Klamath River Expert Panel

FINAL REPORT

Scientific Assessment of Two Dam Removal Alternatives on Resident Fish

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With the assistance of:
ATKINS
(formerly PBS&J)

THE FINDINGS AND CONCLUSIONS IN THIS REPORT ARE THOSE OF THE AUTHORS AND DO NOT NECESSARILY REPRESENT THE VIEWS OF THE FUNDING AGENCY (U.S. FISH AND WILDLIFE SERVICE).

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1.0 Introduction

The allocation of water among competing uses in the Klamath Basin (Figure 1) has often been contentious. In recent years, stakeholders began discussions to reach a settlement agreement that would equitably resolve water resource management conflicts in the basin. In February 2010, this goal was reached when two settlement agreements were signed. Six dams occur along the Klamath River between Upper Klamath Lake and Interstate 5 (Figure 2). These dams include Iron Gate, Copco 2, Copco 1, J. C. Boyle, Keno Dam, and Link River Dam. The Klamath Hydroelectric Settlement Agreement (KHSA) would result in the removal of Iron Gate, Copco 2, Copco 1, and J. C. Boyle dams, as well as facilities of the Klamath Hydroelectric Project located on the Klamath River and operated by PacificCorp, to provide for upstream anadromous fish passage to historically occupied habitat. The Klamath Basin Restoration Agreement (KBRA) addresses basin-wide environmental restoration and resource management issues. The Secretary of the Department of the Interior is required by March 31, 2012 to decide if implementation of the settlement agreements: 1) is in the public's best interest; and 2) will advance salmonid fisheries.

1.1 Secretarial Determination

There are two alternative management scenarios before the Secretary of the Interior that must be addressed in the Secretarial Determination:

- **Conditions with Dams (Current Condition):** No change from current management; and
- **Conditions without Dams and with KBRA (Proposed Action):** Removal of the lower four Klamath River dams that are part of the Klamath Hydroelectric Project and the full range of actions/programs to implement the KBRA.

To evaluate the impacts of these alternative scenarios on native fish resources in the Klamath River Basin, the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) determined that existing and new scientific information regarding native fishes and environmental conditions must be reviewed and evaluated by a panel of experts followed by peer reviews of the expert panel work products. Consequently, four expert panels were created to address native fish issues as they are impacted by the two alternative scenarios. These four panels are: 1) Lamprey; 2) Resident Fishes; 3) Coho Salmon/Steelhead; and 4) Chinook Salmon. This report presents the findings of the resident fish expert panel, hereinafter referred to as the Panel.

1.2 Expert Panel

At the request of the USFWS, Atkins (formerly PBS&J) convened an independent expert panel to evaluate the potential effects of the two alternative scenarios on resident fish in the Klamath River Basin. In order to ensure that the panelists and their work products were not biased, it was Atkins' responsibility to: 1) manage the process in which panelists were screened and

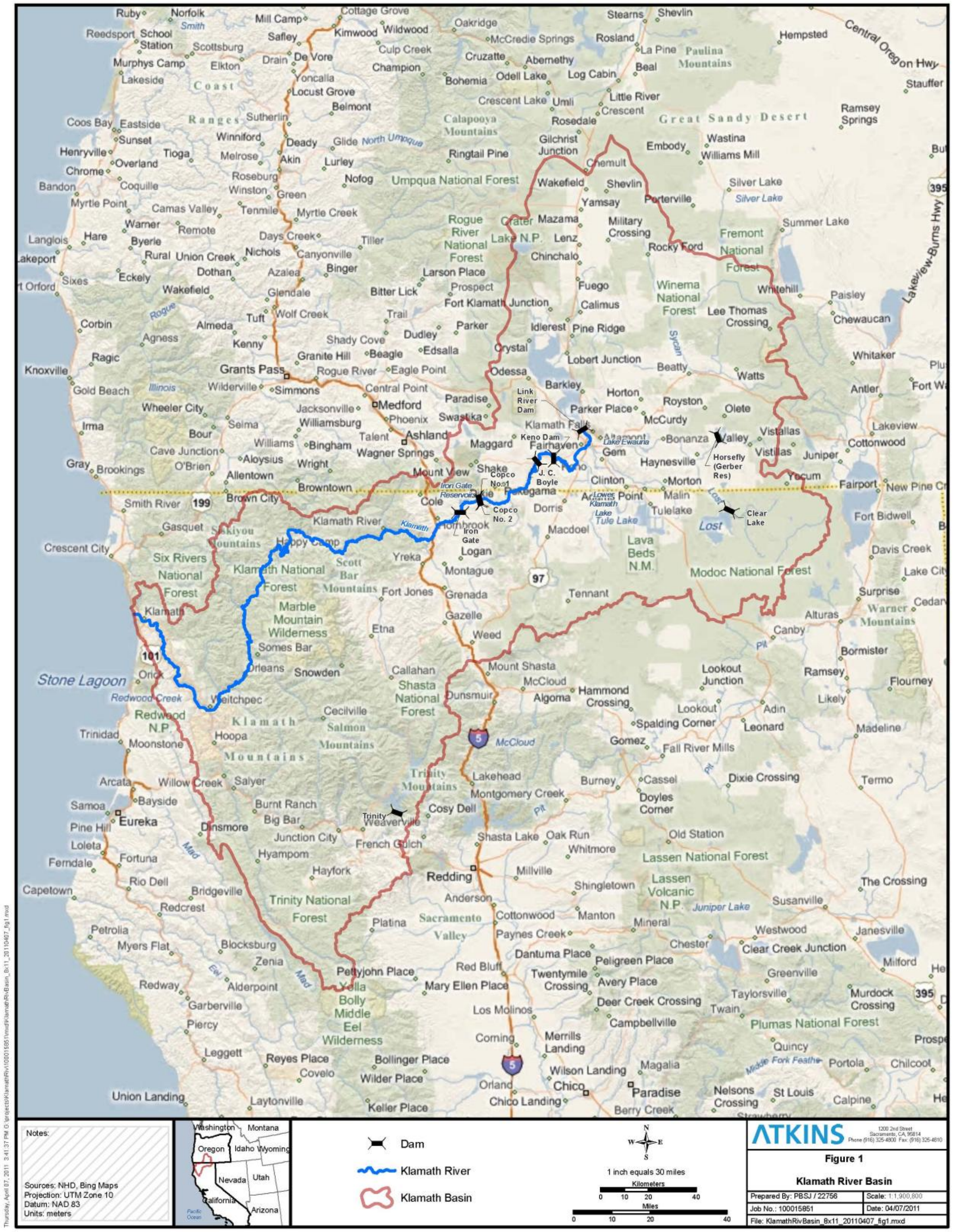

Figure 1. Klamath River Basin.

Figure 2. Klamath Hydroelectric Dams.

selected; 2) facilitate the Panel deliberations; and 3) assist with the preparation of the Panel's conclusions in a report to the USFWS.

Through existing contacts and referral networking, Atkins identified a pool of over 30 potential panelists. Prior to commencing the screening process, Atkins had no working relationship, and only limited direct knowledge of the panelists' expertise or professional affiliations. Attempts were made to contact all potential candidates for the resident fish panel. The goal was to provide a balanced panel of four experts. The Panel was designed to include an ecohydrologist, fish ecologist, an expert on the suckers of the Klamath system, and an expert on redband/ rainbow trout.

Two additional criteria required of each panelist were:

- Ability to meet the tight timeframe for the review process; and
- Ability to provide an expert review that would be widely regarded as both credible and independent.

Initial contacts with the pool of candidates resulted in numerous people who either declined to participate because of the schedule or who were considered to have conflicts of interest (e.g., professional working relationships, past or present, with stakeholders with a perceived interest in the outcome of the Secretarial Determination). Those candidates with conflicts of interest were eliminated from further consideration.

Brief biographies for each of the panelists selected for the expert resident fish panel are as follows (full resumes have been provided previously to the USFWS and are included in Appendix A):

- **David Buchanan**, Fisheries Biologist, Oregon Department of Fish and Wildlife (ODFW), Retired. Mr. Buchanan worked on resident trout of Oregon for over 25 years. He has conducted research for the Alaska Department of Fish and Game, Oregon State University, and ODFW, and has extensive experience monitoring populations, assessing habitat conditions, and managing resident trout species. He worked 10 years on restoring native winter steelhead habitat and populations above Foster and Green Peter dams in the Willamette Valley, Oregon. For the last 15 years of his career, he served as the Native Trout Research Biologist for the ODFW. During that time, he worked extensively on native redband/rainbow trout and bull trout in the Upper Klamath Basin. In 1999, he was awarded the Western Division Award of Excellence from the American Fisheries Society.

- **Mark Buettner**, Fisheries Biologist, USFWS, Retired. Mr. Buettner worked on Klamath River suckers for the last 20 years. He was a member of the Sucker Recovery Team and an integral component in assisting the USFWS in managing these species. He previously conducted life history research and population monitoring on the endangered cui-ui lakesucker in Nevada for 12 years.

- **Dr. Thomas Dunne**, Professor, Donald Bren School of Environmental Science and Management, and Department of Earth Science, University of California, Santa Barbara. He received his PhD from The Johns Hopkins University. Dr. Dunne conducts field and theoretical research in fluvial geomorphology and in the application of hydrology, sediment transport, and geomorphology to landscape management and hazard analysis. He is an internationally recognized expert in fluvial geomorphology with dozens of publications to his credit and has served on over 40 national and international science committees.

- **Dr. Greg Ruggerone**, Vice President, Natural Resource Consultants, Inc., Seattle, Washington. Dr. Ruggerone received his PhD in Fisheries from University of Washington where he is currently an affiliated research scientist with the School of Fisheries. Dr. Ruggerone brings 30 years of experience in anadromous fisheries ecology and management to this project. He has conducted applied research in salmonid predator-prey interactions, species competition, climate change effects on salmon production in the ocean, effects of habitat changes on salmonid production, limnological studies, effects of hydropower operations on downstream smolt and upstream adult migrations, and harvest management. He has participated in extensive field studies in applied fisheries biology and management in Alaska and the Pacific Northwest.

The opinions presented in this report reflect those of the panelists and not the views of their respective employers or professional affiliations.

1.3 Review Process

Atkins was awarded the contract to conduct the expert panel work for all four panels on June 15, 2010. At that time, Atkins staff began assembling a pool of potential candidates for the resident fish panel. The final expert resident fish Panel was confirmed on July 16, 2010. Background files were provided by the USFWS and submitted to the Panel for review on July 21, 2010. The Panel members convened for a meeting in Klamath Falls, Oregon, on August 2 through 6, 2010. The first day of the meeting (August 2) consisted of briefings provided to the Panel by members of the Technical Management Team (TMT) subgroups, whom include scientists with expertise in a variety of technical disciplines relevant to the review process, as well as interested stakeholders. The Panel worked on its report in private for the remainder of the week.

During the course of their work the Panel relied on numerous documents as cited in this report. Key documents reviewed by the Panel included:

- Presentations from the TMT subgroups and stakeholders on July 19 (referenced in the text by author's last name and 'PPT Presentation');
- KHSA, February 18, 2010;
- KBRA, February 18, 2010;
- Synthesis of the Effects of two Management Scenarios for the Secretarial Determination on Removal of the Lower Four Dams on the Klamath River, Draft dated July 16, 2010 (Hamilton et al. 2010a; Hamilton et al. 2010b);
- Redband Trout Synthesis (ODFW letter to Panel, August 1, 2010)
- Upper Klamath Basin Restoration: KBRA Actions above Keno (Barry PPT Presentation, handout)
- Endangered and Threatened Fishes of the Klamath River Basin: Causes of Decline and Strategies for Recovery (NRC 2004)
- Hydrology, Ecology, and Fishes of the Klamath River Basin (NRC 2008)

During the meeting, each panelist took responsibility for specific sections of this report and provided a draft of their text to the other Panel members. Atkins staff facilitated the meeting but provided no substantive technical input. By the completion of the meeting, a draft of the report had been reviewed and approved by each Panel member. Atkins staff reviewed the entire document for formatting and style before creating a draft version.

