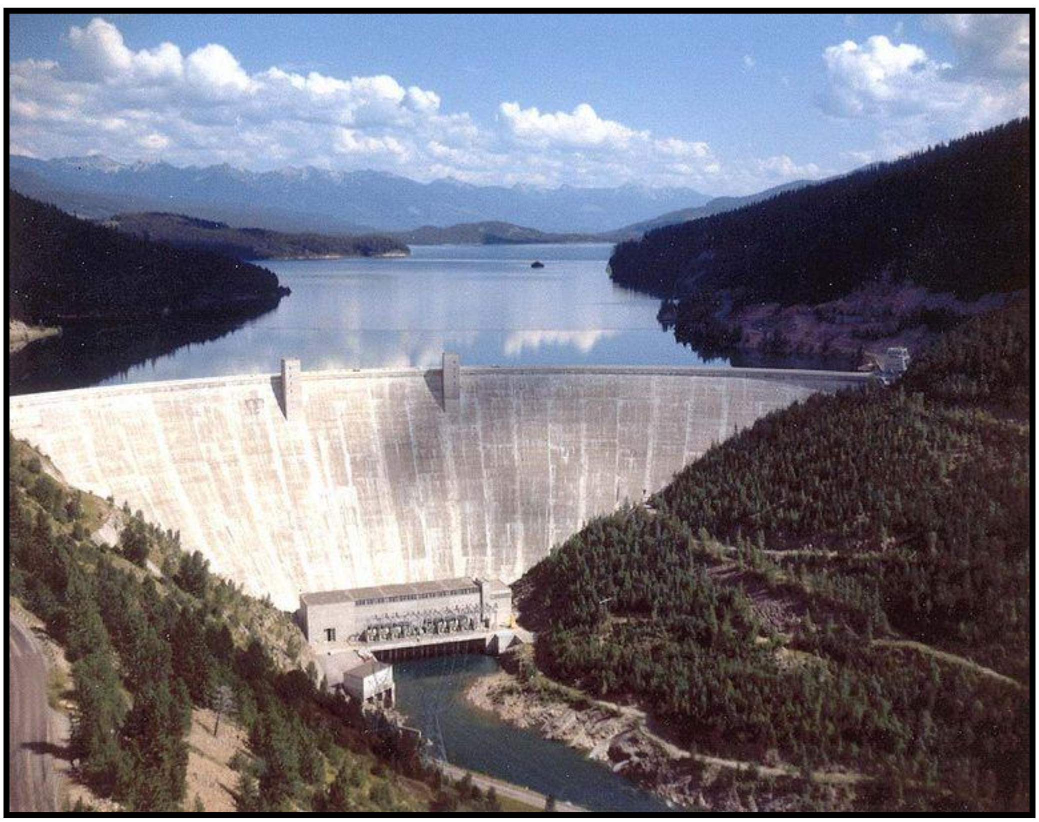
STATE OF MONTANA

Hungry Horse Reservoir, Montana:

Biological Impact Evaluation and Operational Constraints for a proposed 90,000-acre-foot withdrawal

September 14, 2011 (Revised Version)



Introduction

As part of reserved water rights negotiations among the Confederated Salish and Kootenai Tribes (Tribes), the State of Montana (State) and the United States, the Tribes have requested supplemental water, a portion of which (90,000 acre-feet or 90 KAF) is proposed to be withdrawn from Hungry Horse Reservoir. In an effort to address the potential biological impacts of the proposed withdrawals, the State offers the following overview, biological impact evaluation, and operational constraint recommendations. Flow model output from the US Bureau of Reclamation (BoR) was used as input to a Montana Fish, Wildlife & Parks (MFWP) biological model to evaluate impacts. The timing and volume of reservoir releases were based on Montana Department of Natural Resources and Conservation (DNRC) estimates of a highest- impact scenario, in which depletions were modeled as being made on a peak irrigation demand schedule and the reservoir withdrawals were timed to occur in the driest portion of the water year when withdrawals from the reservoir potentially have the highest impact on biota in the reservoir. It is anticipated that actual releases will extend earlier or later into the year and therefore cause fewer impacts than this highest-impact scenario. Based on these findings, the biological impacts of the proposed withdrawals are either non-existent or minimal in all but the driest 15 percentile water years. In those years, releasing the full 90 KAF is likely to significantly degrade the fishery habitat in the Reservoir. To mitigate these impacts, the State presents a withdrawal reduction schedule for operations during those driest water years that includes a suite of constraints to protect reservoir biology. Even with these constraints, no less than 45 KAF will be available for release from Hungry Horse Reservoir in 100% of the water years. The full 90 KAF will be available in approximately 85% of water years. The specific reductions in the withdrawal volume identified here are based on two sliding scales set forth in Appendix B. MFWP modeling indicates that the effects of these releases on the Flathead River downstream of the Reservoir are beneficial to the riverine biota.

Reservoir Overview

Hungry Horse Reservoir (Hungry Horse) is operated by the BoR and is intricately tied to the operation of the Federal Columbia River Power System (FCRPS), and private projects regulated by the Federal Energy Regulatory Commission (FERC), including Kerr Dam on the outlet of Flathead Lake (operated by PPL Montana).

Hungry Horse stores spring snowmelt and fills toward full pool elevation (elevation 3560 ft msl) in July. During fall and winter, the reservoir is drafted for electrical power generation and to evacuate storage space in the pool for flood risk management during spring runoff. Hungry Horse typically reaches minimum pool by mid-April and then begins to refill.

Hungry Horse Dam operations were designed to balance hydropower generation and flood control with fish restoration actions, as per the Columbia Basin Fish and Wildlife Program (NPCC, 2010). These rules are the culmination of two decades of field and laboratory research to determine the effects of dam operation on aquatic resources in Hungry Horse and the Flathead River downstream. The current operating strategy uses rule curves or monthly reservoir elevation targets that adjust up or down based on water supply. Downstream, similar rules limit Flathead River flows and rates of flow change (seasonal flow windows and ramping rates). Monthly water supply forecasts that inform operational decisions are available from January through June of a given water year (earlier forecasts are available but less reliable). Forecasts estimate the inflow volume during the period April 1 through August 31, when inflows are highest.

