (Information from BPA, 1980A, 1980B; Chisholm, 1989; May et al, 1988; and Marotz et al, 1996.)

2. Physical features of Hungry Horse Dam

Hungry Horse Dam, built in 1952 by Montana Water and Power Resources Service for power, navigation, flood control, power storage, and irrigation, is located in Montana on the South Fork of the Flathead River. The drainage area above the dam is 1,700 sq miles. The reservoir covers 23,800 acres, with an average depth of 146 feet. Storage capacity is given as 3.468 million acre feet. Below the dam the Flathead River continues to its entry into Flathead Lake. Big Fork Dam (Pacific Power and Light) is located on the Swan River, which empties into

the north end of Flathead Lake. Kerr Dam (Montana Water Power and Salish Kootenai Tribe) built for power and power storage in 1939, is located 4.5 miles downstream from Flathead Lake. Once in the Lower Flathead River water released from upstream continues to the junction with Clarks Fork River. From that point to the confluence with the Columbia River there are five more hydroelectric projects: Thompson Falls (Montana Water Power Co.), Noxon Rapids (Washington Water Power Co.) , Cabinet Gorge (Washington Water Power Co.), and Albeni Falls (U.S. Corps of Engineers) dams on the Clarks Fork River. Albeni Falls Dam is located just below Lake Pend Oreille where its operations affect the lake elevations. Below Albeni Falls Dam, the Pend Oreille River continues to Boundary Dam (City of Seattle), located just above its confluence with the Columbia River above Grand Coulee Dam.

3. Operations at Hungry Horse and Libby dams

A. Power Production. When operated for power storage (by BPA), water withdrawals from the reservoirs are designed to conform to demand. This leads to both seasonal and daily effects. The hydrograph is shifted so that the usual spring peaks occur later in the year, and are manipulated on a daily basis, leading to large reductions in flow at night compared to the daytime.

B. Flood Control. When operated for flood control (by the COE) drawdown of reservoir elevations is implemented in late winter and early spring to provide space for storage of flood waters, Figures 2 and 3. Decisions on appropriate elevations for drawdown at that time, in addition to considering predicted runoff and storage space for flood control, provide for power storage, the water budget, irrigation and other purposes. The 1987 and 1994 NWPPC Fish and Wildlife Program called for limits on drawdown at Hungry Horse and Libby reservoirs, amounting to 85 feet below normal pool for Hungry Horse and 90-110 feet below normal pool for Libby Dam (FWP Measures 903(a) and (b)).

C. Irrigation. Releases to provide water for irrigation downstream (under the control of the U.S. Bureau of Reclamation) are undertaken during the summer in coordination with BPA..

D. Salmon. Flow augmentation for the Snake River Salmon Biological Opinion uses water stored in the two reservoirs, resulting in a drawdown of their elevations in August. The Biological Opinion specifies minimum elevations for both Hungry Horse and Libby reservoirs in August. In this way, drawdown is limited to a maximum of 20 feet at both projects. Refill by August 1 in 1996, made the full 20 feet of drawdown available for the flow augmentation called for in the NMFS BiOp, Figures 2 and 3. In 1996 at Hungry Horse Reservoir, August drawdown amounted to 20 feet. At Libby Reservoir August drawdown amounted to about 8 feet.

4. Restrictions on operations at Hungry Horse and Libby dams for resident fishes

The NWPPC includes a number of measures that are designed to control operations at Hungry Horse and Libby Reservoirs for the benefit of resident fishes.

A. Hungry Horse Dam. At Hungry Horse reservoir, drawdowns occurred in the water years 1993 and 1994 to 188 feet and 174 feet below full pool respectively. The Fish and Wildlife Program of 1994 at Section 10.3A.4 reads, "Continue to enforce the drawdown limit of 85 feet at Hungry Horse Reservoir, except in years of extremely high runoff, when additional

drafting may be required for flood control. The intent of this measure is to improve historic dam operational practices to provide more favorable biological conditions for resident fish in the reservoir and affected river reaches and to help balance conditions for anadromous and resident fish so that the recovery of one is not done at the expense of the other." (This provision, specifying the same drawdown limits was also included in the 1987 Fish and Wildlife Program of the NWPPC.)

