TO THE FEDERAL ENERGY REGULATORY COMMISSION (FERC)

COMMENTS FOR APPLICATION TO THE

KLAMATH HYDRO ELECTRIC PROJECT

FERC PROJECT LICENSE 2082-027, OPERATED BY PACIFICORP

BY THE

GOVERNING BODY OF THE RESIGHINI RANCHERIA

DEL NORTE COUNTY, CALIFORNIA

A FEDERALLY RECOGNIZED TRIBE

FRANK S. DOWD, III, CHAIRMAN

RESIGHINI RANCHERIA BUSINESS COUNCIL

MARCH 23, 2006

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RECOMMENDED TERMS AND CONDITIONS

Klamath Hydroelectric Project, FERC License 2082-027, Operated by PacifiCorp
Submitted to FERC by the Resighini Rancheria, a Federally Recognized Tribe

INTRODUCTION

This document recommends Terms and Conditions to be applied to the Klamath Hydroelectric Project (hereafter "KHP"), Federal Energy Regulatory Commission (FERC) licensed Project No. P-2082-027 and explains why such terms and conditions are necessary to achieve Klamath River water quality conditions capable of protecting natural resources essential to the lives of the Klamath River Tribal communities.

These comments were prepared with the assistance of the Tribe's consultant, Kier Associates, Fisheries and Watershed Professionals, Arcata, California. A significant portion of these comments is drawn from earlier reviews of KHP FERC license-related documents, and subsequent Klamath River studies completed for the Tribe with the assistance of Kier Associates science team.

With regard to each Klamath River water quality issue attributable to the existence and operation of the KHP, the information presented here, together with the terms and conditions recommended, include (1) background information concerning the relationship of each water quality or river health parameter to essential Klamath River resources, including the river's salmon resources; (2) an explanation of how the existence and operation of the KHP contribute to the degradation of the Klamath River; and (3) recommendation for the removal of KHP facilities from the Klamath River and its tributaries.

A SUMMARY OF THE TRIBE'S RECOMMENDED TERMS AND CONDITIONS

The terms and conditions recommended here are being submitted to FERC pursuant to Title 18 Code of Federal Regulations Section 4.34(b)(2) and Section 10 (16 USC §§ 803) of the Federal Power Act, particularly subsection (a) concerning the protection and mitigation of fish and wildlife resources, including the water quality upon which they depend.

The background information assembled and presented here concerns the deteriorating condition of the water quality of the Klamath River within and downstream of the KHP and its impact on our people. The Yurok people of the Resighini Rancheria rely on the Klamath River to support fish, wildlife, and other resources essential for their very existence. The owners of the KHP tell us little or nothing regarding how they will modify the Project and its operations to improve the river's water quality so that we can sustain our traditional quality of life. It is our opinion that the KHP, coupled with other abuses in the watershed, is destroying the Klamath River. So that we can sustain our traditional quality of life, so that we can continue to preserve and protect the life resources our Creator entrusted to us, so that our future generations can prosper and flourish, we ask that FERC order the decommissioning of all KHP dams and facilities. We believe removal will be best achieved by denying PacifiCorp's license application and ordering dam removal. In the alternative, any license issued by FERC must call for dam removal within a specific time frame.

To meet its trust responsibilities to the Klamath Basin Tribes, FERC should order PacificCorp's to produce a plan for decommissioning those dams, with the order specifying that:

- PacifiCorp shall develop the decommissioning plan in collaboration with the Tribes and the appropriate state and federal agencies, and that those entities shall have authority to approve or deny the final plan.
- The plan shall be completed within one year of FERC's order and shall specify that the dams be removed as soon as possible.
- The plan shall specify details on the environmentally sound techniques to be used, and the order in which the dams will be decommissioned.

Our thorough and exhaustive review of the impacts of the KHP on Tribal Trust resources leads to the inescapable conclusion that removing the dams and returning the Klamath River to a free flowing river is the only remedy for eliminating the adverse effects of the KHP.

AN OVERVIEW OF THE KLAMATH HYDROELECTRIC PROJECT'S IMPACTS UPON WATER QUALITY AND FISH HEALTH

PacifiCorp's KHP straddles a river stressed by human overuses which have accumulated over the past century. While the KHP obviously cannot control the quality of the water entering its upstream end, the project can and does impact water quality and other river conditions both within the project area and for the entire length of the Klamath River below it.

The KHP creates substantial adverse impacts upon the river's water quality and fisheries. The mechanisms through which the KHP adversely impacts the Klamath River are summarized in the following section and are explained in further detail in the section "Detailed justification for the license terms and conditions recommended here" further on.

Cyanobacteria and cyanobacterial toxins

► Microcystin toxins produced by the toxic cyanobacteria (blue-green algae) *Microcystis aeruginosa* represent a substantial threat to human and fish health.
► PacifiCorp's KHP provides ideal habitat for *Microcystis*, leading to massive blooms (Kann 2006).
► A comparison of *Microcystis* in the river upstream form Copco Reservoir shows that Iron Gate and Copco Reservoirs are directly responsible for the high levels of *Microcystis* and microcystin toxin detected in the Klamath River below Iron Gate Dam (Kann 2006).
► The *Microcystis* inoculum supplied by the reservoirs then persisted and occasionally re-grew down river, and was detected in the Klamath River estuary (Kann 2006).

Temperature

Primarily due to the thermal mass of Iron Gate and Copco reservoirs, the KHP significantly alters water temperatures in the Klamath River (PacifiCorp 2004, PacifiCorp 2005c, Deas 2004) in ways that are detrimental to the various runs of anadromous fish in the Klamath River.
► The KHP causes warm temperatures in the fall, negatively impact fall Chinook spawning success and egg survival, and results in a several week delay in run-timing.

► The KHP cools the river in spring, which slows salmonid growth during the critical spring seasons because it keeps water temperature below the optimum growth temperatures for juvenile salmonids. The resulting smaller-sized Chinook salmon juveniles migrate downstream more slowly than would larger individuals (PFMC 1994) and are less likely to survive to maturity and spawn (Nicholas and Hankin 1988). This increased transit time exposes them to prolonged stress, increasing their likelihood of becoming infected with parasites.

Nutrients

The KHP affects the nutrient dynamics of the Klamath River by interfering with natural processes that allow the river to become cleaner as it flows downstream.
► Although nutrient concentrations at Iron Gate are lower than at Link River and Keno, much of the net reduction can be shown to be caused by natural dilution processes, and not the presence of the KHP.
► By replacing a formerly free-flowing river with a series of reservoirs, peaking reaches, and bypass reaches, the KHP has greatly altered the hydrologic, physical, chemical, and biological processes of the Klamath River.
► Such alterations, through the reduction of periphyton habitat and delayed initiation of the river's natural "recovery zone" (see below) increases the downstream extent of the high nutrient concentrations entering the KHP project reach from Upper Klamath Lake.
► The KHP has caused the "recovery zone" to relocate tens of miles downstream to below Iron Gate Dam, where unfortunately it now overlaps with some of the best salmonid habitat in the mainstem Klamath. This causes a multitude of water quality and fish health problems including increased exposure of juvenile salmonids to highly adverse pH/D.O. conditions, toxic levels of ammonia, and high concentrations of spores from myxozoan parasite such as *Ceratomyxa shasta* and *Parvicapsula minibicornis*.
► Removal of the KHP would move the "recovery zone" upstream to the Keno or J.C. Boyle, substantially improving pH/D.O. conditions in the prime salmonid spawning habitat at Iron Gate/Copco.

We present several lines of evidence, discussed in detail below, to support the principle that nutrient concentrations at Iron Gate Dam (and hence points downstream as well) would be lower in the absence of the KHP:
► First, as PacifiCorp itself (2005d) has acknowledged, peaking and bypass operations inhibit the river's capacity to assimilate nutrients within the KHP area.
► Second, Iron Gate and Copco reservoirs do not substantially reduce nutrient concentration, and can act as both sources and sinks of nutrients.
► Third, analysis of nutrient loads in the Klamath River below Iron Gate Dam clearly show that the free-flowing river has substantial capacity to reduce nutrient loads through periphyton assimilation and denitrification, indicating that if KHP were removed, similar load reductions would occur inside the area now occupied by the KHP.

Dissolved oxygen and pH

► pH levels in the Klamath River are often higher than allowed by water quality standards (NCRWCB 2001), and high pH and low dissolved oxygen (D.O.) are major stressors to salmonids in the Klamath River (Kier Associates 2005).

► The KHP has a direct effect on D.O./ pH levels in the Klamath River immediately below Iron Gate Dam. During the summer season the reservoir often releases water with high pH and low D.O., which would harm salmonids in the vicinity of the dam.
► Further downstream, low D.O. and high pH are caused by excessive photosynthesis of aquatic macrophytes and periphytic algae. By increasing nutrient levels, the KHP stimulates growth of aquatic macrophytes and periphyton that drive large diurnal swings in D.O. and pH, including low D.O. at night and high pH during the daylight hours.

Ammonia toxicity

► Data clearly show that ammonia concentrations are often substantially higher below Iron Gate Dam than above Copco Reservoir. These higher concentrations represent a considerable localized toxicity risk to fish in the river below Iron Gate.
► Ammonia releases from Iron Gate also represent a risk to fish in downstream reaches during periods of diminished assimilative capacity of periphyton and macrophytes; such as would occur when cloudy weather, cold temperatures, or turbidity inhibits productivity. Under conditions of reduced productivity, high ammonia would increase its downstream extent rather than be assimilated into organic forms.

Taste and odor compounds

► Taste and odor compounds in the Klamath River impact both recreational and subsistence fisheries.
► The KHP elevates levels of taste and odor compounds because project reservoirs host massive blooms of algal species that produce taste and odor compounds.
► The construction of the reservoirs flooded formerly free-flowing river reaches that removed taste and odor compounds through aeration.
► Organic matter produced by algal blooms in KHP reservoirs also creates taste and odor compounds as it decays.

Fish parasites

► The KHP promotes the myxosporean parasites *Ceratomyxa shasta* and *Parvicapsula minibicornis* in the Klamath River by altering nutrient dynamics, increasing habitat for the polychaete *M. speciosa*, and increasing *C. shasta* infection rates of the polychaete *M. speciosa*. This leads to higher rates of infection and disease in salmonids.
► In addition, through its effects on nutrient dynamics, the KHP deteriorates pH / D.O. conditions and increases ammonia, causing stress and immunosuppression in salmonids, increasing the likelihood that they will become infected and diseased.

COMMENTS CONCERNING PACIFICORP'S MODEL RESULTS

PacifiCorp (2005d) presents the results of water quality and fish passage modeling calibration and verification. Examination of the figures in the appendix shows that the model predicts flow and temperature quite well, but does not accurately predict dissolved oxygen, nutrients, or algae. These results were similar to results reviewed by Wells (2004). It is important to keep the differences in accuracy between the various parameters in mind when evaluating model results Flow and temperature are based on the laws of physics, and modeling them is a long-established practice. Dissolved oxygen, nutrients, and algae are subject not only to the laws of physics, but also to chemistry, biology, and ecology, which are far more complex, unpredictable, and difficult to represent mathematically. To compound the problem, compared to flow and temperature, far less data is available for these parameters to calibrate and verify the model.

For the reasons described above, we do not consider PacifiCorp's water quality model to be accurate enough to justify using it to make management decisions based upon model outputs for any parameters other than temperature and flow.

DETAILED JUSTIFICATION FOR THE TERMS AND CONDITIONS RECOMMENDED HERE

In this section, the following water quality parameters are addressed in order:
- Cyanobacteria and cyanobacterial toxins
- Water temperature
- Nutrients
- Dissolved oxygen,
- pH
- Ammonia toxicity
- Taste and odor compounds
- Fish parasites

For each parameter, we provide background information, as necessary; we present information about the parameter's existing condition in the Klamath River; we discuss how the KHP contributes to the present condition of that parameter; and then we recommend the means by which the parameter's adverse effect on the river's water quality can be remedied.

CYANOBACTERIA AND CYANOBACTERIAL TOXINS

Background information

Cyanobacteria, also known as blue-green algae, are a diverse group of single-celled aquatic organisms found in surface waters worldwide. Lakes, reservoirs, ponds, and slow-moving rivers are especially suitable for cyanobacteria, and given the right conditions, e.g., calm water, light, and adequate concentrations and ratios of nitrogen and phosphorus, these organisms can reproduce at a high rate, forming vast blooms in the water. The resulting high cyanobacterial algal concentrations are not only aesthetically unpleasing, but often produce toxins that have been implicated in human health problems ranging from skin irritation and gastrointestinal upset, to death from liver or respiratory failure (Chorus and Bartram 1999, Chorus 2001). Copco and Iron Gate Reservoirs have been shown to provide ideal habitat for large blooms of *Microcystis aeruginosa* (MSAE). This cyanobacterial species produces the potent hepatotoxin microcystin and both MSAE cells and toxin have been demonstrated to occur in the reservoirs and the Klamath River downstream (Kann 2006).

These hepatotoxins (liver toxins) are powerful cyclical peptides which disrupt the structure of liver cells, causing cell destruction, liver hemorrhage, liver necrosis, and death (Carmichael 1994). In addition to hepatotoxicity, long-term laboratory animal studies indicate that microcystins act as liver tumor promoters and teratogens (Falconer et al. 1988). Microcystin poisoning has been implicated in the largest number of cyanobacteria-associated animal deaths worldwide, and enough work has been done, both with rodents and pigs, on microcystin effects at various levels of exposure, that the World Health Organization (WHO) has issued a provisional guideline of 1 μg/L for microcystin concentration in drinking water. With actual microcystin concentration data frequently unavailable, alert level guidelines based on cell counts have been established for *Microcystis* (as well as other cyanobacteria) blooms in drinking and recreational waters (Yoo et al. 1995, Chorus and Bartram 1999).

Although mammalian health effects of toxins from the blue-green algae *Microcystis aeruginosa* are better studied (WHO, 1998), fish health effects have also been recently researched (Zambrano and Canelo 1995, Wiegland and Pflugmacher 2005), including effects on salmonids (Tencalla et al. 1994, Bury et al. 1996; Fischer et al. 2000, Best et al. 2003). These effects are discussed here because there is evidence that hepatotoxins created by *Microcystis* are a threat to fish health independently, and may also act synergistically with other water quality problems (i.e. pH) in causing cumulative stress or in contributing to immunosuppression and subsequent outbreaks of fish disease epidemics.

Microcystin toxins accumulate in the liver where they disrupt many different liver enzymes and ultimately cause the liver to break down (Fischer et al., 2000). Algae grazing fish species may be the most susceptible to microcystin poisoning, but other fish may ingest whole *Microcystis* cells or breakdown products from the water column (Wiegland and Pflugmacher 2005). In laboratory experiments, rainbow trout were found to excrete microcystin toxins in bile fluids when exposed to them orally. The toxins caused increased drinking in this species and increased water in the gut, which was a sign of osmoregulatory imbalance and could promote diffusion of toxins into the blood (Best et al., 2003).

Tencalla et al. (1994) noted that large scale fish kills around the world have resulted from microcystin poisoning. They postulated that a 60 g rainbow trout would only have to ingest 0.1-0.4 g of algae (wet weight) or 0.2-0.6% of its body weight to experience massive liver damage.

The most definitive effect of microcystin on fish concerns Atlantic salmon reared in net pens in coastal waters of British Columbia and Washington State, USA. As yet unidentified microcystin-producing organisms produce a progressive degeneration of the liver in salmon smolts placed into open-water net pens (Anderson et al., 1993). The disease, referred to as Net Pen Liver Disease (NPLD), has resulted in significant economic losses for the mariculture industry.

Bury et al. (1996) studied brown trout exposed to sublethal levels of microcystin toxins and found greatly altered blood cortisol levels indicating acute stress and reduced immunosuppression. This is a concern in the mainstem Klamath River because of the recognized fish health problems (Foott and Stone, 2003; Nichols and Foott, 2005), and the potential for additional diminishment of resistance to disease caused by microcystin exposure of juvenile salmonids. It also may explain the previously unexplained large-scale fish kill immediately following an intense reservoir algae bloom in 1997 (Belchik, pers. comm.). As summarized in Fetcho (2006), detection of microcystin toxin in steelhead livers collected from the Weitchpec area indicate that these fish were exposed to microcystin in the lower-Klamath River environment.

Existing conditions in the Klamath River

Kann (2006) provides a summary of four datasets that provide information about the distribution and abundance of *Microcystis aeruginosa* (MSAE) in the Klamath River basin. These include data from the Klamath Tribes in 1990-1997, PacifiCorp in 2002-2004, Karuk Tribe/State Water Resource Control Board (SRWCB) in 2005, and Yurok Tribe/U.S. Fish and Wildlife Service (USFWS) in 2005.

The Klamath Tribes' 1990-1997 data showed that while MSAE is found in Upper Klamath Lake and Agency Lake, it was only rarely detected in the outlet to Upper Klamath Lake. PacifiCorp's data showed that MSAE was only detected twice (August 21, 2003 and September 10, 2002) in the Klamath River directly above Copco (river mile 206.42), but then was common in Iron Gate and Copco Reservoirs and below. In Karuk Tribe/SWRCB data from 2005, MSAE and microcystin toxin were never detected at the station above Copco Reservoir, but were common in Iron Gate and Copco Reservoirs and in the Klamath River at the outlet of Iron Gate Dam. Yurok/USFWS data from 2005 showed that MSAE and microcystin toxin were found in the Klamath River all the way from Iron Gate Dam to the Klamath estuary. Based on those results, Kann (2006) concludes:

> Taken together these data provide compelling evidence that Copco and Iron Gate Reservoirs are providing ideal habitat for MSAE; increasing concentrations dramatically from those upstream, and exporting MSAE to the downstream environment.

It should be noted that although PacifiCorp collected algal data for 3 years (2002-2004) and knew that *Microcystis* was a common species in its reservoirs, it did not mention *Microcystis* in its 7000+ page Final License Application to FERC. Additionally, to our knowledge PacifiCorp did not notify the public, inform water quality agencies, or post public health warnings at reservoir access points. When in September of 2004, *Microcystis* was detected in Copco Reservoir (Kann 2005) and brought it to the attention of government agencies responsible for public health, PacifiCorp then acknowledged that it knew that *Microcystis* existed in KHP reservoirs, but no data or details were released until October 28, 2005 when the company posted the phytoplankton data on its website.

Project effects

The results described above from multiple datasets summarized by Kann (2006) indicate that Iron Gate and Copco Reservoirs were directly responsible for the high levels of MSAE and microcystin toxin detected in the Klamath River below Iron Gate Dam. This conclusion is consistent with literature showing that MSAE and other buoyant cyanobacteria do not dominate in conditions of turbulent mixing (e.g., Huisman et al. 2004) such as that known to occur in the Klamath River above Copco and Iron Gate Reservoirs.