Reservoir biota, including aquatic plants, plankton, insects, mollusks, amphibians and fish are influenced mainly by the depth of the annual reservoir drawdown and the extent of reservoir refill. Aquatic productivity is largely controlled by the volume and surface area of the reservoir during the productive summer months (June through September) and limited by the amount of habitat dewatered during the annual low pool (mid April). The fluctuating surface causes an expansive "varial zone" that can become biologically unproductive. Reservoir drawdown eliminates aquatic organisms in the dewatered zone, which must recolonize newly inundated habitat each year when the pool refills. Refill during July eliminates most terrestrial organisms that had become established during low water. Reservoir productivity is greater when the annual drawdown is minimized and reservoir refill is maximized.

Water temperature is another factor influencing biological productivity. A selective withdrawal device was retrofit on Hungry Horse Dam in 1996 to correct thermal pollution in the dam discharge. Prior to selective withdrawal, water released from deep in the reservoir seldom exceeded 41º F all year. Water at this temperature is lower than natural during summer and higher than natural during winter, and adversely impacted riverine biota. Selective withdrawal effectively eliminated artificial cooling during the biologically productive summer months and dam operators can now achieve a nearly natural annual temperature cycle (Christenson et al., 1995 and 1996; Marotz et al., 1996). This factor is therefore now deemed controllable.

Mainstem Amendments and Federal Biological Opinions

The Northwest Power and Conservation Council (Council) adopted Integrated Rule Curves (IRCs) for Hungry Horse Dam in 1994 and the overall operating plan was included in the Council's Mainstem Amendments in 2004. However, the "Montana Operation" was not fully implemented until 2009. The US Fish and Wildlife Service (USFWS) and National Oceanic and Atmospheric Administration (NOAA-Fisheries; 2008) included these specific dam operations as reasonable and prudent alternatives in their respective Biological Opinions (BiOp) concerning the operation of the FCRPS, as per the Endangered Species Act (ESA). The USFWS's BiOp also contains actions to benefit bull trout, which are listed as threatened under ESA and occur upstream and downstream of Hungry Horse Dam. The NOAA-Fisheries' 2008 BiOp and 2010 Supplemental BiOp call for releasing water from Hungry Horse during July through September to aid the recovery of anadromous fish species (mainly salmon) listed under ESA. These BiOps implement the Council's plan to limit reservoir drawdown, improve refill and smooth flows in the Flathead River to benefit bull trout and other native fish species.

Reservoir Operations for Flood Risk Management

Originally, Hungry Horse was drawn down deeply to capture the entire spring snowmelt while maintaining a minimum flow in the Flathead River (3,500 cfs) during the runoff period. Beginning in 2001, a variable flow flood control strategy (VARQ) was implemented by the US Army Corps of Engineers (Corps) and the BoR at Hungry Horse Dam. This strategy aims to replicate a more natural river flow pattern during spring runoff, while maintaining flood constraints. Consequently, VARQ requires less evacuated storage space, resulting in reduced reservoir drawdown and improved reservoir refill probability. When the reservoir fails to refill (due to error in water supply forecasts), the margin of error is minimized (i.e. the reservoir fills closer to full pool than under the earlier rules). VARQ was adopted into the NOAA-Fisheries and USFWS BiOps.

"Sliding" Reservoir Refill Date

The BoR also implemented a "sliding refill date" to prevent uncontrolled spill and associated gas supersaturation, which is harmful to fish downstream. Hungry Horse can safely refill earlier in dry years, but must refill later during high water years to avoid spilling or flooding. The date targeted for refill is calculated based on monthly forecasts of reservoir inflow, real-time observations of snow melt and precipitation and dam discharge. The refill rate is adjusted as the pool fills to assure that inflows decline to less than the maximum turbine capacity before the reservoir completely fills (if not, excess water must be discharged through the spillway).

Summertime Reservoir Drawdown for Salmon Recovery

Since 1995, Hungry Horse has been drafted as much as 20 feet during summer (usually during late August) to augment river flows in the Columbia River to help young salmon swim to the ocean. Previous NOAA-Fisheries BiOps attempted to meet a flow target of 200,000 cfs at McNary Dam in significant part by releasing water from Hungry Horse and Libby dams. This operation caused a damaging "double peak" in the Flathead and Kootenai rivers (an unnatural second peak in August after the naturalized spring freshet in early June). Independent scientists reviewed the operation and concluded that this operating strategy had little to no beneficial effect on salmon recovery, but caused damage to resident fish in the reservoirs and rivers downstream (ISAB, 1997 and 1997b). As a result, Montana contested this operation in two federal lawsuits.

NOAA-Fisheries' 2008 BiOp and 2010 Supplemental BiOp limit the summertime drawdown to 10 feet from full pool when water supply is abundant (during the top 80th percentile water years as measured at The Dalles Dam). During drought years (driest 20th percentile), the pool may be drafted up to 20 feet from full pool. The effects of double peaking in the Flathead River were mitigated by extending flow augmentation from July through September to create a gradually declining river flow after the spring pulse.

To simulate real-time reservoir operations under the BiOps, the following rules are applied:

- Starting on about July 8, Hungry Horse is drawn down linearly from its fullest point to elevation 3550 by the end of September in 80% of the years (normal and wet years)
- Starting on about July 8, Hungry Horse is drawn down linearly from its fullest point to elevation 3540 by the end of September in 20% of the years (dry years)

Flathead River Operations: Minimum Stream Flow

Prior to Hungry Horse's construction, natural annual flows were dominated by spring snowmelt that peaked in late May or early June. The spring freshet cleaned riverbed gravels and flushed fine sediments onto the riverbanks, where soils were bound by riparian vegetation. River stage then gradually declined to stable, low conditions during late summer, fall and winter. Spring floods shaped the river channel and riverine biota adapted to this annual cycle.