Section 10.3A.5. In years when the drawdown limit is exceeded for power purposes at Hungry Horse Dam, Bonneville is to immediately fund the mitigation of fish losses to the extent those losses are caused by power operations.

Section 10.3A.7. In years when the drawdown limit is exceeded for flood control purposes at Hungry Horse Dam, the Corps of Engineers is to immediately fund the mitigation of fish losses to the extent those losses are caused by system flood control operations.

Section 10.3A.9. Resident fish loss estimates identified in the "Fisheries Mitigation Plan for Losses Attributable to the Construction and Operation of Hungry Horse Dam" prepared by Montana Department of Fish, Wildlife and Parks and the Confederated Salish and Kootenai Tribes are incorporated into the program.

Section 10.3A.15. The determination of losses and appropriate measures contained in the Hungry Horse Mitigation Plan assumes that the operation of Hungry Horse Dam will be conducted in accordance with current practices: 1) reservoir drawdown for power purposes is limited by Section 10.3A.4 of this program; 2) reservoir drawdown for flood control is conducted in accordance with the assignment of project flood control responsibility in effect prior to the 1992 operating year; and 3) no drawdown of the reservoir, other than proportional drafting for the existing water budget, takes place for the purpose of increasing downstream flows to benefit salmon and steelhead. In the event that any significant changes to current practices are undertaken, reopen this determination for the purpose of setting appropriate drawdown limitations to ensure that the mitigation measures contained in the plan remain adequate and effective.

B. Libby Dam. At Libby Reservoir, drawdowns were 136 feet in 1993 and 94 feet in 1994 (Marotz et al, 1996). The 1994 NWPPC Fish and Wildlife Program at Section 10.3B.3 reads, "Until the Council takes further action, the COE is to enforce the drawdown limit of 90 feet to 110 feet at Libby Reservoir, except in years of extremely high runoff when additional drafting may be required for flood control. The intent of this measure is to improve on historic dam operational practices to provide more favorable biological conditions for resident fish in the reservoirs and affected river reaches and to help balance conditions for anadromous and resident fish so that the recovery of one is not done at the expense of the other." Clauses similar to those for Hungry Horse operations, calling for mitigation of fish losses if the limits are exceeded, are included in the program [Sections 10.3B.6, 10.3B7].

Sections 10.3B.2,3, and 4. These sections call upon BPA and the COE to implement the integrated rule curves for Koocanusa Reservoir, refine IRC's to limit drawdown of Lake Koocanusa to protect resident fish, and review state and tribal recommendations on the biological effectiveness of the IRCs.

Appendix 3. Operations at Projects Downstream of Hungry Horse and Libby Dams

1. Kerr Dam and Flathead Lake

Water from Hungry Horse Reservoir passes through Flathead Lake to Kerr Dam just below the lake. Water level fluctuations occur at Flathead Lake in response to flows from Hungry Horse and to regulation by Kerr Dam (Cross 1987). Conditions in Flathead Lake itself are also of concern with respect to summer drafting of Hungry Horse Reservoir. Long term limnological studies on Flathead Lake have related declining water quality to anthropogenic loading of nitrogen and phosphorus. Since mass flux of plant growth nutrients through Flathead Lake is controlled by the lake's water budget, water quality in the lake is directly influenced by both Hungry Horse and Kerr Dam operations (Stanford and Hauer 1992; Stanford et al. 1994). The State of Montana has initiated an aggressive nutrient control strategy for Flathead Lake (Flathead Basin Commission, 1994) and the US Environmental Protection Agency currently is in the process of implementing a Total Maximum Daily Load allocation under authority of the Federal Clean Water Act. These nutrient control strategies are affected by summer drafting of Hungry Horse dam for BiOp flows.

2. The Lower Flathead River

Operations at Kerr Dam, also affect flows in the Lower Flathead River. Studies below Kerr Dam have been undertaken since 1981 by the Confederated Salish and Kootenai Tribes with funding from BPA as part of the NWPPC's Fish and Wildlife Program (Cross 1987; Cross et al. 1988), and in Lake Pend Oreille by the State of Idaho Department of Fish and Game (Fredericks et al. 1995). These studies concluded that changes in the hydrograph have brought about shifts in seasonal peak flows that are not in synchrony with spawning and rearing requirements of resident fishes, and unusual fluctuations in flow have reduced production of aquatic insects and other food sources of resident fishes, and can lead to stranding of juveniles in near shore areas. Flow augmentation in August for implementation of NMFS BiOp will, on these grounds, likewise be expected to produce adverse effects on resident fishes in these locations. Only a few of these effects downstream have been quantified.