During the Panel's work in early August, problems with the flow modeling were discovered. This prompted the TMT to recommend that the Panel not use any of the hydrology information that they had been presented on August 2, 2010. The panel completed their work to the extent feasible at the time. The Panel has revised the draft document based on a new set of hydrologic data provided in November 2010 (see Hamilton et al. 2010b). In December 2010, problems with how the hydrology model created daily flow values from monthly values were discovered. The TMT had advised the Panel that the monthly data appears to be accurate, and the draft report was subsequently finalized and posted for stakeholder and agency comment on January 13, 2011. Comments received through January 20, 2011, were cataloged, reviewed and responded to as appropriate by the Panel to create this final report.

1.4 Panel Role and Nature of Report

Task of the Panel occurs chronologically at a very early stage in the decade-long process of evaluation, planning, decision-making, and design leading up to a potential 2020 initiation of dam removal (Table 1). The Panel is asked to make a scientific assessment of the impact of two strategies for river management (Conditions with Dams, versus Conditions without Dams and with the KBRA) on the resident fish species of the Klamath River Basin.

A variety of information is available on the life history of suckers and redband/rainbow trout and types of habitats used by these fishes in the Klamath Basin. Extent and quality of available and potential habitat for spawning and rearing for each species are not well documented. Relative trends in abundance are known for suckers and redband/rainbow trout, a much sought-after sportfish. Some factors affecting population trends have been described, as discussed below, but the relative importance of key factors or mechanisms that affect fish survival is less known. Multiple factors undoubtedly affect fish survival and abundance and the influence of such factors are often synergistic and nonlinear. Thus, projections of future abundance trends in response to management actions has inherent uncertainties, which are further amplified by fluctuating environmental conditions and longer-term shifts caused by climate change.

Table 1. Summary of Klamath Basin Fisheries Program Milestones.

Year	Milestones and Actions
2010	• Klamath Basin Restoration Agreement signed on 18 February (Effective Date). • **Resident Fish Expert Panel Meeting August 2-6.** • Final Drought Plan by November 30.
2011	• Draft Phase I Fisheries Restoration Plan by 18 February. • Draft Fisheries Monitoring Plan by 18 February. • Draft Phase I Oregon Fisheries Reintroduction Plan. • Initiate reintroduction activities in Oregon.
2012	• Initiate assessment of risks and potential impacts of climate change on management of Klamath Basin Resources. • Finalize NEPA for Phase I Fisheries Restoration Plan by 31 March. • Finalize CEQA for Phase I Fisheries Restoration Plan by 31 March. • Final Phase I Fisheries Restoration Plan by 31 March. • Final Fisheries Monitoring Plan by 31 March. • Detailed Plan for Facilities Removal on for before 31 March. • **Secretarial Determination made by 31 March**.
2013	• Final Phase I Oregon Fisheries Reintroduction Plan. • Draft Phase I California Fisheries Reintroduction Plan (presumed). • Dam Removal Entity (DRE) develops Definite Plan for Dam Removal (presumed).
2014	• Final Phase I California Fisheries Reintroduction Plan.
2019	• Draft Phase II Fisheries Restoration Plan
2020	• Target date to begin decommissioning the facilities is 1 January. • Target date for completion of facilities removal is 31 December, at least to a degree sufficient to enable a free-flowing Klamath River allowing volitional fish passage. • Review of fisheries outcomes by 30 June and recommendations for additional measures, if needed.
2020-2021	• Keno Dam fish passage improvements occur.
2022	• Final Phase II Fisheries Restoration Plan by 31 March.
2022	• Finalize NEPA for Phase II Fisheries Restoration Plan by 31 March.
Post-2022	• Draft and Final Anadromous Fish Conservation Plans to be developed by ODFW. • Draft and Final Phase II Fisheries Reintroduction Plan to be developed by ODFW.
2030	• Review of fisheries outcomes by 30 June and recommendations for additional measures, if needed.

Source: KBRA

Some quantitative and qualitative information on physical habitat characteristics within portions of the Klamath Basin have been described, including river flows, lake level, temperature, and dissolved oxygen (DO). The future condition of these physical and chemical variables will depend on drivers such as regional climate change, the stochastic nature of weather and hydrology, regional economic and land-use change, and evolving political and regulatory philosophies of natural resource management. For evaluation of the Proposed Action, the Panel relied upon projections by agencies and consultants of how the physical attributes of the watershed might change in response to dam removal, habitat restoration activities, and climate change, even though many aspects of the Proposed Action have yet to be described, i.e., Fisheries Program, Drought Program, Phase II KBRA. Phase I KBRA describes many goals for habitat restoration, including some general types of restoration projects. The KBRA describes general approaches to improve fish habitat but details of how each activity might influence the specific life stage or specific species of fish have not been described. Likewise, some restoration activities have improvement of water quality as a goal; however, there is contention amongst interested parties regarding the degree to which the Proposed Action achieves the water quality goal and influences fish survival.

The key challenge for the Panel, therefore, is to evaluate the physical and biological information provided to the Panel by agencies and stakeholders, incorporate this information into the knowledge base that the Panel brings to the subject, and to logically describe potential outcomes of the two alternatives. The Panel members bring to the process their general knowledge of fish biology, lake and river characteristics and behavior, and their experience in environmental analysis in other systems including those that have been disturbed or actively managed. Their method of assessment involves assimilating the agency-supplied material described previously, and some limited number of original documents and computational models used as the basis for the agency and consultants' reports. The Panel members can also supply their knowledge of other literature and case studies of similar issues elsewhere. The Panel has no time or resources for original data collection or analysis, even when such actions seem straightforward and necessary for the assigned task. Thus, the analytical method of the Panel involves assessing and interpreting the likely reliability and relevance of the technical information supplied to them, evaluating its relevance to biology of resident fish, and predicting the impacts of the two alternatives on resident fish implied in the questions about potential change in abundance and/or harvest based on the best available information.

The findings presented in this report represent the collective opinion of the Panel developed within a five day workshop involving discussions and evaluations of the provided materials. Information available at such an early stage in a process of this kind is invariably inadequate for a rigorous assessment. Thus, the assessment as conducted by this Panel combined qualitative, quantitative, and professional experience to estimate potential outcomes of the two alternatives which in turn allowed the Panel to address the assigned questions. This assessment, however, can act as a guide for systematic data collection to reduce uncertainty in the future.

Although not within the scope of the project, the panel included a section on bull trout, a federally threatened species present in the Upper Klamath Basin, because this species could be affected by the project alternatives.

2.0 Background

2.1 Life Histories

2.1.1 Sucker Species in the Klamath Basin

There are four species of suckers in the Klamath Basin (Table 2) (Bond 1994): Klamath smallscale sucker (*Catostomus rimiculus*; KSS), Klamath largescale sucker (*Catostomus snyderi*; KLS), shortnose sucker (*Chasmistes brevirostris*; SNS), and Lost River sucker (*Deltistes luxatus*: LRS) (Markle et al. 2005). Lost River and shortnose suckers are federally listed endangered species (USFWS 1988). They are all freshwater resident taxa. The four Klamath Basin suckers are similar in overall body shape, but highly variable, and they are distinguished by mouth parts, adult habitat, and geography (Markle et al. 2005). The Klamath largescale and Klamath smallscale suckers are primarily river dwellers, with Klamath largescale suckers mostly found in the Upper Klamath Basin and Klamath smallscale suckers in the Lower Klamath Basin (Moyle 2002). The Lost River sucker and shortnose sucker are primarily found in lakes (Andreasen 1975; Moyle 2002), but the majority of spawning occurs in tributaries above the lake (Scoppettone and Vinyard 1991).

Table 2. List of sucker species in the Klamath Basin, life history information (Adult habitat, L = lakes, R = rivers, W = warm-water creeks, C = cold-water creeks) and distribution.

Species	Adult Habitat	Distribution	Comments
Lost River Sucker (*Deltistes luxatus*)	R, L	CURRENTLY ABOVE IRON GATE DAM Upper Klamath Lake and its tributaries (Sprague and Williamson Rivers), Lost River, Clear Lake and its tributaries (Willow and Boles Creeks), Tule Lake, Keno Reservoir, J.C. Boyle Reservoir, Copco Reservoir	Listed as endangered
Shortnose Sucker (*Chasmistes brevirostris*)	R, L	CURRENTLY ABOVE IRON GATE DAM Upper Klamath Lake and its tributaries (Sprague and Williamson Rivers), Lost River, Clear Lake and its tributaries (Willow and Boles Creeks), Gerber Reservoir, Tule Lake, Keno Reservoir, J.C. Boyle Reservoir, Copco Reservoir, Iron Gate Reservoir	Listed as endangered
Klamath Largescale Sucker (*Catostomus snyderi*)	R, L, W	CURRENTLY ABOVE IRON GATE DAM Upper Klamath Lake and its tributaries (Sprague and Williamson Rivers), Tule Lake, Keno Reservoir, J.C. Boyle Reservoir, Copco Reservoir, Iron Gate Reservoir	
Klamath Smallscale Sucker (*Catostomus rimiculus*)	R, L, W, C	CURRENTLY ABOVE AND BELOW IRON GATE DAM J.C. Boyle Reservoir, Copco Reservoir, Iron Gate Reservoir, Klamath River, Klamath River tributaries below Keno Reservoir	

Source: Moyle (2002).

Lost River and shortnose suckers are endemic to the Klamath and Lost River drainages of the Upper Klamath Basin, Oregon and California. Their historical distribution is uncertain, but based on current distribution the range was extensive. Gilbert (1898) stated that they primarily occupied deep waters of Tule and Upper Klamath Lakes. Self-sustaining Lost River and shortnose sucker populations are also found in Clear Lake (Contreras 1973; Koch et al. 1975; Buettner and Scoppettone 1991). Lost River and shortnose suckers inhabit J.C. Boyle Reservoir and Copco Reservoir in the Klamath River system but these are not self-sustaining populations (Buettner and Scoppettone 1991; Desjardins and Markle 2000). In pre-historical times, both species were more broadly distributed. The shortnose and Lost River suckers occupied lakes of the Upper Klamath Basin, Oregon and the Lost River system, Oregon and California. With the depletion of water resources and water development of the American West since the last pluvial period, the range and abundance of lake suckers declined to isolated remnants.

Lost River and Shortnose Sucker Life History

The three predominantly Upper Klamath Basin suckers are the SNS, LRS, and KLS. They generally spend most of their lives in shallow lakes and/or warm sluggish rivers/creeks. The lower basin sucker, KSS, lives mostly in warm-water and cold-water streams (Table 2). Spawning occurs in tributary streams (all suckers), at shoreline springs in lakes (LRS) and around springs in rivers (all suckers) (NRC 2004; Moyle 2002). The life cycle and general biology of the LRS and SNS will be described; variations seen in KLS and KSS, as far as is known will be discussed in the next section.

Lost River suckers are large fish (up to 1 meter or 3.28 feet long) and 4.5 kilograms (kg) in weight that are distinguished by their elongate body and sub-terminal mouth with a deeply notched lower lip. Shortnose suckers are distinguished by their large heads with oblique, terminal mouths with thin but fleshy lips. They can grow to about 60 centimeters (cm) or 23.6 inches (in) but growth is variable among individuals (Moyle 2002).

The endangered LRS and SNS are part of a group of suckers that are large, long-lived, late-maturing, and live in lake and reservoirs but spawn primarily in streams; collectively, they are commonly referred to as lake suckers (NRC 2004). The lake suckers differ from most other suckers in having terminal or sub-terminal mouths that open more forward than down, an apparent adaptation for feeding on zooplankton rather than benthic zooplankton, macroinvertebrates, and detritus from the substrate (Scoppettone and Vinyard 1991; Moyle 2002). Zooplanktivory can also be linked to the affinity of these suckers for lakes, which typically have greater abundance of zooplankton than do flowing waters.

