Part 1: Analysis of Sufficiency of the PacifiCorp Klamath Hydroelectric Project Final License Application With Regard to Project Water Quality Impacts

PacifiCorp filed its *Final License Application for the Klamath River Hydroelectric Project* (FLA) on February 25, 2004. At the request of the Klamath Basin Tribal Water Quality Work Group (Work Group), whose members include the Yurok, Hoopa, Karuk, Quartz Valley and Resighini Tribes, a team of specialists assembled by Kier Associates reviewed sections of the FLA relevant to water quality. The sections reviewed include Exhibits E3 - Water Use and Quality, portions of E4 - Fish Resources, Water Resources Final Technical Reports 2 - Compilation and Assessment of Existing Water Quality, Water Resources FTR 3 - Monitoring of Water Temperature and Water Quality Conditions in the Project Area, and Water Resources FTR 4 - Development of Water Quality Analysis and Modeling Framework.

The water quality review team encountered a number of deficiencies in the FLA regarding the degree to which it addresses the impact of the development and operation of the Project on Klamath River water quality. The following are some of the water quality deficiencies in the FLA identified by the team:

1. Failure to take a long-term view of the impact the Project may be having on Klamath River water quality and to recognize the cumulative effects that appear to be occurring in the mainstem Klamath River

2. Insufficient consideration of water quality problems below Iron Gate Reservoir that may be related to Project operation.

3. A decision to remove Keno Dam from the Project license may impair water quality recovery in the Project and downstream

4. A lack of detailed analysis of water quality data

5. A lack of attention to and quantification of nutrient cycling processes

6. Incomplete use of the models necessary to understand water quality problems other than dissolved oxygen and temperature

The additional studies requested to address these deficiencies are described in detail in Part 2.

1. Lack of Long-Term Perspective and Recognition of Cumulative Effects

The PacifiCorp FLA is narrow in its scope and it lacks sufficient long-term vision or history to satisfy questions raised by the Klamath Basin Tribes and their Water Quality Work Group. The Tribes involved in the Work Group have lived in the Klamath River basin and relied on its salmon and other fish for subsistence for over 10,000 years, giving them a longer-term view of conditions in the basin. When the Project last received a license in 1956, salmon and steelhead were still abundant (Coots, 1967). Spring chinook and coho salmon that returned each year to the reaches above Iron Gate were lost to the development of PacfiCorp's Iron Gate Dam (Kier Associates, 1991).

PacifiCorp has addressed relicensing from a business as usual perspective. Hare et al. (1998) point out that the Pacific Ocean alternates roughly every 25 years from rich ocean conditions off northern California, Oregon and Washington to poor conditions, with areas off Alaska showing the opposite trend. A recent science assessment prepared for the North Coast Regional Water Quality Control Board (NCRWQCB, ISRP, 2003) points out that if fresh water habitats are not improved by 2015-2020, when ocean conditions upon which Klamath River salmon depend will once again oscillate, strong salmon stocks may become endangered and weaker stocks will go extinct. That period is less than mid-way through the next Project license period, should the Project be re-licensed. The further loss of Pacific salmon stocks threatens the existence of the Tribes; therefore, the *urgency* of improving conditions before 2015-2020 needs to be acknowledged and addressed by PacifiCorp and the Federal Energy Regulatory Commission (FERC).

Both the National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) require that appropriate consideration be given to adverse environmental effects of a regulated action (in this case, the relicensing of the Klamath Hydroelectric Project) which may be cumulative in nature. The following sections of this analysis detail the failure of PacifiCorp's FLA to address such cumulative effects, as required by these laws.

2. Mainstem Klamath River Water Quality Problems Below Iron Gate

PacifiCorp fails to document the acute water quality problems of the mainstem Klamath River below Iron Gate Reservoir, particularly those below Seiad Valley, despite the fact that their operations appear to be a contributing factor. The Klamath River is experiencing major fish kills of juvenile (Halstead, 1997) and adult Pacific salmon species (CDFG, 2003; Guillen, 2003) and the river is on the verge of ecological collapse (Kier Associates, 1999). Stressors are indicative of advanced cumulative effects related to logging, agricultural diversion and run-off, impoundment, grazing, past mining and riparian removal (Kier Associates, 1999; NAS, 2003).

The discussion of water quality problems in the mainstem Klamath River below Iron Gate is split into two parts here:

a. Nutrients and dissolved oxygen
b. Water temperature

A. Nutrients, pH and Dissolved Oxygen

The NCRWQCB coordinated a water quality reconnaissance of the mainstem Klamath River and many of its tributaries in 1996 and 1997. Those data show a maximum pH of 9.6 in the Klamath River just above the Scott River (Figure 1). These high pH values likely result from algae blooms, with algal photosynthesis creating alkaline conditions during the day. Ammonium (NH_4^+) changes to the lethal un-ionized form of ammonia (NH_3) in conditions of high water temperatures and high pHs (Goldman and Horne, 1983). At a pH of over 8.5, much of the ammonia is in the form of un-ionized ammonia, which is highly toxic to fish (U.S. EPA, 1986). A question that should be answered by PacifiCorp and FERC when considering relicensing is whether Project operations are contributing to the nutrient richness of water being released from Iron Gate Reservoir. A related question is how such potentially nutrient-rich releases might be related to high pH and other adverse water quality conditions downstream. (Figure 1).

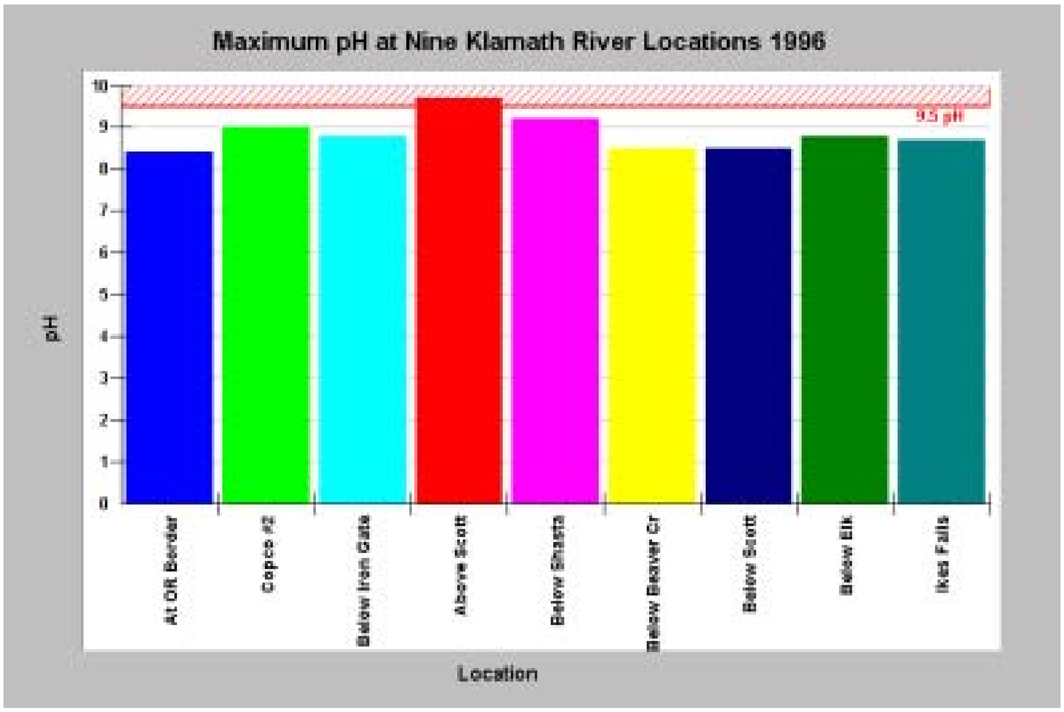

Figure 1. This chart shows pH values at nine Klamath River locations in 1996. Data from the NCRWQCB's water quality reconnaissance study. Chart from the Klamath Resource Information System (KRIS v 3.0).

Excessive algae growth in the Klamath River has been implicated in causing lethal nighttime sags in dissolved oxygen (D.O.) (Kier Associates, 1999). Figure 2 shows that at 3 a.m. on August 10, 1997, the U.S. Fish and Wildlife Service measured a D.O. value of 3.1 ppm at Big Bar on the Klamath River below Orleans (Halstead, 1997). This low D.O. is in the range of severely stressful or lethal for salmonids (Davis, 1975; Deas and Orlab, 1996). At the time of the USFWS water quality testing, juvenile salmonids and even more resilient fish species such as suckers and dace, were observed succumbing to disease and dying (Halstead, 1997). These D.O. sags were almost certainly related to nocturnal algal respiration, either by attached algae (Halstead, 1997) or by algae entrained in the water column (Kier Associates, 1999). The frequency of these low D.O. events in the Klamath River is unknown, but conditions during the day measured in 1996 and 1997 showed frequent day time supersaturated D.O conditions and elevated pH indicating high diurnal photosynthetic activity, which could create more nighttime sags.