Daily fluctuations in river discharge, amounting to more than an order of magnitude at times, during the period of study by Cross et al. (1988) precluded the establishment of habitats usually favored by young riverine fishes. The nearshore food web was reduced by the fluctuations. Constantly changing water depths and velocities were thought to result in behavioral effects on spawning trout, resulting in delayed spawning or lack of spawning. Both cutthroat trout and bull trout are rare in the lower Flathead River, while whitefish, which are broadcast spawners, appear to be doing as well as in other streams of comparable size in western Montana (Cross et al, 1988).

Kerr Dam, below Flathead Lake was relicensed on an interim basis by the FERC in 1985 Cross, (1987), with a condition that a fish and wildlife mitigation plan was to be submitted by 1989. License proceedings are continuing. The EIS prepared by FERC (1996) includes a

provision that Kerr Dam procedures be changed from peaking and load following operations to baseload operating. Other conditions, which follow Dept. of Interior amended Section 4(e) conditions for the adequate protection and utilization of the Flathead Indian Reservation and the Flathead Waterfowl Production Area, include specified minimum flows during the year, divided into six intervals, and sets maximum permissible daily changes in flow, as well as maximum hourly ramping rates. They also provide for protection and development of aquatic and riparian fish and wildlife resources in and along the lower Flathead River including development of natural artesian springs, habitat acquisition and rehabilitation. Minimum flows from August 1 to April 15 are to be 3,200 cfs. Apparently flow augmentation in August for endangered Snake River salmon was not anticipated. The riparian zone of concern presumably will be affected by the augmentation flows requested by NMFS in August.

As an accommodation of the wishes of lakeshore residents and visitors, as well as for storage of water for future power production, the operators of Kerr Dam attempt to hold Flathead Lake at full pool from mid June until October. Hence, summer drafting at Hungry Horse required by the NMFS BiOp has to be accommodated by high discharges from Kerr Dam. This could become a problem, particularly if releases from Hungry Horse Dam are pulsed to follow the load and if the operators at Kerr are at the same time required to maintain the elevation of Flathead Lake and to baseload the powerhouse to mitigate environmental damage downstream and within the Flathead Indian Reservation (FERC, 1996).

3. The Lower Clarks Fork River

There are five other hydroelectric projects in the Hungry Horse system below Kerr Dam at Flathead Lake: Thompson Falls, Noxon Rapids, Cabinet Gorge, and Albeni Falls dams which are located in sequence downstream on the Clarks Fork River. Albeni Falls Dam is located on Lake Pend Oreille, which provides additional storage capacity and regulation of the lake's water level by the COE. Operation of Albeni Falls Dam and associated elevations of Lake Pend Oreille are affected by inflow resulting from flow augmentation out of Hungry Horse Reservoir.

Lake Pend Oreille is the largest natural lake in Idaho, covering about 86,000 acres (IDFG, 1996). It provides opportunity for temporary storage of part of the inflow from Hungry Horse Reservoir through operation of Albeni Falls Dam. The Idaho Department of Fish and Game believes that the kokanee population in Lake Pend Oreille and its associated fishery are at risk due to drawdown of the lake level. Drawdown in Lake Pend Oreille amounts to about 10 feet annually (Fredericks et al., 1995). A project at Priest Lake which empties into Lake Pend Oreille provides additional power and storage. Below Albeni Falls Dam the Pend Oreille River runs to Boundary Dam just above the river's confluence with the Columbia River at Lake Roosevelt, the reservoir above Grand Coulee Dam.

4. The Kootenai River

In the Libby system, the Kootenay River continues from Corra Linn Dam to the Columbia River above Grand Coulee Dam without interruption.