LRS and SNS grow rapidly in their first five to six years in the lake, reaching sexual maturity sometime between years four and six for SNS and four and nine for LRS (Perkins et al. 2000a). LRS have been aged to 57 years (Terwilliger et al. 2010) and SNS to 33 years (Scoppettone and Vinyard 1991).

Spawning Migration

The timing of sucker spawning migration is somewhat variable from year to year, and is apparently dependent on age, species, sex, and environmental conditions. LRS and SNS spawn from February through May (Buettner and Scoppettone 1990; Moyle 2002). At shoreline springs in Upper Klamath Lake, LRS may aggregate as early as February (Perkins et al. 2000) and continue until late May (Janney et al. 2009) or early June (Shively et al. 2000; Hayes and Shively 2001). Temperatures at shoreline springs where spawning occurs (13°C) can be 10°C or higher above ambient lake temperatures at the time (Andreasen 1975; Shively et al. 2000). Spawning runs up Willow Creek, a tributary of Clear Lake, primarily occurred from February through mid-May (Perkins and Scoppettone 1996; Barry et al. 2009). Within the Sprague and Williamson River watershed, LRS begin their spawning migration as early as February with spawning activity often continuing into late May (Andreasen 1975; Buettner and Scoppettone 1990; Perkins et al. 2000a). SNS migrations generally started in April and continue through May or early June (Buettner and Scoppettone 1990; Perkins et al. 2000a; Janney et al. 2009). LRS and SNS spawning migrations peak in the Sprague and Williamson Rivers between mid-April and early May (Andreasen 1975; Markle and Simon 1993; Perkins et al. 2000a). These suckers may migrate as little as 2 kilometers (km) or 1.24 miles (mi) up a stream from a lake (e.g., Willow Creek) to 135 km (83.88 mi) from a lake (e.g., Sprague River) (Perkins and Scoppettone 1996; Ellsworth et al. 2007; Ellsworth et al. 2009). Upstream migrations commence when snowmelt leads to increases in discharge (Moyle 2002).

Spawning

Spawning migrations can occur at temperatures of 5-20°C (Moyle 2002; Perkins and Scoppettone 1996; Buettner and Scoppettone 1990). Peak migration and presumed spawning activities are associated with water temperatures of 10-15°C (Perkins et al. 2000a). Scoppettone et al. (1993) found that for cui-ui a temperature regime of 9-15°C yielded greater larval survival to swim-up than warmer temperature regimes (e.g. 12-18°C). In flowing water, LRS and SNS spawn in riffles or runs with moderate current over cobble or gravel bottoms at depths generally less than 1.3 meters (m) or 4.27 ft (Scoppettone and Vinyard 1991; Perkins and Scoppettone 1996; Buettner and Scoppettone 1990). Gravel appears to be preferred. Females broadcast their eggs and they are buried within the top several centimeters of the substrate. Egg predation by flatworms, fish, and other predators may be significant (Klamath Tribes 1995). Observed velocities over stream spawning areas have ranged from 0.01-0.85 meters per second (m/s) (LRS) and 0.7-1.2 m/s (SNS) (Buettner and Scoppettone 1990; Perkins and Scoppettone 1996). Spawning for both species occurred at water depths of 11-70 cm (4.3-27.6 in), with over 90 percent occurring in 11-50 cm (4.3-19.7 in) for LRS and 20-60 cm (7.9-23.6 in) for SNS (Buettner and Scoppettone 1990). Stream spawning depths in Willow Creek (Clear Lake) ranged from 30-130 cm (11.8-51.2 in) (Perkins and Scoppettone 1996).

Some LRS spawn in Upper Klamath Lake, particularly at shallow springs occurring along the shorelines. Water depth for lakeshore spring spawning sites at Sucker Springs ranged from 15-110 cm (5.9-43.3 in); 95 percent of successful spawning occurred in water deeper than 30 cm or

11.8 in (Reiser et al. 2001). Spawning site fidelity has been documented suggesting two discrete spawning stocks of LRS (i.e., those using Upper Klamath Lake springs and Williamson/Sprague Rivers) (Perkins et al. 2000a). Mark-recapture data show that the two stocks maintain a high degree of fidelity to spawning areas and seldom interbreed (Barry et al. 2007). Spawning occurs in the daytime or nighttime, although in shallow clear springs along the shoreline of Upper Klamath Lake most spawning occurs at night (M. Buettner, pers. observation). LRS and SNS do not die after spawning and can spawn many times during their lifetime. Individual males and females of both species commonly spawn in consecutive years.

Fecundity

Female LRS, SNS, KLS and KSS contain 44,000-236,000 eggs (Buettner and Scoppettone 1990; Andreasen 1975), 18,000-72,000 eggs (Buettner and Scoppettone 1990; Coots 1965), 13,500-120,000 eggs (Buettner and Scoppettone 1990; Andreasen 1975), and 15,300-20,000 eggs (Moyle 2002), respectively. Since the KSS fecundity estimates were based on only three specimens, it is likely that their fecundity may be similar to KLS which are approximately the same size. Large females bear more eggs, as is typical of most fishes (NRC 2004). Little is known about Klamath sucker spawning success, but only a small percentage of the eggs survive to become larvae (USFWS 2008).

Orientation to Spawning Areas

Many fishes have a remarkable capacity to return to natural streams from long distances with a high degree of accuracy, particularly salmonids (Dittman and Quinn 1996). However, the available evidence suggests that lake and river LRS spawners mix only occasionally if at all. Mark-recapture data show that the two stock maintain a high degree of fidelity to spawning areas and seldom interbreed (Hayes et al. 2002; Barry et al. 2007). Displaced adult LRS from Upper Klamath Lake released in Lake Ewauna migrated back to spawning locations in Upper Klamath Lake and the Williamson River (Korson et al. 2008). Some historical spawning areas in Upper Klamath Lake and its tributaries have been abandoned for no apparent physical reason (e.g., Harriman Springs, Barkley Springs, and several tributaries in the Wood River Valley) (USFWS 2008). Abandonment of apparently appropriate spawning sites indicates that the use of a spawning site may be a social tradition, that is, that fish learn about spawning sites by following or observing other fish (NRC 2004). Use of abandoned sites might be renewed spontaneously if populations of adults become substantially more abundant.

Larvae

LRS, SNS, and KLS eggs vary from 2.5-3.2 millimeters (mm) or 0.10-0.13 inches in diameter. Soon after hatching and when larvae reach about 7-10 mm (0.28-0.39 in) total length (TL), they are mostly transparent with a small yolk sac and they move out of the gravel (Buettner and Scoppettone 1990). At 14-15°C, hatch and swim-up times were 9 and 19 days for LRS and 6 and 16 days for SNS (Perkins and Scoppettone 1996). Therefore, after an approximately 2-3 week incubation and hatching period, larval suckers move out of spawning substrates and enter the water column. Most larval suckers spend relatively little time in rivers/stream before drifting downstream to lakes (Cooperman and Markle 2004; Ellsworth et al. 2007). However, in 2006, a large number of larvae resided in the Sprague River until June when they were 25-35 mm (0.98-1.38 in) TL, probably related to better flow and stream habitat conditions (Murphy and Parish 2008). Some in-river rearing does occur as is evidenced by juveniles being collected in the Sprague River (Ellsworth et al. 2008, 2009). In the Williamson River, larval sucker out-migration from spawning sites begins in April and is generally completed by mid-July (Buettner and Scoppettone 1990; Klamath Tribes 1996). Downstream movement takes place mostly at night and near the water surface (Klamath Tribes 1996; Tyler et al. 2004). Larvae move to the river margins, perhaps to seek cover during the day (Klamath Tribes 1996). Once in the lake, larvae disperse to near-shore areas (Cooperman and Markle 2004).

In Upper Klamath Lake, larval suckers are first captured in early April during most years, with peak catches occurring in June, and densities dropping to very low levels by mid-July (Cooperman and Markle 2000). Larval habitat is generally along the shoreline, in water 10-50 cm (3.9-19.7 in) deep and associated with emergent aquatic vegetation, such as bulrush (Buettner and Scoppettone 1990; Cooperman and Markle 2004). Emergent vegetation provides cover from predators, protection from currents and turbulence, and abundant prey (including zooplankton, macro-invertebrates, and periphyton; Klamath Tribes 1996). Cooperman and Markle (2004) found that larger larvae with full stomachs were associated with emergent vegetation rather than submergent macrophytes, woody vegetation or open water. At the Williamson River delta, Erdman and Hendrixson (2009) also found that larvae collected in shallow vegetated habitats had fuller guts that those collected in unvegetated habitats, suggesting that more food was available in vegetated habitats. Water temperature can be higher in emergent vegetation to facilitate larval growth (Crandall 2004). Larval LRS and SNS from Upper Klamath Lake feed primarily on surface prey (adult chironomids and pollen) and plankton (cladocerans and copepods) (Markle and Clauson 2006). Emergent wetlands also may provide cover from predators such as fathead minnows and yellow perch (Markle and Dunsmoor 2007). Additionally, larvae that reside in wetlands are less likely to be swept down lake via wind-driven currents and be entrained into the Link River where most are lost from the population because of low survival rates below Link River Dam (Markle et al. 2009). LRS larvae are less dependent on emergent vegetation and are about equally found in vegetated and unvegetated habitats, but they still primarily occur in shallow water less than 1 m deep (Burdick et al. 2009; Erdman and Hendrixson 2009). Larvae are found over sand, mud and gravel substrates (Terwilliger 2006). Larval suckers in Clear Lake and Gerber reservoirs use unvegetated shallow shoreline areas but emergent vegetation is generally scarce in these environments. Larvae transform into juveniles at about 25 mm (0.98 in) TL by mid-July.

Juveniles

Juvenile suckers are generally considered the life stage from about 25-100 mm (0.98-3.94 in) TL which generally occurs from about July through the first winter (age 0). Juvenile suckers utilize a wide variety of near-shore habitat including emergent wetlands (Reiser et al. 2001) and non-vegetated areas (Buettner and Scoppettone 1990; Terwilliger et al. 2004) and off-shore habitat (Hendrixson et al. 2007). Whereas larvae mostly swim near the surface, juveniles are primarily near-bottom dwellers. Near-shore juvenile sucker habitat is generally in gently sloping areas less than 1.3 m (4.27 ft) in depth, mostly less than 0.5 m (1.64 ft) deep (Buettner and Scoppettone 1990; Markle and Simon 1993; Vanderkooi et al. 2003). Juveniles in un-vegetated habitats have been captured over a variety of substrates including fines, sand, gravel, cobble, and mixed coarse and fine substrates (Buettner and Scoppettone 1990; Burdick et al. 2008; Hendrixson et al. 2007; Terwilliger et al. 2004). Juvenile sucker habitat is generally inversely related to depth (Burdick et al. 2007). Juveniles are more likely to use habitat with smaller substrate (< 64 mm or 2.52 in) than larger substrate (>64 mm or 2.52 in) and habitats with vegetation than without vegetation (Vanderkooi et al. 2006). The higher probability for juvenile suckers to occupy sites with smaller substrates may be due to the high occurrence of vegetation at these sites. Another possibility is that food resources for juvenile suckers, which primarily eat benthic invertebrates and crustaceans (Markle and Clausen 2006) may be greater in areas of small substrate. As they grow during the summer many juveniles move offshore and many move down the lake into Link River and Keno Reservoir (USFWS 2008). Juvenile LRS appear to be less dependent on inshore habitats that do SNS (D. Markle, OSU, pers. comm.).

Sub-Adults and Adults

Sub-adults are the least studied age group. It is assumed that their requirements and habitats are most like those of non-spawning adults. Given that suckers may spend the first 3-8 years of their lives as sub-adults, additional information on this stage could be important. In Clear Lake and Gerber reservoirs, this life stage appears to occupy the same off-shore habitats as the adults (Piaskowski and Buettner 2003; Scoppettone et al. 1995; Reclamation 1994).