Conversely, because MSAE dominates at low turbulent diffusivity (calm-stable conditions) when their flotation velocity exceeds the rate of turbulent mixing, the stable and stratified conditions created by Copco and Iron Gate Reservoirs provide ideal conditions for MSAE and other buoyant cyanobacteria. For example, Kann and Asarian (2005) show that KHP dams increase hydraulic retention time in the reservoirs from ~10 days in the spring to greater than 50 days during the period of MSAE dominance, and depth profiles of temperature and dissolved oxygen indicate highly stratified water column conditions. By contrast, the river environment (absent the KHP reservoirs) in this reach would by well mixed (no stratification) and hydraulic retention would be on the order of 1 day.

The MSAE inoculum supplied by the reservoirs then persisted down river and was detected in the Klamath River estuary. No tributaries downstream of Iron Gate Dam showed the presence of MSAE.

Kann (2006) described how Iron Gate and Copco Reservoirs contribute to downstream blooms of MSAE:

> In areas where turbulent diffusivity may decrease as rivers widen and increase in depth, or such as would occur in backwater areas, the potential also exists for MSAE blooms in slow-moving riverine environments as well …Given the tens of thousands of MSAE cells introduced to the lower-Klamath River from Copco and Iron Gate Reservoirs above, the potential for recurring blooms downstream increases as slower-moving water is encountered. For example, as described above, MSAE cell concentration exceeded 1.3 million cells/ml in a backwater area near the confluence of Coon Creek nearly 100 miles downstream from Iron Gate Dam.

With dam removal and decline in preferred lacustrine habitat for MSAE, the abundance of *Microcystis* would be reduced many fold. Thus, with the inoculant source (Iron Gate and Copco Reservoirs) of MSAE reduced by many orders of magnitude (or even eliminated), even in downstream suitable MSAE habitat such as a quiet backwater, blooms would take longer to develop because they would start from fewer cells, and cells would have less chance of dispersing to suitable habitats.

As stated above, detection of microcystin toxin in steelhead livers collected from the Weitchpec area indicate that these fish were exposed to microcystin in the lower Klamath River environment (Fetcho 2006).

Both Resighini Rancheria and California water quality standard for toxic substances state that "All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in, human, plant, animal, or aquatic life." (NCRWQCB 2001) (Resighini Rancheria Tribal Water Quality Ordinance § 503(N) [TWQO 2002]).

PacifiCorp's KHP provides ideal habitat for the algae *Microcystis*, leading to massive blooms with subsequent increased microcystin toxin concentration in the waters of the Klamath River. This appears to be a violation of the Tribe's and of California's toxic substances water quality standards, as well as being a public health risk and possible fish health and consumption risk.

PacifiCorp's Proposed Remediation

PacifiCorp has not proposed any mitigation for this extremely serious problem.

Tribe's Proposed Remediation

As described above, Iron Gate and Copco Reservoirs provide ideal habitat for MSAE. Major reduction of MSAE algal biomass can be accomplished by removing dams and returning the river to free-flowing conditions that are not conducive to large growths of algae dependent upon the low-turbulence, long retention time conditions created by the KHP reservoirs. Dam removal will eliminate these reservoirs, dramatically reducing available habitat for MSAE and lessening risk to human health and fish health. The KHP dams and facilities must be removed from the Klamath River and its tributaries.

WATER TEMPERATURE

Existing conditions in Klamath River

The Klamath River is recognized as impaired with regard to water temperature by the North Coast Regional Water Quality Control Board (SWRCB 2002). Kier Associates (1999) noted acutely stressful water temperature conditions on the mainstem Klamath River and also potential for temperature stress to contribute to juvenile salmonid disease epidemics. Flint et al. (2005), Bartholow (2005), and Hardy and Addley (2001) provide information on the spatial and temporal patterns of temperature impairment.

Summer water temperatures in the mainstem Klamath River are extremely high. While water temperatures in the mainstem Klamath River vary somewhat between years, the basic patterns are similar between years. Mainstem Klamath River water temperature alone is a sufficient stressor to cause increased susceptibility of disease and even direct mortality of salmonids in many years. Temperature acts in concert with other stressors in affecting fish health and has synergistic effects on other water quality parameters such as pH, D.O. and ammonia.

In addition, summer mainstem temperatures in the Klamath River have been rising in recent decades Bartholow (2005) are likely to continue to rise due to global climate change (NRC 2004).

Project Effects

The KHP significantly alters water temperatures in the Klamath River (PacifiCorp 2004) in ways that are detrimental to the various runs of anadromous fish in the Klamath River. Due to the thermal mass of Iron Gate and Copco reservoirs, water temperatures in the mainstem Klamath below Iron Gate Dam are cooler in spring, and warmer in late summer and fall, than would exist if the KHP were absent (PacifiCorp 2004, PacifiCorp 2005c, Deas 2004)(Figure 1). Due to variations in weather and hydrologic conditions, the timing and magnitude of these temperature deviations will vary somewhat from year to year.

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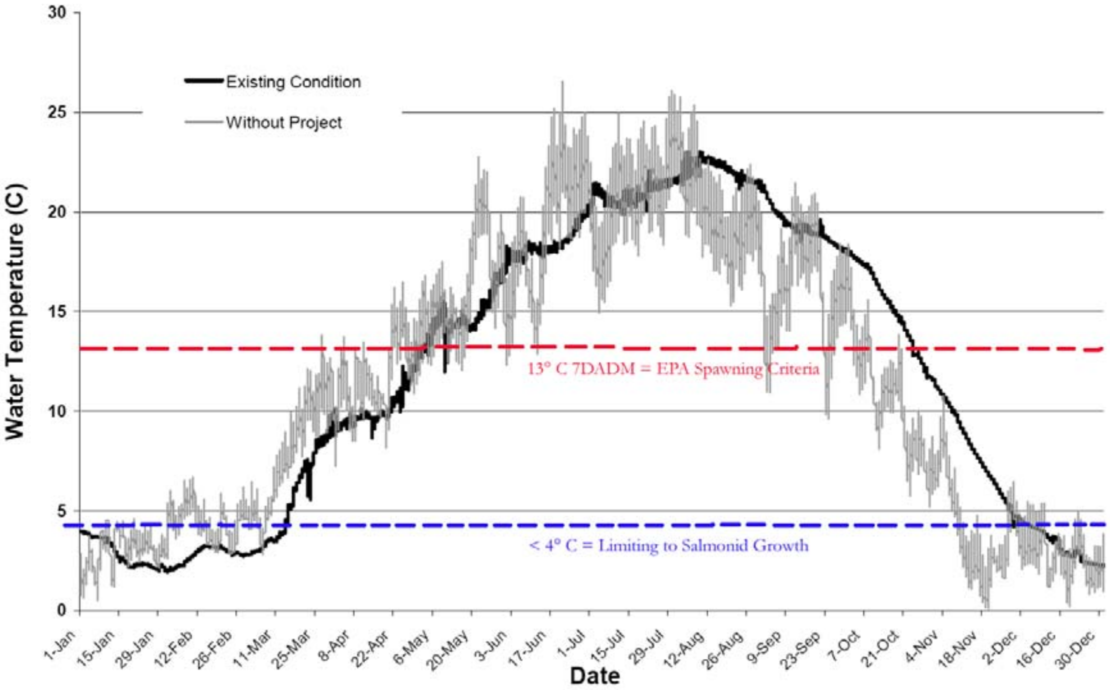

Figure 1. PacifiCorp water quality modeling output showing water temperatures at Iron Gate Dam for the year 2000, comparing existing condition (with project) and without project scenarios (PacifiCorp 2005c). References for salmonid spawning and the lower limit for salmonid growth are from U.S. EPA (2003).

The document entitled *EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards* (U.S. EPA 2003) recommends temperature limits for various life history stages for the protection of Pacific salmon species. For spawning, U.S. EPA recommends that the maximum seven day floating average (7DADM) not exceed 13° C, which is shown on Figure 1 as a reference line. Chinook salmon spawning from Iron Gate Reservoir to Happy Camp begins on approximately October 15 and peaks in late October or early November (Figure 2) (Catalano et al. 1997, Magnusen et al. 2001). Model outputs in Figure 1 show that the Klamath River water temperature without the KHP would begin to fall to lower than 13° C for at least brief periods, as early the first week in September. Without the KHP, temperatures would generally meet U.S. EPA thresholds (13° C 7DADM) three weeks earlier than they would with the KHP in place under current conditions. Eggs laid in the Klamath River below Iron Gate at higher than optimal conditions are likely to have higher pre-hatch mortality, a greater rate of developmental abnormalities, and lower weight as alevins (McCullough 1999).

As water flows downstream from Iron Gate, the thermal lag becomes less pronounced, but is still visible at Seiad Valley (river mile 128.5), 60 miles downstream of Iron Gate Dam, increasing temperatures between 2˚ C to 5˚ C for most of October and November (Figure 3). The Klamath River without the Klamath Hydroelectric project (WOP) alternative would attain fall temperatures suitable for Chinook salmon spawning weeks before current existing conditions (EC), similar to just below Iron Gate Reservoir. Since this reach is heavily used by fall Chinook salmon for spawning, detrimental effects on fecundity, fertility and egg survival are likely to occur here as well.

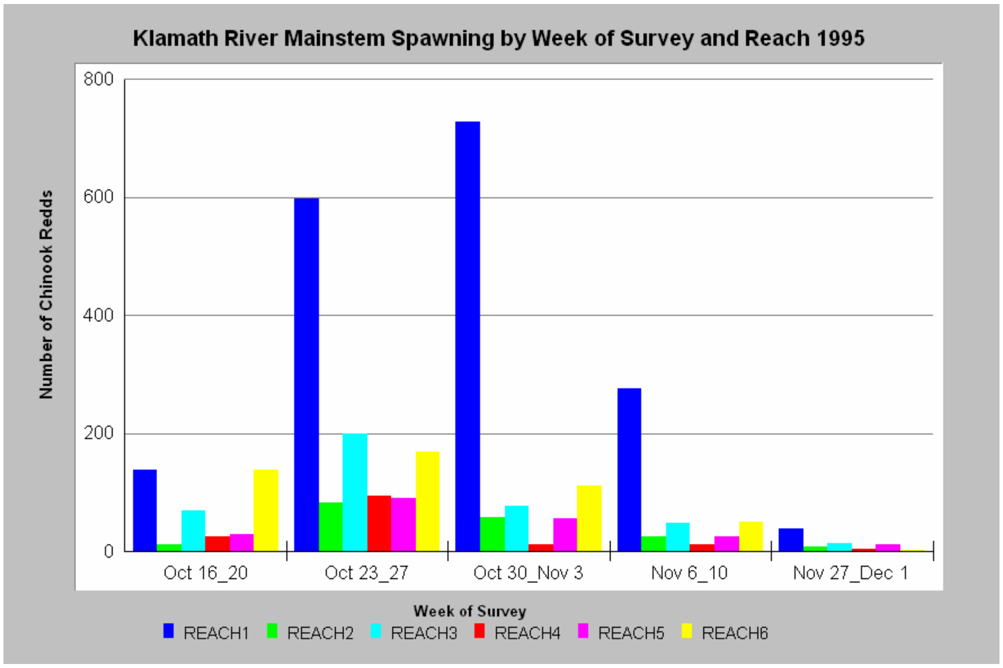

Figure 2. Chinook salmon spawning surveys between Iron Gate Dam and Happy Camp show that spawning begins in mid-October and peaks in late October. Reach 1 = Iron Gate Dam river access (river mile 190.2) to Ash Creek river access (rm 175.0), Reach 2 = Ash Creek river access (rm 175.0) to Beaver Creek Riffle river access (rm 159.8), Reach 3 = Beaver Creek river access (rm 159.8) to Blue Heron river access (rm 144.1), Reach 4 = Blue Heron river access (rm 144.1) to Seiad Bar river access (rm 132.2), Reach 5 = Seiad Bar river access (rm 132.2) to China Point river access (rm 118), Reach 6 = China Point river access (rm 118) to Indian Creek confluence (rm 106.3). Data from USFWS (Catalano et al. 1997).

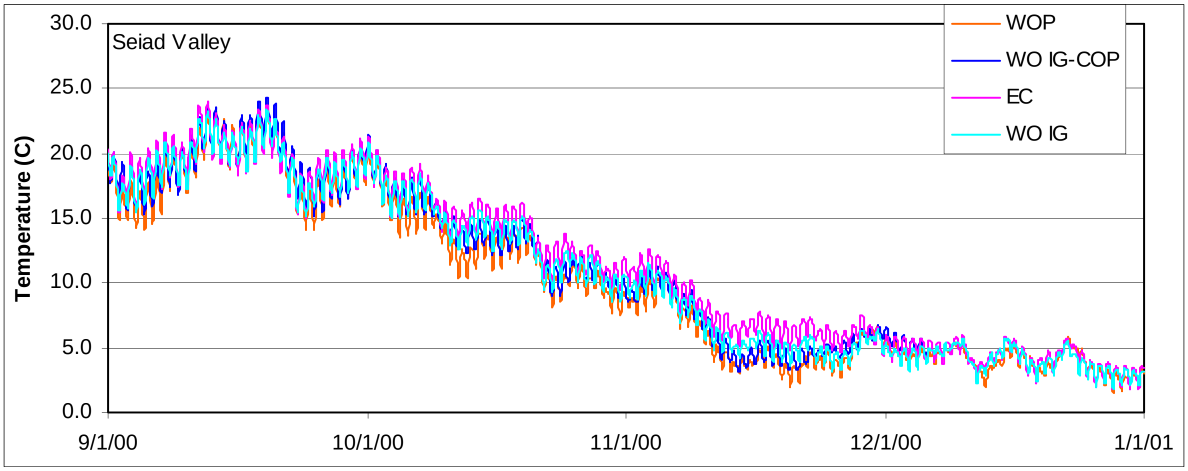

Figure 3. Results from PacifiCorp's water quality model comparing water temperatures in the Klamath River at Seiad Valley in the year 2000 under four different scenarios. WOP = without project (all dams but Link removed), WO IG-COP = existing condition with Iron Gate and Copco removed, EC = existing condition, WO IG = existing condition with Iron Gate removed. Figure from Deas (2004). Unfortunately, PacifiCorp has not made these data available in an intelligible form that would allow the graph to be re-created in a more legible form.

Since the construction of Iron Gate dam, there has been a shift in the timing of the fall Chinook spawning run, arguably due to the KHP's impact on river temperatures (Huntington 2006 (Klamath River Anadromous Fish Reintroduction Plan). The Klamath fall Chinook run has shifted several weeks later so it now overlaps more with the later-running Trinity River fish in the lower Klamath River, leading to increased fish density and risk of disease transmission. A high concentration of salmon in the lower Klamath River was one of the factors that contributed to the September 2002 Klamath River fish kill (CDFG 2003, Guillen 2003, Belchik et al. 2004).

The optimum growth temperatures for juvenile salmonids are 10-15˚C (McCullough 1999). The KHP cools the river in spring because it keeps water temperatures below 10˚C (Figure 1), which is detrimental to salmonids because it keeps water temperature below the optimum growth temperatures for juvenile salmonids. Chinook salmon juveniles in the Klamath River that are small in size migrate downstream slowly (PFMC 1994). Increased residence time in the mainstem exposes fish to prolonged stress, increasing their likelihood of becoming infected with parasites (see Fish Disease section below). In addition, the larger a smolt is before entering the ocean, the higher its chances of surviving to maturity and returning to spawn (Nicholas and Hankin 1988).

Modeling results (PacifiCorp 2005c) indicate that the KHP early summer cooling effect may provide some limited benefit to juvenile fish, but the period of time is short (less than one month total in 2000), and the magnitude is small (Figure 1). For example, modeling from 2000 (Figure 1) (PacifiCorp 2005c) shows that the project had: beneficial cooling of 0-5˚C for the last 10 days of May, detrimental heating of 0-4˚C for the first half of June; beneficial cooling of 3˚C for two weeks in late June; detrimental heating of approximately 4˚C in the first 7 days in July; no difference for most of July; a cooling benefit of approximately 2˚C for approximately 5 days in late July/early August; and then detrimental heating beginning in August and lasting through the end of fall. *Due to the short duration and small magnitude of this beneficial cooling, the benefits are far outweighed by the detrimental effects to spring, late summer, and fall temperatures.*

Iron Gate Dam forms a complete barrier and prevents anadromous salmonids from migrating upstream, denying anadromous salmonids access to high-quality thermal refugia. In the J.C. Boyle Bypass Reach, located between Copco and Keno Reservoirs, there are springs that contribute approximately 225 cubic feet per second of clean, cool water. These springs could be among the most significant thermal refugia on the entire mainstem of the Klamath River and there is evidence they were supporting summer holding by spring-run chinook prior to the construction of Copco Dam. Fall, Jenny, Shovel, and Spencer Creeks are also significant thermal refugia that anadromous salmonids are currently denied access to by the KHP.

Spring-run chinook were historically the most abundant salmonid species in the Klamath Basin, but have declined due to blockage of migration and deterioration of habitat (NRC 2004). The U.S. EPA (2003) points out that access to thermal refugia is essential for river systems where attainment of optimal mainstem temperatures is not possible. The critical role of thermal refugia in maintaining the viability of anadromous salmonids in the Klamath

Basin has become increasingly clear in recent years (Belchik 1997, McIntosh and Li 1998, Watershed Sciences 2002).

PacifiCorp's Proposed Remediation

In response to FERC's AR-1 request, PacifiCorp used its water quality model to analyze various possible ways to reduce the KHP's effects on temperature. PacifiCorp (Scott 2005) summarized its findings as follows:

> "The results of the analyses indicate that potential reservoir water temperature management using selective withdrawals, curtains, or flow augmentation offers only modest, if any, improvements to water temperatures in the Klamath River downstream of Iron Gate dam. Furthermore, the alternatives examined do not provide appreciable differences in regard to their relative effect on fish."

FERC then requested PacifiCorp to complete additional modeling regarding selective withdrawal options. Subsequent PacifiCorp investigations (2005b) showed that the measures would be ineffective in mitigating project impacts:

> Based on these results, PacifiCorp concludes that the additional revised selective withdrawal scenarios do not provide effective control of temperatures below Iron Gate dam, and therefore do not merit more detailed design evaluation under Part (b) of this AIR.

Even if the alternatives PacifiCorp investigated *could* reduce water temperature, it would not be a good idea because it would likely lead to increased nutrients being released downstream. Regarding Copco reservoir, PacifiCorp (2005a) stated:

> "Consideration was given to turning the lake over earlier through implementing selective withdrawal earlier in the season. However, concerns over mixing nutrient rich bottom waters into the photic zone and possibly creating beneficial conditions for primary production was deemed undesirable."