5. Mainstem Columbia River

After entering the mainstem Columbia River above Grand Coulee Dam, water from Hungry Horse and Libby reservoirs passes seven dams (Grand Coulee, Chief Joseph, Wells, Rocky Reach, Rock Island, Wanapum and Priest Rapids) before joining the Snake River above McNary Dam. Juvenile salmon in the portion of the Columbia River from that point (the confluence of the Snake River) to the mouth are the target of the flow augmentation provisions of the NMFS BiOp. Figure 6 illustrates the probable effects of the August flow augmentation on flows at McNary Dam, (as presented by Mark Reller).

Appendix 4: Risk of extinction for endangered and petitioned stocks: General background

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1. Bull trout in Montana

A. Summary of Thomas, 1992

This study was conducted using an opinion survey of local biologists from state, federal and tribal entities to provide a qualitative assessment of extinction risks to bull trout in portions of the Upper Columbia River Basin (Thomas 1992). Opinions about the severity of extinction risks for local populations were based upon abundance of bull trout, quality of habitat, and risk of hybridization with brook trout. The resulting ratings of risk of extinction were assigned on a scale ranging from 3 (minimal risk of extinction) to 12 (maximum risk of extinction).

For the Montana portion of the Libby system (including tributaries) the average rating assigned to bull trout in 99 tributaries or segments was 9.5, indicating that the overall risk is thought by knowledgeable professionals to be on the high side. There were 10 segments identified where the risk of extinction was thought to be at a maximum, receiving the 12 rating. None were rated in the range from 3 to 5 that would have indicated minimum risk. In the Montana portion of the Hungry Horse system, the average rating assigned to bull trout in 372 segments was 7.4, indicating a perceived medium risk of extinction. Six segments were rated as 3, with a minimum risk, and 27 were rated as 12, with maximum risk.

This study was conducted in 1992, prior to the effects or anticipated effects of flow augmentation for Snake River salmon. An additional survey would be required to develop opinions on the question whether an increased risk of extinction would likely occur due to implementation of provisions for flow augmentation due to the Biological Opinion for Snake River salmon. It would be reasonable to conclude, on the basis of studies summarized further in the text below, that in the absence of measures taken to improve their situation, their risk of extinction is not likely to improve.

B. Summary of Montana Bull Trout Scientific Group Reports

In 1994 Governor Racicot appointed the Bull Trout Restoration Team to assess the status of bull trout in Montana and recommend measures for restoration. In turn, the team appointed a Montana Bull Trout Scientific Group to provide the team with information on bull trout status to assist in making decisions on the restoration and conservation of bull trout in Montana (MT Bull Trout Scientific Group, 1996A, 1996B, etc). Status reports have been prepared for bull trout populations in 12 areas, including the Upper Kootenai River above Libby Dam, the Middle Kootenai River, and Lower Kootenai River, the South Fork of the Flathead River above Hungry Horse Dam, Swan Lake and Swan River, Flathead Lake, including the North and Middle Forks of the Flathead River, Middle Clark Fork River and Lower Clark Fork River, which are located in the Hungry Horse and/or Libby systems.

The procedure for determining the risk of extinction for bull trout in the areas named consisted of specifying and qualitatively evaluating sources of risk, such as environmental instability, introduced species, barriers, habitat, and population factors, based on the degree to

which each was presumed to contribute to past and present status of the species in the given area. Information in the reports is not of a sort that can be used to evaluate whether or to what extent the BiOp flow augmentation operations might affect the risk of extinction for bull trout in the areas.

2. Kootenai River White Sturgeon

The Kootenai River white sturgeon is a species of particular interest because of its listing under ESA by the USFWS. More information is needed on sturgeon requirements to direct further model development specifically for sturgeon management (Marotz et al., 1996). The white sturgeon found in the Kootenai River from Kootenai Falls below Libby Dam in Montana, downstream to Kootenay Lake, British Columbia, Canada is a landlocked population that differs genetically from sturgeon elsewhere. The population is estimated at less than 1400 fish (USFWS, 1996). No significant recruitment has occurred for 20 years, as indicated by age analysis of sampled fish. The start of this period coincides with the construction of Libby Dam. Limited spawning occurs; however, few young-of-the-year sturgeon have been observed in spite of intensive sampling. The U.S. Fish and Wildlife Service listed this population in 1994. A draft Recovery Plan was produced in 1996, along with a Biological Opinion (Hallock testimony and USFWS, 1996).