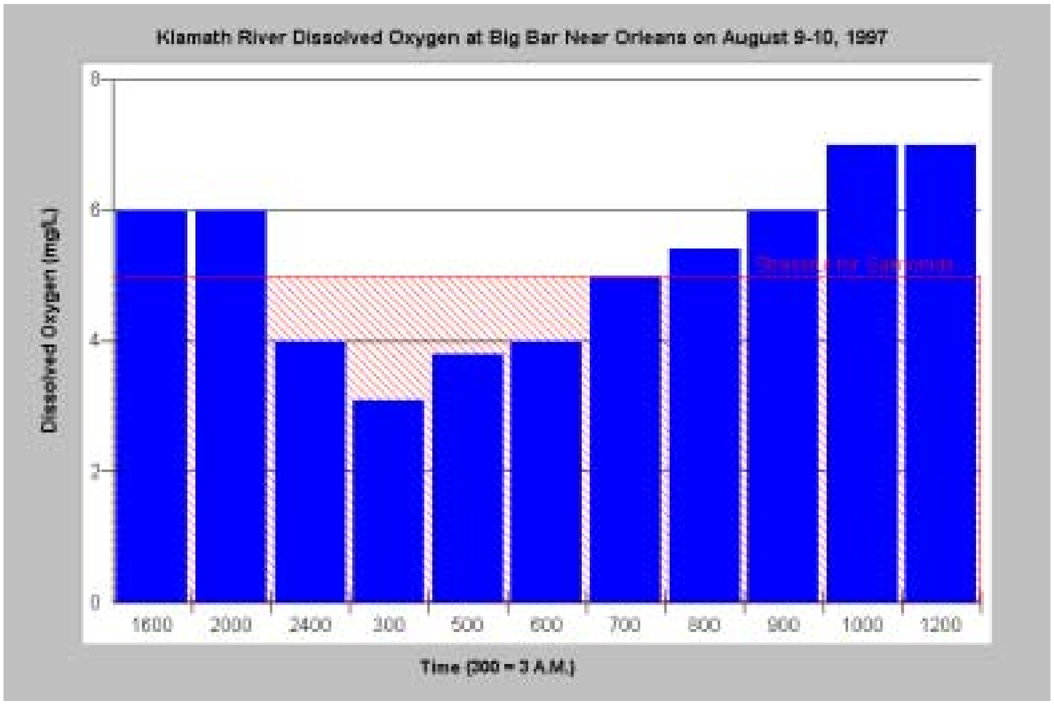

Figure 2. Dissolved oxygen of the mainstem Klamath River taken during the evening and night of August 9 and morning of August 10, 1997 at the Big Bar fish trap near Orleans by the U.S. Fish and Wildlife Service (Halstead, 1997). Chart from KRIS Version 3.0.

Water quality data collected on August 6, 1997, just prior to the fish kill and D.O. sag described above, show pulses of un-ionized ammonia in Project waters. Un-ionized ammonia levels were calculated by using temperature, pH and total ammonia. The NCRWQCB Section 104(b) data collected in the J.C. Boyle peaking reach above Shovel Creek showed a spike in un-ionized ammonia to 0.030 milligrams per liter. This value exceeds the 0.025 milligrams per liter recognized as lethal to fish life by the U.S. EPA (Winchester et al., 1995). Un-ionized ammonia increased substantially below Copco 2 (Figure 3) to 0.057 milligrams per liter, nearly double the amount above Shovel Creek. While un-ionized ammonia levels coming out of Iron Gate Reservoir dropped to levels similar to those above Shovel Creek, they were the highest measured in the 1997 season (Figure 4) and still above the U.S. EPA lethal threshold (Winchester et. al., 1995). The presence of this high level of un-ionized ammonia would be accompanied by an even greater quantity of ammonium, which would stimulate algae and plant growth in the Klamath River downstream.

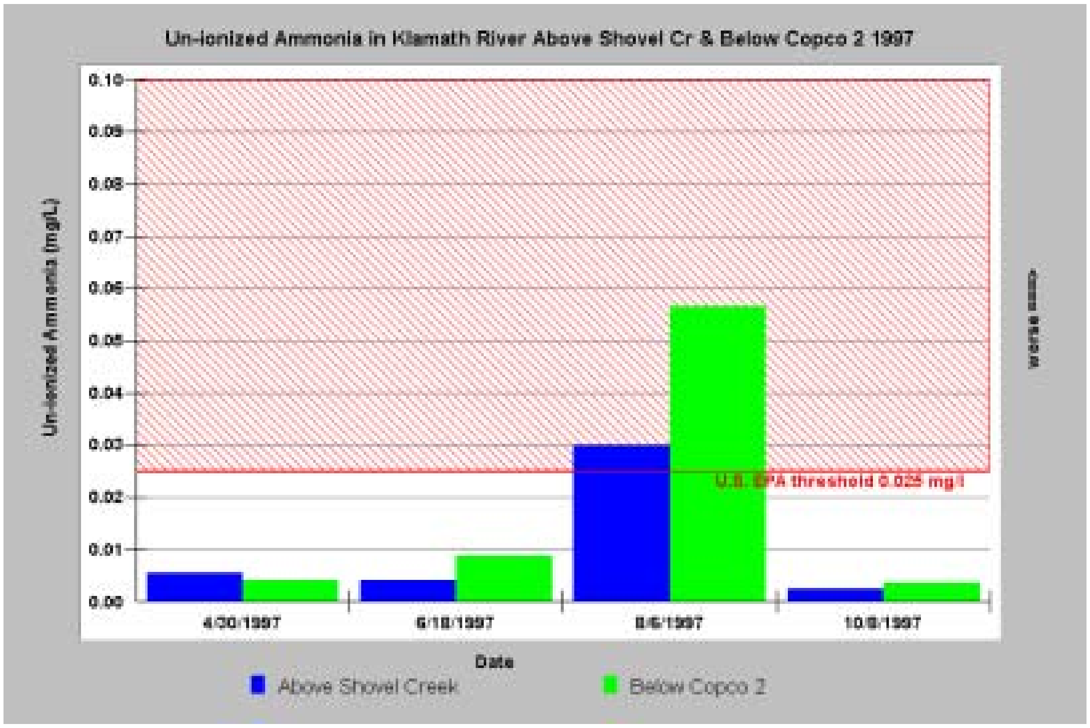

Figure 3. Un-ionized ammonia in the mainstem Klamath River during 1997 above Shovel Creek and below Copco 2 Reservoir shows an increase between the two locations, which was most pronounced on August 6, 1997. Data from the NCRWQCB Sect. 104(b) study.

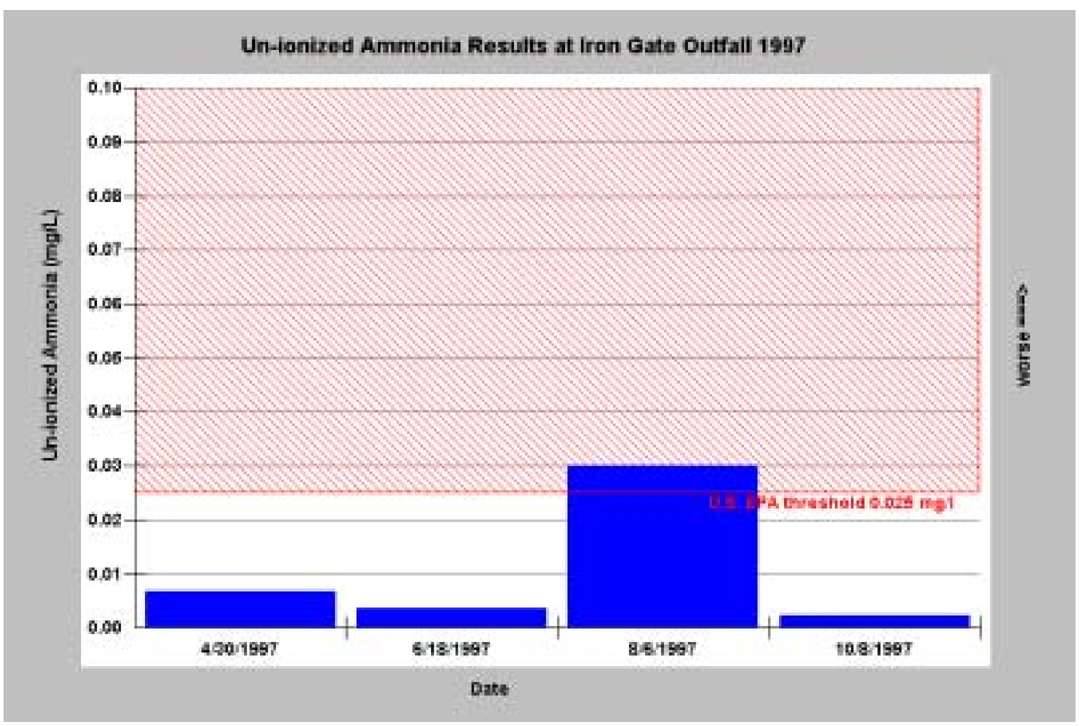

Figure 4. Un-ionized ammonia below Iron Gate Reservoir in 1997 was highest on August 6, 1997, just before a major fish kill downstream. Data from NCRWQCB Sect. 104(b) study.

As noted earlier, concentrations of the toxic form of ammonia increase at high pH and high temperature levels (Goldman and Horne, 1983). The pH conditions that caused the transformation of ammonia to un-ionized ammonia were likely caused by algae blooms, which increase pH levels during the day when algae are photosynthesizing. The peak in un-ionized ammonia at Iron Gate was roughly coincident with the adverse water quality conditions downstream at Orleans and the fish kill, suggesting a potential linkage that warrants further study. Project reservoirs may be contributing to these un-ionized ammonia peaks if they are fixing nitrogen and increasing pH and ammonia levels. These linkages with Project operations need to be evaluated (see Section 5C below).

High levels of unionized ammonia were also detected many miles below the Project. In June, 1997, an un-ionized ammonia level of over 0.050 milligrams per liter, more than two times the recognized lethal level, was measured upstream of Orleans at Ike's Falls. This means that it is likely that photosynthetic activity was high enough at that location to drive pH up to the level where ammonia converts to unionized ammonia, and it is an indication of major water quality issues for the Klamath River.

Water quality in the Klamath River is poor enough during the summer months that if the Project contributes even in a minor way to further degradation, it could result in significant impacts. Any increase in nutrients contributed by the Project would act with other nutrient and thermal loading sources to cumulatively impact the mainstem Klamath River by stimulating algae growth and degrading water quality, occasionally even to the point of being lethal to salmonids and other fish species.