To mimic these natural conditions as much as practicable, minimum flow targets have been established for the mainstem of the Flathead River at Columbia Falls. These targets range from 3,500 cfs to 3,200 cfs based on water availability. Hungry Horse Dam releases water to maintain this minimum flow when the combined flow of the North and Middle Forks of the Flathead River is less than 3,500 cfs. The minimum flow in the South Fork Flathead River downstream of Hungry Horse Dam is 900 cfs during abundant water years (wettest 60th percentile water years) and adjusts linearly from 900 cfs to 400 cfs as water supply declines (driest 40th percentile) (Marotz and Muhlfeld, 2000).

Minimum flow requirements below Hungry Horse Dam and below Columbia Falls were established by the USFWS BiOp. The minimum flow in the South Fork Flathead River is determined monthly starting with the January inflow forecast for Hungry Horse during the period of April 1 to August 31. These minimum flow requirements are shown in the table below.

If the April-August forecast is:	**below Hungry Horse Dam**	**below Columbia Falls**
greater than 1,790 KAF	900 cfs	3.500 cfs
1,190-1,790 KAF	400-900 cfs	3,200-3,500 cfs
less than 1,190 KAF	400 cfs	3,200 cfs

If river height at Columbia Falls reaches flood stage (at 13 feet, approx. 44,230 cfs), the minimum flow in the South Fork below Hungry Horse Dam can be reduced to 300 cfs.

Bull Trout Flow

The USFWS BiOp calls for stabile summer flows in the Flathead River mainstem. Instream Flow Incremental Methodology (IFIM) research in the Flathead River revealed that stable flow in the range of 3,500 to 5,000 cfs provides optimal conditions for bull trout and other native fish species. Water released to augment flows for salmon recovery in the Columbia River now extends from July through September 30. Stable or gradually declining summertime flows are an improvement over the previous double peak operation. However, these unnaturally high flows during summer and fall provide less trout habitat than would be available at natural, pre-dam flow levels (USGS, 2010).

Ramping Rates and Restrictions downstream of Hungry Horse Dam

Flow fluctuations are harmful to fish, especially during the biologically productive summer months. The speed at which river flows can change is limited by flow ramping rates published in the USFWS BiOp. Ramping rates were developed based on the shape of the Flathead River channel and differ within three ranges of river flow, low, medium and high. Flows are allowed to increase faster than they can decline to reduce stranding of fish and insects. Flows can change more rapidly when the river is high and less rapidly when the river approaches minimum flow.

If the discharge below Columbia Falls is:	Restrict ramping UP by:
greater than 10,000 cfs	12,000 cfs /day
8,000 – 10,000 cfs	3,600 cfs / day
below 8,000 cfs	1,800 cfs / day
If the discharge below Columbia Falls is:	**Restrict ramping DOWN by:**
greater than 12,000 cfs	5,000 cfs /day
8,000 – 12,000 cfs	2,000 cfs / day
6,000 – 8,000 cfs	1,000 cfs / day
below 6,000 cfs	600 cfs / day

Biological Impacts of 90 KAF withdrawals

Hydrologic modeling by BoR assessed the potential systemic consequences of water depletions from Hungry Horse (BoR, 2010). The BoR modeling assumed that releases would occur during the period July through September, with the understanding that the timing of actual depletions may vary. The model output showed that releasing 90 KAF from Hungry Horse had no impact to reservoir refill during the highest 50th percentile water years (Figure 1), but indicated that water depletions may impact reservoir refill by causing a refill reduction of up to approximately 4.5 feet lower than the Base Case (current operating strategy) during years of low water supply. These impacts were greatest during the driest 15th percentile water years. During below average water years (15th to 50th percentile) the impact to reservoir refill was 1.5 feet or less, proportional to water supply. This deficit in reservoir elevation during July persists through fall, winter, and the following spring, and could be compounded when the inflowing water supply remains low for consecutive years, as could occur during successive years of drought.

Downstream, increased dam discharges generally enhance biological conditions in the river, except when releases from the dam fluctuate or deviate greatly from the natural annual hydrograph. Specifically, artificially high discharges during summer and fall results in less available fish habitat than would be present under natural, pre-dam conditions (USGS, 2010).

Additional simulations were performed by MFWP using the quantitative biological reservoir model (HRMOD) and a river model (RivBio) that calculates benthic biomass. Simulations used modified depletion schedules provided by the DNRC. The intent of these simulations was to evaluate potential biological responses to depletions of varying volumes, distributed over a longer period, May through October (Table 1). Habitat degradation as a result of reservoir withdrawal was linear as the depletion volume is incrementally increased. Data showed that biological impacts gradually increase proportional to the volume of water depletions. Biological impacts increase as the annual water supply decreases. Further, impacts to reservoir refill and depth of the annual reservoir drawdown are compounded during consecutive years of low water supply.

Model simulations showed that biological production in the reservoir food web declined proportionally to the extent of reservoir refill failure and the depth of the annual low pool elevation. As expected, biological impacts during below average water years (15th to 50th percentile) were less severe than during the driest 15th percentile water years. This result was likely due to the subtle difference in reservoir elevation (<1.5 ft), surface area, and volume in the euphotic zone (warm sunlit surface waters) during the productive, warm months (July through September).

The greatest detectable impact caused by the <1.5 ft lower pool during the annual minimum in mid-April, was caused by desiccating more acres of reservoir bottom (approx. 150 acres or less) located in the SE end of the reservoir (Appendix A). Desiccation kills benthic insect larvae (Diptera, midges); pupae and emerging adult midges are the primary food for fish during spring and early summer. Greater than 1.5 foot pool reductions can also lead to complete desiccation of the entire upper bench, thereby eliminating rooted vegetation from an area in which would otherwise retain rooted hydrophytes. At times of higher reservoir fill, this bench provides substantial vegetation cover, thermal refugia, and terrestrial insect habitat overhanging the water that adds macro invertebrates to the aquatic food chain.