Even if water temperatures could be altered for spawning or rearing periods, only dam removal will provide access to important thermal refugia.

Tribe's Proposed Remediation

PacifiCorp's own analyses make it clear that the KHP's effects on water temperature are immitigable; therefore, the Tribe recommends that FERC order the removal of the KHP's dams and facilities from the Klamath River and its tributaries.

NUTRIENTS

Background information

Nutrients affect salmonids by stimulating the growth of algae and aquatic macrophytes to nuisance levels that can adversely impact dissolved oxygen and pH levels in streams. U.S. EPA (2000) and Tetra Tech (2004) provide excellent summaries of the literature on the subject. In addition, ammonia is a form of nitrogen that can be acutely and chronically toxic to fish (U.S. EPA 1999), and has its own section in the comments below.

Existing conditions in the Klamath River

The Klamath River is listed by the state of California as impaired by nutrients, dissolved oxygen, and temperature (SWRCB 2002). The Klamath River is not listed for pH, but pH levels routinely exceed water quality standards across much of the river (Kier Associates 2005). Although the quality of water coming out of Upper Klamath Lake in the summer is extremely poor and often full of live and/or dead algae that are associated with high nutrient concentrations, nutrient concentrations generally decline as the Klamath River flows downstream (Figure 4).

Total nitrogen generally decreases as the river flows downstream, though the pattern varies among years (Figure 4). Nitrogen concentrations are generally highest in Link River and decline slightly to Keno Dam (Figure 4). Nitrogen levels in the Boyle Bypass Reach are low due to dilution from springs. By the above Copco station in the J.C. Boyle Peaking Reach, the bulk of the Klamath River water has rejoined the river channel and nutrient concentrations increase. From above Copco to below Iron Gate, nitrogen levels increased substantially in 2000, decreased slightly in 2002 and 2003, increased slightly in 2004, and there was no data above Copco in 2001. From Iron Gate to Orleans, nitrogen concentrations generally decrease (with the exception of some increases from Iron Gate to above Shasta in some years) before flattening out (Figure 4).

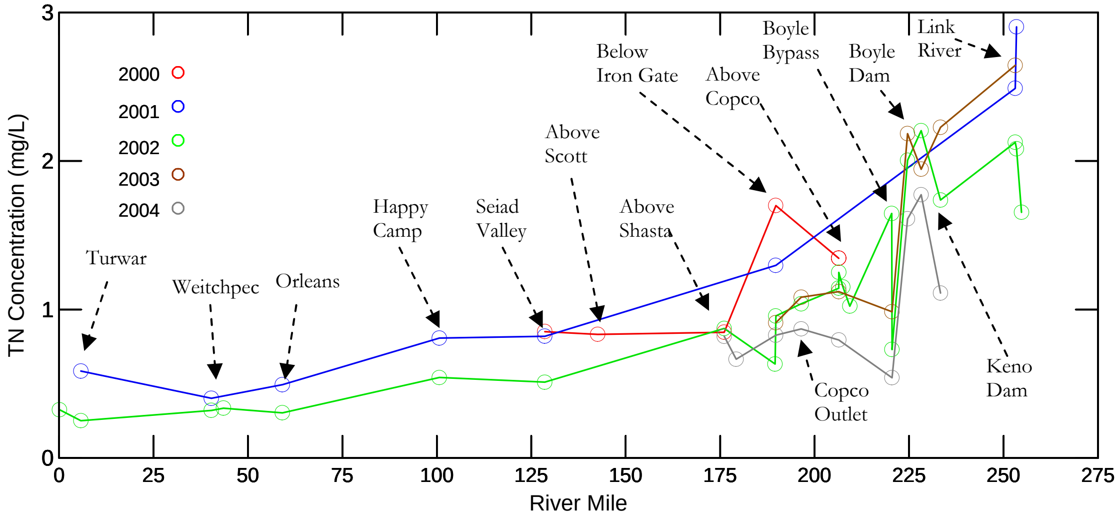

Figure 4. Longitudinal profile of mean summer (June 1 – August 31) total nitrogen concentrations in Klamath River mainstem sites for the year 2000-2004 (reservoirs excluded). Sites with less than three measurements in a summer were excluded from this graph. It is important to note that this graph, originally in Kier Associates (2005), summarizes data from a wide range of agencies, sampling frequencies, and laboratories with different reporting limits. It is intended to show general trends at broad spatial scales.

Project effects

Outline for project effects on nutrients

This section of our comments is lengthy and complex, so it is necessary to provide an outline here to help the reader understand how it is organized.

1. Summary
2. Understanding Key Water Quality Processes
3. Effect of dilution on nutrients
4. "Recovery zone" dynamics
5. Effect of free-flowing river reaches on nutrient dynamics
    - Denitrification in the river's hyporheic zone
    - Assimilative capacity of periphyton
    - Data analyses showing the combined effect of assimilative capacity and denitrification
6. Effect of peaking and bypass river reaches on nutrient dynamics
7. Effect of reservoir processes on nutrient dynamics

1. Summary

The KHP affects the nutrient dynamics of the Klamath River by interfering with natural processes that allow the river to become cleaner as it flows downstream. Although nutrient concentrations at Iron Gate are lower than at Link River and Keno, the net reduction can be shown to be primarily caused by natural dilution processes, and not the presence of the KHP.

Further, by replacing a formerly free-flowing river with a series of reservoirs, peaking reaches, and bypass reaches, the KHP has greatly altered the hydrologic, physical, chemical, and biological processes of the Klamath River. For example, in the area where the KHP now resides, the Klamath River was once approximately 62 miles of free-flowing river and 2 miles of Lake Ewauna. In its present configuration, the KHP impact area is approximately 37 miles of reservoirs; 5 miles of bypass reaches, where the river is almost entirely diverted; a 16-mile peaking reach, where flow rates fluctuate drastically on a daily basis; and only 6 miles of free-flowing river (PacifiCorp 2004).

Such alterations, through the reduction of periphyton habitat and delayed initiation of the river's natural "recovery zone" (see below) increases the downstream extent of the high nutrient concentrations entering the KHP project reach from Upper Klamath Lake. In other words, without the KHP, resulting nutrient levels would decrease sooner and nutrient concentrations at Iron Gate Dam would be even lower than could be gained from dilution alone.

Further evidence for the natural assimilative capacity of a free flowing Klamath River is shown in longitudinal nitrogen data between Iron Gate Dam and the Klamath River estuary. These data clearly show a reduction in total nitrogen loads even with additional tributary loads entering the river. They also show a substantial decrease in inorganic nitrogen in the reach below Iron Gate where both periphytic assimilation and denitrification processes operate.

There are several lines of evidence, discussed on more detail below, to support the principle that nutrient concentrations at Iron Gate Dam (and hence points downstream as well) would be lower in the absence of the KHP:
► First, as PacifiCorp itself (2005d) has acknowledged, peaking and bypass operations inhibit the river's capacity to assimilate nutrients within the KHP area.
► Second, Iron Gate and Copco reservoirs do not substantially reduce nutrient concentration, and can act as both sources and sinks of nutrients.

► Third, the Klamath River below Iron Gate Dam exhibits substantial capacity to reduce nutrients levels through periphyton assimilation and denitrification. If the KHP were removed, similar periphyton assimilation and denitrification would occur throughout the area now occupied by the KHP.

2. Understanding key water quality processes

PacifiCorp (2004) cited the fact that water exiting the KHP is higher quality than water entering the KHP in support of its argument that the project benefits water quality. To understand the impacts of the KHP on water quality, the real question 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 without the KHP?*"

Although nutrient levels exiting the KHP are better than KHP inflow (Figure 4), this does not mean that the Project has a beneficial impact on water quality. As described above, even absent the KHP, due to freshwater inflows and the capacity of the system to assimilate nutrients, water quality in the Klamath River would improve naturally as it flows downstream. Through dilution alone, nutrient concentrations at Iron Gate Dam should only be 64% of what they are at Keno Dam (Figure 5). Furthermore as mentioned above, the KHP has relocated the start of the "recovery zone" of intense periphyton activity from Keno downstream tens of miles to below Iron Gate. The result is that the KHP slows the rate at which nutrient concentrations decrease as water flows downstream. Without the KHP, nutrient levels would decrease sooner.

To understand how the KHP affects nutrient dynamics, it is necessary to understand the nutrient dynamics of the reservoirs, free-flowing river reaches, the peaking reach, and bypass reaches. Only after those individual components are understood is an adequate understanding of the KHP's effects on nutrient dynamics possible.

3. Effect of dilution on nutrients

An important reason for the decrease in nutrient concentrations as the river flows downstream from Keno to Iron Gate is the dilution of low-quality Klamath River water with high-quality water from tributary and spring flow inputs.

Although PacifiCorp (2004) claimed that water exiting the KHP is higher quality than water entering the KHP in support of its argument that the project benefits water quality, they did not properly emphasize that the primary reason for this is natural dilution. The tributaries and springs that clearly pre-date the KHP cannot legitimately be claimed as part of the KHP's "benefit" to water quality.

To quantify the effect of dilution, we examined U.S. Geological Survey stream gage data over a 10-year period from 1995-2004 during the time of year with low flows and poor water quality- June 1 – August 31. The J.C. Boyle gage is located downstream of the J.C. Boyle Powerhouse return at river mile 219.7, the Iron Gate gage is located downstream of Iron Gate Dam at river mile 189.5, and the Keno is located downstream of Keno Dam at river mile 233.3. We examined a four-month period, rather than a shorter period such as August, to minimize "errors" due to differences in reservoir management (e.g. if the amount of water stored in a reservoir were to increase or decrease substantially over a short period of time).

Mean streamflow averages 674 cfs at Keno, 939 cfs at J.C. Boyle (141% of Keno), and 1036 cfs at Iron Gate (156% of Keno) (Figure 5). This translates into accretions of 265 cfs between Keno and the J.C. Boyle gage, primarily due to springs in the J.C. Boyle Bypass Reach, with much smaller contributions from Spencer Creek and other tributaries. Accretions between J.C. Boyle and the Iron Gate gage average 97 cfs include Shovel, Jenny, Fall, Camp, and Bogus Creeks (note that while Bogus Creek is below Iron Gate Dam, it is upstream of the USGS gage). These flow accretions are associated with much lower nutrient concentrations than the mainstem Klamath, especially the springs in the bypass reach which account for the vast majority of the accretions. PacifiCorp (2005d) estimates that nutrient concentrations in the springs are very low, with orthophosphate and nitrate at 0.15 mg/L, and little or no organic forms of nutrients. Hence, it follows that through dilution alone, nutrient concentrations at Iron Gate Dam should be only 64% (inverse of 1.56) of what they are at Keno Dam. It should be noted that this calculation slightly overestimates (likely by a few percentage points) the effect of dilution on nutrients because the accretions, although low in concentration, are not totally devoid of nutrients.

Continuing downstream as the Klamath River flows from Iron Gate Dam to the Klamath Estuary, the river picks up many substantial tributaries. With the exception of the Shasta, and perhaps the Scott, nearly all these tributaries are cleaner and cooler than the mainstem Klamath, further increasing the likelihood of improved water quality.

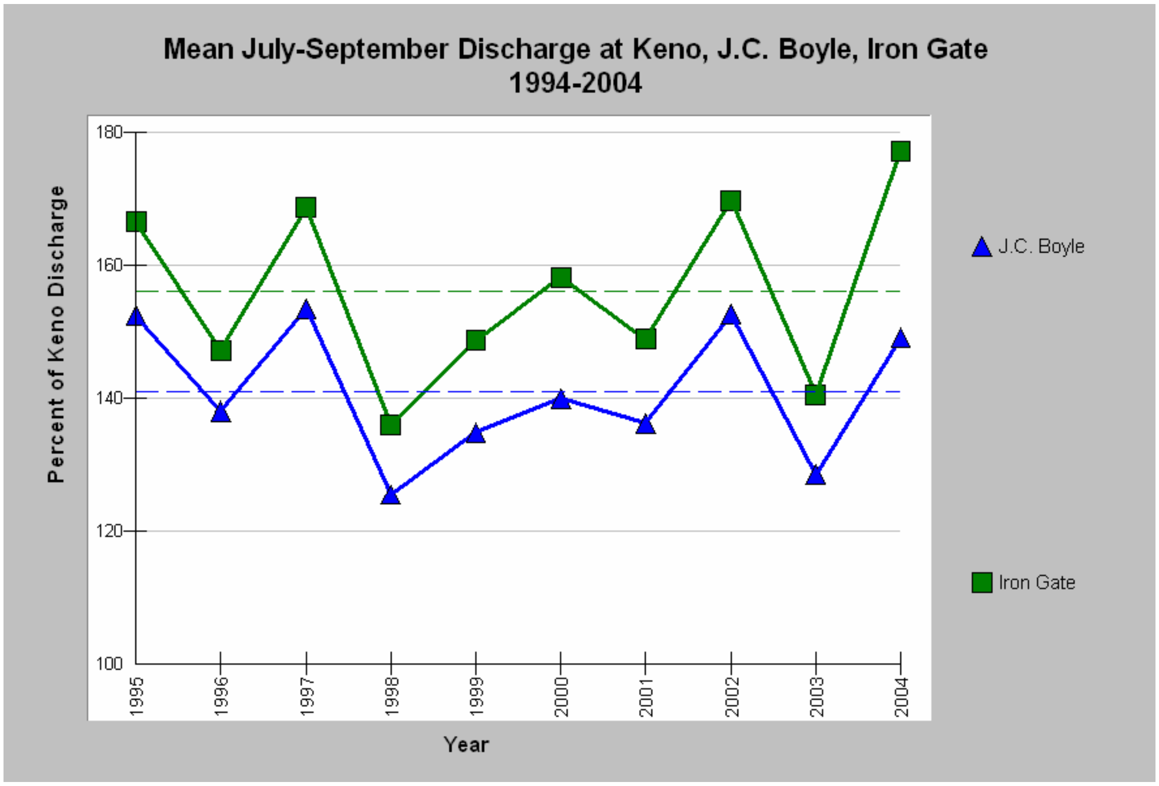

Figure 5. A comparison of mean discharge each year for the period July 1 - September 30 at U.S. Geological Survey gaging stations on the mainstem Klamath River. Data for J.C. Boyle and Iron

Gate are expressed as a percentage of mean discharge at the Keno gage for the same period, with dotted lines showing the mean of all years.

4. "Recovery zone" dynamics

Rivers around the world follow common patterns in response to localized nutrient pollution (Biggs 2000). As long as substantial additional nutrient inputs do not occur, nutrient concentrations typically diminish as the river flows downstream. There is a "recovery zone" where massive amounts of periphyton (including diatoms, filamentous green algae, and cyanobacteria) growing on the bottom of the river absorb nutrients (Biggs 2000). Examples where this phenomenon has been observed include the Klamath River (described here), Oregon's South Fork Umpqua River (Tanner and Anderson 1996), and Alberta's Bow River (U.S. EPA 2000). Due to extreme periphyton activity in the "recovery zone", water quality parameters such as dissolved oxygen (D.O.) and pH can be inhospitable to salmonids, but the nutrient assimilation that occurs results in water being released to the "purified zone" downstream with substantially lower nutrient concentrations, less periphyton growth (and diatoms are much more common than filamentous green algae), and better pH/D.O. conditions. Hence, while there is localized degradation of water quality conditions within the recovery zone, overall it benefits the river system because downstream water quality is improved.

Downstream of the recovery zone, nutrients are still assimilated but the rate is slowed because the there are lower levels of inorganic nitrogen (ammonia, nitrate, and nitrite, the forms of nitrogen readily available for algal growth). This additional assimilation is important because it allows nutrients concentrations to be reduced still further as the river continues downstream.

Irrespective of the existence of the KHP, as long as agricultural land and water use practices in the upper basin remain similar to today, there will be a "recovery zone" reach of the Klamath River with high nutrients levels, extreme periphyton growth, and hence poor pH /D.O. conditions. The existence of that reach is not due to the KHP; however, ***the existence and operation of the KHP further contributes to poor water quality conditions in that "recovery zone" reach, and determines how long it is, where it is, and how it affects anadromous fisheries***.

One mechanism by which the KHP alters the capacity of the Klamath River to assimilate nutrients is by moving the recovery zone downstream, thus increasing the downstream extent of high nutrient levels. For example, due to the following three KHP components, initiation of a functional recovery zone is prevented from starting until the section of free-flowing river below Iron Gate Dam:

1. *Reservoirs* at Keno, J.C. Boyle, Copco, and Iron Gate impound formerly free-flowing river reaches. What could a free-flowing periphyton-dominated recovery zone is instead reservoirs full of nitrogen-fixing algae that further impair nutrient levels.
2. *Bypass Reaches* below J.C. Boyle and Copco Reservoirs have reduced periphyton habitat and biomass because less water leads to a narrower wetted channel.
3. *Peaking operations* between J.C. Boyle and Copco inhibit periphyton by diurnally desiccating near-shore areas, reducing light penetration during peak flows, and increasing velocity and associated scour.

The KHP has pushed the recovery zone downstream so that it now begins at Iron Gate Dam (river mile 190). The length of the recovery zone varies from year to year, likely depending on nutrients, weather, and hydrologic conditions, but extends downstream to approximately Seiad Valley (RM 128.5) or the Scott River (RM 146). Unfortunately, this overlaps with some of the best salmonid habitat in the mainstem Klamath River, and causes a multitude of water quality and fish health problems that are described in detail in the below sections of these comments. Some of these consequences of this overlap include increased exposure of juvenile salmonids to highly adverse pH/D.O. conditions, toxic levels of ammonia, and high concentrations of spores from myxozoan parasite such as *Ceratomyxa shasta* and *Parvicapsula minibicornis*.

Dam removal will move the recovery zone upstream; the more dams that are removed, the further upstream the recovery zone will move. Moving the start of recovery zone upstream increases the length of the "purified zone" downstream.

For example, if all dams from Iron Gate to Keno (including Keno) were removed, the recovery zone will begin at the outlet to Lake Ewauna. If Iron Gate, Copco 1-2, and J.C. Boyle Dams were removed, the recovery zone would begin at the outlet of Keno Dam. These areas provide better recovery zone locations as they do not provide as high of quality spawning habitat for anadromous salmonids as the Iron Gate/Copco area. For example, the mainstem Klamath between Keno Dam and Shovel Creek (several miles upstream of Copco Reservoir) is mostly high-gradient and gravel-deficient, though it does have important tributaries with high-quality spawning/rearing habitat such as Spencer and Shovel Creeks, and coldwater refugia such as the springs in the J.C. Boyle Bypass reach.

It is our hope that over the long-term land and water use practices in the basin will improve, guided by regulations such as the Total Maximum Daily Loads for Upper Klamath Lake, Lost River, and the mainstem Klamath. The resulting decrease in Klamath River nutrient concentrations would benefit water quality and decrease the length of the recovery zone.