B. Water Temperature

There is no assessment in the FLA of how the release of poor quality water from Iron Gate reservoir affects downstream salmonid habitat during different, critical life stages. The FLA acknowledges that due to its thermal mass, Iron Gate Dam releases cooler water to the mainstem Klamath in spring, and warmer water in late summer and fall than would exist absent the Project (FLA E3-206), but there is no analysis of the impact that these thermals alterations attributable to the Project are having on the growth and survival of the river's salmon and other resources.

The Project decreases water temperature in the spring and summer by at least 5° C, and increases the temperature by at least 5° C during the late summer and autumn. Due to variations in weather, the timing and magnitude of temperature variation will vary from year to year. The differences between temperatures with and without the Project are shown in Figure 5, from Kanz (2004). The Yurok Tribe also made this point in their comments on the Draft License Agreement (FLA, E-1A Appendix B Second Stage - 109).

Given that these stream temperature alterations are the Project's single greatest documented impact on water quality, the FLA should have explained their significance for the health of the river.

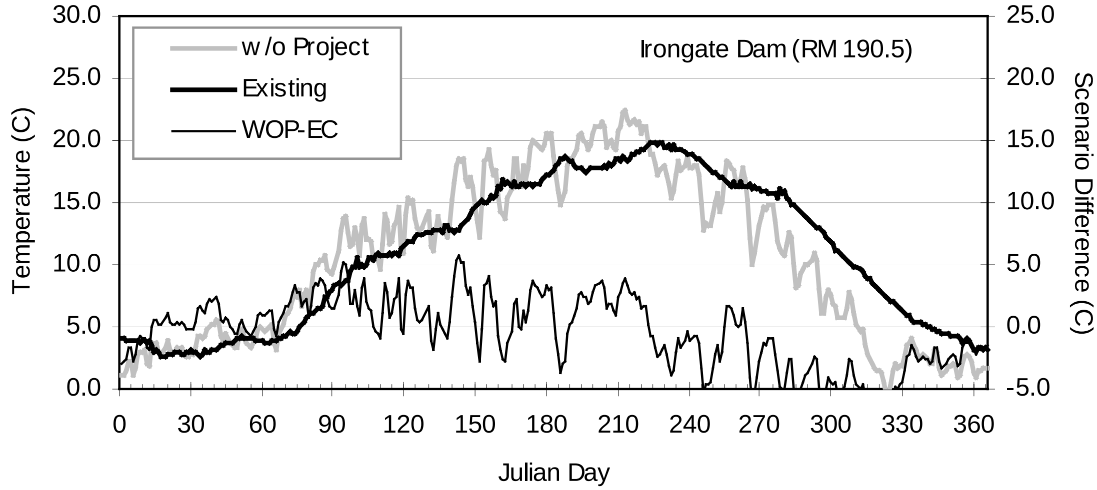

Figure 5. Results from the Water Course Engineering model showing a comparison of water temperatures below Iron Gate with and without the Project, and the difference between the two. Chart from Kanz (2004).

Warmer water temperatures in late summer and fall affect fall run chinook salmon that are arriving to spawn in reaches of the Klamath River below Iron Gate Dam. Bell (1986) states that preferred spawning temperatures are between 5.6-17.2 °C, which is exceeded below Iron Gate well into September. National Marine Fisheries Service (1996) characterized properly functioning conditions for adult Pacific salmon as between 10-13.9° C and temperatures from 13.9 to 15.5° C as "at risk." McCullough (1999) noted that egg size and development was substantially altered when adults were exposed to temperatures over 17.5° C.

Since the construction of Iron Gate dam, there has been a shift in the timing of the fall chinook spawning run possible due to the Project's impact on river temperatures (Michael Belchik, pers. comm.). Compression of the run timing of fall chinook not only makes fish more vulnerable to harvest but may also cause higher densities in the stream as they join later-running Trinity River fish in the lower Klamath River. High concentrations of salmon in combination with high water temperatures are thought to have contributed to the September 2002 fish kill (CDFG, 2003 and Guillen, 2003).

The egg stage is the most temperature-sensitive salmonid life history stage (Hicks 2000). Reiser and Bjornn (1979) defined optimum temperatures for salmon and steelhead egg incubation as 4.4-14.4^{o}C, which is exceeded well into September below Iron Gate. Eggs laid in the Klamath River below Iron Gate at higher than optimal conditions are likely to have higher pre-hatch mortality and a greater rate of developmental abnormalities and lower weight as alevins (McCullough, 1999).

Warmer water temperatures through December would then accelerate hatching and alevin emergence. Project-impaired stream temperatures in January, however, drop below those which would occur absent the Project. McCullough (1999) notes that optimal growth temperatures for chinook salmon are between 10-15.6 ^{o}C, while Klamath River temperatures at Iron Gate Dam remain below 5 ^{o}C through mid-February and continue to be below optimum levels into March.

It is likely that juvenile fall chinook salmon emerging from the gravel early and then having to withstand Project-depressed stream temperatures and related depressed food production experience slower growth and a decreased rate of survival.

Although PacifiCorp did model water quality in the mainstem Klamath from Iron Gate Dam to the mouth, there are problems with the model. These issues with the modeling runs are discussed in the section of this memorandum titled “Water Quality Modeling Effort is Incomplete”.

3. Keno / Lake Ewauna

PacifiCorp’s decision to remove Keno dam from the Project relicensing application may impair water quality recovery in the Project if it results in Keno dam remaining in place, because the dam decreases dissolved oxygen and increases nitrogen levels. The impacts of the Keno dam on water quality need to be fully investigated and quantified so that the costs and benefits of its continued existence or decommissioning can be weighed.

Had the Keno dam remained in the Project license and under FERC jurisdiction, that analysis would likely have occurred and dam removal would likely have been considered. Now that PacifiCorp has attempted to remove Keno dam from the Project license, the dam has become the subject of an undetermined consultation process involving the State of Oregon.

Keno reservoir has the worst water quality of all Project reservoirs. On page E3-128 of the FLA, PacifiCorp states:

> “The invertebrate community of Lake Ewauna/Keno reservoir displayed a number of distinct characteristics indicative of more stressed conditions than the other reservoirs. Although possessing greater invertebrate abundance (but not of mollusks), diversity was low and the community was dominated by only a few species… Lake Ewauna/Keno reservoir has highly enriched conditions, excessive algae growth, and summertime depletion of dissolved oxygen”

Aside from nutrient and algae inputs from Upper Klamath Lake, one reason for the poor water quality is that Lake Ewauna / Keno Reservoir provides ideal conditions for blooms of *Aphanizomenon flos-aquae*, a blue-green algae discussed in detail in section 5, which adds nitrogen to water. Chlorophyll *a* concentrations average between 20 and 40 micrograms per liter, and can be as high as 300 micrograms per liter (FLA E3-89).

Even though Keno reservoir is shallow and does not often stratify, dissolved oxygen (D.O.) levels in it are low during the summer months. The 1950-2001 historical data presented in the FLA show that many sites have had D.O. readings at or near zero (Water Resources FTR – App. 2C-29).

The FLA contains no mention of fish kills occurring in Keno reservoir, but at least one substantial fish kill there has been documented (Smith, 1998). On July 27, 1998 dead fish were observed by a Keno resident. On July 31 and August 1, USFWS and Oregon Department of Fish and Wildlife personnel investigated and discovered approximately 50,000 dead tui chub and "some yellow and Sacramento perch as well as two dead suckers". On July 31, D.O. measurements of zero ppm were taken near Columbia Plywood and 2 ppm in the Keno area, indicating that lack of oxygen was likely the cause of death.

4. Lack of Detailed Analysis of Water Quality Data

PacifiCorp has made a large effort on data assimilation and presentation, however, the FLA lacks comprehensive data synthesis and analysis. Much of the data summaries presented are lumping multiple time periods together. For example, Water Resources FTR Appendix 2C presents box plots that combine data for the years 1950-2001. Such summaries are useful for getting an idea of the ranges of values that have been measured at various locations, but to really understand the dynamics and processes occurring in the Project more specific analyses and summaries must be conducted.

Although PacifiCorp does an excellent job of presenting seasonal variations of water quality at a range of depths in Project reservoirs for recent years, an analysis of seasonal variation in river reaches is notably absent. Looking at seasonal variation in data is the key to understanding and quantifying the nutrient cycling processes occurring in the system (see next section of this analysis for more information). Most valuable would be a look at seasonal variations in the quality of the inflow and outflow of each Project reservoir.

If sufficient data for such an analysis does not exist, it needs to be collected.

5. Lack of Quantification of Water Quality Processes

Quantifying the relevant river and reservoir processes is essential to understanding the impacts of the Project on water quality. The reason for this was well-stated by the Klamath Tribes of Oregon in their comments on the Draft License Application (FLA E-1A Appendix B Second Stage - 42):

> "The Klamath Tribes request that the assimilative capacity of the Klamath River be quantified in a manner that clearly compares its present assimilative capacity with that of a series of alternative Project configurations involving removal of mainstem dams. We need to understand the incremental changes in assimilative capacity as individual Project components are removed, and the resulting impacts on water quality within and below the KHP in order to understand Project impacts and to develop our recommended PME's." (Protection, Mitigation, and Enhancement measures)

PacifiCorp responded to this request in the FLA (E-1A Appendix B Second Stage - 42) by stating that quantifying the assimilative capacity of the river was the responsibility of the State-federal Total Maximum Daily Load planning process. The TMDL process is currently underway for the mainstem Klamath River from Link River dam to the Pacific Ocean, but is not expected to be released in draft form until December 2005. PacifiCorp's Klamath Project FERC license expires only weeks later, in March 2006. Because the TMDL will not be released in time for full consideration of nutrient questions, PacifiCorp should be required to conduct such an assimilative capacity study, or the FERC's relicensing EIS should be postponed until after the mainstem Klamath TMDL is complete.