Adult LRS and SNS are widely distributed in Upper Klamath Lake during the fall and winter (NRC 2004; Banish et al. 2009). In the spring months, they congregate in the northern end of the lake near Goose Bay and Modoc Point prior to moving into tributaries or shoreline spawning areas for spawning (Hendrixson et al. 2004). During summer months adults are primarily found in the northern portion of the lake above Bare Island (Peck 2000; Banish et al. 2009). Reasons for this summer distribution are not clear but may be related to better water quality near spring-fed Pelican Bay and the Williamson River (Reiser et al. 2001; Banish et al. 2007; Banish et al. 2009). During the summer and early fall, Upper Klamath Lake water quality conditions periodically deteriorate to stressful and lethal levels for suckers as a result of decomposition of massive algae blooms and resultant low levels of DO (Perkins et al. 2000b; Loftus 2001; Wood et al. 2006; Morace 2007). Multi-year radio telemetry studies have documented LRS and SNS concentrating in or near Pelican Bay during periods of deteriorating water quality, presumably to seek refuge at area of better water quality (Peck 2000; Banish et al. 2009). Adult LRS and SNS generally used water depths greater than 2 m (6.56 ft) (Banish et al. 2009). Adult LRS and SNS were captured in open water areas of other lakes including Tule Lake (Scoppettone et al. 1995; Hodge and Buettner 2007; Hodge and Buettner 2008), Clear Lake (Buettner and Scoppettone 1991; Scoppettone et al. 1995; Barry et al. 2008), Gerber Reservoir

(Piaskowski and Buettner 2003), and Klamath River impoundments (Buettner and Scoppettone 1991; Desjardins and Markle 2000; Piaskowski 2003).

Adult LRS in Upper Klamath Lake forage primarily on zooplankton and benthic macro-invertebrates (Scoppettone and Vinyard 1991). In Clear Lake LRS consumed benthic macro-invertebrates (mostly chironomid larvae) and detritus (Parker et al. 2000). SNS fed predominantly on cladoceran zooplankters, and benthic macro-invertebrates in Clear Lake (Scoppettone et al. 1995; Parker et al. 2000).

Genetics

Recent genetic studies found LRS and SNS share a common gene pool with other Klamath Basin suckers in the genus *Catostomus* and hybridization was identified at the time of listing as a threat. New data suggest that hydridization among four Klamath Basin suckers probably does occur (Dowling 2005; Tranah and May 2006). Hybridization can be cause for concern for an imperiled species, however, at this time scientists who have studied Klamath suckers consider hybridization among them is not unusual. The evidence indicates that hybridization has been common throughout the evolutionary history of suckers, in general, and Klamath Basin suckers, in particular (Dowling 2005). LRS and KSS were genetically distinct from each other and from SNS and KLS. The latter two species were genetically indistinguishable based on mtDNA and nuclear gene characters. However, all four species were distinct based on a combination of morphological, genetic, and life history information.

Klamath Largescale and Klamath Smallscale Sucker Life History

Although the life history and ecology of the KLS and KSS in the Klamath River Basin has not been extensively studied, it is unlikely that it differs in any major respect from the life history of other typical suckers (Moyle 2002). KSS seem to be most abundant in deep, quiet pools of main rivers and in slower-moving stretches of tributaries, but they can be found in faster-flowing habitats when feeding or breeding (Moyle 2002). They are also common in Copco and J.C. Boyle reservoirs (Desjardins and Markle 2000). KSS migrate up tributary streams to spawn in spring; spawning in tributaries to Copco and J.C. Boyle reservoirs has been observed from mid-March through April. Juvenile KSS are most abundant in small streams used for spawning.

Although abundance of largescale and smallscale suckers is somewhat small, the trend in abundance of both species appears to be stable. In contrast to declining abundance of lake suckers, the stable population of stream-dwelling suckers suggests key factors of decline for the lake sucker are related to population limiting factors in the lake (e.g., poor water quality, non-native fish predation and competition, lack of emergent vegetation rearing habitat).

The Klamath largescale sucker seems to be the least lake-dependent of the three Upper Klamath Basin suckers, although it is found in lakes and reservoirs of the upper basin (Moyle 2002). There is some evidence that it needs fairly high quality water because it is largely absent from open water areas of Upper Klamath Lake, except in some areas where inflowing streams improve water quality (Buettner and Scoppettone 1990; Hendrixson et al. 2007; Burdick et al. 2008). Although these suckers can apparently withstand for short periods, temperatures as high as 32°C, DO levels of 1 milligrams/liter (mg/l) and pH levels in excess of 10 (Castleberry and Cech 1993; Falter and Cech 1991), conditions in polluted lakes may exceed even their limits. KLS were rare in fish surveys in Copco and Iron Gate Reservoirs (Buettner and Scoppettone 1991; Desjardins and Markle 2000). Tributary streams that support KLS rarely exceed 25°C. It is likely that historically the majority of large adults were found in lakes whereas juveniles lived either in streams or in shallow areas of lakes (Moyle 2002). However, there are reproducing populations in a number of larger rivers (e.g., upper Williamson River, Sprague River, Sycan River). KLS are presumably benthic omnivores as are other large *Catostomus* species.

Spawning migrations from Upper Klamath Lake, occur from February through early May, depending on flows and temperatures. A stock that migrates up the Sprague to the Beatty Gap area migrates in February and March, typically before LRS and SNS (Buettner and Scoppettone 1990). Genetically, KLS has not been differentiated from SNS (Tranah and May 2006).

2.1.2 Redband/Rainbow Trout

Variable Life Histories

Redband/rainbow trout (*Oncorhynchus mykiss* ssp.) possess diverse life history patterns throughout their range. An anadromous form of these fish, called steelhead, rears as young juveniles in freshwater for 1 to 3 years before migrating to the ocean as smolts, and then after 1 to 3 years at sea returns as adults to spawn in freshwater. The resident form of *O. mykiss* ssp. spends its entire life in freshwater, however, migratory life history groups are common. Redband/rainbow in the Klamath Basin can be fluvial (movement or migration within streams or between streams) or adfluvial (movement within lakes or between streams and lakes).

Phenotypic and life history variations are apparent within the Klamath Basin resident redband/rainbow groups (Li et al. 2007). The timing of redband/rainbow trout spawning migration varies among resident groups that occur throughout the Basin. Some of the factors that affect spawning migration times of resident redband/rainbow trout in the Basin include availability and connectivity of habitat, capacity of habitat at spawning grounds, water temperatures, and other physical factors such as water flow and depth.

Headwater Trout

Resident trout from upper reaches of Jenny Creek, upper Sprague River, and upper Williamson River typically spawn in April or May but only for short periods. They usually spawn for a 3 to 4 week period that varies depending on the temperature and water flow for a given year (Buchanan et al. 1990). These headwater trout are generally small in size because limited habitat in the smaller, shallower streams limits growth (Buchanan et al. 1990; R. French, ODFW, pers. comm.). However redband/rainbow trout migrating downstream from Deming Creek can reach sizes over 20 in (50.8 cm) when they enter and rear in Campbell Reservoir (Buchanan et al.

1990; R. French, ODFW, pers. comm.) All headwater trout are genetically distinct from the Upper Klamath Lake and lower river groups.

Lake/River Trout Above Keno Dam

Large numbers of adfluvial redband/rainbow trout rear to adult size in and near Upper Klamath Lake, and then migrate to spawn in Spring Creek or Kirk Springs on the lower Williamson River, near Kamkaun Springs on the lower Sprague River, or in the Wood River system (Messmer and Smith 2007; Tinniswood PPT Presentation 8/2/2010). The majority of the spawning occurs in the cold groundwater discharge areas found in these areas (Table 3). Some unusual life history variations are found in these groups of trout. Redband/rainbow trout from Spring Creek on the lower Williamson River spawn in every month of the year except for September (Buchanan et al. 1990). While only 6.2 mi (9.98 km) upstream at Kirk Springs, also on the Williamson River, redband/rainbow trout only spawn from November through February. Several years of tagging and recapture of spawners in these two areas suggest that both populations are reproductively isolated from each other. Tagged Spring Creek fish were never recovered at Kirk Springs. Likewise, fish tagged at Kirk Springs were not recovered in Spring Creek (Hemmingsen and Buchanan 1993).

Table 3. Estimated Groundwater Discharge (springs) into Upper Klamath basin River Systems.

River System	Section	Groundwater Flow (CFS)
Lower Williamson River and Tributaries	River Mile 16.5-22.2	350
Wood River and Tributaries	Crooked Creek confluence (RM 2) to headwaters	490
Sevenmile Creek and Tributaries	Crane Creek confluence to headwaters	90
Sprague River	South Fork Sprague (RM 10.2) to Sprague River (RM 20.1)	202
Upper Klamath Lake	Springs in Upper Klamath Lake including Malone, Crystal, Sucker, and Barclay	350
Klamath River	Keno Dam (RM 231.5) to Powerhouse (RM 219)	285
Klamath River and Fall Creek	Powerhouse to Iron Gate Dam	128
Total		**1,895**

Source: USGS (2007); Tinniswood (2010 and 2011)

Little information is known about juvenile life history of these adfluvial lake/river trout. Juvenile redband/rainbow trout are thought to spend up to 1 year rearing in the tributaries near their natal spawning sites before migrating downstream to the Upper Klamath Lake area (W. Tinniswood, ODFW, pers. comm.). A screwtrap was operated between November 2005 and October 2006 on the lower Sprague River 6.8 mi (10.94 km) above the confluence of the Williamson River. In spite of a very low capture efficiency rate, this trap captured 4,443 downstream moving juvenile redband/rainbow trout. Most of these juveniles were 80-100 mm (3.15-3.94 in) (fork length) and peak movement occurred in the spring before temperatures in the lower Sprague peaked to 25°C in July (M. Buettner, USFWS retired, pers. comm.; W. Tinniswood, ODFW, pers. comm.). Kamkaun Springs, located in the middle reach of the Sprague River, is a very successful spawning site for large redband/rainbow trout from the Upper Klamath Lake area. A single snorkel spawning survey at Kamkaun Springs recorded approximately 100 large Upper Klamath Lake sized spawners (W. Tinniswood, ODFW, pers. comm.). These trout can grow to sizes over 34 in (86.36 cm). Scale analysis shows that these fish first spawn at age 3 and then may spawn in consecutive years up to age 8 (Borgerson 1991; Messmer and Smith 2007).

Trout Below Keno Dam

The redband/rainbow trout downstream of Keno Dam have been adversely affected by J.C. Boyle Dam and Powerhouse, constructed in 1959, and the three other downstream dams (Figure 1 from Starcevich et al. 2006). Immediately below Keno Dam is the free flowing Keno Reach (5.9 mi or 9.5 km). Then waters flow into 4.0 mi (6.4 km) of Topsy Reservoir (also called J.C. Boyle Reservoir) which is formed by J. C. Boyle Dam. Spencer Creek, 15-18 mi (24.1-29 km) in length, enters the Klamath River just upstream of J.C. Boyle Dam near the slack waters at the head of Topsy Reservoir, and is an important spawning area and source of juvenile recruitment (Buchanan et al. 1990; Buchanan et al. 1991; Hemmingsen et al. 1992; Starcevich et al. 2006; Hamilton et al. 2010a). Downstream of J. C. Boyle Dam is the Bypass Reach where most of the natural channel margins of the Klamath River is dewatered and only 100 cfs flows downstream except for short, infrequent periods of spill when the flow exceeds 3000 cfs. Further downstream in this 4.3 mi (6.9 km) reach, natural groundwater springs (with discharges of 285 cfs) augment flow (Starcevich et al. 2006; Tinniswood 2011). The temperature of this groundwater remains constraint year-around at approximately 48°F (Carlson 1991). Below J.C. Boyle Hydroelectric Powerhouse, Klamath River waters rejoin the natural channel in a typical daily fluctuating flow from about 350-385 cfs when there is no power production up to 1850 cfs during peak power production this 17.3 mi (27.8 km) reach is known as the “peaking reach” (see Starcevich et al. 2006 and Tinniswood 2010 for a more complete description).