4. Effect of river reaches on nutrients

The following discussion and presentation of data illustrates how a free-flowing functional river processes nutrients as it flows downstream. Benthic algae, also known as periphyton or attached algae, take up nutrients dissolved in water and assimilate them into their cells as they grow. In addition, denitrification by micro-organisms in the hyporheic zone of free-flowing rivers can reduce nitrogen concentrations in streams. These two natural processes substantially enhance water quality in the Klamath by removing nutrients from the water column. The free-flowing river below Iron Gate Dam is particularly effective at removing inorganic forms of nitrogen (ammonia, nitrate, and nitrite).

It should be noted that while these processes can substantially reduce nutrient concentrations, the rate at which this occurs varies depending upon conditions, and also has an upper limit. The algal assimilation and denitrification processes are most likely responsible for this reduction in inorganic nitrogen levels are temperature-dependent processes (Sjodin 1997, Biggs 2000), so are most effective during the warm summer (July and August especially) and early fall months. These two processes are described in more detail below.

Assimilative capacity of periphyton
Benthic algae, also known as periphyton or attached algae, can take up nutrients dissolved in water and assimilate them into their cells as they grow. These algae can also release nutrients when they die and decompose. The nutrient uptake and assimilation process can reduce nutrient concentration, while the decomposition/release process can increase nutrient concentration. The net effect on nutrient concentration is reach-specific, and an evaluation of these processes is necessary when comparing pre and post KHP conditions.

The processing or spiraling of nutrients may have a variety of implications to downstream ecosystems. Uptake may sequester nutrients for long periods resulting in seasonal alterations of downstream nutrient loads. Processing may also alter the partitioning of the nutrient forms (inorganic/organic, dissolved/particulate) with attendant implications to the availability of the nutrient reaching the downstream system. In the case of nitrogen, significant in-stream removal may occur through denitrification (see below for details). In the case of dissolved organic carbon (DOC), more intense utilization within the stream ecosystem directly reduces the downstream loading.

Biggs (2000) described the factors governing periphyton biomass growth and decay, indicating that the most important include the amount of available nutrients, light, temperature, and number of days since scour (Biggs 2000). Deas (2003) also reviews these factors.

Kier Associates (2005) summarizes the results of periphyton investigations in the Klamath River in 2004, including Eilers (2005), NCRWQCB et al. (2005), and U.S. EPA (2002), noting that the general pattern in 2004 was that biomass accrual began in July and continued until the first scouring flow. Tanner and Anderson (1996) similarly found that scour triggered periphyton sloughing decay in Oregon's South Fork Umpqua River.

U.S. Geological Survey investigations of South Fork Umpqua River in Oregon found that periphyton played a key role in nutrient dynamics (Tanner and Anderson 1996). In that river, the major nutrient sources are four municipal wastewater treatment plants distributed along the river. After each wastewater treatment plant, there is 5 to 10 mile reach of massive periphyton biomass and attendant reduction in nutrient concentration (Tanner and Anderson 1996), similar to the "zone of recovery" phenomenon described by Biggs (2000). Tanner and Anderson (1996) summarize:

> Periphyton act as an effective sink for nutrients entering the South Umpqua River. Nutrient input causes a distinct increase of algal activity immediately downstream and results in the transfer of nutrients from the water column to storage in algal tissue. Consequently, in the first few miles below a nutrient source, concentrations and loads of nutrients in the water column decrease markedly. Assuming that algal growth is nutrient limited, biomass and net productivity of the benthic community are expected to decline in conjunction with decreasing nutrient loads. Where nutrient loads do not limit algal growth, the nutrient profile may decrease over the length of the reach until nutrient uptake reduces loads to limiting levels, even though plant biomass and productivity remain relatively steady. Successive nutrient uptake by downstream periphyton mats further decreases nutrient loads, gradually limiting overall biomass, net productivity, and magnitude of exceedances of the DO and pH standards.

In the period September 23-25, 1991, the calculated sum of all upstream dissolved inorganic nitrogen (DIN) loads 5-10 miles below the third wastewater treatment plant was approximately 105 kilograms/day, yet the measured load was only 10 kilograms/day, indicating that periphyton had assimilated approximately 90% of the DIN over a 60-mile study reach (Tanner and Anderson 1996).

U.S. EPA (2000) describes the effects of long-term reductions in nitrogen and phosphorus loading from wastewater treatment plants on periphyton in the Bow River in Alberta, Canada. In the years before load reductions, periphyton biomass averaged approximately 300-400 mg chlorophyll a/m^2, with maxima up to 600 mg chlorophyll a/m^2. After load reductions, similarly high levels of periphyton are still observed within the first 10 kilometers of the wastewater treatment plant, but periphyton levels are now substantially lower in downstream reaches. This indicates that the "zone of recovery" (Biggs 2000) shortened due to load reductions.

Denitrification in the river's hyporheic zone

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 (Sjodin et al., 1997 and Holmes, 1996). 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 to denitrification can be extraordinary, especially those with a 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).

Denitrification has unique benefits to water quality. First, it permanently removes nitrogen from the river system. In contrast, nutrient assimilation by periphyton stores the nutrients in algal cells where it will eventually be released (though often that release does not occur until the fall when water temperatures have decreased and the nutrients will have less impact on water quality). Second, denitrification removes nitrogen without affect dissolved oxygen and pH levels. In comparison, when periphyton are growing and assimilating nutrients, they contribute to diurnal cycles of dissolved oxygen and pH.

Data analyses showing the combined effect of assimilative capacity and denitrification

Figure 6 shows a typical example of the longitudinal gradient in nitrogen concentrations in August at the peak of the summer. Only inorganic forms of nitrogen (nitrate and ammonia) are immediately available to fuel growth of periphyton and aquatic plants, organic nitrogen must first decay into ammonia before it can be utilized. Organic nitrogen is the most common form of nitrogen across the Klamath River (Figure 6). High levels of inorganic nitrogen are present throughout the upper reaches of the Klamath River. Beginning at the outlet of Iron Gate Dam (river mile 189.73), dense mats of periphyton and aquatic plants cover the river bed during summer. They are extremely efficient at removing nutrients, and within approximately 40 miles, above the Scott River at river mile 146.12, most inorganic nitrogen has been removed from the water column. It should be noted that it is unknown how much of this decrease is due to de-nitrification and how much is due to periphyton assimilation, but given the high biomass of periphyton in this reach it is likely that periphyton assimilation has a large effect.

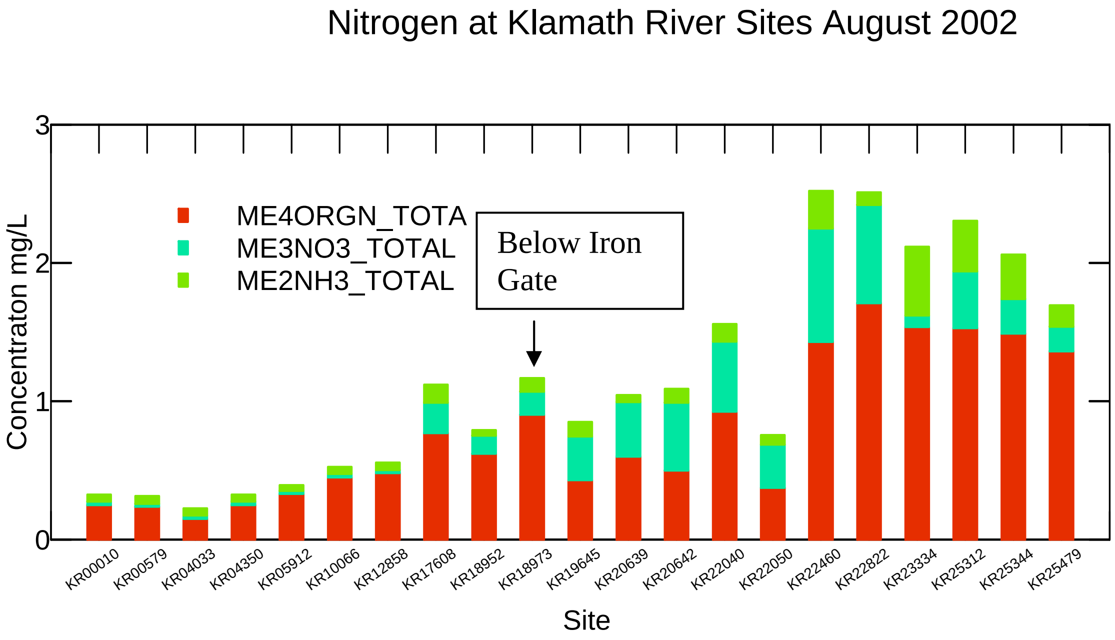

Figure 6. This graph shows the longitudinal gradient in average nitrogen concentrations in the Klamath River from Link River to the estuary in August 2002. The total height of the bars is total nitrogen concentration, and the colors represent the three major forms of nitrogen: organic (ME4ORGN_TOTA), nitrate/nitrite (MENO3_TOTAL), and ammonia (MENH3_TOTAL). Figure is from Kier Associates (2005). Sites are arranged by river mile, with the furthest downstream on the left.

Nutrient loads are calculated by multiplying nutrient concentration by discharge and are typically expressed in units of kilograms per day. They are a valuable tool for understanding nutrient dynamics in the Klamath River because they make it possible to differentiate between dilution (clean water added) and assimilation (nutrients removed from the water column). The U.S. Geological Survey (Flint et al. 2005) calculated nutrient loads at various sites in the mainstem Klamath sites below Iron Gate Dam for the year 2002. The results show clearly that the free-flowing Klamath River has substantial assimilative capacity (Figure 7). The river seems especially able to assimilate inorganic forms of nitrogen, with large amounts of nitrate/nitrite and ammonia are rapidly removed from the water column in the 60 miles from Iron Gate Dam to Seiad Valley. In summer 2002, total nitrogen loads declined between 22%-35% from Iron Gate to the estuary (Table 1).

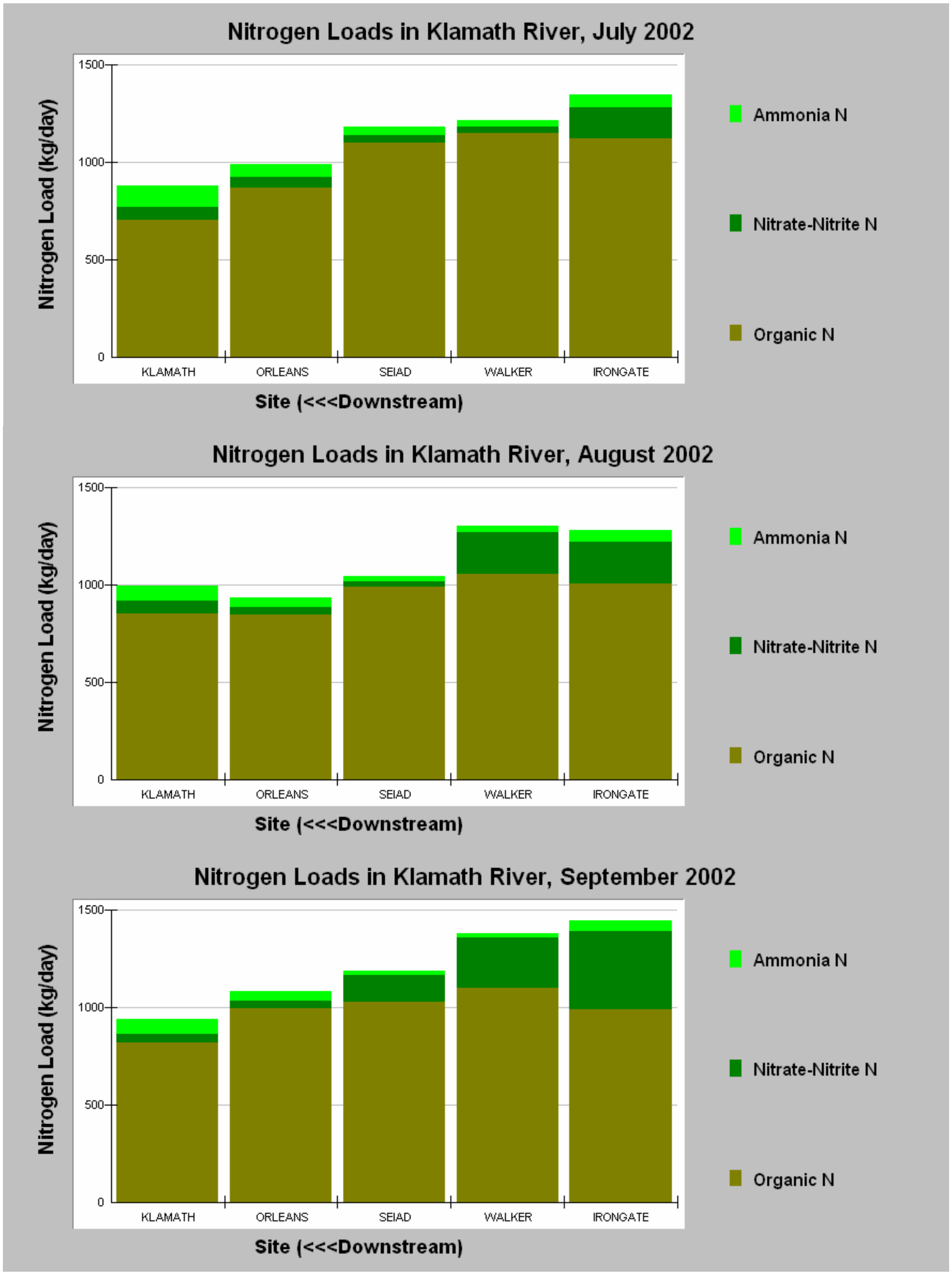

Figure 7. Nutrient loads in the Klamath River, as calculated by the USGS (Flint et al. 2005). The total height of the bars indicates the total nitrogen load and the colors indicate loads for individual nitrogen parameters. KLAMATH = Klamath River near estuary, ORLEANS= Klamath River near

Orleans, SEIAD= Klamath River at Seiad Valley, WALKER = Klamath River at Walker Road Bridge, IRONGATE = Klamath River below Iron Gate Dam.

Table 1. Total nitrogen load and percentage decrease in total nitrogen loads in the mainstem Klamath from Iron Gate to the estuary. Data are from the USGS (Flint et al. 2005). KLAMATH = Klamath River near estuary, ORLEANS= Klamath River near Orleans, SEIAD= Klamath River at Seiad Valley, WALKER = Klamath River at Walker Road Bridge, IRONGATE = Klamath River below Iron Gate Dam.

	July		August		September	
Site	Total N Load	Load Decrease (relative to Iron Gate)	Total N Load	Load Decrease (relative to Iron Gate)	Total N Load	Load Decrease (relative to Iron Gate)
	(kg/day)	(%)	(kg/day)	(%)	(kg/day)	(%)
IRONGATE	1350	0%	1283	0%	1445	0%
WALKER	1218	10%	1303	-2%	1379	5%
SEIAD	1183	12%	1045	19%	1190	18%
ORLEANS	993	26%	934	27%	1083	25%
KLAMATH	880	35%	996	22%	939	35%

Because the high volume tributaries that enter the Klamath River between Iron Gate and the Klamath estuary do contain some nitrogen (although generally cleaner than the mainstem), the actual assimilative capacity of the Klamath River is far greater than is indicated by Figure 7 and Table 1. For example, the Klamath River gained between 1257-2123 cfs as it flowed from Iron Gate to the Klamath estuary (Table 2), and applying the TN value of 0.25 mg/L (this is the value PacifiCorp used for accretion in their water quality modeling) it is clear that the Klamath's tributaries (accretions) add a substantial nitrogen load to the Klamath River (Table 2). Accretion loads ranged between 53% and 96% of the observed Iron Gate load (Table 2). Thus, if the river had no assimilative capacity, the expected load at the Klamath estuary should be equal to Iron Gate load plus the accretion load. *In fact, the observed load at the Klamath estuary is only 33% to 46% of the expected load; translating to a 54%-67% assimilation of the expected load.* (Table 2).

Kier Associates and Aquatic Ecosystem Sciences are currently performing data analyses for the Yurok Tribe that will provide additional quantitative details on the assimilative capacity of the Klamath River.

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Table 2. Calculation of the assimilative capacity of the Klamath River from Iron Gate Dam to the USGS gage at Klamath near the estuary for July, August, and September 2002. Discharge and observed load data are from USGS (Flint et al. 2005). Nitrogen concentration for accretion is the same value PacifiCorp (2005e) used in their water quality model (0.15 mg/L organic nitrogen + 0.05 mg/L nitrate + 0.5 mg/L nitrite nitrogen = 0.25 mg/L total nitrogen). Klamath= Klamath River near estuary, Iron Gate= Klamath River below Iron Gate Dam.

	Discharge (cfs)						Estimated Total N Conc.		Calculated Load
	Klamath (cfs)		Iron Gate (cfs)		Accretion (cfs)		Accretion (mg/L)		Accretion (kg/day)
July	3020	-	897	=	2123	x	0.25	=	1298
Aug.	2110	-	665	=	1445	x	0.25	=	884
Sept.	2030	-	773	=	1257	x	0.25	=	769

	Estimated Load		Observed Load		Expected Load		Observed Load		Load Assimilated	
	Accretion (kg/day)		Iron Gate (kg/day)		Klamath (kg/day)		Klamath (kg/day)		(kg/day)	%
July	1298	+	1350	=	2648	-	880	=	**1768**	**67%**
Aug.	884	+	1283	=	2167	-	996	=	**1171**	**54%**
Sept.	769	+	1445	=	2214	-	939	=	**1275**	**58%**

5. Effect of peaking and bypass operations on nutrient dynamics

Power peaking operations in the reach below J.C. Boyle have reduced the amount of benthic algae in the KHP area (PacifiCorp 2004). This degrades downstream water quality because it reduces the assimilative capacity of benthic algae in the peaking reach, allowing nutrients to pass on downstream instead of being absorbed. In contrast, as shown above (Figure 7, Table 1, Table 2), the free-flowing Klamath River between Iron Gate Dam and the Klamath estuary has substantially assimilative capacity. PacifiCorp (2005d) has acknowledged that the assimilative capacity in the peaking reach is diminished by project operations. There are three reasons for the decrease of benthic algae in the KHP flow-peaking area:

- diurnal desiccation of near-shore areas
- reduced light penetration during peak flows
- high velocities and associated scour

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, substantially decreasing algal biomass at the edges of the channel. According to PacifiCorp (2004), peaking operations reduce the area of wetted streambed in the J.C. Boyle peaking reach by about 10 to 25 percent, because of the "varial zone" at the edge that is wetted and dried on a daily cycle. This reduction in wetted width likely diminishes the capacity of the peaking reach to assimilate nutrients.