Figure 1. Exceedence plot of annual maximum pool elevations at Hungry Horse Reservoir cpmparing three alternative operating strategies. The Base Case and Natural flow(Q) alternatives are identical, to the red line is covered by the green line. Source: Reclamation 2010.

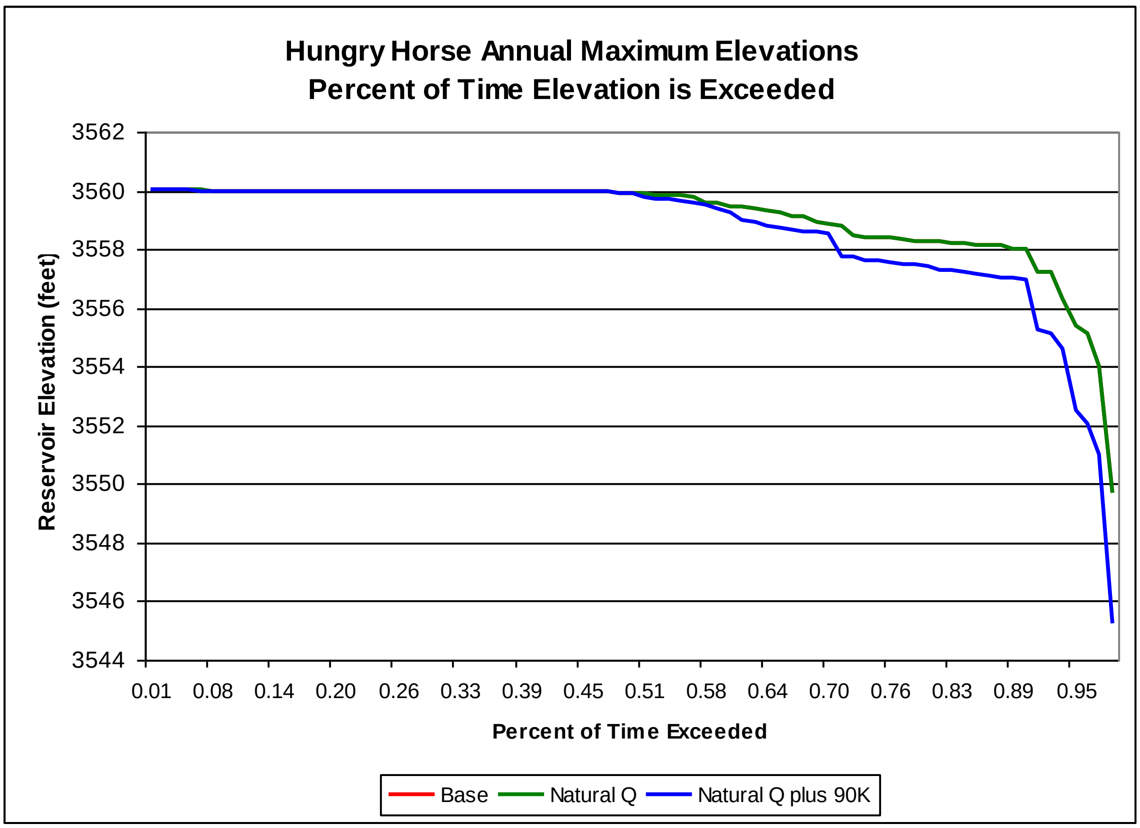


Table 1. Estimated monthly water depletions during the period May through October (the timing of actual depletions may vary) and incremental reductions.

May-Oct CSKT consumption (100%, 75%, 50%, and 25% of requested Volume)

ESTIMATED UPPER LIMIT												
HKM Total Depletions to Flathead Lake and River - 128,158 AF Volume												
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
-1,078	-824	-311	-188	8,693	21,613	36,219	38,024	27,521	2,347	-2,163	-1,696	128,158
Total Depletions to Flathead Lake and River - % Distribution of 134,417 AF May-Oct Depletion												
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
0.0%	0.0%	0.0%	0.0%	6.5%	16.1%	26.9%	28.3%	20.5%	1.7%	0.0%	0.0%	100%
100% Requested: Total Depletions to Flathead Lake and River - 90,000 AF Volume												
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
0	0	0	0	5,820	14,471	24,251	25,459	18,427	1,571	0	0	90,000
75% of CSKT HH Request: Total Depletions to Flathead Lake and River - 67,500 AF Volume												
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
0	0	0	0	4,365	10,853	18,188	19,094	13,820	1,179	0	0	67,500
50% of CSKT HH Request: Total Depletions to Flathead Lake and River - 45,000 AF Volume												
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
0	0	0	0	2,910	7,236	12,125	12,730	9,213	786	0	0	45,000
25% of CSKT HH Request: Total Depletions to Flathead Lake and River - 22,500 AF Volume												
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
0	0	0	0	1,455	3,618	6,063	6,365	4,607	393	0	0	22,500