The major redband/rainbow trout spawning areas below Keno Dam are Spencer Creek and Shovel Creek (Beyer 1984; Starcevich et al. 2006). In 1988, 348 redds were counted in an 8.5 mi (13.7 km) section of Spencer Creek in April and May. Also 132 and 113 redds were found in a 5.2 mi (8.4 km) section in 2003 and 2004, respectively. Because spawning in Spencer Creek is thought to occur from late February through June these counts represent only a small amount of the total number of redds (Starcevich et al. 2006). In 1990 and 1991, respectively, a trap located in Spencer Creek captured 926 and 1,813 large adult trout up to 23 in (66 cm) in size returning to spawn (Buchanan et al. 1990; Buchanan et al. 1991).

Borgerson (1992) analyzed the change in scale growth patterns from 99 adult trout captured in April of 1990 and 1991 that suggested these fish migrated from Spencer Creek at ages 1 and 2 then returned to spawn for the first time at age 3 (range 2-4). Ages of spawning fish ranged from 2 to 8 years.

Downstream migratory juvenile redband/rainbow trout in Spencer Creek were captured by a weir and trap in 1990 and 1991. The number of out-migrating juveniles peaked in May when nearly 6,000 and 17,000 were captured in 1990 and 1991 respectively. The total number of juveniles captured from March to November was 8,809 in 1990 and 26,029 in 1991. Fry were also recorded with a peak out migration of over 2,000 in August of 1991 with a total fry count of 4,552 from June to November 1991 (Buchanan et al. 1990; Buchanan et al. 1991; Buchanan et al. 1992; Starcevich et al. 2006).

Shovel Creek is also an important spawning area for redband/rainbow trout because much of the mainstem Klamath River is dammed and exposed to unnatural fluctuating peaking flows. Only the first 2 mi (3.2 km) of Shovel Creek is accessible to migrating adult trout because of an upstream barrier falls (Beyer 1984). In spawning surveys conducted from April through June 1982, 79 trout redds were counted (Beyer 1984). Beyer (1984) estimated over 1,000 adults returned to spawn in 1982 based on mark and recapture data. However, sampling errors may account for the discrepancy between a low redd count and a high adult count.

The downstream weir and trap in Shovel Creek only captured 104 juvenile trout and 2,750 trout fry between April through October 1982. An additional estimated 30,000 trout fry and 174 trout juveniles therefore remained in Shovel Creek, as estimated by electrofishing studies during July (Beyer 1984).

Redband/rainbow trout spawning in the mainstem Klamath River is difficult to detect because of turbulent flow and poor visibility. During snorkel and bank spawning surveys in April 2003, 56 redds were estimated in the Bypass Reach (PacifiCorp. 2004).

Since the construction of J.C. Boyle Dam, upstream movement of adult redband/rainbow trout is greatly reduced and rare, although fish passage facilities do exist (Adm. Law Judge Orders 2006; FERC 2007; CH2MHILL 2003). Also, downstream movement of juveniles from Spencer Creek past J.C. Boyle Dam is restricted largely to short periods when spill occurs (Starcevich et al. 2006). The Keno Reach, where rearing adults increase to sizes over 23 in (58.4 cm), is the main source of spawning adult trout in Spencer Creek. Movement patterns suggest that diversity of life histories displayed by Spencer Creek spawners is reduced by J.C. Boyle Dam and Powerhouse. This dam has created an unusual life history pattern where adults from the Keno Reach migrate downstream into Spencer Creek and the juveniles produced in Spencer Creek migrate upstream into the free-flowing Keno Reach to mature (Buchanan et al. 1990; Buchanan et al. 1991; Starcevich et al. 2006).

Redband/rainbow trout can survive high water temperatures and high pH exposures, which allows these fish to use and move through a variety of locations within the Klamath Basin. Trout in the flowing Keno Reach of the Klamath Basin produce large-sized fish and healthy population abundance while being exposed to pH of up to 9.6 and water temperature up to 27°C throughout the summer period (Li et al. 2007).

Genetics

Upper Klamath Basin resident redband/rainbow trout are unique stocks of fish that have adapted to local habitat conditions (Buchanan et al. 1994). The subdivision of a species into local populations, or stocks, which possess adaptive genetic differences, is the fundamental basis of the stock concept (Nehlsen et al. 1991). Genetic and phenotypic variability are key factors that enable a species to persist in a changing environment.

The historical record of steelhead and anadromous redband/rainbow trout in the Upper Klamath River basin before construction of a series of blocking dams was documented by 11 written reports and one personal communication (Hamilton et al. 2005). According to Puckett et al. (1966) steelhead were present as far upstream as Link River but their presence above Upper Klamath Lake could not be accurately documented. Fortune et al. (1966) agrees with Puckett et al. that accurate information is limited due to the difficulty of separating steelhead from large lake-reared trout. But Fortune et al. (1966) also states that there were accounts of anadromous steelhead in the lower Wood, Sprague, and Williamson rivers. Hamilton et al. (2005) cites the Fortune et al (1966) distribution for the larger streams upstream of Upper Klamath Lake, but does not include steelhead in the upper headwaters of the Sprague or Williamson rivers saying that accurate information was not obtainable for the upper watershed. Recent analysis of fish bones collected at several archeological sites in the Sprague and Williamson rivers verified that steelhead and Chinook salmon occurred above Upper Klamath Lake (Butler and Stevenson 2010).

There is a concern that steelhead reintroductions will have an adverse effect on Klamath Basin resident redband/rainbow trout. Observations of interbreeding and gene flow between resident male redband/rainbow trout and female steelhead have been documented in the Babine River basin and Yakima River basin (Zimmerman and Reeves 2000; Pearsons et al. 2007). Both these systems contain healthy populations of each life history and support active steelhead and resident trout fisheries (Narver 1969; Zimmerman and Reeves 2000; Pearsons et al 2007).

Steelhead and resident trout in the Deschutes River basin are believed to be reproductively isolated populations (Zimmerman and Reeves 2000). Healthy populations of steelhead and resident trout are found in the Deschutes River and each group supports trophy fisheries. Deschutes steelhead spawn from March through May and Deschutes resident trout spawn from March through August. Spawning sites selected by Deschutes steelhead are in deeper water and had larger substrate than those selected by Deschutes resident trout. All adult steelhead from the Deschutes River were progeny of steelhead and all resident trout were progeny of resident rainbow trout (Zimmerman and Reeves 2000).

Genetic differences within two and possibly three groups of redband/rainbow trout from the Klamath Basin were evaluated using protein electrophoresis (Buchanan et al. 1994; Currens et al. 2009). The first major genetic group consisted of redband/rainbow trout from the high headwater tributaries of the Sprague and Upper Williamson rivers, and above an ancient waterfall on Jenny Creek. A second group of trout consisted of redband/rainbow near the

Upper Klamath Lake, the lower Williamson River, the lower Sprague River up to Trout Creek, and the Klamath River near and in Spencer Creek. A possible third anadromous group of redband/rainbow has been identified based on sampling within Bogus Creek located immediately downstream of Iron Gate Dam (Buchanan et al. 1994; Currens et al. 2007; Currens et al. 2009).

Ken Currens (as a co-author of Buchanan et al. 1994) wrote that the somewhat close genetic similarity of redband/rainbow trout in 1) Spring Creek on the lower Williamson River, 2) Spencer Creek and the Klamath River below Upper Klamath Lake, and 3) the anadromous form of redband/rainbow from Bogus Creek suggests that populations near the Upper Klamath Lake were once associated with runs of anadromous trout. After analyzing 240 collections of redband/rainbow trout throughout the species range, Currens et. al. (2009) now believes that e redband/rainbow trout include:

1) A previously unrecognized group associated with populations in the headwaters of the basin.
2) A different subspecies from type locations for Upper Klamath Lake redband trout *O. mykiss newberrii* (found in Upper Klamath Lake, Lower Williamson River, Lower Sprague River up to Trout Creek, Wood River, and Klamath River including Spencer Creek).
3) A third group from Bogus Creek on the Klamath River below Iron Gate Dam and Soda Creek from the Rogue River.

Further analysis indicated that coastal anadromous redband/rainbow trout from the Klamath Mountains (Bogus Creek and Soda Creek) were more closely related to other Klamath River populations (near Upper Klamath Lake and Spencer Creek) than to coastal redband/rainbow trout from the lower Columbia River (Currens et al. 2009).

Disease

Differential immunity to diseases such as *Ceratomyxa shasta (C. shasta)* among different populations of redband/rainbow trout in the Klamath Basin results from a co-adapted history between the myxosporean parasite and its host (Li et al. 2007). Trout in the lower Williamson River, Upper Klamath Lake, and in the Klamath River below Upper Klamath Lake where *C. shasta* is found are highly resistant to this parasite while trout in Jenny Creek and the headwaters of the Sprague and Williamson rivers (where *C. shasta* is not found) are susceptible (Hemmingsen et al. 1988, Bartholomew 2008). The presence of *C. shasta* throughout the lower Klamath River downstream of Iron Gate Dam suggests that the native lake/river redband/rainbow trout (both resident and anadromous forms) co-evolved over time with *C. shasta* (Bartholomew 2008).

Size and Distribution

Redband/rainbow trout in the Klamath Basin are a pioneering species. These trout are continuously probing and moving to new acceptable habitats found throughout the Upper Klamath Basin. Redband/rainbow are both fluvial and adfluvial. Current distribution patterns and relative change of distribution are useful indicators of population health and status (Buchanan et al. 1992; Hemmingsen et al. 1992).

Scale analysis and tagging studies on redband/rainbow in the Basin have shown that these trout can spawn in consecutive years up to age 8 (Borgenson 1991; Messmer and Smith 2007). Historically, the largest redband/rainbow captured in a trout fishery from the Upper Klamath Lake was caught in 1956. It was 34 in (86.4 cm) and weighed 25 pounds (lbs) or 11.3 kilograms (kg). Another large redband/rainbow trout was found dead in a spawning tributary to Upper Klamath Lake. It was measured at 37 in (94 cm) and estimated to weigh over 30 lbs (13.6 kg) (Messmer and Smith 2007). Tagging records in the early 1990s found that redband/rainbow trout feeding in Upper Klamath Lake and spawning repeatedly in Spring Creek can typically reach sizes over 28 in (71.1 cm) (Buchanan et al. 1992). Redband/rainbow trout feeding in the Keno reach of the Klamath River below Keno Dam and spawning in Spencer Creek also reach trophy sizes over 24 in (61 cm) (W. Tinniswood, ODFW, pers. comm.). These size data suggest redband/rainbow trout have abundant food supply to support rapid growth.

Population Trends

Beginning in the 1920s, the Upper Klamath Basin has been stocked throughout with over 4.8 million hatchery rainbow trout, predominately non-native coastal rainbow trout strains. Most hatchery trout were stocked as small unfed fry until 1960 (Buchanan et al. 1991; Messmer and Smith 2007). No hatchery rainbow trout have been stocked in the Upper Klamath Lake area since 1979. Stocking of all streams in the basin except for Spring Creek, was discontinued after 1991 (Messmer and Smith 2007). Almost all of these stocked fish did not likely survive to maturity because these hatchery strains are highly susceptible to *C. shasta* (see Disease section) and are not adapted to high pH and high summer temperatures found in the Upper Klamath Basin (Messmer and Smith 2007). Because of the wide range of effects to different redband/rainbow trout populations in the Upper Klamath Basin over time, the discussion of population trends is separated into the following two report sections: Headwater Trout and Lake/River Trout Above and Below Keno Dam.