The Recovery Plan for Kootenai River white sturgeon states criteria for delisting and proposes management actions that are thought to offer some promise of achieving recovery. A minimum of 10 to 25 years will be required to meet the criteria. Management actions are specified, with emphasis on restoring habitat, particularly during the spawning season in May through July. A hatchery supplementation program is included in the plan. Maintenance of stable river flows in the Kootenai River during the spawning season of sturgeon is thought to be a primary element in habitat protection. Accordingly, experimental flow releases were attempted in 1991 and 1992 at the request of Idaho Department of Fish and Game and in 1993 at the request of the "Kootenai White Sturgeon Technical Committee", a group made up of representatives of a number of interested governmental agencies, including British Columbia interests (USFWS, 1996). However, conflicts occurred between the need for flood control and recreational interests and the requested flows were not maintained in 1992 or 1993. In 1994, the USFWS issued a formal Conference Opinion on the effects of the 1994-1998 Federal Columbia River Power System, in which it was concluded that the proposed operation of the hydropower system was not likely to jeopardize the sturgeon. But it proposed an action to provide, in 3 out of 10 years, flows of 15,000 cfs at Bonners Ferry during May each year, 20,000 cfs for 35 days during the extended spawning season for sturgeon, and maintain 11,000 cfs for 28 days. In addition, it called for keeping flow releases constant during the May through July spawning period during years when such flows are provided. This plan was followed rather closely in 1994 and 1995. White Sturgeon spawning was detected, but no larval sturgeon were found. (USFWS, 1996)

In 1995, the USFWS, NMFS, BPA, COE, and BUREC formally consulted during a series of meetings to consider how the Federal Columbia River Power System (FCRPS) could avoid jeopardy to the Kootenai River White Sturgeon. In July, 1995, the Service issued a final BiOp

addressing the effects of the FCRPS on sturgeon. This BiOp defined reasonable and prudent alternatives to regulate flows at Libby Dam for the years 1995 to 1998.

In 1995, it was found that water temperatures remained below the optimal range for sturgeon spawning during most of the flow augmentation period. In July, flows were increased in response to the NMFS BiOp requirement for flow augmentation to benefit endangered Snake River salmon downstream. This peak can lead to stranding of fish eggs and larvae (USFWS, 1996 p.23).

Appendix 5: Effects of drawdown on aquatic systems in reservoirs

1. General.

Reservoirs have three longitudinal zones - the riverine, transition, and lacustrine zones - that differ in biophysical properties and processes (Thornton 1990A). The presence and longitudinal extent of each zone depends upon factors such as water inflow, water density-flow characteristics, and reservoir operation (Kimmel et al. 1990). The riverine zone is the zone furthest upstream in the reservoir and is a well-mixed zone with sufficient advective flow to transport finer organic and inorganic particles while coarser particles settle out. The food web should be detritus-based (Thornton 1990B). Nutrient concentration is high but light penetration is limited and consequently total phytoplankton and zooplankton production is lower than in the transition zone (Kennedy and Walker 1990, Kimmel et al. 1990, Marzolf 1990).

Periodic drawdowns.

Water level fluctuations (periodic, temporary drawdowns) can expose previously-inundated portions of stream channels and tend to shift the riverine zone downstream along the reservoir's longitudinal axis. Furthermore, such drawdowns alternately expose and inundate large areas of littoral substrate and inhibit development of functional wetlands along the reservoir margin (Wetzel 1990). Effects of drawdowns depend on a number of factors including edaphic conditions in the watershed and reservoir, lake morphometry (which influences the amount of littoral area in the reservoir), climatic factors, and factors related to the operation of the reservoir including length and timing of drawdowns (McAfee 1980, Ploskey 1986).

Erosion.

Erosion caused by fluctuating water levels can mobilize sediments deposited in littoral areas and upstream sections of the reservoir and transport the sediments downstream into the pool (Thornton 1990B). At Flathead Lake, the construction and operation of Kerr Dam has led to increased erosion of the shoreline as lake elevations have been raised for extended periods with storage of spring runoff and increased flow from Hungry Horse Reservoir (Stanford and Hauer, 1992). Drawdown enhances transport of nutrients stored in littoral areas into the pelagic region of the reservoir (Ford 1990, Kennedy and Walker 1990). Alternating patterns of water inflow can alter longitudinal gradients of nutrient concentrations creating complex patterns of nutrient distribution throughout the reservoir (Kennedy and Walker 1990). Although little appears to be known about specific effects of drawdown on phytoplankton and zooplankton, alteration in nutrient concentrations and distributions could influence distribution and abundance of both of these taxonomic groups (Ploskey 1986).