HKM summary figures
DNRC Calculations

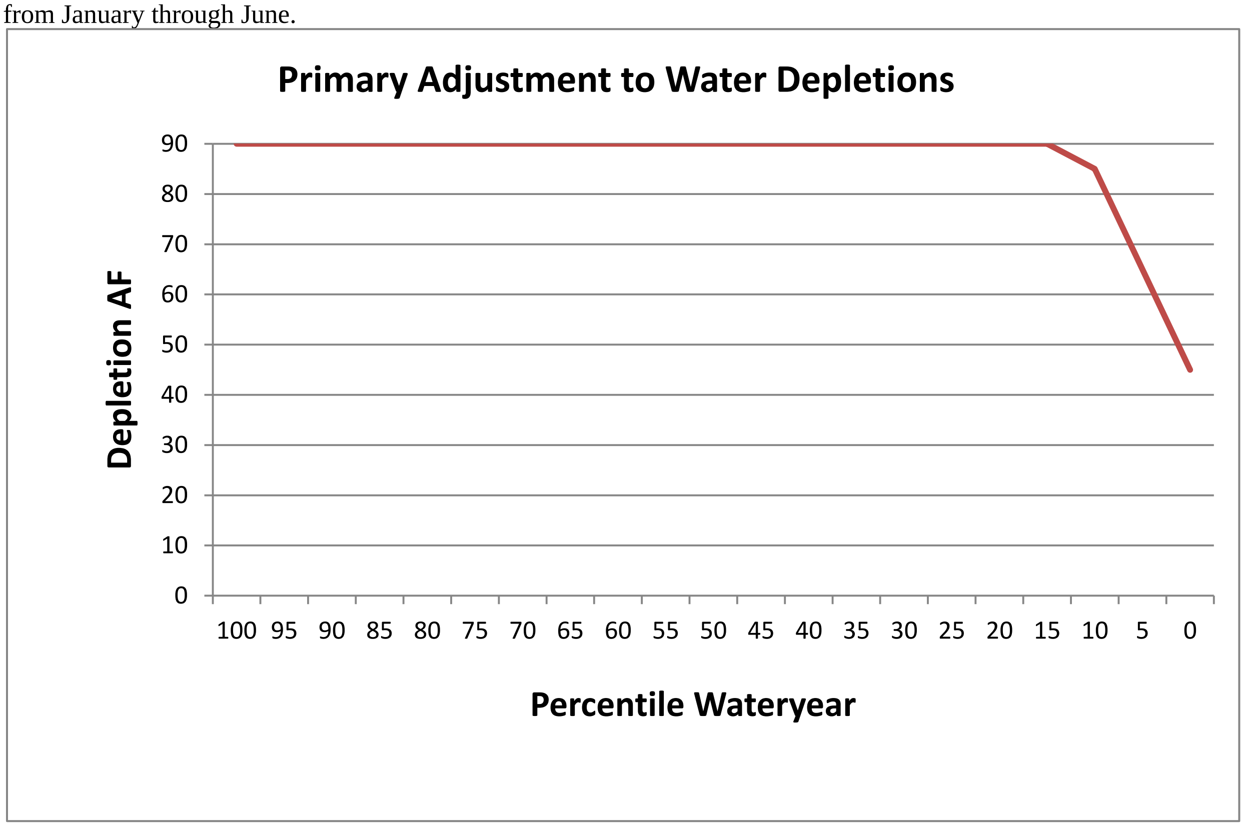
Operational Controls (Appendix B)

Biological impacts in Hungry Horse Reservoir can be reduced by 1) minimizing the depth of annual drawdown, 2) refilling to within 5 feet of full pool without creating a reduction in river discharges, 3) shaping reservoir refill to gradually fill and draft, so that maximal area of the shoreline substrate remains wet for more than 40 days during the biologically productive warm months July through September, 4) shaping water depletions during spring runoff to reduce demands during the basal, low flow period (e.g. store spring runoff for use during late summer and fall in off channel storage and/or aquifer injections), 5) or spreading depletions over a longer period (e.g. May–Oct period) to achieve 2-4 above, and 6) by standardizing the timing and volume of water depletions each year, as well as possible, to facilitate planning.

The first level or "primary" adjustment to annual water depletions can be accomplished using monthly water supply forecasts. Further "secondary" adjustments are required to respond to inflow forecasting error (over- or under-predictions). Secondary adjustments can be fine tuned using real-time observations of water supply and actual reservoir elevations. Implementation of these adjustments can be achieved using computer simulations and "flow enveloping", a procedure that compares forecasted inflows with observed inflows to estimate the amount of runoff expected after a given date. For example, if the May 1st forecast for the period April 1 -August 31 is 1.5 MAF and 0.5 MAF flowed into the reservoir during April, the remaining 1.0 MAF can be reasonably expected to flow into the reservoir during May through August. Flow enveloping is useful for predicting reservoir refill probability, or the maximum summer elevation that can be achieved by differing dam discharge scenarios.

Trigger points for adjustments are continuous, on a sliding scale, to avoid any large incremental jumps when inflow forecasts approach various thresholds, such as the 15th percentile transition point. The primary adjustment, based on inflow forecasts, would begin to curtail releases to less than 90 KAF during the driest 15th percentile water years (Figure 2). No primary adjustment to water depletions is necessary during the highest 85th percentile water years, unless the reservoir pool is at a deficit (lower than expected due to water depletions in previous years, forecasting error etc.).