Headwater Trout

Nineteen groups of redband/rainbow trout were sampled throughout the Upper Klamath Basin for genetic analyses and possible introgression (or hybridization) between the native, wild redband/rainbow trout groups and the introduced non-native hatchery groups (Buchanan et al. 1994). Only fish from upper Jenny Creek and Fall Creek suggest recent hybridization of introduced hatchery and wild trout. Fish in both creeks are isolated by barrier waterfalls from the rest of the Upper Klamath Basin. *C. shasta* has not been found in these waters and introduced hatchery rainbow trout strains which are highly susceptible to the disease *C. shasta* could survive in spring groundwater sections of Jenny and Fall creeks.

Redband/rainbow trout found in the headwaters of the upper Williamson River, Sprague River and parts of Jenny Creek did not exhibit introgression with non-native hatchery strains and were genetically separate from the native stocks above and below Upper Klamath Lake (see Genetics section).

Headwater habitat degradation from channelization, water withdrawals, removal of stream vegetation, and other disturbances have altered the aquatic environment by elevating water temperatures, reducing water quantity and quality, and increasing sedimentation on both private and public lands in these streams. Both abundance and distribution of redband/rainbow trout populations and resident bull trout (*Salvelinus confluentus*) are limited and scattered in these headwater streams (Buchanan et al. 1994; Light et al. 1996).

Lake/River Trout Above and Below Keno Dam

Genetically, the redband/rainbow trout above and below Keno Dam are similar and show no introgression from the large numbers of hatchery non-native trout stocked into the basin (See Genetics section).

These native trout have abilities to thrive in extreme warm waters with high summertime pH (Li et al. 2007). High groundwater discharges of approximately 1900 cfs from the lower tributaries draining into the Upper Klamath Lake, within Upper Klamath Lake, and from sections of the Klamath River below Keno Dam provide special rearing, spawning and harvest areas for salmonids (Table 3).

For thousands of years, Upper Klamath Lake has been an eutrophic lake system. Waters flowing out of eutrophic lakes are warmer with abundant nutrient loads. Coleman et al. (1988) noted that these traits are primarily due to high surface area to depth ratio (mean depth of Upper Klamath Lake is less than 9 ft or 2.7 m) with naturally high concentrations of nutrients in the groundwater (Miller and Tash 1967). Phinney and Peek (1959) state that the great area of Upper Klamath Lake provides an extensive trap for the conversion of radiant energy into plant material. This conversion is aided by the fact that this lake is so shallow.

Upper Klamath Basin redband/rainbow have appeared to have adapted to these local eutrophic conditions over time as predicted by the stock concept (Nehlsen et al 1991). They support robust populations that subsequently produce trophy redband/rainbow trout fisheries. However, Upper Klamath Lake and waters draining from this lake have become hypereutrophic (extremely high nutrient levels and biological productivity) over the last century due to 1) diking and farming of the wetlands near or in the lake, city, and farms, 2) run-off from farms and ranches, and 3) internal lake sediment sources (i.e. trapped sediments containing nutrients that have settled in the lake bottom, and when stirred-up by wind and wave action, contribute to hypereutrophic conditions) (ODEQ 2002; IMST 2003; Bradbury et al.

2004; Eilers at al. 2004; NRC 2004). These hypereutrophic conditions have occurred rapidly over time, leading to possible stressful conditions for some fishes. Continued degradation of conditions in Upper Klamath Lake could have an adverse impact on the current robust populations of redband/rainbow trout.

2.1.3 Bull Trout

Although not part of the official request for inclusion in the Panel's review, the Panel decided that bull trout (*Salvelinus confluentus*) need to be considered since they are listed as a threatened species under the Endangered Species Act (ESA) and are native to the Upper Klamath Basin (USFWS 1998).

Genetics

Based on allozyme analysis, bull trout have relatively low levels of genetic variation within populations when compared to other salmonids (Leary et al. 1993). These same patterns are observed at microsatellite loci and are supported by the few alleles identified across the range of the species (Spruell et al. 2003). Bull trout from the Upper Klamath Basin contain virtually no genetic variation at either microsatellite or allozyme loci. Klamath bull trout populations have been geographically isolated for thousands of years and may have been founded by a limited number of individuals or experienced a severe bottleneck (Leary et al. 1993; Spruell et al. 2003).

Spruell et al. (2003) studied 65 bull trout populations from British Columbia, Montana, Idaho, Washington, Oregon, and Nevada. Two populations from the Upper Klamath Basin (South Fork of the upper Sprague River and Long Creek, a tributary of the upper Sycan River) were included in their samples. Their microsatellite analysis supported the existence of at least three major genetically differentiated groups of bull trout: (1) Snake River populations (2) upper Columbia River populations (primarily from the Clark Fork basin) and (3) "Coastal" populations. The bull trout from the Upper Klamath Basin were included in this "Coastal" group. The "Coastal" group also included bull trout from the Puget Sound and Olympic Peninsula. Columbia River tributaries downstream and including the Deschutes River were also included in this "Coastal" group.

Life History

Only smaller-sized resident forms of bull trout are currently found in the Upper Klamath Basin (Buchanan et al. 1997). The largest bull trout captured in Deming Creek (Upper Sprague River) was 8.6 in or 21.8 cm, whereas bull trout captured in the Brownsworth, Leonard and Boulder/Dixon Creeks (Upper Sprague River) were all less than 7.5 in (19.1 cm). The largest bull trout captured in Long Creek (Upper Sycan River) was 9.2 in (23.4 cm) (Buchanan et al. 1997).

Scales were taken from 133 bull trout sampled from Long Creek in 1991 to develop a length frequency and age class relationship. Juvenile bull trout 1+ and 2+ in age were less than 4.9 in

(12.4 cm) in size while older adult bull trout (ages 5+ and 6+) were few in number and over 7.9 in (20.1 cm) in size (Buchanan et al. 1997).

Bull trout have been observed spawning in the Upper Klamath Basin from mid-September to mid-November. For example, spawning bull trout and freshly constructed redds were found in upper Long Creek on 21 September 1994, and 9 new redds were observed in a small section of Three Mile Creek (near Upper Klamath Lake) on 20 November 1995 (Buchanan et al. 1997).

Other life history trends, habitat needs, and bull trout distributions in the Upper Klamath Basin are further discussed in Section 3.4.

2.2 Alternatives

There are two alternatives being considered by the Secretary of the Interior. These are described in detail here along with the Panel's interpretation of what is included within these alternatives.

2.2.1 Conditions with Dams (Current Conditions)

Current Conditions: No change from current management, which includes on-going programs under existing laws and authorities that contribute to the continued existence of listed threatened and endangered species, as well as species relied upon for ceremonial, subsistence, and commercial purposes by the Native American Tribes of the Klamath Basin (The Yurok, Hoopa, Karuk, and Klamath Tribes), hereinafter referred to as Tribal Trust species. The Panel interprets the Current Conditions to include:

1. Continued operation of the Klamath Hydroelectric Project (Federal Energy Regulatory Commission [FERC] Project No. 2082) in the same manner it is currently operated without any new operating requirements related to the relicensing of the project by FERC;
2. Requirements of the NMFS Biological Opinion (BO) for coho in the Klamath Basin;
3. Implementation of Non-Interim Conservation Plan (ICP) Interim Measures;
4. Implementation of the Upper Klamath Lake Drainage Total Maximum Daily Load (TMDL) and Water Quality Management Plan (WQMP) as required by the Oregon Department of Environmental Quality (ODEQ) (ODEQ 2002);
5. Implementation of the Action Plan for the Klamath River TMDLs Addressing Temperature, Dissolved Oxygen, Nutrient, and Microcystin Impairments in the Klamath River in California and Lower Lost River Implementation Plan required by the California North Coast Regional Water Quality Control Board (NCRWQB 2010);
6. Various fishery management plans prepared by the ODFW and the California Department of Fish and Game (CDFG); and

7. Predictions of the effects of climate change on streamflow for the Klamath River watershed presented by Blair Greimann, U.S. Bureau of Reclamation (PPT Presentation 8/2/2010).

2.2.2 Condition without Dams and with KBRA (Proposed Action)

Proposed Action: Removal of the lower four Klamath Hydroelectric Project dams (Iron Gate, Copco 1, Copco 2, and J.C. Boyle), currently facilities of the Klamath Hydroelectric Project, and the full range of actions/programs to implement the KBRA. The Panel interprets the Proposed Action and the KBRA to include:

1. Removal of the four dams and reservoirs listed previously, thereby opening the Klamath River to fish access upstream in the mainstem river as far as Keno Dam, currently a facility of the Klamath Hydroelectric Project.
2. Implementation of various KBRA restoration actions that could benefit resident fish through actions listed in Appendix C-2 of the KBRA. These actions include, but are not limited to: water quality remediation actions, aquatic and riparian habitat restoration, water conservation and water rights acquisition, addition of large wood and gravel, channel and floodplain reconfiguration, erosion control, and fish passage (including at Keno Dam). Detail regarding these actions (where they would occur and the miles or acres of area treated) was provided to the Panel on August 2 (M. Barry, U.S. Fish and Wildlife Service, PPT Presentation) and is summarized within Table 4 summary of KBRA in upper watershed.
3. Implementation of ICP Interim Measures.
4. Implementation of the two TMDLs cited previously; and
5. Predictions of the effects of climate change on streamflow for the Klamath River watershed presented by Blair Greimann, U.S. Bureau of Reclamation (unpublished 2011 available at: ftp.usbr.gov/tsc/mdelcau/Klamath/Reports/Hydrology_Sediment).

2.3 Questions

Three sets of questions were provided to the Panel. The first set consisted of general questions developed by the TMT and stakeholders. The second two sets were specific questions for redband/rainbow trout and suckers developed by the TMT. In the following narrative, the general questions are identified by G-1 through G-10. Sucker-specific questions are identified as S-1 through S-9. Redband/rainbow-specific questions are identified by R-1 through R-5. Because the Panel's assignment was to assess the effects of the two management alternatives on resident fish, the Panel addressed the general questions from a viewpoint that focused on the sucker species and redband/rainbow trout respectively.

The original set of questions included extensive background information and commentary (Appendix B). The text highlighted below is the question with the introductory commentary removed. The report sections where answers to the questions are found are referenced below and provided in the narrative in Sections 3.0 through 6.0.

2.3.1 General Questions

G-1) Geomorphology: How will the alternatives affect geomorphology in the short-term (1-2 years) and over the 50-year period of interest? What are the expected short- term effects of dam removal on the fish abundance and how long will it take these populations to return to baseline levels?

Question G-1 is addressed in Sections 2.4.1 through 2.4.8, Sections 4.1.1 and 4.1.2, Sections 4.2.1 and 4.2.2, Section 4.3, and Section 4.4.

G-2) Water quality: Given the possible trends in water quality during the 50-year period of interest, how will the two alternatives differ in reaching the goal of harvestable fish populations?

Question G-2 is addressed in Sections 2.5.1 and 2.5.2, Section 3.1.2, Section 3.2.2, Section 3.3.2, and Section 5.1 through 5.3.

G-3) Water temperature: What are the likely effects of the water temperature regimes under the two alternatives on rearing, spawning, and use of thermal refugia by native salmonids that might be manifest in harvestable fish?

Question G-3 is addressed in Sections 2.5.1 and 2.5.2, Section 3.2.2, Section 3.3.2, Section 3.4, and Section 5.2.

G-4) Habitat and restoration (KBRA): The two proposed alternatives will result in different paths and timelines for habitat management. What are the likely effects of the two alternative habitat management paths on the recovery of ESA-listed fish or in the level of harvest of fish populations?

Question G-4 is addressed in Sections 3.1.3 through 3.1.5, Sections 3.2.3 through 3.2.5, Sections 3.3.3 through 3.3.5, Section 3.4, Section 4.2.2, and Sections 5.1 through 5.3.

G-5) Climate change: To what extent might potential changes in habitat, the hydrograph, and thermal refugia mitigate the effects of climate change under the two alternatives? What are the likely effects of climate change on the harvest levels of fish under the two alternatives?

Question G-5 is addressed in Section 2.6.

Table 4. KBRA Restoration Needs for Klamath Basin Upstream of Keno Dam.