Peaking flows occur at times of peak electrical demand, which in the summer is typically weekday afternoons and early evenings (PacifiCorp 2004). During peak flows, water depths are greater than they would be were J.C. Boyle operating as a run-of-the-river facility. This, along with possible increases in turbidity, can decrease the amount of light available to benthic algae during photosynthetic hours. This would lead to less algal growth, less algal 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.

Just as peaking affects periphyton (and, hence, water quality), so do bypass operations. The low flows in the J.C. Boyle bypass reach result in a narrow channel width. The flows in the bypass reach between Iron Gate and Copco are even lower, though this reach is much shorter in length. This affects the amount of periphyton that can grow in the channel bottom, which affects the amount of nutrients that the periphyton can remove from the water column, which affects downstream water quality.

Benthic algae are included in PacifiCorp's 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 (Wells et al. 2004). Additionally, the model does not take into account factors such as scour and desiccation on the ability of algae to grow.

6. Effect of reservoirs on nutrient dynamics

Our best current understanding is that Iron Gate and Copco reservoirs do not substantially reduce nutrient concentration, and can act as both sources and sinks of nutrients.

The only year-long study of Iron Gate reservoir found that an annual basis, it was a net source for nitrogen (U.S. EPA, 1978). In addition, they appear to be sinks in April-May (Kann and Asarian 2005) and a mix of sources and sinks in June-September (Kann and Asarian 2005). Data from the fall are relatively scarce, especially during and after turnover, but it is likely that the reservoirs are sources during this season. There has been almost no data collection and analysis in the winter months, so that season remains an unknown.

A comparison of total nitrogen concentrations in Klamath River below Iron Gate Dam and above Copco Reservoir in 2000 and 2002-2004 indicates that the reservoirs do not reduce nitrogen concentration in the critical months of June through September (Figure 8). *In fact, concentrations above and below the reservoirs are quite similar, in spite of dilution from clean tributaries such as Shovel Creek, Jenny Creek and Fall Creek.* For the years 1995-2004, average June to September streamflow in the Klamath River increases from 1056 cfs at J.C. Boyle to 1163 below Iron Gate, an increase of 107 cfs, or 10%. It should be noted that the USGS gage below Iron Gate includes flows from Bogus Creek, which is downstream of the water quality sampling station at Iron Gate Hatchery Bridge, so actual dilution is lower, approximately 8-9%. *Therefore, these data suggest that at best there is no change, and that if tributary dilution did not* *exist, Iron Gate and Copco Reservoirs could increase nutrient concentrations by 8-9% on average for June-September in the years 2000 and 2002-2004.*

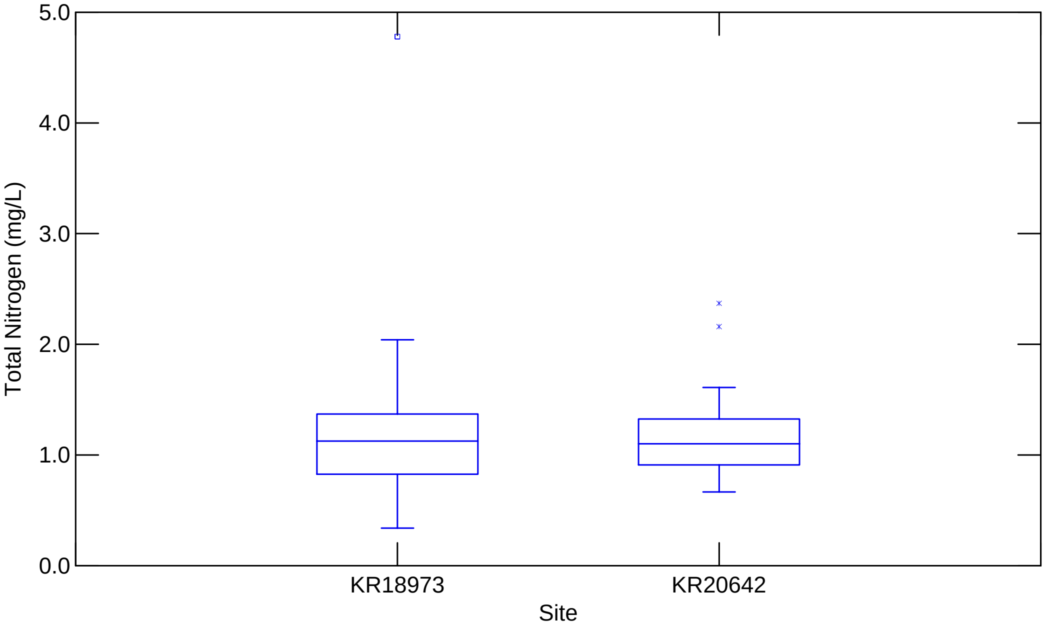

Figure 8. Box plots of total nitrogen concentrations in the Klamath River and below Iron Gate (KR18973) and upstream of Copco Reservoir at Shovel Creek (KR20642) for the months June-September in 2000 and 2002-2004. There were no data collected at KR20642 for 2001, so that year was excluded from the graph. The June-September period was chosen because those months have high temperatures, low flows, poor water quality, and are when nutrients can be most utilized by algae. The line inside each box is the median and the edges of each box are the 25th and 75th percentiles. Whiskers represent data points beyond 1.5 times the interquartile (75th-25th) range, while individual points shown are outliers. Data are from U.S. Fish and Wildlife Service and PacifiCorp.

The effects of Iron Gate and Copco Reservoirs on nutrient dynamics vary between years. For instance, the average summer total nitrogen concentrations shown in Figure 4 suggest that between the above Copco and below Iron Gate monitoring stations, nitrogen concentrations increased substantially in 2000, decreased slightly in 2002 and 2003, and increased slightly in 2004 (no data above Copco in 2001).

In cooperation with the SWRCB and the California National Guard, the U.S. EPA (1978) conducted nutrient sampling in Iron Gate Reservoir in 1975 as part of its National Eutrophication Study (U.S. EPA, 1975). Samples at tributaries and the Klamath River inlet and outlet were taken once per month for 12 months, but the reservoir itself was only sampled on three occasions. The analysis summed the incoming and outgoing loads for the year and concluded *the annual mass of nitrogen outflow from Iron Gate Reservoir was 21% higher than inflow*, and that annual outflow mass of phosphorus was 7% less than inflow.

PacifiCorp's (2004) Final License Application presented limited analysis of water quality data; however, some important details were obscured by averaging data over broad spatial and temporal scales. They postulated that retention of organic matter and nutrients in the reservoirs results in a net decrease in organic matter and nutrients that would otherwise continue downstream (PacifiCorp 2004); however, the most complete analyses to date do not support that assertion (Kann and Asarian 2005, U.S. EPA 1978).

Kann and Asarian (2005) used water quality data collected by PacifiCorp and the U.S. Fish and Wildlife Service to calculate nutrient budgets for Copco and Iron Gate Reservoirs. The report concludes:

> "These preliminary analyses indicate that for the Copco/Iron Gate Reservoir system, the April-November period is characterized by periods of positive and negative retention for both phosphorus and nitrogen (net positive values denote a sink and net negative values denote a source). Despite acting as net sinks for P and N over the entire Apr-Nov period, both Copco and Iron Gate Reservoirs can act as a nutrient source during critical periods (e.g., June through September), making nutrients available at such periods for downstream growth of algae and macrophytes.
>
> The more robust seasonal analysis presented here does not support an earlier PacifiCorp (2004; 2005d) broad postulation that the reservoirs benefit water quality by processing organic matter and nutrients from upstream sources. With the given data set, there is a clear indication that the reservoirs periodically increase nutrient loading downstream. Likely pathways for this increased load include internal sediment loading and nitrogen fixation by cyanobacteria.

The California State Water Resources Control Board (SWRCB) recently received a Clean Water Act Section 104(b)(3) grant from the U.S. Environmental Protection Agency Region IX to conduct a nutrient cycling study on Iron Gate and Copco Reservoirs (Kanz 2005). Once collected, the data will be used to construct a detailed nutrient budget for each reservoir. Because nutrient data will be collected more frequently (every two weeks rather than monthly) and will encompass an entire year (rather than March to November), as well as include additional spatial coverage and algal sampling, the 2005 study is expected to be an improvement over the analysis of existing data conducted by Kann and Asarian (2005) because it will use data with higher spatial and temporal resolution. The study is expected to provide information on important reservoir processes that have not yet been fully evaluated, including seasonal patterns of nutrient flux and the potential for nitrogen fixation by blue-green algae. Sampling began in May 2005 and will continue through May 2006, with final results available soon after.

PacifiCorp's Proposed Remediation

PacifiCorp has not proposed any mitigation measures to minimize or eliminate the effects of the KHP to Klamath River nutrient dynamics, and their detrimental effects to Klamath River anadromous fish and water quality conditions.

Tribe's Proposed Remediation

We are not aware of remediation measures that could help with these issues. Therefore, our recommendation is that FERC order the removal of theKHP's dams and facilities from the Klamath River and its tributaries.

DISSOLVED OXYGEN

Existing conditions in the Klamath River

Dissolved oxygen (D.O.) data for the Klamath River are less robust than for temperature and pH because the continuous recorders can have problems resulting from fouling of probes and incorrect readings. Continuous data from 2004 are the most reliable because it is the only year in which data were post-processed to correct for bio-fouling of the probes.

Data collected for the Klamath River at various locations from below Iron Gate Reservoir (RM 189.13) to the river mouth (RM 0) between the years 2000 and 2004 show a wide range of conditions. Figure 9 shows the mean daily minimum D.O. for 2000-2004 by river mile and the reference line of 7.0 mg/L on the chart above reflects research showing reduced swimming ability of juvenile chinook salmon (WDOE 2002). Only one location near the mouth of the river at Terwer Creek (RM 5.73) meets the proposed NCRWQCB (2005) standards for D.O., which is a minimum of 8.0 mg/L. All locations near Iron Gate Reservoir show significantly depressed D.O. in 2001 and 2004. The 2004 D.O. daily average minimum for August 2004 shows depressed levels all the way down to the Scott River with average daily minimum D.O. dipping below 6.0 mg/L, well into the stressful ranges for salmonids (Reiser and Bjornn 1979).

While monthly mean minimum D.O. levels indicate chronic stress for juvenile salmonids, daily minimum data from some mainstem Klamath River locations show levels dipping more toward acutely low D.O. levels of 5 mg/L. Figure 10 shows daily minimum, average and maximum D.O. above the Scott River. Minimums continue under 6 mg/L into October, which raises concerns about D.O. levels needed for spawning. NCRWQCB (2006) proposed D.O. standards for spawning are 8.0 mg/L in redds and 11 mg/L in the water column, values clearly not met according to gauge results.

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Mean Daily Minimum D.O. in Klamath River Mainstem Sites, August 2000-2004

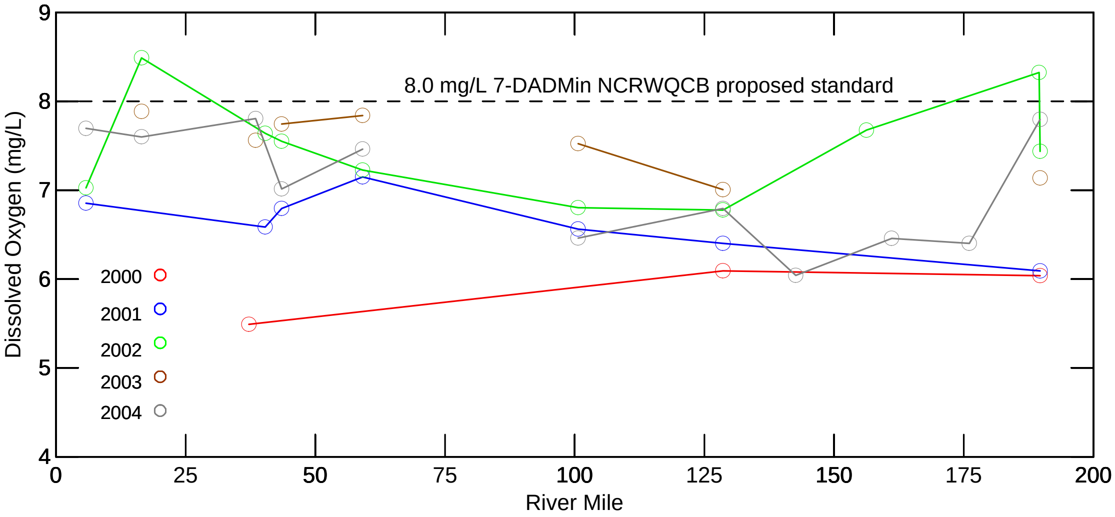

Figure 9. The mean daily minimum D.O. for August in various years from 2000-2004 are displayed here by river mile (RM) with a reference line showing the NCRWQCB (2006) proposed year-round standard that the seven-day average of the daily minimum (7-DADMin) D.O. should be 8 mg/L or greater. River miles range from the outlet of Iron Gate Reservoir at River Mile 189.73 to above the estuary at RM 5.79. Data are from the USFWS, Karuk Tribe, Yurok Tribe and USGS. It should be noted that D.O. data for 2000-2003 were not adjusted to correct for biofouling of the probes over the course of a deployment; the only year of D.O. data that have been adjusted to correct for biofouling is 2004. The USFWS (Zedonis 2005), who distributed these data collected by the USFWS, Karuk Tribe, and Yurok Tribe, notes that "the adjusted dissolved oxygen data periodically display a trend of decay through the course of deployment suggesting that the correction was inadequate to account for all bias."

Minimum, Average, Maximum Daily D.O. in Klamath River above the Scott River 2004

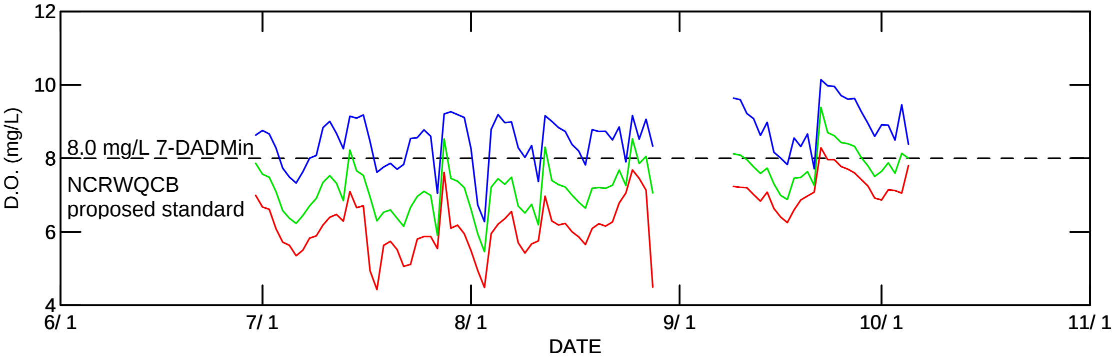

Figure 10. This chart shows minimum (red), average (green) and maximum (blue) D.O. values for the Klamath River above the Scott River (RM 142.61) with a reference value showing the NCRWQCB (2006) proposed year-round standard that the seven-day moving average of the daily minimum D.O. should be 8 mg/L or greater. The proposed standard during spawning is that the seven-day moving average of the daily minimum concentrations should be at least 11.0 mg/L in the water column. Data are from the USFWS, Karuk Tribe, Yurok Tribe and USGS.

While data collected by the U.S. Fish and Wildlife Service Arcata Fisheries Office in August of 1997 were extreme, it bears mention because it likely represents rare worst-case conditions that can occur in the Klamath River. WDOE (2002) set acute lethal D.O. limits for warm water species at 3.5-4.0. USFWS crews measured Klamath River D.O. of 3.1 during nocturnal swings on August 9-10, 1997 (Figure 11) and mortality of Klamath smallscale suckers and speckled dace both confirm that conditions at that time had reached acute lethality. Other limnological conditions such as pH and dissolved ammonia were not measured, but may have been cumulatively adding to fish stress and mortality.

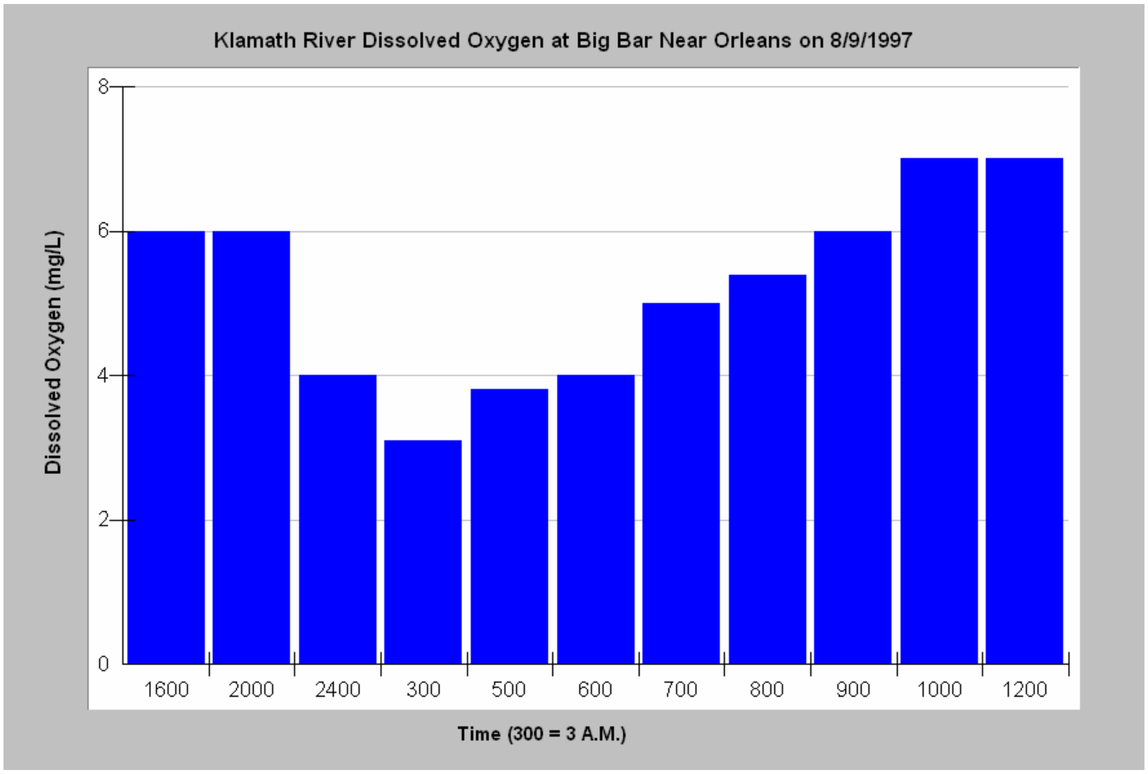

Figure 11. USFWS Arcata Fisheries Office measured D.O. levels at night and in early morning hours of August 9-10, 1997 and discovered minimum nocturnal levels of 3.1 mg/L, which are lethal for salmonids according to WDOE (2002).