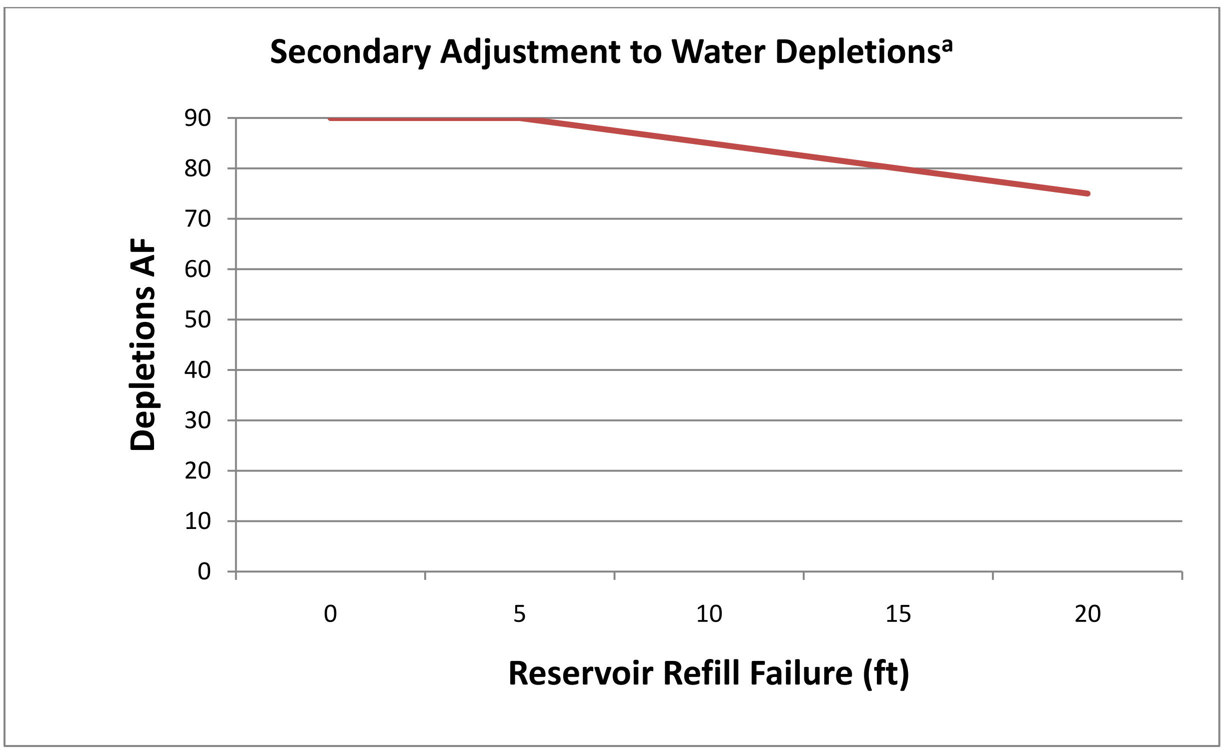
Figure 2. Primary adjustment to the depletion volume based on monthly inflow forecasts to Hungry Horse Reservoir during the period April 1 through August 31. Inflow forecasts become available during the first week of each month from January through June.



Dam operators will need to make the primary adjustment each month as inflow forecasts become available. Additional adjustments could be made in half-month increments using "early bird" forecasts. The primary adjustment would begin when the inflow forecast for Hungry Horse Reservoir during the period April 1 through August 31 declines to the lower 15th percentile water years. Downward adjustments to water depletions would initially be subtle as water supply decreased from the lowest 15th percentile toward extreme drought (lowest 10th percentile). During severe drought (lowest 5th percentile), depletions would reduce linearly from 90 KAF at the 15th percentile to 85 KAF at the 10th percentile then linearly to 45 KAF when the water supply approaches the lowest inflow volume on record.

Secondary adjustments would be made based on real-time observations of water supply and reservoir elevations, and would curtail releases based on the difference in reservoir elevation as compared to the Base Case. A secondary adjustment would be made weekly, based on observed inflows and reservoir elevations. During the period April 1 through July 31, if actual inflows are greater than predicted, or the reservoir elevation is at or above the end-of month target, the primary adjustment could be relaxed proportionally until any surplus is exhausted. Ramping rates should be followed to avoid sudden changes in dam discharge or short-term flow reductions. Conversely, if flow enveloping indicates that the reservoir will fail to refill by greater than 5 feet from full pool during late June or July, water depletions would be no greater than 85 KAF volume. This secondary downward adjustment would further reduce depletions linearly from 85 to 80 KAF when refill failure exceeds 15 feet. If the predicted reservoir refill failure would be greater than 20 feet below full pool, depletions would be further reduced linearly to 75 KAF (Figure 3).

Figure 3. Secondary adjustment to the depletion volume based on the difference between the observed Hungry Horse Reservoir pool elevation and the Base Case elevation. This figure pertains to the period January through August (footnote a).



From July through the remainder of the water year, dam operators rely on observed conditions, as opposed to inflow forecasts. River discharges should remain stable or gradually declining during the biologically productive warm months. By October, dam discharges typically begin to increase to meet heightened electrical demand as weather cools. Also, Hungry Horse Dam has a 10-foot fall draft target to avoid potential spill during a winter storm or thaw. Adjustments to water depletions during September through December would be based on the end of September draft target (i.e. the BiOp target of 10 feet from full pool when water supply is in the top 80^{th} percentile at The Dalles and 20 feet during the lowest 20^{th} percentile drought years). Similar to the secondary adjustment above, water depletions during August through October would be adjusted downward proportionally to the observed deviation from elevation targets established for the base case (Figure 4).