Fluctuating water levels can reduce the abundance and diversity of benthic taxa and alter their vertical distribution in the reservoir, either through direct mortality or indirectly by altering habitat via mechanical sorting of substrates through wave action during drawdown (Benson and Hudson 1975) and elimination of macrophytes (Hunt and Jones 1972, Fillion 1967, Kaster and

Jacobi 1978, Ploskey 1986). Exposure of substrates following drawdown can cause direct mortality through dessication or freezing of invertebrate taxa that are unable to follow the receding water level (Paterson and Fernando 1976, Benson and Hudson 1975, Kaster and Jacobi 1978, Ploskey 1986) or to burrow deep into sediments (Paterson and Fernando 1969, Kaster and Jacobi 1978). Fluctuating water levels may inhibit establishment of benthic taxa with long life cycles such as Hexagenia mayflies in the regulated zone (Benson and Hudson 1975). Often the benthos in the regulated zone is dominated by taxa such as chironomids and oligochaetes that have short generation times and that are capable of burrowing into silt substrates to better withstand dessication and freezing (Kadlec 1962, Fillion 1967, Paterson and Fernando 1969, Hunt and Jones 1972, Benson and Hudson 1975, Kaster and Jacobi 1978). In reservoirs that are non-fluctuating, abundance and diversity of benthic taxa tends to decrease with increasing depth, while in reservoirs with fluctuating water levels abundance of benthic taxa tends to be greatest just below the drawdown limit (Grimas 1961, Fillion 1967, Kaster and Jacobi 1978, Ploskey 1986). Kaster and Jacobi (1978) found that benthic taxa were able to reestablish in the regulated zone following reinundation, probably via recolonization from the portion of the reservoir that remained under water.

Effects on fish.

Effects of drawdown on fish depend on the timing of drawdown relative to the period of spawning, and the duration and frequency of drawdown. Water level fluctuations can adversely affect reproductive success of fish that spawn in nearshore areas. Drawdown can limit access to preferred spawning areas (Martin 1955, Gaboury and Patalas 1984) and cause fish to spawn in less favorable habitats (Martin 1955). Exposure of nests during periods of drawdown can increase egg mortality from dessication and freezing for shoreline spawners such as kokanee salmon (Gipson and Hubert 1995) and lake trout (Martin 1955). Alternatively, fish may spawn in previously-inundated sections of streams, and reinundation of these streams following spawning can destroy the incubating eggs (McAfee 1980). Stranding of fish following drawdown also has been reported (Gaboury and Patalas 1984). Elimination of littoral macrophytes through water level fluctuations can reduce spawning success and survival. Many species of warm-water fishes use macrophytes in the littoral zone for spawning (Ploskey 1986). Furthermore, littoral macrophytes provide food resources and refugia from predators for small fish (Wegener et al. 1976, Ploskey 1986). Drawdown can concentrate small fish and other prey outside littoral refugia and expose them to predation (Ploskey 1986, OBrien 1990), resulting in increased piscivore growth (Wegener and Vincent 1976, Alexander 1988) which may persist until prey populations become depleted (Ploskey 1986). Reduced abundance of fish associated with draw-downs also has been attributed to reductions in abundance of littoral invertebrate prey organisms resulting from loss of macrophytes and alteration of benthic substrates (Hunt and Jones 1972, Bryan 1982, O'Brien 1990).

2. Biological models describing the Hungry Horse and Libby systems

A. Boundaries of the Models.

The Hungry Horse model simulates natural flows in the North and Middle forks of the Flathead River, as well as the regulated flows from Hungry Horse Reservoir, Flathead Lake elevations and discharges to the Lower Flathead River from Kerr Dam at Flathead Lake (Marotz et al, 1996). The Libby model represents the reservoir downstream to Corra Linn Dam on the Kootenay River, British Columbia (Marotz et al., 1996). While the models include biological features only in the reservoirs themselves, they include hydrological features such as flow and temperature in the rivers downstream, and these have been used to predict probable effects on trout growth and reproduction there based on information in the scientific literature (Brian Marotz personal communication). Studies in the rivers downstream have provided information on the effects of operation of the two dams on resident fishes there, as described previously.