In its analysis, PacifiCorp treats the Project like a black box, focusing more on inputs and outputs than on quantifying processes taking place inside the system. PacifiCorp claims that the Project has a net benefit on the Klamath River. It supports this claim by simply stating that water quality entering the Project is better than water quality leaving the Project. This approach is deficient, because it answers the wrong question. To understand the impacts of the Project on water quality, the question that PacifiCorp should have attempted to answer in the FLA is not "Is current water quality outflow from the Project better than current water quality upstream?" but "*How does water quality in the Project area and downstream of the Project area compare to what the water quality would be in those same areas under a variety of Project and no-Project options?*"

Just because water quality exiting the Project is better than Project inflow does not mean that the Project has no impact on water quality. Project operations could very well be delaying water quality recovery. The water quality in the Klamath River should improve naturally as it flows downstream, due to freshwater inflows and the capacity of the system to assimilate nutrients. The rate at which that assimilation occurs may be altered by the Project. To understand the impacts of the Project the relevant processes must be understood and quantified. Several processes impact how the quality of the water changes as it flows downstream, including:

c. Dilution
d. Nutrient cycling in reservoirs
e. Algae blooms in reservoirs, including nitrogen fixation
f. Assimilative capacity of periphyton in river reaches
g. Denitrification in river reaches

To have a thorough understanding of the impact of the Project on water quality, all of these processes need to be quantified and understood . The FLA deals with some of these processes, but not others. The ideal would be to have all these processes represented in a calibrated and verified model. Currently the model is neither calibrated nor verified for nutrients, so it cannot legitimately be used to evaluate Project impacts and options for reducing or eliminating nutrient impacts. Further comments on the modeling effort are presented below in Section six of this memorandum.

A. Dilution

Even if the river did not have a capacity to assimilate nutrients, the water quality would still improve as it flows through the Project due solely to dilution of low-quality Klamath River water with high-quality water from tributary and spring flow inputs. These inputs include springs in the J.C. Boyle bypass reach (225 cfs) and tributaries between Link River dam and Iron Gate dam. The tributaries are Spencer Creek (approximately 20 to 200 cfs), Shovel Creek (10 to 100 cfs), Fall Creek (30 to 100 cfs) and Jenny Creek (30 to 500 cfs), although Spencer, Shovel, and Jenny creeks all have irrigation diversions, so the actual quantity of water entering the Project may be less than stated here (FLA E3-20). The sum of these inputs ranges from 315 to 1125 cfs. Given that the Bureau of Reclamation (2003) *Klamath Irrigation Project Operations Plan* calls for low-flow summer releases from Iron Gate dam ranging from 515-1149 cfs depending on water year type (FLA E3-34), these inputs significantly improve water quality and may mask the Project's water quality-degrading effects.

B. Nutrient Cycling in Reservoirs

PacifiCorp claims that the Project reservoirs have a net beneficial effect on nutrient levels below Iron Gate Reservoir. On page E3-215 of the FLA, PacifiCorp states that:

> "…reservoirs are more effective than the river in retaining organic matter, especially particulate forms, and nutrients delivered from Upper Klamath Lake and the Klamath Irrigation Project. Retention of organic matter and nutrients in the reservoirs results in periodic seasonal blooms of planktonic algae and contributes to low dissolved oxygen below the thermocline. This results in a net decrease in organic matter and nutrients that would otherwise continue downstream and contribute to increased algae growth in the Lower Klamath River."

This claim may or may not be true. PacifiCorp offers little data or documentation to support it. No attempt is made to quantify this effect and weigh it against other processes operating in the reservoirs. Clearly, the reservoirs must have an impact on nutrient cycling in the system because they increase hydraulic residence time and allow particulates to settle out.

Nutrients may not be locked in the reservoir sediments forever, they may just be temporarily delayed. The reservoirs may not be nutrient sinks, but merely affecting the timing of nutrient movement through the system. For example, during the periods of low dissolved oxygen in the hypolimnion of Copco and Iron Gate, nitrate is reduced to ammonia, and phosphate is released from the sediments (FLA E3-108), resulting in relatively high levels of ammonia and orthophosphate. During this time, ammonia levels in reservoir outflows are higher than reservoir inflows (Figure 6). Although Boyle does not stratify, it also increases ammonia levels (Figure 7). The density gradient in Iron Gate and Copco decreases and the reservoirs become isothermal around mid-November (FLA

E3-103). There are several critical questions that need to be answered before the impacts of the Project on water quality can be accurately assessed:

- Are sampling plans focused on catching key events such as lake turnover?
- Where do the ammonia and phosphate end up?
- Are pulses of nutrient-rich water being flushed downstream?
- If such pulses occur, what are the effects on downstream water quality and aquatic resources?

The way to examine if such events occur is to conduct more detailed analysis than is presented in the FLA, such as comparing inflow quality for each reservoir with outflow quality over time (see Section 4 of this memorandum). The water quality grab samples taken by PacifiCorp may not be extensive enough to detect nutrient pulses. Existing water quality data show evidence of a pulse of phosphorus being released from Iron Gate and Copco reservoirs after the breakdown of stratification in November 2002 (Figure 8). The lowest levels of phosphorus are at the end of the J.C. Boyle bypass reach (KR u/s JCB PH) where spring water is diluting Klamath River water. Downstream of the bypass reach, phosphorus levels climb steadily, suggesting that phosphorus is being released from Iron Gate and Copco reservoirs.

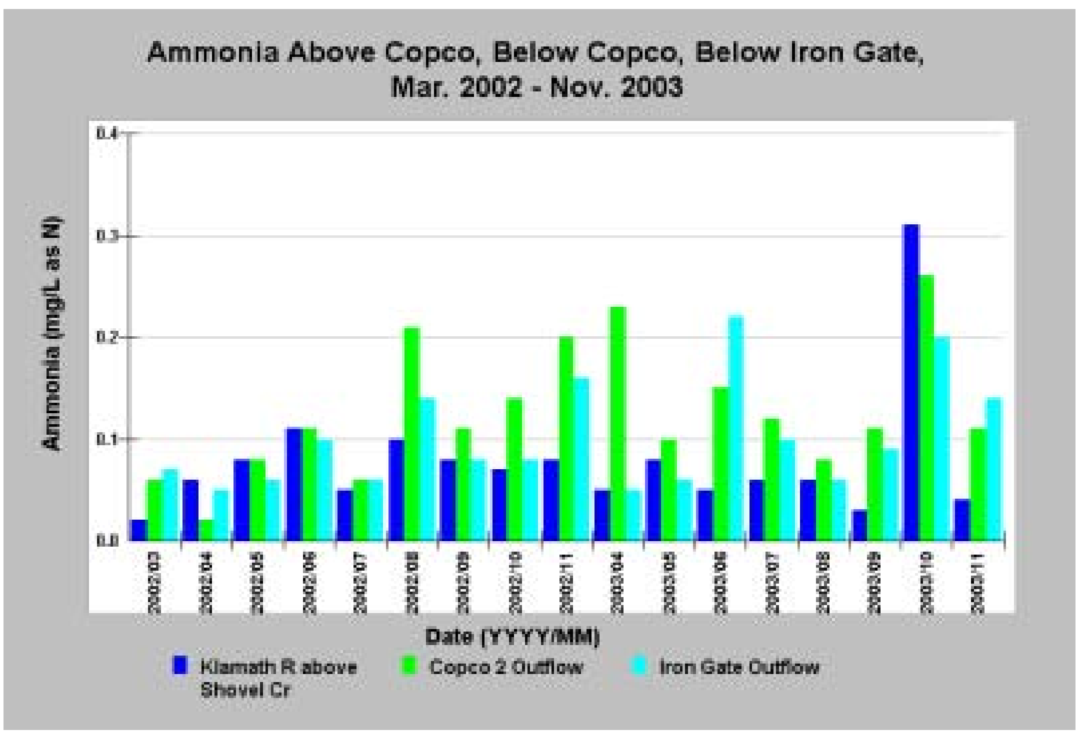

Figure 6. Ammonia levels were generally higher in the outflow of Copco 2 and Iron Gate reservoirs than they were in the Klamath River above Shovel Creek, indicating that the reservoirs may be degrading water quality. August 2002, June 2003, and July 2003 showed the most dramatic differences. Values shown are the mean of all ammonia measurements for each month. Data are from PacifiCorp's 2000-2003 water quality database.

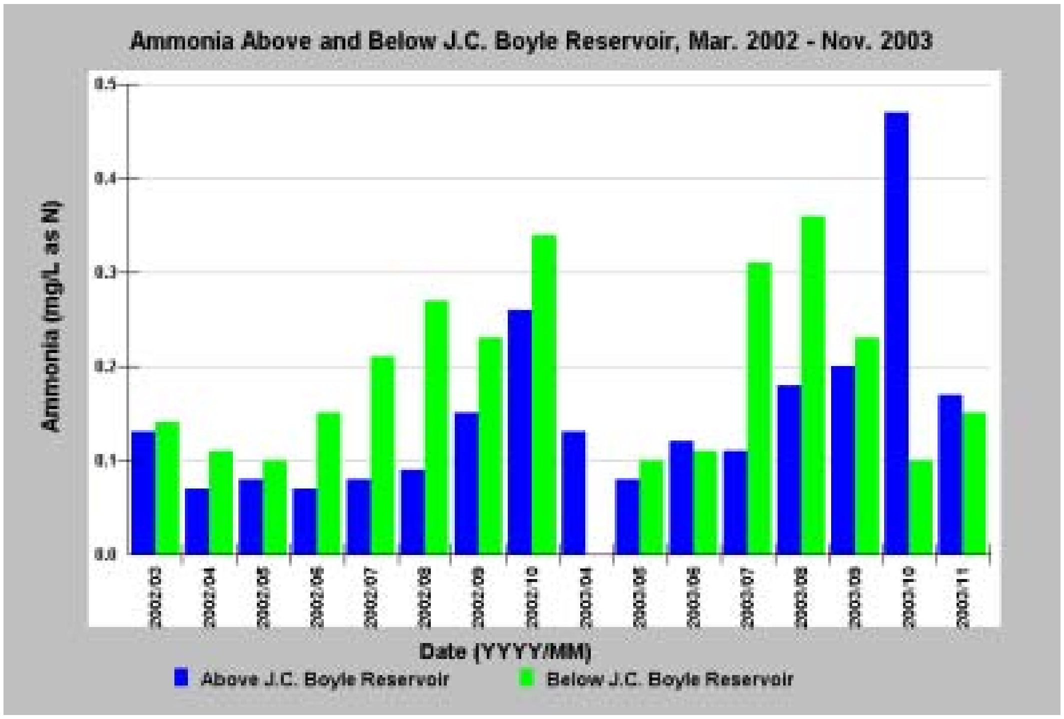

Figure 7. Monthly mean ammonia levels greatly increased from above J.C. Boyle Reservoir to below J.C. Boyle reservoir, indicating the reservoir may be degrading water quality. July and August showed the largest differences. Data are from PacifiCorp.