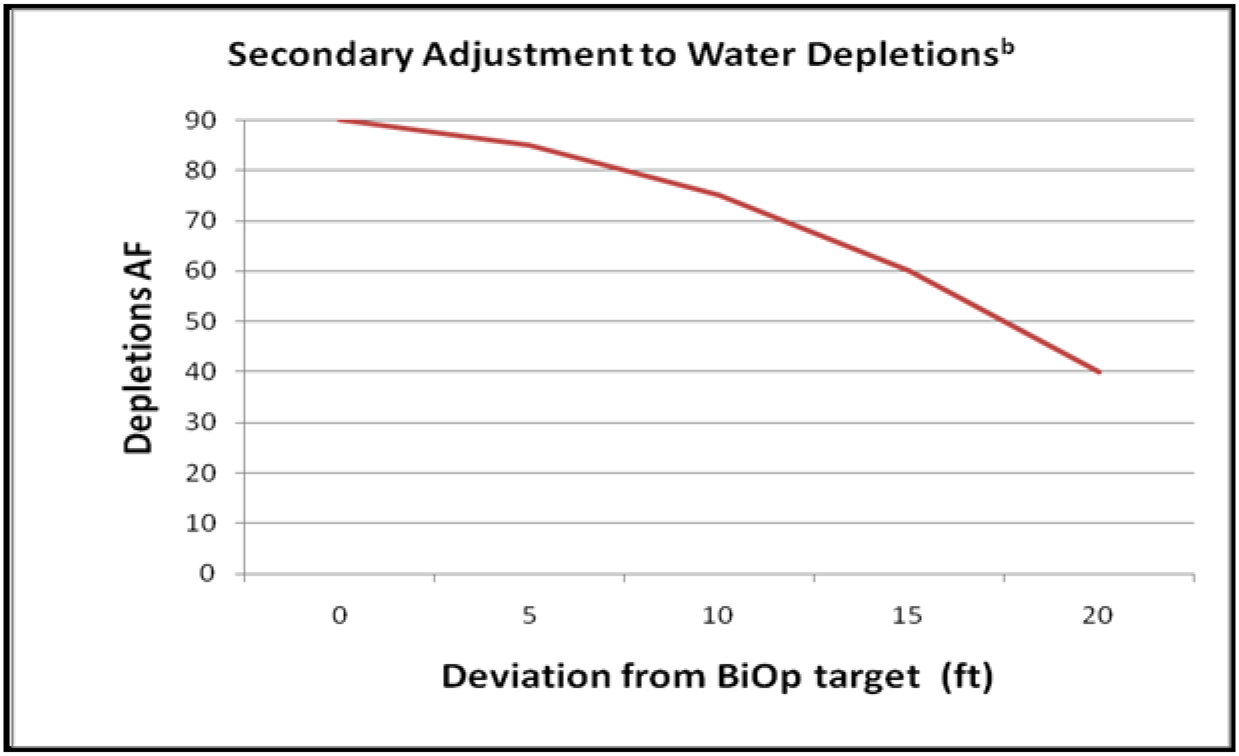
Avoid Short-term Flow Reductions in the Flathead River

There are additional factors that should be considered when shaping the schedule of the 90 KAF releases as well. When streamflow decreases, aquatic life may become stranded in the dry area and die. This impact can occur rapidly (in about 1 day) when the weather is hot and dry or freezing, or in 2-5 days when weather is temperate and moist. The river biota is “reset” to the lowest river stage, and recovery takes about 40 days after flow increases again. This can eliminate nearly half of Montana’s short, three-month season of biological growth in aquatic systems. Thus it is critical to avoid significant sudden decreases to river flow levels.

Channel Maintenance Flows Should Occur Every Two to Three Years

Before Hungry Horse dam began regulating Flathead River flows, river beds and banks were flushed of fine sediments and cleaned once per year during the spring freshet (late May through early June). Clean gravels are needed for spawning, security cover for young fish and for fish food production. The space between gravels and cobbles provides habitat needed by aquatic insects (fish food). This habitat is lost when gravels and cobbles fill in with fine sediment. To maintain the river channel and clean the stream bed, river flow should rise to bank full capacity for at least 48 hours every two to three years. Intermittent pulsing of river flows can wash fine sediments back into the channel, because vegetation cannot reclaim the shoreline each year after the spring freshet. Stabilizing river flows to mimic a more natural annual hydrographs allows riparian vegetation to stabilize the streambanks and hold fine sediments deposited on the shore during the spring freshet.

Figure 4. Secondary adjustment to the depletion volume based on the difference between the observed Hungry Horse Reservoir pool elevation and the end of September draft target elevation (to 3550 in the highest 80th percentile wateryears and 3540 during the driest 20th percentile). This figure pertains to the period September through December (footnote b).



References

Bureau of Reclamation (BoR). 2010 (April). Draft Flathead Basin tribal depletions study. U.S. Department of Interior, BoR, Pacific Northwest Region, Boise, ID.

Christenson, D, R. Sund, R, Christensen, J. Kubitschek, C. Morell, and B. Marotz. 1995. Hungry Horse Withdrawal System. United States Committee on Large Dams. 1995(108): 12-13.

Christenson D.J., R.L. Sund, and B.L. Marotz. 1996. Hungry Horse Dam's successful selective withdrawal system. Hydro Review 15(3):10-15.

ISAB. 1997. The Normative River. Independent Scientific Advisory Board report to the Northwest Power Planning Council and National Marine Fisheries Service. Portland, OR.