Project effects

The KHP has both direct and indirect effects on dissolved oxygen in the Klamath River.

The KHP has a direct effect on dissolved oxygen (D.O.) levels in the Klamath River immediately below Iron Gate Dam because during the summer season, the reservoir often releases water with low levels of oxygen (Figure 9), which would harm any salmonids in the vicinity of the dam.

During times when the KHP is increasing nutrient levels, it stimulates growth of aquatic macrophytes and periphyton that drive large diurnal swings in D.O., including low D.O. at night.

As described above, the KHP has moved the "recovery zone" of high periphyton productivity downstream so that it overlaps with the high-quality salmonid spawning habitat below Iron Gate Dam, degrading D.O. conditions in that reach. If the dams were removed, then D.O. conditions in the Iron Gate / Copco area would be much better.

Another issue is the phytoplankton (free-floating algae) that are flushed from Iron Gate and Copco Reservoirs into the Klamath River below. The discharging of algae from Iron Gate reservoir into the river below has been documented (Kann 2006). Whatever the fate of algal cells in the river, they would have a detrimental effect on dissolved oxygen in the river. If the algal cells survive and continue to grow, then they contribute to diurnal fluctuations of dissolved oxygen. If they die, the micro-organisms that decompose them will respire, removing oxygen from the water.

PacifiCorp's Recommended Remediation

To mitigate KHP impacts to dissolved oxygen, PacifiCorp (2005b) has proposed an oxygen diffuser system for Iron Gate reservoir. If the information presented in the report is correct, it appears that the diffuser would be effective in increasing dissolved oxygen levels in Iron Gate Dam releases, although the area of the river that would benefit from this increase is very small. Due to high nutrient concentrations, low D.O. and large diurnal swings are a problem for a large portion of the river, not just right below the dam. PacifiCorp's proposed diffuser system does nothing to remedy the KHP's exacerbation of nutrient problems in the river, a major pathway by which the KHP degrades D.O. conditions in the Klamath River.

Additionally, PacifiCorp has not provided detailed information regarding how the diffusion system would affect reservoir chemistry, and also has not provided examples of evaluations of this technology's effectiveness in other eutrophic reservoirs. While we agree that if this system is put into place, monitoring and testing will be required during installation and operation, additional up front evaluation should be required. For example, it is not clear if the hypolimnion structure would be preserved, and hypolimnetic water is source water for Iron Gate Hatchery. Thus, PacifiCorp's proposed mitigation may have profound negative impacts to hatchery operations.

Tribe's Recommended Remediation

Although PacifiCorp's proposed aeration system could partially mitigate the KHP's effects on dissolved oxygen in a relative small reach of the river below the dam, this mitigation measure only focuses on one of the many KHP effects to water quality and fisheries. Thus, because decommissioning the KHP is the only way to mitigate all the project's significant effects, we recommend that FERC order the removal of the KHP's dams and facilities from the Klamath River and its tributaries.

PH

Background information

Evidence from laboratory studies indicates that any pH over 8.5 is stressful to salmonids and 9.6 is lethal (Wilkie and Wood 1995). Studies show that as water reaches a pH of 9.5, salmonids are acutely stressed and use substantial energy to maintain pH balance in their bloodstream (Wilkie and Wood 1995), while pH in the range of 6.0 to 8.0 is normative.

Wilkie and Wood (1995) note that when the gill membranes of bony fishes, including salmonids "are exposed to alkaline water there is an immediate reduction in ammonia excretion rate and a corresponding increase in plasma ammonia concentration." The direct stress effects of increased pH in the Klamath River are compounded by increasing unionized ammonia, which is triggered by increasing pH in conjunction with typically warm water conditions in summer (see below).

Prolonged exposure to pH levels of 8.5 or greater may exhaust ion exchange capacity at gill membranes and lead to increased alkalinity in the bloodstream of salmonids (Wilkie and Wood 1995). This internal shift in chemistry facilitates conversion of internal ammonium to dissolved ammonia (Heisler 1990). In case of extreme pH swings "NH_3 and NH_4^+ concentrations rise too rapidly and/or approach toxic levels, internal ammonia can ultimately contribute to high pH induced mortality" (Wilkie and Wood 1995). Dissolved ammonia causes a similar diffusion pressure on the gills to high pH as salmonids try to convert NH_3 into more benign NH_4^+, thus causing loss of H^+ ions at the gill membrane. This compounds problems in maintaining pH balance in the bloodstream of juvenile and adult salmonids exposed to both stressors.

Existing conditions in the Klamath River

The NCRWQCB (2001) Basin Plan and the Resighini Rancheria (TWQO 2002) water quality standard for the Klamath River is that pH should not exceed 8.5, but this standard is exceeded on a daily basis across large portions of the river during the summer months (Figures 12 and 13). Figure 12 shows the average maximum pH during the month of August at all locations monitored on the Klamath River from 2000-2004. The pH rises above levels known to be stressful to salmonids at locations immediately below Iron Gate Dam (RM 189.13) downstream to the mouth of the Shasta River (RM 176.08). The data show considerable variability between sites and between years. The variability of pH between years is reflective of changes in flows, climatological conditions, and other factors, but the consistent exceedance of the NCRWQCB pH standard of 8.5 is an indication of pervasive nutrient pollution and consequently a high probability of problems for fish health. Figures 12-13 clearly shows that the high maximum pH values occur most often in the zone of assimilation and high algal productivity between Iron Gate Dam and Seiad Valley.

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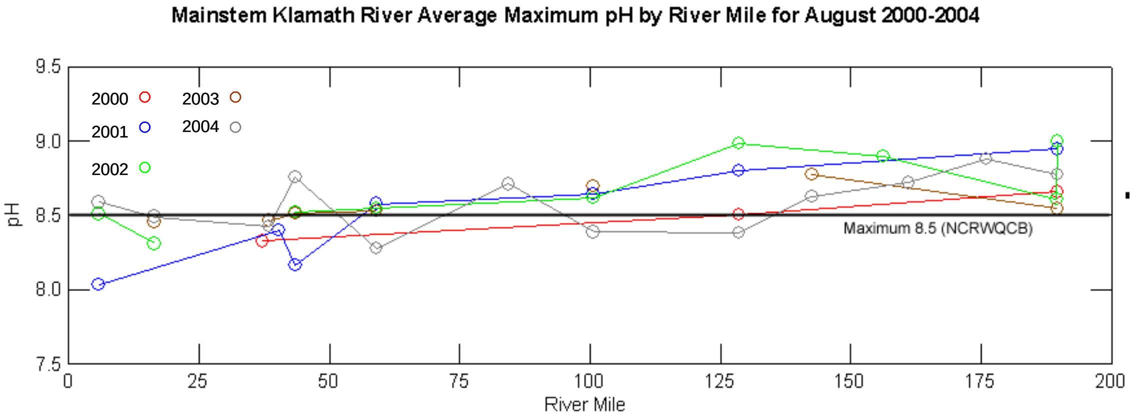

Figure 12. Average maximum pH of the Klamath River by river mile showing patterns for the years 2000-2004. The horizontal line shown on the graph is the NCRWQCB (2001) standard for pH. Data are from the USFWS, Karuk Tribe, Yurok Tribe and USGS. Figure is from Kier Associates (2005).

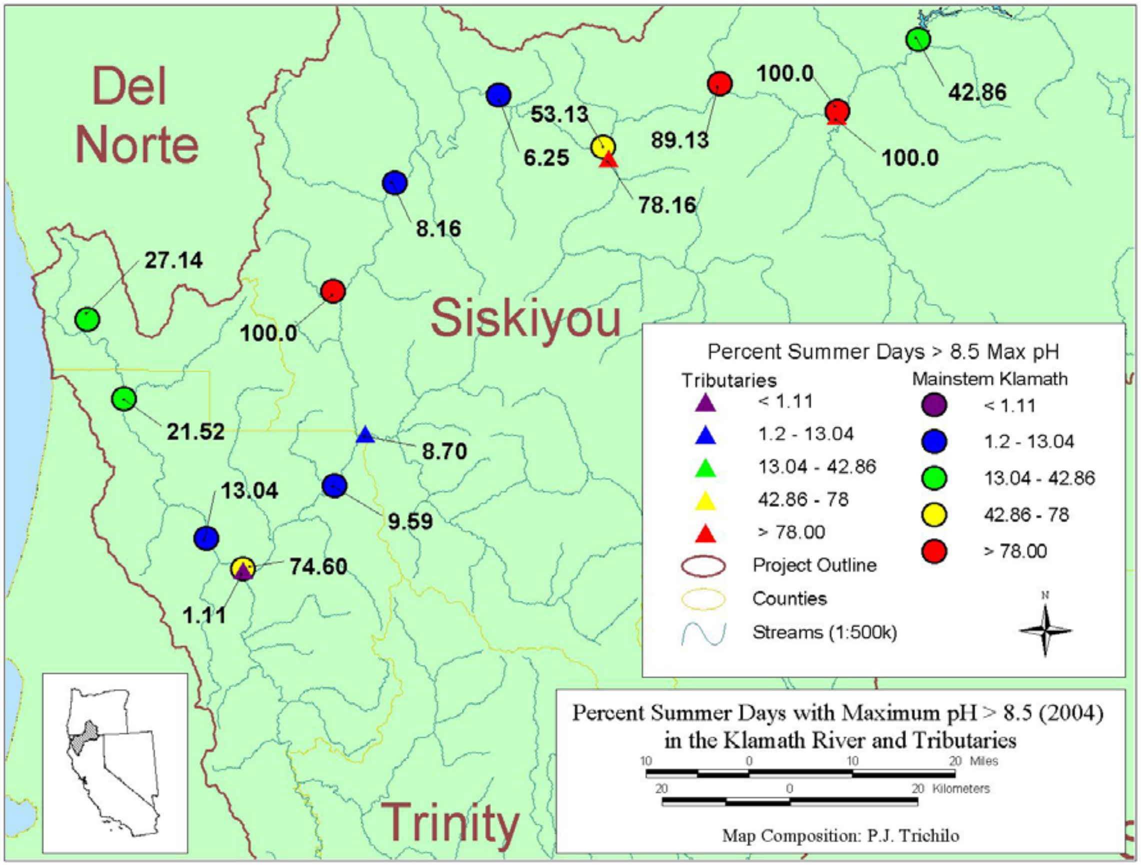

Figure 13. Map showing the percent of summer days in 2004 where maximum pH exceeded 8.5. Data are from Yurok Tribe, Karuk Tribe, and U.S. Fish and Wildlife Service. Figure adapted from Kier Associates (2005).

Project effects

The KHP has both direct and indirect effects on pH in the Klamath River.

The KHP has a direct effect on pH levels in the Klamath River immediately below Iron Gate Dam, as during the summer season the reservoir often releases water with high pH (Figure 12), which would harm salmonids in the vicinity of the dam.

Further downstream of the dam, high pH is caused by excessive photosynthesis of aquatic macrophytes and periphytic algae. By increasing nutrient levels, the KHP stimulates growth of aquatic macrophytes and periphyton that drive large diurnal swings in pH, including high pH during the daylight hours.

As described above, the KHP has moved the "recovery zone" of high periphyton productivity downstream so that it overlaps with the high-quality salmonid spawning habitat below Iron Gate Dam, degrading pH conditions in that reach. If the dams were removed, then pH conditions in the Iron Gate / Copco area would be much better.

In addition, as biomass of algae is released from Iron Gate, the potential for continued growth downstream increases, further contributing to pH exceedances. PacifiCorp has not evaluated this potential effect.

PacifiCorp's Proposed Remediation

PacifiCorp has not proposed any mitigation measures to reduce the KHP's contribution to high pH levels in the Klamath River.

Tribe's Proposed Remediation

Dam removal will eliminate both the KHP's direct (release of high pH) and indirect effects (increasing nutrient levels) on pH. For this and other reasons, we recommend that FERC order the removal of the KHP's dams and facilities from the Klamath River and its tributaries.

AMMONIA TOXICITY

Background information

Ammonia is a nitrogen-containing compound this is toxic to fish, but is also a nutrient for aquatic plants and algae. Ammonia's toxicity to fish depends on ammonia concentration, temperature, pH, and duration of exposure (U.S. EPA 1999). As pH and temperature increase, ammonia converts from ammonium ions to dissolved (unionized) ammonia that is lethal to salmonids at very low levels. For instance, at 25^{O} C and a pH of 9.0, 38% of ammonia would be dissolved (Goldman and Horne 1983)(Figure 14). Temperatures often exceed 25^{O}C and pH 9.0 in the Klamath River during the summer months.

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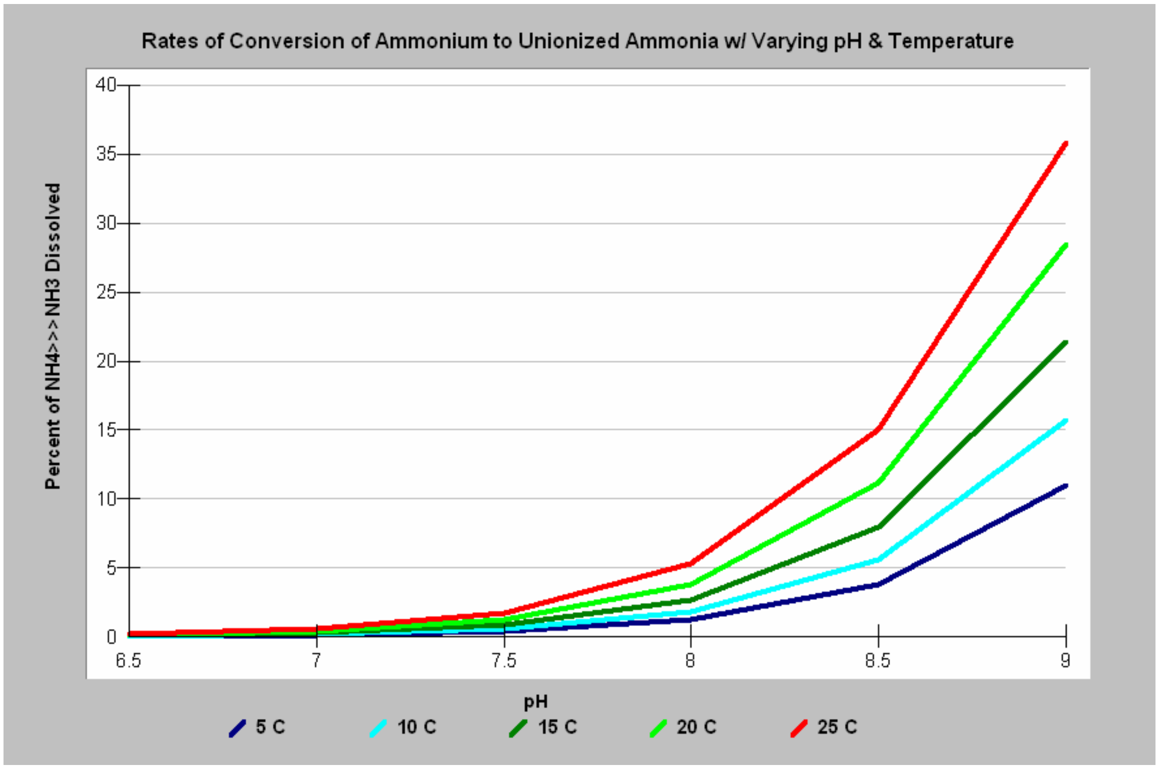

Figure 14. Chart showing the percent conversion of ammonium to dissolved ammonia with increasing pH and water temperature. Data from Goldman and Horne (1983). Figure from Kier Associates (2005).

Existing conditions in the Klamath River

Most nutrient data that have been collected on the Klamath River have been processed by laboratories that did not have adequately low reporting limits. Consequently, a sample could be reported as a non-detect, but ammonia levels could be high enough to be acutely toxic to fish, or even lethal. The upcoming Mainstem Klamath Total Maximum Daily Load (St. John 2004) will include ammonia toxicity analysis (St. John. pers. comm.).

One of the few datasets with adequate reporting limits for ammonia was the North Coast Regional Water Quality Control Board 104b water quality data from 1996 and 1997. These data show that maximum dissolved ammonia can reach levels well above those recognized as acutely stressful to salmonids (Heisler 1990). Maximum levels of dissolved ammonia for 1996 and 1997 by Klamath River location indicate that problems with this substance may be more pronounced in reaches further downstream from Iron Gate Dam (Figure 15).

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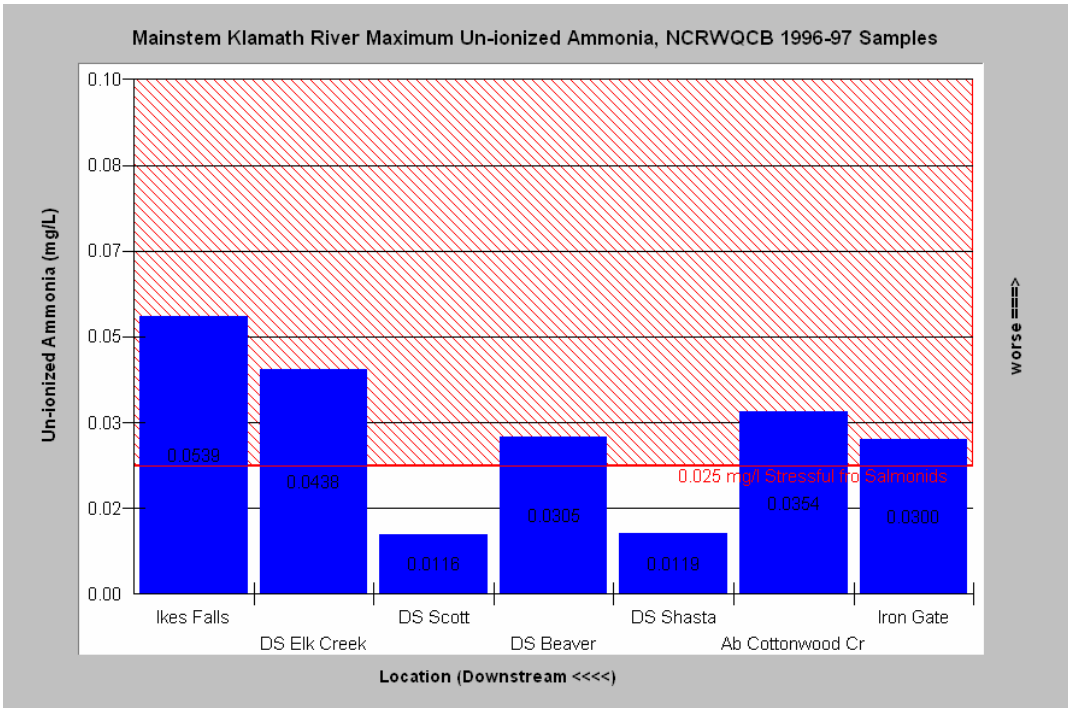

Figure 15. The maximum dissolved ammonia (also known as unionized ammonia) levels measured in grab samples collected in 1996 and 1997 show levels in the highly stressful to lethal range for salmonids as far downstream as Ikes Falls near Orleans (RM 65.93). Data were collected by the North Coast Regional Water Quality Control Board as part of the 104b program.