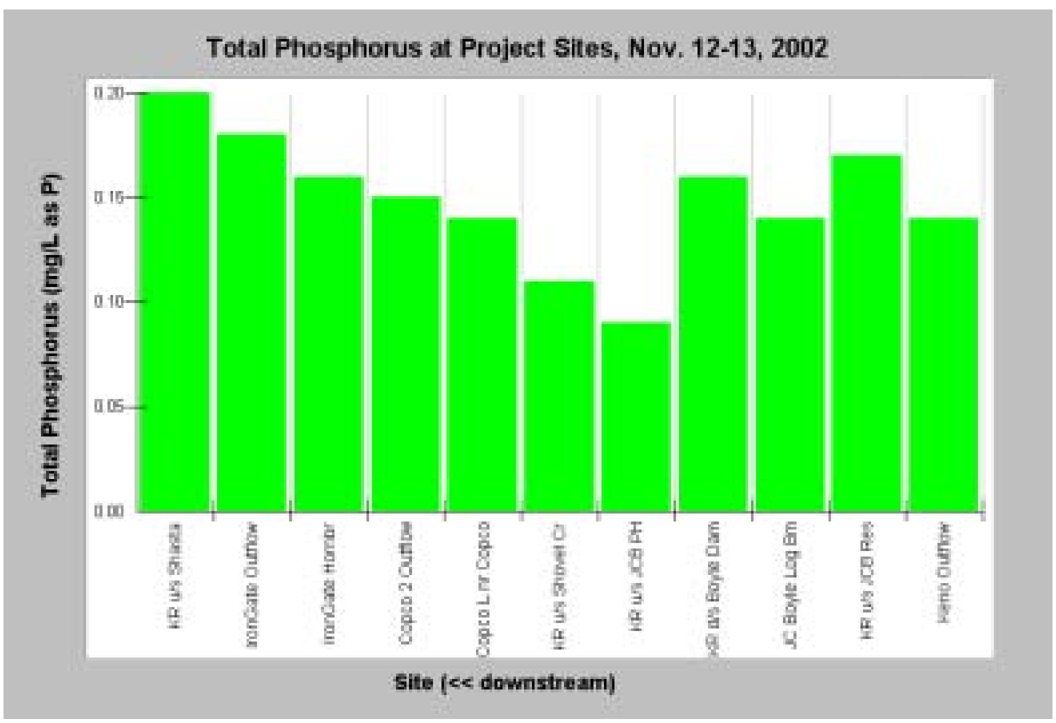

Figure 8. Total phosphorus levels at 11 sites in the Klamath River and the surface of Project reservoirs on November 12-13, 2002, near the time when the reservoirs have mixed after their summer stratification. Data are from PacifiCorp 2000-2003 water quality database.

C. Nitrogen Fixation by Algae Blooms in Project Reservoirs

In its review of water quality standards on page E3-156 of the FLA, PacifiCorp makes a key false statement that is contradicted by other facts presented in the FLA:

> "The Project does not cause or enable transformations in forms of nitrogen that could contribute to excess production in the Klamath River below the Project area."

In fact, information presented in the FLA clearly indicates that blooms of the blue-green algae *Aphanizomenon flos-aquae* in Project waters are fixing nitrogen gas from the air and adding it to Project waters, potentially exacerbating downstream water quality problems. While separately stating all the facts necessary to support this conclusion, the FLA fails to assemble them together and follow them to their logical conclusion.

The FLA states in several places that *A. flos-aquae* is "nitrogen-fixing" (FLA E3-89, E-112, E-153, E-154), but it never defines or explains the significance of the term. Atmospheric nitrogen occurs primarily in an inert form (N_2) that few organisms can use because it is extremely stable. Nitrogen-fixing organisms have the ability to split the molecule in half and combine it with hydrogen to form ionized ammonia (NH_4^+), which then can be assimilated into cells. As *A. flos-aquae* removes N_2 from the water and converts it into NH_4^+, N_2 from the air moves in to replace the removed N_2.

The FLA states on page E3-88 that algae blooms are adding nitrogen to Upper Klamath Lake:

> "Upper Klamath Lake is also a seasonally significant source of nitrogen (Kann and Walker, 2001; ODEQ, 2001). The primary source for this nitrogen loading is from nitrogen fixation by *Aphanizomenon*. As a consequence of algal nitrogen fixation, ODEQ (2002) reports that the average outflow total nitrogen load was about 3.5 times the inflow load in 1992-1999."

The FLA states that there are algae blooms each July and August in Copco and Iron Gate reservoirs (FLA E3-113). It is reasonable to assume, and FLA provides no specific reasons to the contrary, that *A. flos-aquae* blooms are adding significant quantities of nitrogen to the Project area, just as they are to Upper Klamath Lake.

Project reservoirs provide ideal conditions for *A. flos-aquae* to thrive and fix nitrogen. Free-flowing river reaches do not support *A. flos-aquae* blooms, but are instead inhabited by periphyton incapable of fixing nitrogen. If the Project reservoirs did not exist, then *A. flos-aquae* blooms would not occur in the Project area, and therefore could not fix nitrogen. The only factor that would block nitrogen fixation by A. *flos-aquae* would be if availability of nitrogen relative to phosphorous were high (Deas and Orlob, 1999). The FLA (page E3-90) points out that, based on the nitrogen to phosphorous ratio of the Klamath River between Link River and the Iron Gate Dam, "phytoplankton growth in the Klamath River is strongly nitrogen-limited". It follows that it is highly likely that nitrogen fixation is taking place in the Project reservoirs.

For there to be periphyton blooms in the Klamath River downstream of Iron Gate, there must also be sufficient quantities of nitrogen and phosphorus present. If algae blooms in Project reservoirs are causing an increase in nitrogen levels in the water downstream of Iron Gate, then there would likely be an increase in periphyton growth below Iron Gate. Hence, the *A. flos-aquae* blooms in the Project reservoirs have the potential to cause what page E3-156 denies, i.e., "excess production in the Klamath River below the Project area." This is important, because water quality below Iron Gate is poor during summer and fall, and as described in Section 2, above, excessive periphyton growth can impair water quality by increasing daily dissolved oxygen fluctuations and availability of un-ionized ammonia, which lead to fish stress or mortality.

The amount of nitrogen added to the system during algae blooms in Project reservoirs needs to be quantified. There are several ways to quantify the amount of nitrogen being fixed in Project reservoirs (Jacob Kann, pers. comm.). One way is to calculate the mass-balance of nitrogen flowing in and out of each reservoir. This requires data for the flow and nutrient concentrations coming in and out over time. If the amount of nitrogen coming out of a reservoir is higher than amount in, then it is likely that fixation is occurring. Nitrogen fixation can also be measured in-situ using the acetylene reduction method. Currently, PacifiCorp's water quality model currently does not include the process of nitrogen fixation by *A. flos-aquae*.

<u>D. Assimilative Capacity of Periphyton in Project-Affected River Reaches</u>

Benthic algae, also know as periphyton or attached algae, can take nutrients dissolved in water and assimilate them into their cells as they grow. This can enhance water quality by removing nutrients from the water, but it can also release nutrients when the algae decompose, and cause diurnal dissolved oxygen concentration swings by photosynthesis/ respiration cycles. In contrast to the blue-green algae *A. flos-aquae* found in Project reservoirs and discussed above, benthic algae in the Klamath River cannot fix nitrogen.

The development of the reservoirs along the Klamath River likely significantly reduced the amount of benthic algae in the Project area because they inundated free-flowing river reaches where benthic algae live. Power peaking operations in the reach below J.C. Boyle have reduced the amount of benthic algae in the Project (FLA E4-78). While the FLA acknowledges that this has impacts on fish populations in the peaking reach, it does not acknowledge that it may also have impacts on local and downstream water quality because of reduced benthic algae and related decreased nutrient stripping capacity. There are three reasons for decrease of benthic algae in the Project flow-peaking area:

- Diurnal desiccation of near-shore areas
- Reduced light penetration during peak flows
- High velocities and associated scour

Only diurnal desiccation of near-shore areas is discussed in detail in the FLA (E4-79). During peaking operations, flows in the J.C. Boyle peaking reach are ramped daily from a 325 cfs base flow to a 1500 cfs flow (one turbine) or a 3000 cfs flow (two turbines). The result is that the edges of the river alternate between wet and dry, dramatically decreasing algal biomass at the edges of the channel. To quantify the impact of peaking on aquatic ecosystems, the FLA calculates the continuously wetted streambed perimeter with peaking (325 cfs to 1500 or 3000 cfs) and without peaking for summer (700 cfs) and spring (1400 cfs) flows. The percent reduction was calculated for all habitats (11.4% at 700 cfs, 19.4% at 1400 cfs) and also for riffles only (16.3% at 700 cfs, 24.3% at 1400 cfs). PacifiCorp proposed an increase in base flows from 325 cfs to 425 cfs to reduce the magnitude of the problem (FLA E4-154).