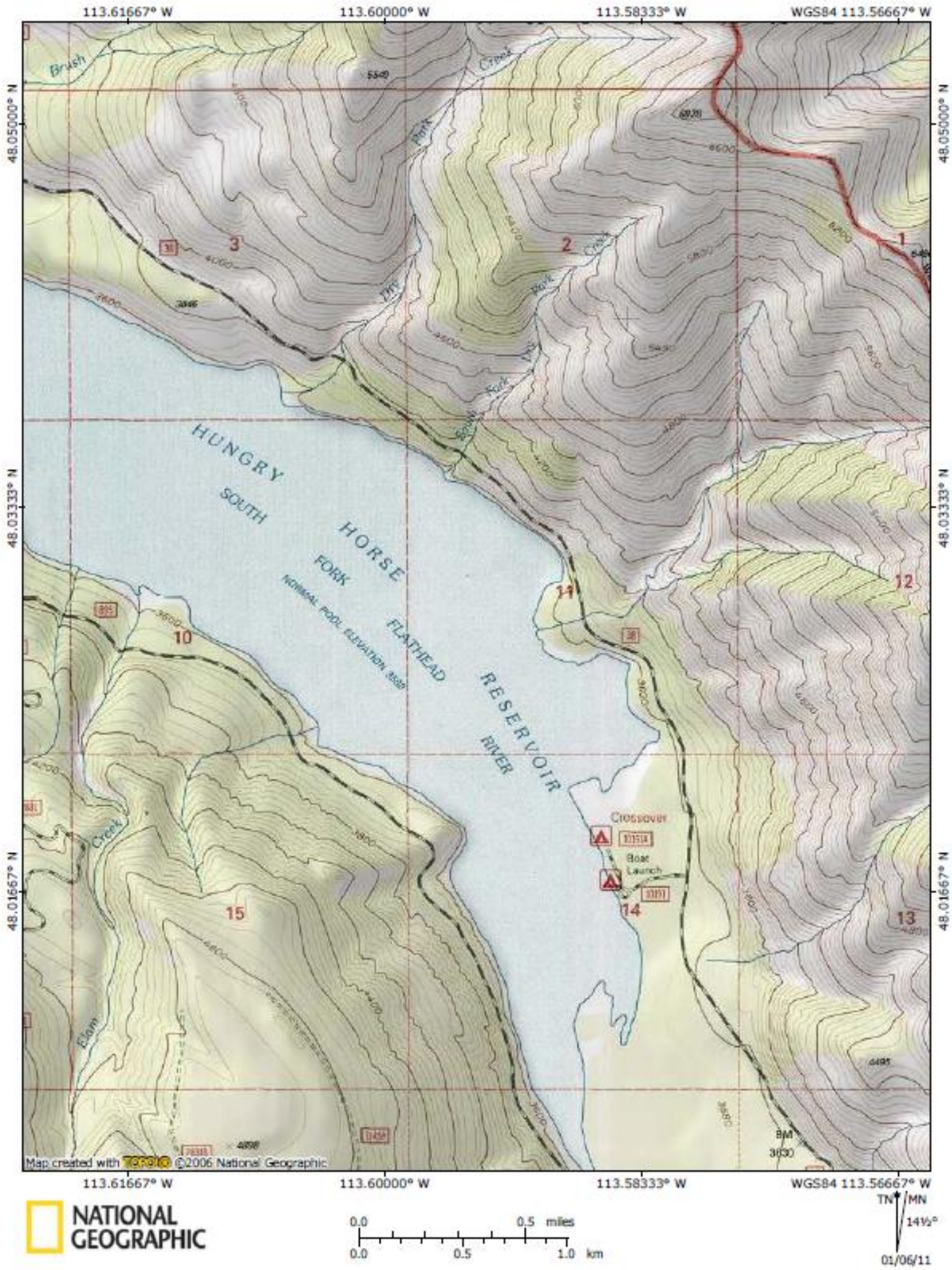
ISAB. 1997b. Ecological impacts of the flow provisions of the Biological Opinion for endangered Snake River salmon on resident fishes in the Hungry Horse, and Libby systems in Montana, Idaho, and British Columbia. Independent Scientific Advisory Board. Report 97-3 for the Northwest Power Planning Council and National Marine Fisheries Service. Portland, OR.

Marotz, B., D. Gustafson, C. Althen, and B. Lonon. 1996. Model development to establish Integrated Operation Rule Curves for Hungry Horse and Libby reservoirs, Montana. Montana Fish, Wildlife & Parks report to Bonneville Power Administration, Portland, OR DOE/BP-92452-1. 114 p.

Marotz, B. and C. Muhlfeld. 2000. Evaluation of Minimum Flow Requirements in the South Fork Flathead River Downstream of Hungry Horse Dam, Montana. Bonneville Power Administration contract 92 BI 60559, project 19-19-3. Montana Fish, Wildlife & Parks, Kalispell.

NOAA-Fisheries. 2008. Federal Columbia River Power System Biological Opinion, Chapter 15 RPAs Hydropower Strategy 1. National Oceanic and Atmospheric Administration Fisheries Service.

Appendix A: Map of the SE portion of Hungry Horse Reservoir



Appendix B: Reservoir Release Rules Based on Water Year

Water Supply Condition	**Primary Adjustment** Based on monthly inflow forecasts available from January to June, for the period April 1 through August 31	**Secondary Adjustment** Based on real time observations of actual water supply and reservoir elevations	
		January - August	September - December
Highest 50th Percentile	none	Water supply and/or reservoir elevation higher than predicted; no adjustment	Reservoir elevation higher than predicted; no adjustment
		Water supply and/or reservoir elevation lower than predicted; reduce depletions based on sliding scale [a]	Reservoir elevation lower than NOAA-Fisheries BiOp; reduce depletions based on sliding scale [b]
<50th to 20th Percentile	Linear reduction in water depletion from 0% during average WY to 50% less at 20th Percentile	Water supply and/or reservoir elevation higher than predicted; relax reduction until surplus is exhausted	Reservoir elevations higher than predicted; relax reduction until end-of-month elevation target is achieved.
		Water supply and/or reservoir elevation lower than predicted; reduce depletions based on sliding scale [a]	Reservoir elevation lower than NOAA-Fisheries BiOp; reduce depletions based on sliding scale [b]
Lowest 20th Drought	Linear reduction in water depletion from 50% at 20th Percentile to 25% when water supply is the lowest on record	Water supply and/or reservoir elevation higher than predicted; relax reduction until surplus is exhausted	Reservoir elevation higher than predicted; maintain primary adjustment
		Water supply and/or reservoir elevation lower than predicted; reduce depletions to 25%	Reservoir elevation lower than called for by NOAA-Fisheries BiOp; reduce depletions to 25%

a – Sliding scale is based on reservoir refill elevation. Refill failure >5 ft, reduce depletion to 85 KAF; >10 ft, reduce depletion to 80 KAF; >20 ft, reduce depletion to 75 KAF. This could be described as a continuous formula.
b – Sliding scale is based on reservoir elevations, relative to the Base Case. NOAA-Fisheries BiOp drafts Hungry Horse Reservoir 10 to 20 ft from full pool by the end of September depending on water supply at The Dalles. Reservoir drawdown is then controlled by draft targets for electric generation and flood risk management. Adjustments to water depletions are based on the degree of deviation from the Base Case drawdown trajectory, >5 ft, reduce depletion to 85 KAF; >10 ft, reduce depletion to 80 KAF; >20 ft, reduce depletion to 45 KAF. This could be described as a continuous formula