Project effects

Data from PacifiCorp and U.S. Fish and Wildlife Service clearly show that ammonia concentrations are often substantially higher in the Klamath River below Iron Gate Dam than above Copco Reservoir (Figure 16), providing strong evidence that Iron Gate and Copco reservoirs are sources of ammonia.

Ammonia releases from Iron Gate Dam represent a considerable localized toxicity risk to fish in the river below Iron Gate. Furthermore, Ammonia releases from Iron Gate also represent a risk to fish in downstream reaches during periods of diminished assimilative capacity of periphyton and macrophytes, such as would occur when cloudy weather, cold temperatures, or turbidity inhibits productivity. Under conditions of reduced productivity high ammonia would increase its downstream extent rather than be assimilated into organic forms. High levels of unionized ammonia have been detected far downstream of Iron Gate (figure 15), indicating that this condition does occur.

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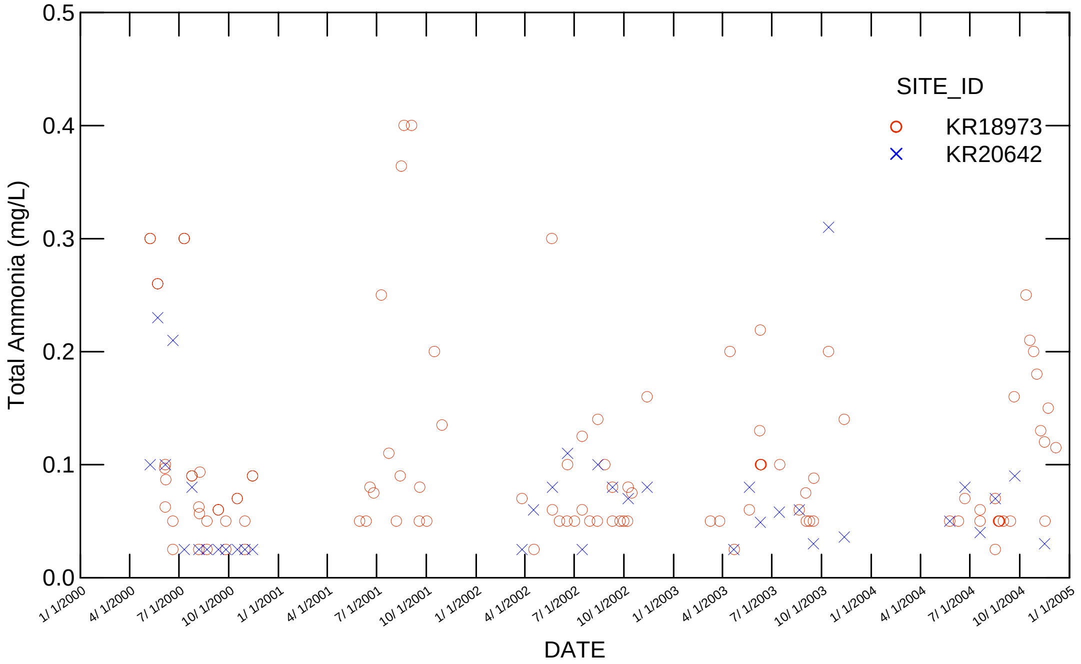

Figure 16. Total ammonia concentration in the Klamath River below Iron Gate Dam (site KR18973) and above Shovel Creek upstream of Copco Reservoir (site KR20642) for the years 2001-2004. Data collected PacifiCorp and U.S. Fish and Wildlife Service.

PacifiCorp's Proposed Remediation

Ammonia accumulates in the hypolimnion of both Copco and Iron Gate reservoirs (PacifiCorp 2004). An oxygenation system could potentially reduce ammonia concentrations in the bottom of the reservoir because in the presence of oxygen, micro-organisms can transform ammonia into nitrate.

Tribe's Proposed Remediation

Dam removal will remedy the KHP's effects on ammonia levels by eliminating the anoxic depths in Copco and Iron Gate reservoirs where large amounts of ammonia are produced and stored. Thus, since there is no alternative feasible method to remedy the problem, our recommendation is that FERC order the removal of the KHP's dams and facilities from the Klamath River and its tributaries.

TASTE AND ODOR COMPOUNDS

Background information

Taste and odor compounds are an important issue in the Klamath River Basin. Fish growing in water containing taste and odor compounds take these compounds into their tissues, and both recreational and subsistence fishing can be adversely affected by off-flavored fish. This, in turn, can have negative economic effects on recreational economies, including bait and tackle sales and boat and cottage rentals (EPA 1986). Moreover several Native American Tribes in the Klamath basin have subsistence fisheries that are impacted by taste and odor problems.]

A likely source of taste and odor compounds in the Klamath River is algae. As it grows and decays, algae can produce undesirable tastes and odors in water (EPA 1996, Droste 1997). Smith and deNoyelles (2001) provide a summary of the background and history of taste-and-odor compounds in surface water, as does Mau et al. (2004). Droste (1997) and Palmer (1977) provide lists of algal genera that are known to produce taste and odor compounds. Some of the most severe taste and odor problems have been associated with blooms of cyanobacteria (Mau et al. 2004). Two chemical compounds found within certain species of cyanobacteria, geosmin and 2-methylisoborneol (MIB), are responsible for many of the taste and odor problems associated with cyanobacteria blooms (Gerber 1969, Tabachek and Yurkowski 1976). *Actinomycetes* are moldlike bacteria than can break down organic matter and produce many taste and odor compounds including geosmin, an earthy-smelling byproduct which is also produced by Cyanobacteria (Droste 1997). An increase in these organisms will have a consequential increase in the taste and odor complaints. .

***Existing Conditions in the Klamath River*:**
While we are not aware of any quantitative data regarding the types and concentrations of taste and odor compounds in the Klamath River, it is widely recognized that salmon caught on the middle Klamath River (between Iron Gate Dam and the Trinity River) have poor odor and taste. This was eloquently stated by staff of the Quartz Valley Indian Reservation during a meeting with FERC (2004):

> "Around here, when people say that they got salmon, the first question that you ask is where did you get it from? If they got it up river, you don't want to eat it. People that don't know, eat it. But people that know get it farther down."

PacifiCorp conducted a survey of recreational users in the KHP area and results are included in Water Resources Final Technical Report Appendix 13a Klamath Water Quality/Aesthetics Survey Responses (PacifiCorp 2004). Thirty-six percent of recreational users indicated that water quality affected their visit to the Klamath River and many respondents commented on the excessive algae, green water, foam, suds, and bad odors found in the KHP reservoirs and river reaches. Comments included the following:
- "Bad smell this year" (regarding Keno and Lake Ewauna)
- "Slimy, green, foamy – yuck" (regarding Copco/Lower Klamath)
- "Extremely filthy (also dead fish everywhere)" (regarding J.C. Boyle)

Humboldt State University graduate students are conducting studies of the relationships between nutrients, *Actinomycetes*, and geosmin in the mainstem Klamath River but have not published their results yet (Gearheart, pers. comm.).

***Project effects*:**
Data on taste and odor compounds is lacking in the Klamath River, but analysis of phytoplankton and nutrient data, combined with information about taste and odor compounds from literature derived in other locations, suggests that the KHP is increasing taste and odor compounds in the Klamath River.

Each year, KHP reservoirs such as Iron Gate and Copco host massive algae blooms (Kann 2006). Organic matter (likely live and dead algae) can be flushed downstream in the Klamath River below (Kann and Asarian 2005). These blooms are likely contributing to taste and odor problems both directly through metabolic byproducts of the algae. Of the 25 species most often detected in PacifiCorp's 2002-2004 phytoplankton sampling in Iron Gate and Copco Reservoirs, eight are known to produce taste and odor compounds, including *Melosira* and *Aphanizomenon* which were found in over 50% of samples (Table 3).

In fact, PacifiCorp's 2001-2004 phytoplankton data shows that two important taste and odor producing cyanobacterial species, *Microcystis aeruginosa* (MSAE) and *Aphanizomenon flos-aquae* (APFA) substantially increased in both frequency and biomass when comparing stations above and below Copco and Iron Gate reservoirs. For MSAE, June-October frequency increased from 12% above to 40% below, and mean biomass increased by 10 times below the reservoirs. For APFA, frequency increased from 47% to 80%, and mean biomass increased by 18 times.

The project can also increase taste and odor compounds when the massive blooms of algal organic matter are flushed downstream and geosmin and other taste and odor compounds are produced as decomposition by *Actinomycetes* takes place. In addition, anaerobic conditions in the bottoms of the reservoirs may also produce taste and odor compounds.

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Table 3. The 25 most commonly detected genera in PacifiCorp's 2002-2004 phytoplankton sampling in Iron Gate and Copco reservoirs. The total number of samples taken was 128. Literature sources for the list of genera that produce taste and odor compounds include Droste (1997), Mau et al. (2004), Palmer (1962), (Palmer (1977) and Smith and deNoyelles (2001).

Genus	**Number of Detections**	**Percent Detections**	**Taste and Odor Causing?**
Nitzschia	109	85%	
Rhodomonas	90	70%	
Fragilaria	85	66%	
Stephanodiscus	84	66%	
Ankistrodesmus	76	59%	
Cryptomonas	76	59%	
Aphanizomenon	67	52%	Yes
Melosira	65	51%	Yes
Cocconeis	41	32%	
Cyclotella	40	31%	Yes
Asterionella	39	30%	Yes
Navicula	36	28%	
Rhoicosphenia	36	28%	
Gomphonema	33	26%	
Chlamydomonas	33	26%	Yes
Achnanthes	30	23%	
Synedra	29	23%	Yes
Microcystis	25	20%	Yes
Chromulina	24	19%	
Scenedesmus	23	18%	
Sphaerocystis	23	18%	
Anabaena	16	13%	Yes
Chrysococcus	11	9%	
Glenodinium	11	9%	
Selenastrum	10	8%	

As noted in PacifiCorp's (2004) Final License Application, California's Water Quality Objective for taste and odor compounds (NCRWQCB, 2001) states:

> "Waters shall not contain taste- or odor-producing substances in concentrations that impart undesirable tastes or odors to fish flesh or other edible products of aquatic origin, or that cause nuisance or adversely affect beneficial uses."

PacifiCorp (2004) states "there are no data to suggest and no reason to believe that the Project or any constituent of the waters within the Project imparts an undesirable taste or odor to fish or other edible products." While taste and odor compounds in Klamath River have not yet been directly studied, PacifiCorp's phytoplankton data suggest that the KHP reservoirs are indeed causing an increase in taste and odor compounds, which would be a violation of California water quality objectives.

PacifiCorp's Proposed Remediation

PacifiCorp has not proposed any measures to remediate the KHP's contribution to high levels of taste and odor compounds in the Klamath River.

Tribe's Proposed Remediation

The reduction of the source of algal-caused taste and odor compounds, in this case the large blooms produced in the KHP reservoirs, would provide the most effective means to reduce taste and odor problems in the Klamath River downstream of the KHP reservoirs. Reduction of reservoir algal biomass can be accomplished by removing dams and returning the river to free-flowing conditions that are not conducive to large growths of algae dependent upon the low-turbulence, long retention time conditions created by the KHP reservoirs. The Tribe recommends that FERC order the removal of the KHP's dams and facilities from the Klamath River and its tributaries.

Further, dam removal will reduce or eliminate anaerobic conditions, likely reducing taste and odor compound production. Taste and odor-causing compounds are often volatile and can be removed to a significant extent by aeration (Droste 1997). Adding oxygen to water can improve the taste of water to a limited extent (Droste 1997). Dam removal will replace anaerobic reservoirs with many miles of a free-flowing river that has a much higher surface area to volume ratio than the reservoirs, which will allow for more replenishment of oxygen. In addition, free-flowing rivers feature naturally-occurring gravity-powered aeration features known as riffles, which further serve to oxygenate the water. The increase in surface area to volume ratio and increase in the number of riffles will likely result in more aeration and hence more removal of taste and odor compounds from the waters of the Klamath River.

FISH PARASITES

Background information

In recent years, myxozoan parasites have received increasing attention in the Klamath River, especially for their role in causing fish kills of juvenile salmonids. The two that have been most closely studied are *Ceratomyxa shasta* and secondarily *Parvicapsula minibicornis*. The life cycle of *C. shasta* utilizes two different hosts- the freshwater polychaete worm *Manaynukia speciosa* and a salmonid. A summary of the life cycle is provided in Stocking and Bartholomew (2004) with details described in Bartholomew et al. (1997). *C. shasta* myxospores develop in the salmonid, which are then released to infect the polychaete; in the polychaete, actinospores develop and when released they can infect salmonids (Figure 17). Bartholomew (2006) recently discovered that *Parvicapsula minibicornis* also uses the same polychaete host.

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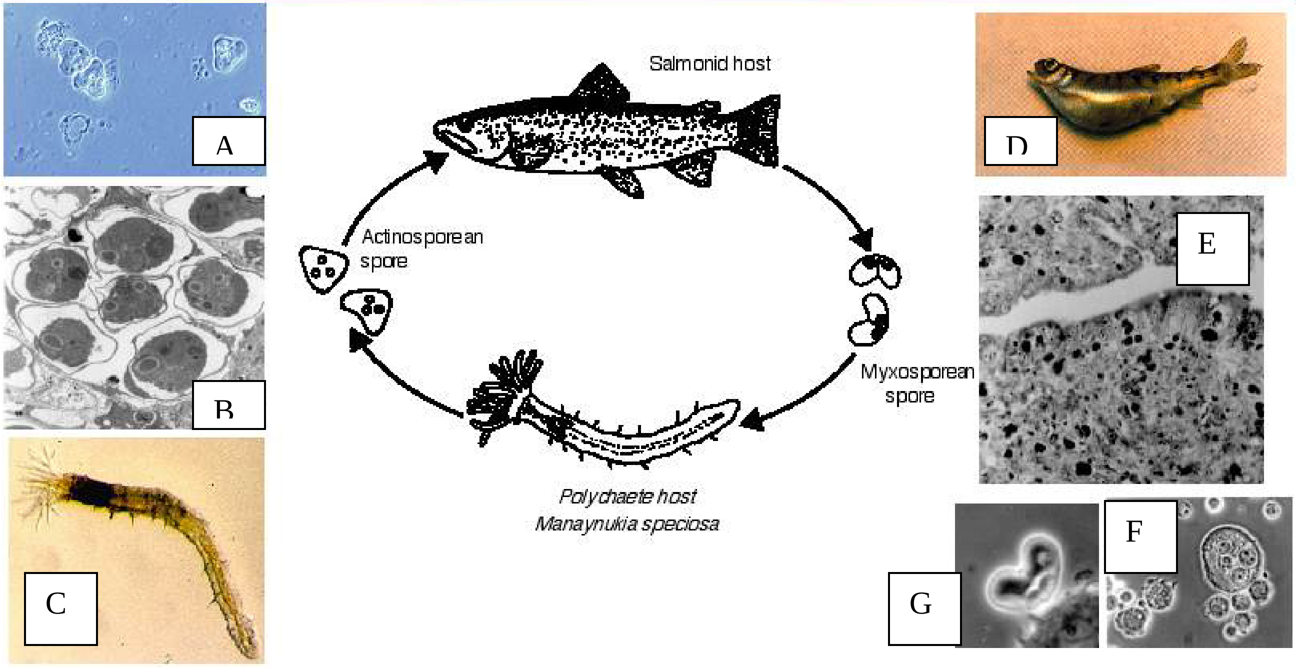

Figure 17. Life cycle of *Ceratomyxa shasta* showing release of the myxospore stage from the infected fish, the polychaete alternate host, and release of the alternate actinospore stage from the polychaete. A. released actinospores, B. electron micrograph of actinospores in the polychaete, C. polychaete, D. infected fish, E. histological section of infected intestine, F. trophozoite stages, G. myxospore (Bartholomew et al. 1997).

Existing conditions in the Klamath River

C. Shasta was first detected in the Klamath River in the 1980s (Hendrickson 1989) and was first identified as being a serious fish health issue in 1995 (Foott et al. 1999). The recent high incidence of *C. Shasta* in the Klamath River may be due to an increase in polychaete populations caused by an increase in polychaete habitat (Stocking and Bartholomew, 2004).

Unpublished data from recent surveys on the Klamath River have shown that the polychaete's primary habitat is sand with fine benthic organic matter (Stocking 2006). Its secondary habitat is dense beds of *Cladophora*, a filamentous green algal species. There are some notable differences between these two habitats. Polychaetes living on the sand with fine benthic organic matter substrate are restricted to low-velocity areas, whereas polychaetes can exist in *Cladophora* in areas with higher water velocities (Stocking 2006). In addition, sand with fine benthic organic matter is a less stable substrate than *Cladophora*. For instance, Stocking (2006) sampled an extremely large and dense population of polychaetes at Tree of Heaven (approximate river mile 170) in March 2005. When Stocking returned to sample again in July after a high-flow event (discharge below Iron Gate Dam peaked at 5380 cubic feet per second on May 18), much of the organic matter was gone and all polychaetes had disappeared (presumably both had been washed downstream). In contrast, polychaete populations in *Cladophora* beds remained intact.

To date, there has been no systematic effort to map the distribution and abundance of *Cladophora* in the Klamath River and its tributaries. *Cladophora* distribution in the Klamath River appears to be patchy. When present it often covers large areas with a dense mat (Stocking, pers. comm.). Stocking (pers. comm.) says that *Cladophora* is most common between Iron Gate (river mile 190) and Happy Camp (approximate river mile 100), and he has not seen it downstream of the Klamath's confluence with the Trinity (river mile 44).

A recent unpublished study examined the rates of C. *shasta* and *P. minibicornis* infectivity in their polychaete host *M. speciosa* at many Klamath River sites from near the outlet of Upper Klamath Lake to China Point near Happy Camp (Stocking 2006). The study found that in the year 2005, the sites with highest *C. shasta* infection prevalence in polychaetes were the Tree of Heaven (approximately river mile 170) and Interstate 5 (approximately river mile 179). The most likely explanation for this high infection prevalence at these sites is their proximity to the salmon spawning grounds below Iron Gate Dam (Bartholomew and Stocking, pers. comm.). Returning adult salmon can become infected with *C. shasta* as they move upriver. When they spawn and die, the *C. shasta* myxospores contained inside them are released and can infect polychaetes.