Peaking flows occur at times of peak electrical demand, which in the summer is typically weekday afternoons and early evenings (FLA B9-1). During peak flows water depths are greater than they would be if the J.C. Boyle Dam were operating as a run-of-the-river facility. This, along with possible increases in turbidity, may decrease the amount of light available to benthic algae during photosynthetic hours. This could lead to less algae growth, less algae biomass, and less nutrient removal. High flows (1500-3000 cfs) during peaking may also scour benthic algae from the substrate and prevent their establishment and growth.

Benthic algae are included in the Project water quality model, but the model is not calibrated and verified for nutrients, so the effects of algae cannot be reliably determined from the model. A more comprehensive survey of benthic algae and the role it plays in dissolved oxygen concentration dynamics as well as nutrient conditions within the Project area should be explored and included in the modeling effort to compare Project/no Project scenarios.

The peaking operations are reducing the assimilative capacity of the peaking reach. No surveys have been done of algae abundance, but this lack of information does not necessarily mean there is not a problem. The ability of benthic algae to remove nutrients from water should be quantified, along with the impact of whether, and how much, peaking operations reduce this capacity. How does the nutrient-stripping capacity of free-flowing river reaches compare to the ability of reservoirs reaches to trap nutrients? Which has a greater net benefit to downstream water quality: a reservoir or a river?

E. Denitrification in River Reaches

Denitrification is a process in which certain organisms can convert nitrate (NO_3) to atmospheric nitrogen (N_2). The result is enhanced water quality, due to the reduction in productivity that occurs because a form of nitrogen readily available to organisms (nitrate) is converted into a stable form of nitrogen that is essentially unusable by most organisms (atmospheric nitrogen). For denitrification to occur, adequate nitrate levels and low levels of dissolved oxygen must be present.

Denitrification is known to occur in the hyporheic zones of rivers and streams. The hyporheic zone is the area of water-saturated sediment beneath and beside streams where ground water and surface water mix (Edwards, 1998). Denitrification most often occurs with the following conditions: low hydraulic conductivity, long flow path, reduced oxygen supply, adequate nitrate supply, and adequate supply of labile organic carbon (Edwards, 1998). The amount of nitrogen removed from some rivers due by denitrification is extraordinary, especially those with high rate of interchange between surface water and gravel alluvium. In Colorado's South Platte River, denitrification rates varied between 2 and 100 mg of nitrogen per square meter per hour. During mid-summer, a 90% reduction of nitrate was achieved in a 6 km long reach. On an annual basis, close to half the nitrate input to a 100-km reach was removed by denitrification (Sjodin et al., 1997).

PacifiCorp's water quality model includes denitrification in Project reservoirs, but no such assessment is made for river reaches. CE-QUAL-W2 , the model used to model water quality in Project reservoirs, contains a coefficient titled NO3S that is the de-nitrification rate from sediments. RMA-2, the model used to model water quality in river reaches, does not contain any coefficients or processes concerning denitrification. As described above, denitrification can occur in river reaches, so the model outputs may be inaccurate because they fail to address river denitrification.

It is unknown how much denitrification is currently occurring in Project river reaches. Reservoir construction has flooded the alluvial reaches in the low-gradient areas of the Project. The remaining river reaches are higher gradient, with less gravel and hence likely less hyporheic function and less denitrification potential. Dam removal may increase denitrification in river reaches. The amount of denitrification occurring in the river reaches needs to quantified, or at least investigated, as does the amount of denitrification that would occur if Project reservoirs were removed.

6. Water Quality Modeling Effort is Incomplete.

PacifiCorp's water quality modeling of Klamath River reaches lacks sufficient calibration and verification. The focus of model calibration/verification was for temperature and dissolved oxygen (DO), however, these parameters were typically calibrated and verified only for short continuous durations of three to five days within the same hydrologic calendar year. Model verification should be undertaken for data from varying hydrologic water years (e.g. wet, moderate, dry) and it should be continuous across seasons in order to verify the model's accuracy in different hydrologic and meteorological conditions. For example, the Link River Reach was only calibrated for May 21-23, 2002 and validated for July 16-18, 2002, respectively. Other reaches were calibrated and not validated, such as Iron Gate Reservoir. Nutrients (ammonia, nitrate, and orthophosphate) were not calibrated and typically lack sufficient data for verification.

More effort is needed in model calibration and verification. The PacifiCorp FLA uses model results to compare existing and theoretical Without Project conditions to applicable water quality standards (Sections E3.3 and E3.5). However, this model cannot properly represent how the Project contributes to or controls water quality conditions in and downstream of the Project until the model is adequately calibrated and verified.

One problem with the Without Project (WOP) model runs is that the temperature results may be inaccurate because the model uses a much wider and shallower river channel than would actually exist of the dams were removed. The reason for this is that the WOP model runs use the present bathymetry of the reservoirs. Because the reservoirs have partially filled with sediment, their bottoms are much flatter (in cross-section) than the historic river channel in those areas. It is likely that within the first few years after dam removal, high-flows would cut a new channel that would be significantly narrower than the old reservoir bottom. The channel used in the WOP model runs has a greater width-to-depth ratio, which would likely influence the temperature outputs because a wider channel has more surface area available to absorb solar radiation and exchange heat with the air. The result is that WOP modeled temperatures are probably skewed higher, and show greater daily temperature fluctuations, than would exist in reality. A sensitivity analysis should be performed on No Project channel widths above Iron Gate.

Due to these deficiencies, the model fails to achieve what would be its most useful purpose: evaluating water quality scenarios for a range of Project and no-Project options. The evaluation of multiple scenarios is critical to understanding Project impacts and proposing solutions. At a minimum, the following scenarios need to be examined:

- Existing Project with Iron Gate removed
- Existing Project with Iron Gate, Copco 1, and Copco 2 removed
- No Project (WOP) scenario with more accurate (narrower) channel geometry and with Keno Dam removed
- No Project (WOP) with real unimpaired flows (no agriculture diversions in upper basin), not the recent Bureau of Reclamation (2003) report
- Hardy Phase II flows
- Reduced nutrient inputs from Upper Klamath Lake (for instance, use Upper Klamath TMDL as input water quality)

Part 2: Additional Study Requests

This Part contains the Tribe's recommendations for additional studies that need to be completed prior to the Federal Energy Regulatory Commission's determination that the FLA is ready for environmental analysis. These additional study requests are presented here in accordance with the requirements of 18 CFR 4.32 (b) (7).

1. *Nitrogen Cycling and Transport Study, including Nitrogen Budgets for Reservoirs.*

2. *Water Quality Modeling Study*.

3. *Benthic Algae Study*.

The Tribe did not request these studies during the pre-filing consultation process because it did not have the capacity for doing so. Tribal environmental protection departments did not have personnel to dedicate to the relicensing process. After July 31, 2003 the Tribe received funding from the U.S Environmental Protection Agency with which to enhance their water quality investigation capabilities. Consultants were then hired in February 2004 to assist with a variety of water-quality tasks, including Project relicensing review.

1. Nitrogen Cycling and Transport Study, including Nitrogen Budgets for Project Reservoirs

Recommended Study

PacifiCorp should conduct a study of how nitrogen moves through the Project in time and space. This should include detailed nitrogen budgets for Iron Gate, Copco, and J.C. Boyle reservoirs, where nitrogen inputs and outputs are accounted for.

Most analysis of nutrient levels in the FLA lump multiple years and different seasons together. Such analyses are useful, but can mask changes in nutrient concentrations over different times of year, and in the differences between years. Through complex biological, physical, and chemical processes, nitrogen and phosphorus are transformed, stored, and released as water flows downstream. Without detailed data analysis it is impossible to understand the relative importance of the complex processes that are occurring in the Klamath River and in Project reservoirs. To understand the impacts of the Project on water quality, it is essential to quantify and understand these processes.

The FLA overlooks an important process that may significantly affect water quality within and downstream of the Project – the fixation of atmospheric nitrogen in Project reservoirs by blooms of the blue-green algae *Aphanizomenon flos-aquae* (see Part 1, Section 5C for more detail). The amount of nitrogen being fixed in Project reservoirs needs to be quantified.

Development of a nitrogen budget for each reservoir will probably require collection of additional water quality data. If additional data are collected, it should be collected in a way that contributes to the needed calibration and verification of the water quality model (see Additional Study Request 1).

Basis for Request

PacifiCorp has made a large effort on data assimilation and presentation; however, the FLA lacks comprehensive data synthesis and analysis. Many of the data summaries presented in the FLA lump multiple time periods together. For example, Water Resources FTR Appendix 2C presents boxplots that combine data for the years 1950-2001. Such summaries are useful for getting an idea of the ranges of values recorded at various locations, but to really understand the dynamics and processes occurring in the Project more specific analyses and summaries must be conducted.

Although PacifiCorp does a good job of presenting seasonal variations of water quality at a range of depths in Project reservoirs for recent years, it does not compare reservoir inflow and outflow water quality in a systematic fashion. Preliminary data analyses show ammonia increasing below the Project reservoirs, compared to above Project reservoirs (See Part 1, Section 5B, Figures 6 and 7, above)

An analysis of seasonal variation in river reaches is notably absent. Looking at seasonal variation in data is the key to understanding and quantifying the nutrient cycling processes going on in the system (Part 1, Section 5B).

Information presented in the FLA clearly indicates that blooms of the blue-green algae *Aphanizomenon flos-aquae* in Project waters are fixing nitrogen gas from the air and adding it to Project waters, potentially exacerbating downstream water quality problems. While separately stating all the facts necessary to support this conclusion, the FLA fails to assemble them and follow them to their logical conclusion (Part 1, Section 5C above). The amount of nitrogen added to the system during algae blooms in Project reservoirs needs to be quantified, since it may be significant.