KBRA Activity	Miles, Riparian Acres (Along Stream Banks), or Number of KBRA Activity										
	Williamson River		Sprague River		Wood River				Upper Klamath Lake		
						Tributaries					
	Mainstem	Tributaries	Mainstem	Tributaries	Mainstem	Sevenmile Creek/Canal System	Fourmile Creek/Canal System	Others	Upper Klamath/ Agency Lake	In or Above Keno Reservoir	TOTAL
Fence Construction and Offstream Watering (Miles)	50	4.4	130	76	25	6	1	26	–	–	318.4
Maintain Existing Fences, Manage Weeds and Exotic Plants (Miles)	112	10	220	132	42	46	16	38	–	–	616
Riparian Corridor Management Agreements (Acres)	1,386	91.2	6,202	1,897	720	175	–	–	–	–	10,471.2
Levee Removal, Setback, or Breaching (Miles)	2	–	30	16	3	–	–	–	–	–	51
Physical Habitat Improvements[1] (Miles)	12	5	22	15	15.4	–	–	7	–	–	69.4
Native Vegetation Management (Acres)	5,500	–	–	–	–	–	–	–	–	–	5,500
Improve Quality and Connectivity of Endangered Sucker Nursery Habitats[2] (Acres)	5,500	–	–	–	–	–	–	–	–	–	5,500
Channel Narrowing (Miles)	–	2.1	–	–	–	–	–	–	–	–	2.1
Grazing Management[3] (Full-Time Equivalent)	–	–	1 FTE	–	1 FTE	–	–	–	–	–	2 FTE
Improving Dryland Range to Reduce Need for Riparian Pastures (Acres)	–	–	19,000	–	–	–	–	–	–	–	19,000
Whole Channel Reconstruction (Miles)	–	–	15	10		4.5	2.3	3	–	–	34.8
Spring Improvement, Enhancement, and Reconnection[4] (Number of Springs)	–	–	20	20	–	–	–	–	–	–	40
Barrier and Impediment Removal (Number of Impediments)	–	–	2	6	–	–	–	–	–	–	8
Treatment Wetlands for Irrigation Drainwater (Number of Wetlands)	–	–	–	3	–	–	–	–	–	–	3

	Miles, Riparian Acres (Along Stream Banks), or Number of KBRA Activity										
	Williamson River		**Sprague River**		**Wood River**				**Upper Klamath Lake**		
						Tributaries					
KBRA Activity	**Mainstem**	**Tributaries**	**Mainstem**	**Tributaries**	**Mainstem**	**Sevenmile Creek/Canal System**	**Fourmile Creek/Canal System**	**Others**	**Upper Klamath/ Agency Lake**	**In or Above Keno Reservoir**	**TOTAL**
Floodplain Wetland Restoration and Storage[5] (Mile)	–	–	–	–	–	–	–	–	10		10
Enhance Endangered Sucker Spawning Habitat in Springs[6] (Number of Spawning Sites)	–	–	–	–	–	–	–	–	10		10
Study of Management and Reduction of Organic and Nutrient Loads	–	–	–	–	–	–	–	–	–	1	1
Implement Recommended Organic and Nutrient Reduction Actions[7]	–	–	–	–	–	–	–	–	–	Yes	–
Restore Wetlands on Keno Reservoir	–	–	–	–	–	–	–	–	–	TBD from Study	–
Screening Pumps and Diversions [8] (Number of Diversions)	–	–	–	–	–	–	–	–	–	Yes	–
Screening Pumps and Klamath Irrigation Project Diversions[9]	–	–	–	–	–	–	–	–	–	Yes	–
Acquisition of 30,000 acre-feet of water	Focused in the Sprague River, but acquisition could occur in any of these streams.										

Notes:

[1] Physical Habitat Improvements include treatments of large wood and gravel placement to maximize productivity and capacity for early life stages of anadromous fish to facilitate reintroduction.

[2] Includes future earthwork and other activities directed at the Lower Williamson Delta.

[3] Covers one Full Time Equivalent (FTE), defined as one grazing management specialist, 5 years full-time, part-time thereafter, to assist landowners with developing ranch management plans and maintain/enhance riparian corridor.

[4] Includes revegetating and reconstructing outlet channels, substrate treatments, and morphological changes to spring ponds.

[5] Targeted miles of lake fringe wetlands restoration to include removal of levee material and re-use for habitat features such as raised channels or island habitats.

[6] Targeted number of spawning sites to include gravel augmentation.

[7] Actions will likely be a combination of treatment wetlands, engineered water treatment facilities, physical removal of particulate organics, and treatments to precipitate nutrients.

[8] A total of 100 diversions targeted along Williamson, Sprague, and Wood Rivers; 20 diversions targeted at Upper Klamath Lake

[9] Studies are underway.

G-6) Abundance: How will the two alternatives affect abundance of the fish population and what are the expectations for the enhancement of the fisheries? This question may have several milestones along a timeline or population trajectory. For example, inasmuch as some fish populations have been extirpated from the Upper Klamath Basin for more than 90 years, when might fish be available for tribal ceremonial use within the Upper Klamath Basin? Using a time trajectory, when will a sustainable fishery start and at what levels?

Question G-6 is addressed in Sections 3.1.3 through 3.1.5, Sections 3.2.3 through 3.2.5, Sections 3.3.3 through 3.3.5, Section 3.4, Section 4.2.2, and Sections 5.1 through 5.3.

G-7) Productivity: What are the most likely expectations for productivity over time and what is the effect of productivity on the number of harvestable fish? What is the role of hatcheries in relation to productivity?

The role of hatcheries is generally not applicable to resident fish. The first part of Question G-7 is addressed in Sections 3.1.3 through 3.1.5, Section 3.2.4, Section 3.3.4, and Sections 5.1 through 5.3.

G-8) Diversity: What will the effect of the two alternatives be on diversity of fish populations? How will the resulting diversity be manifest in the harvestable population of fish? How will potentially low baseline populations and/or introductions of hatchery fish affect diversity under the two alternatives?

Question G-8 is addressed in Section 3.1.5, Sections 3.2.4 and 3.2.5, Sections 3.3.4 and 3.3.5, Section 3.5, Sections 4.1.1 and 4.1.2, Sections 4.2.1 and 4.2.2, Section 4.3, Section 4.4, and Sections 5.1 through 5.3.

G-9) Spatial structure: Will the two alternatives result in improved spatial structure of fish populations and to what extent is that improved structure likely to result in harvestable fish?

Question G-9 is addressed in Sections 2.5.3 through 2.4.5, Sections 3.1.3 and 3.1.4, Sections 3.2.3 through 3.2.5, Sections 3.3.3 through 3.3.5, Sections 4.1.1 and 4.1.2, Sections 4.2.1 and 4.2.2, Section 4.3, Section 4.4, and Sections 5.1 through 5.3.

G-10) Ecosystem restoration: How do the proposed alternatives address ecosystem function and connectivity sufficiently to recover the lost harvest opportunities of fish populations?

Question G-10 is addressed in Section 2.4.5, Sections 3.1.1 through 3.1.4, Sections 3.2.1 through 3.2.3, Sections 3.3.1 through 3.3.3, Section 4.1.2, Section 4.2.2, and Sections 5.1 through 5.3.

2.3.2 Suckers-Specific Questions

S-1) Sucker Restoration: How might the two proposed alternatives affect the primary restoration strategies for the Lost River and shortnose suckers during the 50 year period being considered? Given that there will likely be lake level effects to sucker habitat, which of the two alternatives before the Expert Panel is likely to be most beneficial to sucker populations considering competing demands for water?

Question S-1 is addressed in Sections 3.1.1 through 3.1.4.

S-2) Water Quality: How might actions identified in KBRA aimed at improving water quality (e.g., reestablishing functions of former wetlands around Upper Klamath Lake, repairing riparian areas, and reducing input of nutrients from agricultural/grazing land) potentially influence water quality in Upper Klamath Lake and the health of suckers populations over the next 50 years?

Question S-2 is addressed in Section 2.5.1 and Section 3.1.2.

S-3) Tribal Harvest: The KBRA defined harvest opportunities to mean: full participation in Tribal, ceremonial, and commercial, ocean-commercial and recreational harvest. What is the most likely effect of the two proposed alternatives during the 50 year period on having harvestable populations of suckers?

Question S-3 is addressed in Section 5.1.

S-4) Climate Change: How might climate change affect major processes such as watershed function, water quality, primary production, trophic interactions, and other processes that could affect suckers? To what degree do you think the adverse effects of climate change will be mitigated under the two alternatives being considered?

Question S-4 is addressed in Sections 2.6.

S-5) Non-Native and Reintroduced Species: What is the likely effect of the two proposed alternatives on non-native species and reintroduced species, including their predatory and competitive interactions with suckers? What effect will the two alternatives have on non-native species, lake level management, wetland restoration, and the restoration of suckers?

Question S-5 is addressed in Sections 3.1.5.

S-6) Drought and Declining Water Supplies: During drought conditions how would the alternatives affect the three primary restoration strategies (i.e., water level management, water quality improvement, and restoration of wetlands) for suckers during the 50 year period?

Question S-6 is addressed in Sections 3.1.1 through 3.1.4.

S-7) Uncertainty: Water quality and quantity, restoration affects, droughts, toxic algae, and invasive species are examples of factors whose effects on suckers are uncertain over the 50-year period. How might this uncertainty affect the sucker populations under the two alternatives?

Question S-7 is addressed in Section 1.4, and Sections 3.1.1 through 3.1.5.

2.3.3 Redband/Rainbow Trout-Specific Questions

R-1) The Four-Dam Project Reach: Please identify the activities associated with the two alternatives that would increase or decrease potential size, growth, and abundance of redband/rainbow trout.

Question R-1 is addressed in Sections 2.4.3 through 2.4.5, Sections 3.2.1 through 3.2.5, Sections 3.3.1 through 3.3.5, and Sections 4.2.1 and 4.2.2.

R-2) Water quality: Over the 50 year period of interest, what are the likely effects of water quality changes on redband/rainbow trout populations and the sport fishery in Upper Klamath Lake and the tributaries?

Question R-2 is addressed in Section 3.2.2 and Section 3.3.2.

R-3) Fishery for redband/rainbow trout: How might fish size and abundance in the Williamson and Wood rivers be affected by the two alternatives?

Question R-3 is addressed in Sections 3.3.1 through 3.3.5, and Section 5.2.

R-4) Genetics of redband, rainbow, and steelhead trout: Will the restoration of anadromous steelhead to the PR and above Upper Klamath Lake have deleterious effects on capacity to produce trophy redband/rainbow? Under the two alternatives, what are the likely scenarios for redband/rainbow trout harvest over the 50 year time period?

Question R-4 is addressed in Sections 3.2.4 and 3.2.5, Sections 3.3.4 and 3.3.5, and Section 5.2.

R-5) Thermal conditions for redband trout: Please describe the extent to which the two alternatives differ in terms of redband access to and use of thermally adequate habitats, and how such differences might influence the resilience of Upper Basin redband populations, and the harvest opportunities they might provide.

Question R-5 is addressed in Sections 2.5.1 and 2.5.2, Section 3.2.1 through 3.2.5, Sections 3.3.1 through Section 3.3.4, Section 4.2.2, and Section 5.2.