Ceratomyxa shasta causes major problems for the health of juvenile salmonids in the Klamath River. *C. Shasta* infection rates are extremely high and in many years results in the death of significant portion of the juvenile salmonids in the Klamath River. Nichols and Foott (2005) estimated that in 2004, 45% of juvenile fall-run chinook salmon were infected with *C. Shasta*, 94% of the population was infected with *P. minibicornis*, Histological examination of infected fish revealed that tissue damage was extensive, suggesting that mortality was likely to occur in these fish.

Hallet et al. (2006) found that *C. shasta* parasite densities in water samples below Iron Gate Dam was several orders of magnitude greater than above. We now know that resistance to *C. shasta* can be overwhelmed by prolonged exposure to the parasite or by high infectious dose (Ratliff 1981, Ibarra et al. 1992). Exposures conducted in June 2004 revealed that Iron Gate Hatchery fall Chinook salmon are resistant to the parasitic densities above Iron Gate Dam, but that resistance was overwhelmed below (Stocking et al. 2006). The density threshold at which these fish succumb to infection is not known but is under investigation.

In a recent unpublished study, the Karuk Tribe collected water samples biweekly (once every two weeks) at many sites between Iron Gate Dam and the Klamath estuary from May through September (Bartholomew 2006). A technique known as QPCR was used to quantify the amount of *C. shasta* DNA in the water samples. Known quantities of *C. shasta* spores were also processed with QPCR, which allows development of quantitative relationship between QPCR results and the number of spore in a sample. The biological significance (to fish) of specific spore concentrations is still unknown at this time, but this knowledge will be developed over time by performing QPCR on water samples in the same locations as sentinel fish studies are being conducted. Even in the absence of accurate knowledge of the biological significance of spore counts, knowing spore counts is still useful because it allows comparison of the relative exposure risk between sites and time periods.

Unpublished preliminary analyses of the 2005 QPCR sampling results suggested some trends (Bartholomew 2006). Spore counts were generally highest in June and July, except for sites downstream of the Trinity River where there were never many spores detected at any time during the season. The longitudinal pattern was that spore counts were low at the site immediately below Iron Gate, then increased to very high levels (approximately 10-20 spores/L) at the Klamath River above the Shasta, and then decreased as water flowed downstream past each successive monitoring station. Spore concentrations remained relatively high until downstream of Seiad Valley (concentrations were relatively high at Klamath River above the Scott and the Klamath River at Seiad Valley).

Project effects

As described below, the KHP promotes myxosporean parasites in the Klamath River by altering nutrient dynamics, increasing habitat for the polychaete *M. speciosa*, increasing *C. shasta* infection rates of *M. speciosa*. In addition, through its effects on nutrient dynamics, the KHP deteriorates pH / D.O. conditions and increases ammonia, causing stress and immunosuppression in salmonids, increasing the likelihood that they will become infected and diseased.

It has been documented that the reservoirs can periodically release pulses of organic matter downstream (Kann and Asarian 2005). When this organic matter settles in depositional zones of the Klamath River, it provides ideal habitat for *C. shasta*'s polychaete host *M. speciosa*. This likely contributes to higher polychaete populations, higher actinospore loads of *C. shasta* in the water column, *C. shasta* infection in salmonids, and hence salmonid disease and death.

Biggs (2000) notes that reservoirs (such as Iron Gate) disrupt downstream transport of gravel, leading to substrate coarsening and armoring of the streambed, which favors the establishment of green filamentous algae such as *Cladophora*. This likely contributes to larger populations of *C. shasta*'s polychaete host *M. speciosa* by expanding the quantity of its secondary habitat (*Cladophora* beds). This likely contributes to higher polychaete populations, higher *C. shasta* actinospore loads in the water column, *C. shasta* infection in salmonids, and hence salmonid disease and death.

Removal of the dams will likely decrease *C. shasta* infection rates in *M. speciosa* polychaetes for two reasons.

First, the Iron Gate and Copco reservoirs have decreased the amount of spawning habitat available to anadromous salmonids because Iron Gate (river mile 190) is a complete barrier fish passage, and because Iron Gate and Copco Reservoirs flooded many miles of high-quality spawning habitat. This contributes to massive aggregations of spawning fish in the mainstem Klamath River below the dam (Figure 2). As noted above, the highest rates of *C. shasta* infection in polychaetes were found at Tree of Heaven (approximately river mile 170) and Interstate 5 (approximately river mile 179). These high infection rates may be due to Iron Gate Dam causing a blockage in salmon migration, as well as the impoundment of spawning habitat under the reservoirs. With dam removal the salmon will likely spawn over a more dispersed area, and there will not be concentrated release of *C. shasta* myxospores that occurs with the spawning and death of thousands of salmon in a relatively small area.

Second, as described above, the KHP has moved the "recovery zone" of high periphyton productivity downstream so that it overlaps with the high-quality salmon spawning habitat below Iron Gate Dam. This means that salmonids are spawning in close proximity to the *M. speciosa* polychaetes that live on *Cladophora* (a green algal species common in the recovery zone), increasing chances that the *C. shasta* myxospores will infect polychaetes when the salmon die after spawning and release them.

As discussed above in the Temperature, pH, Dissolved Oxygen, and Ammonia Toxicity sections above, the KHP is detrimental to physical and chemical water quality, which contributes to fish stress and immunosuppression, increasing chances of infection and disease.

The upstream ends of KHP reservoirs have some of the largest populations of polychaetes discovered anywhere in the Klamath system (Stocking 2006). Polychaetes are not found in other portions of the reservoirs, suggesting that optimal living conditions for the polychaete exist at the inflow and/or water quality in the deeper portions of the reservoir may be a limiting factor (Stockings, pers. Comm..). On extreme high-flow events, polychaetes could potentially be flushed from the upper ends of the reservoirs into the river below, though it is unknown if this occurs.

PacifiCorp's Proposed Remediation

PacifiCorp has not proposed any measures to mitigate the project's effects on fish parasites.

Tribe's Proposed Remediation

Removal of KHP dams will reverse the KHP effects described above, including reversing the KHP-driven expansion of habitat for *C. shasta*'s polychaete host *M. speciosa* by reducing the amount of organic matter and *Cladophora* in the Klamath River. With dam removal the salmon will likely distribute salmon spawning over a larger area, reducing *C. shasta* spore counts. Dam removal will also improve water temperature, pH, dissolved oxygen, and ammonia levels, which will reduce salmonid stress and hence help restore salmonid immune systems.

For these reasons, it is likely that dam removal will contribute to enhanced fish health and lower the rate of myxosporean parasite infection and disease in Klamath River salmonids. Therefore, our recommendation is that FERC order the removal of KHP's dams and facilities from the Klamath River and its tributaries.

TIME IS OF THE ESSENCE FOR THE KLAMATH RIVER

Recent fish health studies of the Klamath River by the U.S. Fish and Wildlife Service California-Nevada Fish Health Center (Nichols and Foott, 2005) indicate a high incidence of disease in juvenile salmonids:

> "We estimated that 45% of the population was infected with *C. shasta* and 94% of the population was infected with P. minibicornis. The prognosis for P. minibicornis infection by itself is not well understood. The high incidence of dual myxozoan infection (98% of *C. shasta* infected fish), and associated pathology suggests that the majority of the *C. shasta* infected juvenile Chinook would not survive."

The loss of 45% or more of juvenile downstream migrants to disease shows epidemics of disease that threaten persistence of Pacific salmon stocks in the Klamath River. Recent record low escapements of fall (Figure 18) and spring (Figure 19) Chinook to the Salmon River and two consecutive record lows in the Scott River basin (Figure 20) in 2004 and 2005 suggest that mainstem Klamath River water quality is precipitating a basin wide Chinook salmon stock collapse. While we acknowledge that there are other factors in the Scott River basin causing salmonid declines besides that fact that Scott fish must migrate through the mainstem Klamath, the Salmon River has the most undisturbed watershed of any large tributary in the Klamath Basin.

Higgins et al. (1992) discussed the risk of extinction of northwestern California Pacific salmon stocks and discussed minimum viable population sizes:

> "When a stock declines to fewer than 500 individuals, it may face a risk of loss of genetic diversity which could hinder its ability to cope with future environmental changes (Nelson and Soule 1986). A random event such as a drought or variation in sex ratios may lead to extinction if a stock is at an extremely low level (Gilpin and Soule 1990). The National Marine Fisheries Service (NMFS, 1987) acknowledged that, while 200 adults might be sufficient to maintain genetic diversity in a hatchery population, the actual number of Sacramento River winter run chinook needed to maintain genetic diversity in the wild would be 400-l,100."

Despite favorable or average ocean conditions (Collison et al. 2003) and wet years with at least average flows, the populations of fall chinook in the Salmon River and Scott River have plummeted to all-time lows for two years running. These populations have some additional ability to rebound without loss of genetic diversity because chinook spawn at different ages (Simon et al. 1986), but the low adult returns should be viewed with alarm.

Several mainstem Klamath River water quality parameters approach or exceed lethal conditions for salmonid juveniles below the Scott and Salmon Rivers throughout summer as described by Kier Associates (2005) and above in this document. High water temperature currently couples with nutrient enrichment (exacerbated by the KHP's detrimental effects on nutrient dynamics) that sets off nutrient spiraling and high rates of photosynthesis, leading to high pH, depressed D.O. and periodic problems with highly toxic dissolved ammonia. To compound those factors even more, the recently discovery of the toxic algae *Microcystis aeruginosa* indicates yet another threat to salmonids (and humans).

When all these indicators are considered together, it becomes clear that the Klamath River is in serious trouble and that the dismantling of the KHP is an essential step on the road to recovery for the river and its peoples.

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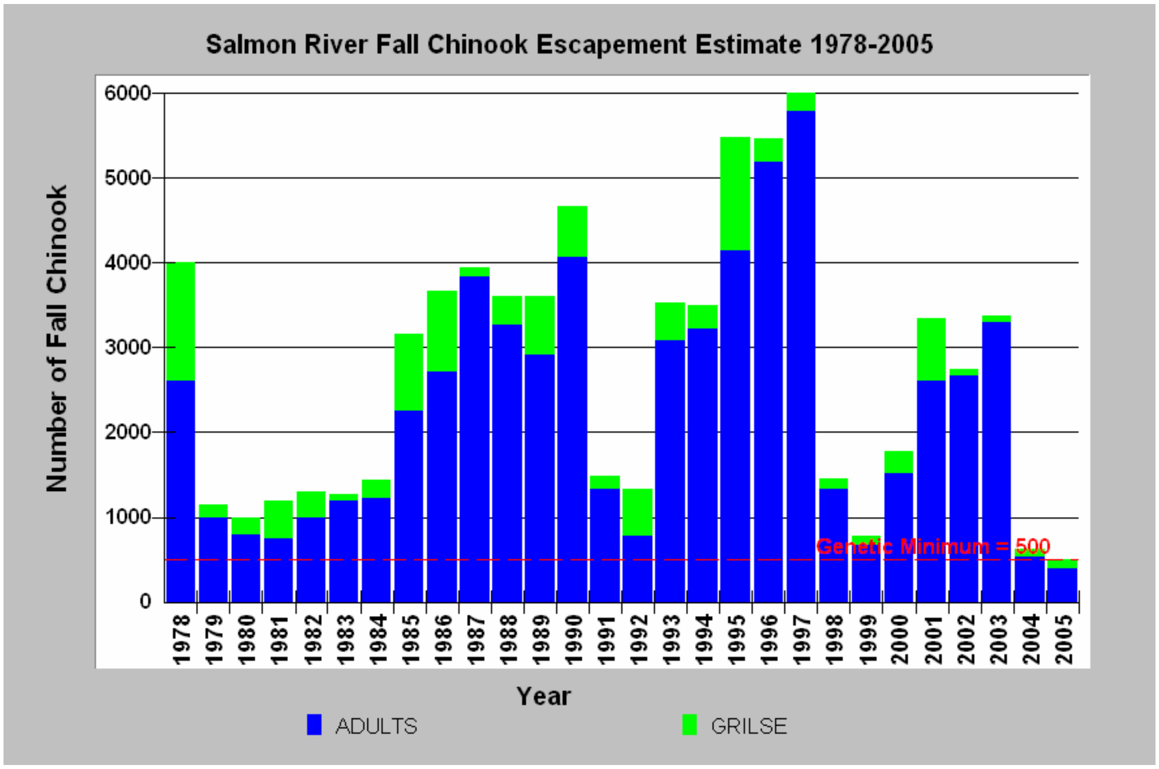

Figure 18. Salmon River fall chinook escapement plummeted in 2004 and 2005 to the lowest escapement on record since 1978 two years in a row. Data from CDFG (2006).

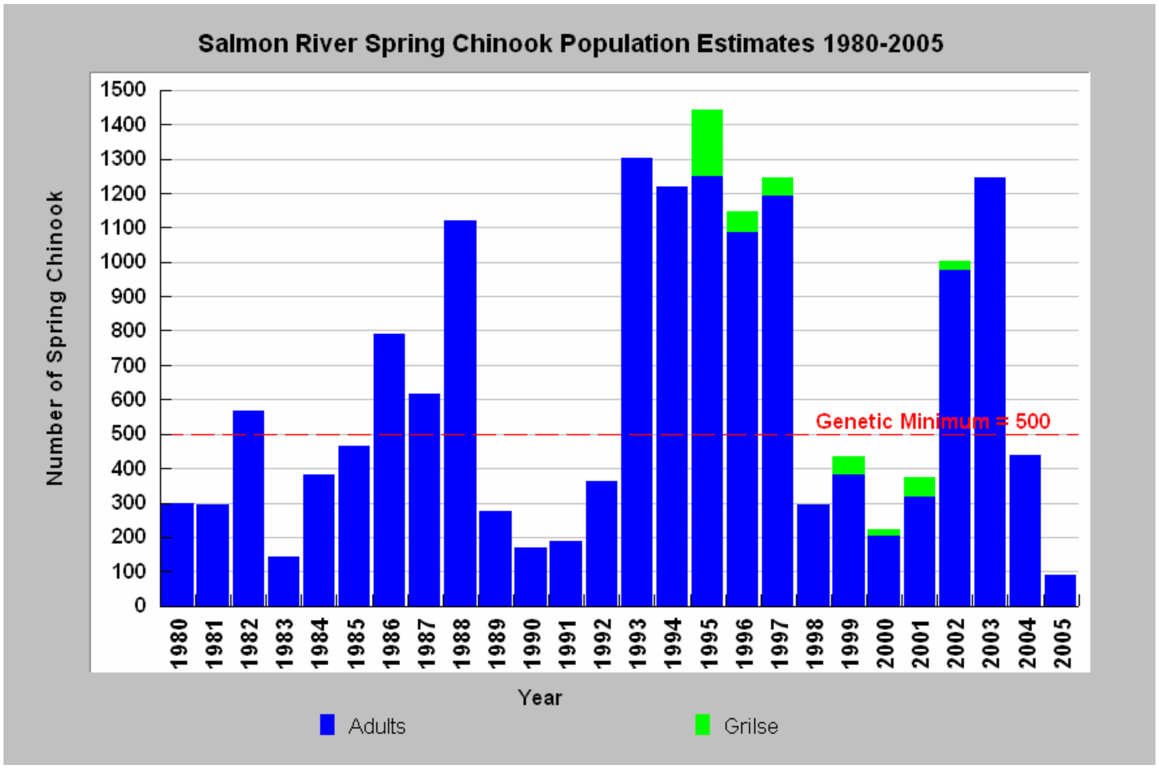

Figure 19. Salmon River spring chinook fell to an all time low in 2005. Data from Salmon River Restoration Council.

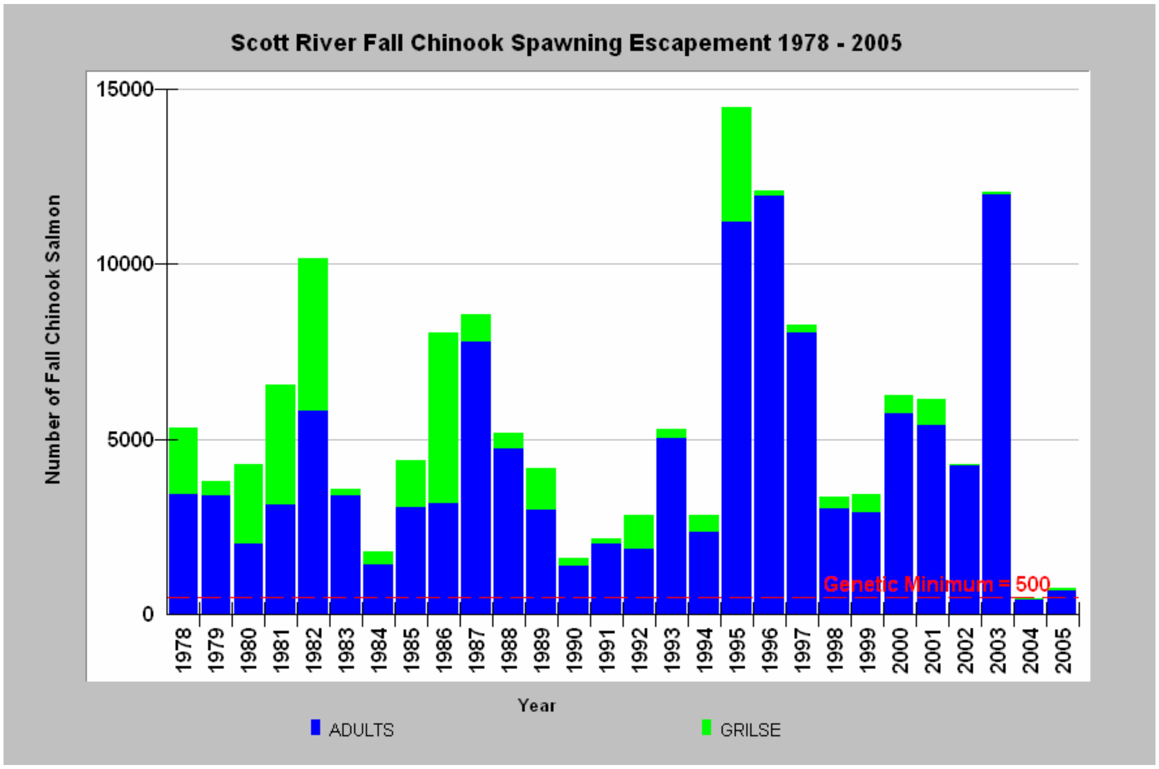

Figure 20. Scott River fall chinook escapement shows a similar trend to Salmon River populations, with both 2004 and 2005 well below average and the lowest years on record

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