PacifiCorp claims in the FLA that Project reservoirs have a net benefit to water quality because they trap particulate matter and nutrients. Instead of substantiating this claim by presenting a detailed data analysis, PacifiCorp presented boxplots summarizing all recent data (E3-98 and E3-99), and data for *one day*: June 18, 2002 (E3-100 to E3-102). Analysis of data from a varying timescale and different geographic areas within the Project area is necessary to determine whether PacifiCorp's claim of Project water quality improvement is correct or not.

Project reservoirs may not be nutrient sinks, they may just affect the timing of when nutrients flow through the system, holding nutrients during one season and releasing them during another. No analysis was presented in the FLA to answer this question. A nitrogen budget would help to resolve this question for nitrogen.

Responsible Entity

As PacifiCorp is the applicant and the primary beneficiary of Project operations, PacifiCorp should conduct this study.

Participants

Direct oversight of this study should be provided by the team of State, federal, and tribal scientists and NGO representatives who have been operating as a Project stakeholder group.

<u>Study Objectives and Methods</u>

Study Objectives

- To increase understanding of how nutrients, especially nitrogen, move through the systems

- To quantify the amount of nitrogen being fixed in Project reservoirs

Study Methodology

It is necessary to investigate how nutrient concentrations change as water flows downstream through the Klamath River and Project reservoirs. This is best accomplished by synoptic sampling, where samples are taken at many locations in a short period of time. This provides a “snapshot” of how the quality of water changes as it flows downstream, and can reveal spatial trends. Although synoptic samples were taken on many days in 2000 to 2003, the FLA charts the results for only one day, June 18, 2002 (E3-100 to E3-102). The results for other days of synoptic sampling need to be analyzed, as it likely that nutrient concentrations show different geographic patterns, depending upon the year and season.

Of particular benefit would be the comparison of the quality of reservoir inflow to that of reservoir outflow over time. This would include looking at monthly averages of nitrate nitrogen, ammonia nitrogen, Kjeldahl nitrogen, total phosphorus, and orthophosphorus concentrations above and below each Project reservoir.

Development of a detailed nitrogen budget would enhance our current understanding of how water quality processes function in the Project reservoirs. A nitrogen budget is developed by calculating all nitrogen inputs and outputs to a reservoir. To do this, the mass-balance of nitrogen flowing in and out of each reservoir needs to be determined. This requires data for the flow and nutrient concentrations coming in and out over time, as well as nutrient concentrations in the reservoirs over time.

Nitrogen budgets for other water bodies in the Klamath basin have already been developed, including Upper Klamath Lake (Kann and Walker, 2001), and similar methods could be applied to Project reservoirs. The nitrogen budget should be calculated for at least one year, with input and output broken down by increments of shorter time units, such as months, to help determine how the reservoirs affect water quality at different times of the year.

Developing a nitrogen budget would help to determine the magnitude of nitrogen fixation. If the amount of nitrogen coming out of a reservoir is higher than the amount entering, then it is likely that fixation is occurring. However, even if the amount of nitrogen leaving the reservoir is less than the amount of nitrogen entering the reservoir, there is likely still nitrogen fixation occurring, but other processes may then be reducing nitrogen.

Nitrogen fixation should be measured in each Project reservoir using the acetylene reduction method (Stewart et al., 1967), or other methods of comparable accuracy. Measurements should be made repeatedly from May through September. During that same period, water quality parameters such as chlorophyll *a*, dissolved oxygen, pH, temperature, nitrate nitrogen, ammonia nitrogen, Kjeldahl nitrogen, total phosphorus, and orthophosphorus should be measured. Measured along with nitrogen fixation, these water quality parameters will help to determine how much nitrogen algae fix under different conditions. These results can then be used in the construction of the nitrogen budget and can also be fed into the model, which as described in Additional Study Request 1 above, needs to take into account nitrogen fixation.

Acceptance of Recommended Study Methods

Nitrogen budgets are a commonly used technique for lake and reservoir management planning. The acetylene reduction method is an established standard technique for measuring nitrogen fixation in lakes and reservoirs (Goldman and Horne, 1983).

Usefulness of Requested Studies in Furthering Resource Goals

The requested study will provide understanding about the biological, physical, and chemical processes affecting nutrient cycling within and downstream of the Project. PacifiCorp has claimed the reservoirs are a net benefit to water quality, but has not substantiated this claim. This study will help to determine the specific effects of the Project on water quality. Stakeholders and decision makers such as Tribes, state and federal agencies, and NGOs can then use this knowledge to help evaluate which configurations of the Project relicensing or decommissioning will have the greatest benefit upon water quality. Especially important to Tribes are the effects of water quality on anadromous salmonid production.

Study Duration

A thorough analysis of existing data would take approximately one month. The nitrogen fixation and additional water quality studies necessary to produce a nitrogen budget would take eight months (April to November), plus another month for the construction of the nitrogen budget, for a total of nine months.

Why Study Objectives Cannot Be Achieved Using Available Data

As described in the Basis For Request above, current data analysis is inadequate to determine the effects of the Project on water quality. No attempt has been made to determine the quantity of nitrogen being fixed in Project reservoirs. Without that knowledge, stakeholders cannot determine which configuration of the Project, including modifications to the Project, would most benefit water quality and anadromous salmonids.

2. Water Quality Modeling Study

Recommended Study

PacifiCorp should improve its water quality model in the following four ways:

A) Analyze a full range of Project and without-Project scenarios
B) Incorporate nitrogen fixation information
C) For scenarios with dam removal, use more realistic channel geometry
D) Calibrate and validate the model for nutrients and benthic algae.

PacifiCorp should model a full range of Project configuration scenarios. An assessment of several scenarios is necessary to clearly illustrate the impact of the Project, and Project alternatives, on water quality and beneficial uses.

It is likely that nitrogen fixation is occurring in Project reservoirs. If it is occurring, then it needs to be incorporated in the water quality model.

Without Project (WOP) model runs currently use a much wider and more shallow river channel than would actually exist if the dams were removed, potentially skewing temperatures. This should be corrected.

The calibration and validation of the existing model are insufficient for temperature and dissolved oxygen, and are non-existent for nutrients and benthic algae. Additional calibration and validation are necessary for model results to be reliable and useful. Currently, there are not enough data to sufficiently calibrate and verify the model, so more data needs to be collected.

After completing these model runs, PacifiCorp should provide all the data inputs and model outputs to all interested parties. These data should be released in their most useful format, electronic data files.

Basis for Request

PacifiCorp has chosen to model only four scenarios, and has not analyzed the range of scenarios between these extremes. The reason why many scenarios need to be modeled, and why the model needs to be as accurate as possible, was well-stated by the Klamath Tribes of Oregon in their comments on the Draft License Application (FLA E-1A Appendix B Second Stage - 42):

> "The Klamath Tribes request that the assimilative capacity of the Klamath River be quantified in a manner that clearly compares its present assimilative capacity with that of a series of alternative Project configurations involving removal of mainstem dams. We need to understand the incremental changes in assimilative capacity as individual Project components are removed, and the resulting impacts on water quality within and below the KHP… "

PacifiCorp's water quality model currently does not include the process of nitrogen fixation by *A. flos-aquae* in Project reservoirs. PacifiCorp has not addressed whether or not algae blooms in Project reservoirs fix nitrogen. The requested Nitrogen Cycling and Transport Study should help to determine whether it is necessary to include that process. If that study determines there is significant nitrogen fixation occurring, then it must be incorporated into the water quality model, or the model will be inaccurate because it will be missing an essential component.

One problem with the Without Project (WOP) model runs is that the temperature results may be inaccurate because the model uses a much wider and shallower river channel than would actually exist of the dams were removed. The reason for this is that the WOP model runs use the present bathymetry of the reservoirs. Because the reservoirs have partially filled with sediment, their bottoms are much flatter (in cross-section) than the historic river channel in those areas. It is likely that within the first few years after dam removal, high-flows would cut a new channel that would likely be significantly narrower than old reservoir bottom. The channel used in the WOP model runs has a greater width-to-depth ratio, which would likely influence the temperature outputs because a wider channel has more surface area available to take absorb solar radiation and exchange heat with the air. The result is that WOP modeled temperature are likely skewed higher, and with greater daily temperature fluctuations, than would exist in reality.

PacifiCorp's water quality modeling of Klamath River reaches typically lack sufficient calibration and verification. The focus of model calibration/verification was for temperature and dissolved oxygen (DO), however, these parameters were typically calibrated and verified only for short continuous durations of three to five days within the same hydrologic calendar year. Model verification should be undertaken for data of varying hydrologic water years (e.g. wet, moderate, dry) and it should be continuous across seasons in order to verify the model's accuracy in different hydrologic and meteorological conditions. For example, the Link River Reach was only calibrated for May 21-23, 2002 and validated for July 16-18, 2002, respectively. Other reaches were calibrated and not validated, such as Iron Gate Reservoir. Nutrients (ammonia, nitrate, and orthophosphate) were not calibrated and typically lack sufficient data for verification.

The water quality model cannot properly represent how the Project contributes to or controls water quality conditions in and downstream of the Project until the model is adequately calibrated and verified. Without proper validation, it is impossible to know how accurate the model is, which makes its utility limited. If the model cannot accurately predict nutrients, then it is unlikely that it will be able to accurately predict benthic algae and dissolved oxygen, because it is an integrated system.

Responsible Entity

As PacifiCorp is the applicant and the primary beneficiary of Project operations, PacifiCorp should conduct this study.

Participants

PacifiCorp should perform the additional model runs with direct oversight from an interagency team of state, federal, and tribal biologists and NGO representatives from the stakeholder group. This team should provide overall guidance and assist with developing model inputs and reviewing model outputs.