B. Fish Species Included in the Model Analysis.

Background. - Numerous studies and models, a few of which have been conducted in the Hungry Horse and Libby systems, describe the various probable and possible effects of drawdowns. The biological portions of the models encompass the reservoirs, while the hydrological portions extend downstream; in the case of the Libby system to Corra Linn Dam, and in the case of the Hungry Horse system to Kerr Dam below Flathead Lake. The biological portions of the models incorporate the food chain leading to kokanee in Libby Reservoir and westslope cutthroat trout in Hungry Horse Reservoir.

Bull Trout. - Bull trout in the Pacific Northwest are believed at risk of local and regional extinctions (Rieman and McIntyre, 1993, 1995, 1996). However, stable populations do exist, a fact that has contributed to the USFWS indecision concerning listing of the bull trout under the Endangered Species Act. A final listing decision is expected in mid-1997. Bull trout populations in the Flathead and Kootenai river systems are fragmented and thought to be at some risk of extinction. See Appendix 4.

Both Hungry Horse Reservoir and Libby Reservoir (Lake Koocanoosa) contain "stable", but low populations of bull trout (Marotz et al, 1996; Thomas, 1992). The Montana Department of Fish Wildlife and Parks closed the recreational fishery for bull trout in Hungry Horse Reservoir in 1992 and it remains closed. Populations of bull trout in the Kootenai River Basin (Libby Dam drainage) are considered to be at rather high risk of extinction, as previously noted (Thomas, 1992).

In the North, South and Middle forks of the Flathead River and mainstem above Flathead Lake bull trout are thought to be at moderate risk of extinction (Thomas, 1992). Below Flathead Lake in the Lower Flathead River and in the Clark Fork River, bull trout populations are fragmented (Williams et al. in press) and at rather high risk of extinction, based on the subjective evaluations of biologists in the field (Thomas, 1992). See Appendix 4.

Westslope Cutthroat Trout. - Trout growth was modeled as being dependent upon water temperature and food availability (Marotz, et al., 1996). In field collections, terrestrial insects made up the bulk of the diet of cutthroat trout on an annual basis, followed by aquatic insects and zooplankton. Model simulations using 1993 water year conditions suggested that terrestrial insect input was reduced 68.7% and resulting trout growth reduced 32 to 38%, by a simulated BiOp drawdown in August superimposed on the late winter early spring drawdown. Population fluctuations of trout are thought to be a response to effects of drawdown. Analysis of

lengths at age as indicated by scales suggested there is size selective mortality, with the smallest fish being most vulnerable.

Kokanee. - Kokanee was modeled in Libby Reservoir. The model suggests that conditions are best for kokanee if the reservoir remains at full pool at least through September and declines only gradually into November (Marotz et al., 1996).

Other Species of Interest

Kootenai River White Sturgeon. - The Kootenai River white sturgeon is not directly included in the model, but it is a species of particular interest because of its listing under ESA by the USFWS. While the model is capable of assessing an array of alternate water volumes and shapes, more information is needed on sturgeon requirements to direct model development (Marotz et al., 1996).

3. Analysis using the models

Data from field studies in the Hungry Horse and Libby systems were included in the models (Marotz et al., 1996). They illustrate that aquatic plants and insects are killed as water recedes from the littoral zone. Fish in the near shore zone are forced into the open water, where food availability and cover are reduced. Loss of zooplankton was greatest when the reservoir waters were isothermal and when reservoir elevation approached the depth of outflow. Biomass of insects was found to be lowest in areas subject to frequent dewatering. Normally, the shallow zone is most productive for insects. The limnological studies found that two years are required for recovery of aquatic insect populations after a sharp drawdown. With annual drawdown, of course, full recovery does not occur. Terrestrial insects were found to be an important source of food for fish at times. Normally, they are most abundant in August and September in the near shore zone where they tend to fall from overhanging vegetation. Drawdown at that time results in a loss of a portion of this food source and affects growth of trout, as described above (Marotz et al, 1996).

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