Study Objectives and Methods

Study Objectives

- To permit a thorough evaluation of the potential effects of Project operations on water quality within and downstream of the Project.

- To analyze water quality for a full range of Project and no Project alternatives

Study Methodology

PacifiCorp should use their use existing models to evaluate water quality at each reservoir and river reach, including downstream of the Project. They should model more scenarios than are currently being modeled. At a minimum, the following scenarios need to be examined:

- Existing Conditions
- Existing Project with Iron Gate removed
- Existing Project with Iron Gate, Copco 1, and Copco 2 removed
- No Project (WOP) with real unimpaired flows (no agriculture diversions in upper basin), not the recent Bureau of Reclamation (2003) report
- Hardy Phase II flows
- Reduced nutrient inputs from Upper Klamath Lake (for instance, use Upper Klamath TMDL as input water quality)

If the requested Nitrogen Cycling and Transport Study determines that significant of quantities of nitrogen are being fixed by blue-green algae blooms in Project reservoirs, PacifiCorp should add the process of nitrogen-fixating to CE-QUAL-W2, the reservoir water quality model. If the Nitrogen Cycling Study determines that nitrogen fixation in the Project is insignificant, then there is no need to incorporate nitrogen fixation into the model.

To determine if more realistic channel geometry is required for Without Project (WOP) scenarios, a sensitivity analysis should be performed on the WOP channel widths above Iron Gate. If the sensitivity analysis shows that narrowing the channel widths changes the temperatures predicted by the model, then a geomorphic analysis should be used to generate a more realistic (narrower) channel, and then that narrower channel should be used instead.

To improve calibration and validation of the model, more data collection is necessary. The requested Benthic Algae Study and the Nitrogen Cycling and Transport Study both call for additional data collection. Data collection should be coordinated among those two studies and this requested study to generate data that will be sufficient to calibrate the model for nutrients and benthic algae.

Acceptance of Recommended Study Methods

Modeling Project operations is commonly used for river management planning, including FERC proceedings.

Usefulness of Requested Studies in Furthering Resource Goals

This study would greatly enhance the utility of the PacifiCorp water quality model. This study will help to properly calibrate and validate the model, which will help to improve its accuracy. Proper model calibration and validation are required to have reliable model results. Once the model is properly calibrated and verified, its results can be used to help evaluate the effects of a range of Project alternatives. It can answer questions such as: How does the assimilative capacity of free-flowing river reaches compare to the ability of reservoirs reaches to trap nutrients? Which has a greater net benefit to downstream water quality: a reservoir or a river?

Stakeholders and decision makers such as Tribes, state and federal agencies, and NGOs can then use this knowledge to help them evaluate which configurations of the Project relicensing or decommissioning will have the greatest benefit to water quality. Especially important to Tribes are the effects of water quality on anadromous salmonid production.

Study Duration

Collecting the additional data required for calibration should take approximately eight months (April-November), with several more months to incorporate that data into the model.

Why Study Objectives Cannot Be Achieved Using Available Data

PacifiCorp has so far modeled only four scenarios. These scenarios do not provide information needed to compare Project impacts under current conditions to a variety of Project and Without Project alternatives.

For scenarios that have been modeled, calibration and verification is insufficient. Due to its deficiencies in calibration and verification, the model fails to achieve what would be its most useful purpose: evaluating water quality scenarios for a range of Project and no-Project options. The evaluation of multiple scenarios is critical to understanding Project impacts and proposing solutions.

3. Benthic Algae Study

Recommended Study

PacifiCorp should conduct this study to understand and quantify the capacity of benthic algae (also known as attached algae, bed algae or periphyton) in the river reaches to uptake nutrients and how that capacity has been altered by peaking and reservoir development.

The recommended study consists of surveying river reaches within and downstream of the Project to measure the biomass of benthic algae at many locations, and observing how the biomass changes through spring, summer, and fall. Flow, nutrients, dissolved oxygen and temperature need to be measured at the same time to determine the response of benthic algae to changes in meteorological conditions, water quality, and flow conditions.

Information from this study should be used to improve the water quality model (see Additional Study Request 2), which will help to assess the impact of the Project and Project alternatives on water quality.

Basis for Request

Benthic algae are important to the maintenance of water quality in rivers because they can remove nutrients from the water column and assimilate it into their cells. The Project has reduced the biomass of benthic algae because the construction of Project reservoirs inundated free-flowing river reaches where benthic algae lived. In addition, the flow regime in the J.C. Boyle peaking reach has likely decrease benthic algae biomass because of scour, low light conditions, and diurnal desiccation of the river's edge (see Part 1, Section 5D). Because PacifiCorp has impacted benthic algae, they should determine what impacts their actions have caused to water quality.

Little is known about the distribution and abundance of benthic algae in the Project area. For instance, water quality modeling scenarios for all four river reaches used 5 grams per square meter as the initial bed algal mass (Water Resources FTR Appendix A). No reasons or references are provided as to why this value was chosen, and no sensitivity analysis was performed on how this might affect model outputs. Given the adverse conditions for benthic algae in the J.C. Boyle bypass reach, it seems unreasonable to use the same estimate of bed algae mass for that reach as for the other reaches.

PacifiCorp's Study Plan 1.2 describes the U.S. Bureau of Reclamation's sampling of attached algae downstream of Iron Gate dam in June, July, and September of 2000. These data were used to determine algae growth rates for the water quality model.

Although the Water Resources Final Technical Reports 3, 4, and Appendix 4A showed a need for additional studies on benthic algae, PacifiCorp has not committed itself to performing them or including them in a study plan.

Section 3.11 of the Water Resources Final Technical Report Appendix 4A contains recommendations for improving model calibration and verification. For the Bypass/Peaking Reach, it states:

> Exploratory field work was carried out in 2003 to assess the benthic algae community. If further model refinement is necessary it is recommended that a more comprehensive survey of benthic algae and the role it may play in dissolved oxygen concentration dynamics as well as nutrient conditions within the reach should be explored.

For Iron Gate to Turwar, the same section states:

> During 2003 benthic algae surveys were completed providing information on the distribution and approximate biomass at multiple locations within this reach. This information was important in improving the understanding of algal dynamics. Expansion of this information, coupled with the appropriate water quality conditions, could further improve the application of the model.

In the sensitivity analysis, where model parameters are varied to see their effect on results, it is stated (Water Resources FTR Appendix 4A-207):

> Nutrients were generally moderately sensitive or experienced low sensitivity to algal growth parameters; however, the ammonia preference factor suggested sensitivity for ammonia and nitrate. The nutrients were moderately sensitive to extinction in certain river reaches – under high extinction rates benthic algal growth was light limited and nutrient uptake

suppressed. Algae was very sensitive to growth and respiration rates as well as light extinction.

The water quality model has not been calibrated or validated for benthic algae. Collecting additional data to calibrate and validate for benthic algae will improve the ability of the model to predict other water quality parameters, as benthic algae are a major factor in water quality, especially below Iron Gate Reservoir.

Responsible Entity

As PacifiCorp is the applicant and the primary beneficiary of Project operations, PacifiCorp should conduct this study.

Participants

PacifiCorp should conduct this study with direct oversight from an interagency team of state, federal, and tribal scientists and NGO representatives from the stakeholder group.

Study Objectives and Methods

Study Objectives

- To increase understanding of how benthic algae affect water quality within and downstream of the Project.

- To acquire enough data to calibrate the water quality model for benthic algae parameters, and hence improve the ability of the model to predict nutrient and dissolved oxygen levels

Study Methodology

The U.S. Bureau of Reclamation's 2000 study below Iron Gate used floating periphyton samplers and unglazed ceramic tiles to assess algae growth conditions (Study Plan 1.2). Floating samplers were used to reduce the impacts of grazing, and ceramic tiles were placed on the bed to determine how grazing impacted growth. Algae samples were collected from the floating samplers for laboratory analysis, while unglazed ceramic tiles provided a qualitative assessment of changes in substrate composition and impacts of grazing. Similar methods should be applied to examine algal growth rates in other reaches, including Keno dam to J.C. Boyle Reservoir, J.C. Boyle Bypass Reach, and below Iron Gate Reservoir to see if they differ from those measured at Iron Gate Reservoir in 2000. Benthic algal respiration rates and light extinction coefficients need to be determined as well, as PacifiCorp's sensitivity analysis showed them to have important influence on model outputs.

In addition to the measuring growth rates, the distribution and abundance of benthic algae needs to be quantified for many river reaches within and downstream of the Project.

These results can be used as an input into the water quality model as the initial bed algae mass. The results can also be used to calibrate and verify the model for benthic algae.

The FLA contains no description of the methods used in the 2003 benthic algae surveys mentioned in Section 3.11 of the Water Resources FTR Appendix 4A, and PacifiCorp did not respond to request for information on methods, so it is difficult to comment on the specific methodology of needed studies. It is likely that the general methodology used in 2003 studies is adequate, but should be conducted in a more intense and detailed fashion.

Acceptance of Recommended Study Methods

The chosen method should be an accepted, standard protocol.

Usefulness of Requested Studies in Furthering Resource Goals

The results of this study will provide data on how benthic algae influence water quality. These data will help with model calibration and validation, which will help to improve the accuracy of the water quality model. Proper model calibration and validation are required to have reliable model results. Once the model is properly calibrated and verified, its results can be used to help evaluate the effects of a range of Project alternatives. Of particular important to Tribes are the effects of water quality on anadromous salmonid production.

Study Duration

This study should be conducted from April to November (eight months) with the most intensive periods of data collection occurring during summer and early fall, when water quality conditions are worst.

Why Study Objectives Cannot Be Achieved Using Available Data

Current data are insufficient to adequately understand how benthic algae affect water quality. Also, due to lack of data, the water quality model is not calibrated for nutrient levels, phytoplankton and benthic algae (Water Resources FTR Appendix 4A-99).

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