2.4 Hydrology and Geomorphology

The Upper Klamath River Basin (drainage area 5,700 square-mi or 14,763 square-km) (NRC 2004, page 53) is underlain by two geological provinces: the Basin and Range Province and the High Cascade Province. The Basin and Range in the most eastern, upstream part of the Klamath catchment consists of low north-south-trending, fault-bound, mountain ranges separated by wide valleys. Sediments from the ranges have accumulated in the valleys, providing aquifers with significant groundwater storage potential, draining to lakes, marshes, or directly to the tributaries of the Klamath River. The High Cascade Province consists of high tablelands and wide, shallow valleys developed in the deep, permeable volcaniclastic deposits associated with geologically recent eruptions. In both provinces, water from snowmelt and rainfall recharge the deep aquifers and travel to the stream network as groundwater, which enters the stream network as both diffuse lateral inflow and as concentrated spring flows. As a result of the high permeability of these sedimentary and volcaniclastic aquifers, the density (and therefore total channel length) of the drainage network is low, and the rate of erosion and sediment supply (especially of mechanically resilient gravel) are all low. The rivers flow on low gradients, originally through broad marshy riparian zones that were sustained by the outcropping of water tables. However, extensive seasonal lowering of the water table, and more localized long-term lowering, through a combination of channel straightening and diking, droughts, and ground water extraction (Leonard and Harris 1974, p. 56; Gannett et al. 2007, p. 60) have dried out these riparian zones and diminished their capacity for augmenting flow and sustaining woody vegetation. This dewatering of the riparian zone is least intensive in the lower reaches of the tributaries. The channels have been degraded further by grazing, browsing, and trampling mainly by cattle. This herd management impact has resulted in the addition of fine sediment to the stream channels, and the filling of pools and springs with fine sediment.

This upper basin also contains approximately ten shallow lakes, the largest survivor of which is Upper Klamath Lake (area ~67,000 acres) (NRC 2004, page 53). Several other large lakes, some of which were originally larger than Upper Klamath Lake, have shrunk dramatically over the past century as a result of drainage, diversion, and consumptive use of water that formerly entered them. Upper Klamath Lake has an average depth of about 6-8 ft (1.8-2.4 m) with local depths of up to 20-30 ft (6.1-9.1 m). The maximum depth of Upper Klamath Lake is 61 ft (18.6 m). In addition to distributed and concentrated inputs of groundwater, the lake is fed by two large tributaries: the Wood and Williamson rivers, the latter receiving much of its flow from the Sprague River.

2.4.1 Upper Klamath Lake Inflows

The headwater streams in the upper Williamson River are formed from rainfall, snow melt, and groundwater springs beginning at Yamsey Mountain (elevation of 8,196 feet). The headwater streams from the upper Sprague River originate in the Gearhart Mountain Wilderness (elevation of 8,135 feet). The Williamson-Sprague system supplies about 50 percent of the total inflow to the Upper Klamath Lake, the Wood River and Sevenmile Creek 23 percent, springs and ungaged streams 16 percent, agricultural pumps 3 percent and precipitation 7 percent (ODEQ 2002). Water enters these stream networks from the deep, permeable aquifer through diffuse lateral inflows of groundwater and concentrated flows of groundwater in the form of large springs. The aquifer-modulated tributaries, the storage in Upper Klamath Lake, and the former much larger storage of runoff in the other lakes and marshlands of the upper basin previously delayed the timing of Klamath flow past the Keno and Iron Gate locations so that mean monthly streamflow peaked in April, whereas it now peaks in March before declining rapidly to 35-60 percent of the original unimpaired flow in the period May-July (Figure 3 below; from Hardy et al. 2006, Figure 4, p. 36).

Uncertainties in the reconstruction of the pre-Euroamerican natural flow regime have been catalogued exhaustively by the NRC (2008), but the same committee concluded that the reconstruction of historical monthly flows by the USBR (2005) Natural Flow Study, incorporated into Figure 3 above, has "utility in providing a generalized picture of unimpaired natural flows in the system and in providing a general sense of minimum flows that should be provided to ensure safety of the basin's fishes, although not precisely enough to lead to day-to-day management of the system." (NRC 2008, p. 130).

The longer-term pattern of water supply to Upper Klamath Lake from the Williamson River has also been monitored since 1918, before the rapid increase in agricultural development which began around 1950 (NRC 2008, p. 114). The record shows that the total annual supply from this river system exhibits persistent periods of low and higher supply. For example, the first 30 years of the record were on average lower than during the following thirty years (Figure 3; from NRC 2008, Figure 4-11). This is a general characteristic of climatic and streamflow behavior in western U.S. hydroclimatic regions that are subject to the influence of enduring oceanic and atmospheric patterns such as the Pacific Decadal Oscillation and the Southern Oscillation.

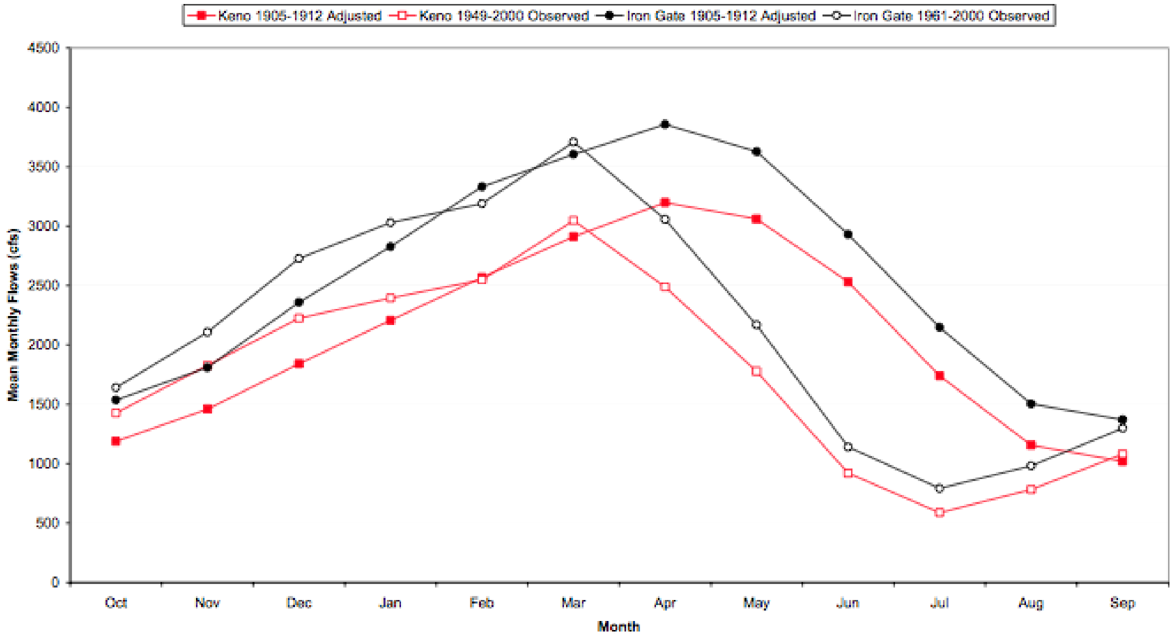

Figure 3. Estimated historical (before-1912) mean monthly flows at Keno (red) and Iron Gate (black) compared to the mean monthly flows at Keno (1949 to 2000) and Iron Gate (1961 to 2000) (From Hardy et al. 2006, Figure 4, p. 27).

Under current management direction, changes in tributary inflows related to anthropogenic influences are not likely to occur. Under the Proposed Action, up to 30,000 acre-feet of water would be acquired for flows which would likely increase the baseflows sometime during the summer and fall in the tributaries where the water is acquired, but there is not yet much specificity or apparent agreement about when these increases would occur, how they would be provided, and how landowners who sell their surface water rights would respond by pumping groundwater that sustains streamflow (see Figure 4 below in Section 2.4.6 for one scenario which indicates increases in early summer but decreases in late summer and fall). Measures to increase water supply in Upper Klamath Lake include reconnecting Barnes Ranch and Agency Lake Ranch to add approximately 63,700 acre-feet of storage; and reconnecting Wood River Wetlands to provide approximately 16,000 acre-feet of storage (80,000 acre-feet total). However, much of the storage would be offset by evaporation and evapotranspiration.

2.4.2 Upper Klamath Lake Levels

A significant hydrological characteristic of Upper Klamath Lake is its surface elevation, which fluctuates annually by about 3 ft (0.9 m) in near-normal years and about 5-6 ft (1.5-1.8 m) in dry years. Upper Klamath Lake is a natural water body, but lake surface elevations have been regulated since 1921 when Link River Dam was completed. Water is released from it for irrigation, wildlife refuge maintenance, hydropower generation, flood control, and instream flows to support downstream fish habitat. Upper Klamath Lake levels rise from fall through spring associated with increases in inflows and reductions in agricultural diversions. The upper range of lake level fluctuations, which occur in the spring, control the area of seasonally inundated lakeshore wetlands, which have been reduced in the past century by diking and drainage. These wetlands are considered to be favorable rearing habitat for resident juvenile fishes and to be a sink for phosphorous and a source for tannic acids which counter the growth of blue-green algae in lake waters (NRC 2004; ASR 2005). During late-spring and summer, lake levels decline in response decreasing tributary inflow, support of downstream flow targets, and agricultural withdrawals. In recent droughts, the level has fallen 2-3 ft (0.6-0.9 m) below the minimum elevation needed for inundation of lakeshore wetlands.

Under the proposed Conditions without Dams and with KBRA, lake levels will be similar to those for Conditions with Dams during most water years. However, during drought years, they may be up to 1 foot (0.3 m) higher under Conditions without Dams and with KBRA compared to Conditions with Dams, thereby resulting in inundation of more shoreline spring spawning habitat for Lost River suckers during late winter and spring; increased inundation of lakeshore wetlands for rearing of larval and juvenile resident fishes during the summer; and, deeper water in water quality refuge areas near tributary inflows during the late summer.

2.4.3 Channel Habitat in Upper Klamath Lake Tributaries

The western and southern portion of the Upper Klamath Lake basin is drained by spring-fed streams including Wood River and several smaller tributaries. These streams have reliable natural hydrographs of cold water (5-12°C) but low sediment supplies. The springs and adjacent river channel beds tend to be covered with pumice rather than gravel. The west side streams have been channelized and large wood debris removed. In the Wood River Valley, most streams have also been channelized, rerouted, and diverted for agriculture.

There is significant spring contribution to the flow of the Williamson River during the spring months, and water quality is generally good (supporting a world-class fishery for redband/rainbow trout and historically supporting anadromous fishes); conditions in Wood River are similar (Hamilton et al. 2010a). The Sprague River is currently listed as water-quality impaired and shows serious habitat degradation throughout most of its lowland reach in the mainstem and both forks of the river, but it historically provided excellent habitat for resident and anadromous fishes. The KBRA includes plans for aquatic habitat restoration in the Sprague, Wood, and Williamson rivers and Upper Klamath Lake (Table 3), and Hetrick et al. (2009) estimated that over 420 mi (675.9 km) of interconnected river and stream channels currently exist upstream of Iron Gate Dam that may provide functional spawning and rearing habitats for anadromous fish species with requirements that are generally similar to those of the resident fishes discussed here. Hetrick et al. (2009) further proposed that up to an additional 60-235 mi (96.6-378.2 km) of potential habitat exists that could be rehabilitated into a functional condition. The Panel could not confirm this statement which is at odds with the older field surveys by Fortune et al. (1966) who reported that only a small portion of accessible streams have suitable spawning and rearing habitat for salmonids. Fortune et al. (1966) conducted the most thorough on-the-ground survey of habitat availability and quality in these tributaries, and reported significant limitations on the area of spawning gravels because of the shortage of gravel supply from the catchment, and the widespread occurrence of pumice and silt. Other limitations on habitat quality included low DO, high temperatures between spring-fed reaches, some barriers to fish passage, and limited rearing habitat complexity. It remains to be documented whether recent restoration and livestock and water management have had any effect on the extent of favorable aquatic habitat documented forty years ago, but Hetrick et al. (2009) provide no systematic survey of recent progress. Such an assessment would be straightforward to conduct through a rapid field survey.

Apart from the lowermost reaches of the Williamson and Wood rivers and the upper reaches of the North and South forks of the Sprague River (about which more will be said below), the degree of degradation is so intense that the prospects for restoration to a "functional level" of spawning and rearing habitat are not obviously positive. For example, because of the geology of the basin there is a shortage of spawning gravel, and therefore of bars and pools. The seasonal and, in some places, long-term lowering of ground water tables by extraction has dried out riparian marshlands and does not support woody riparian vegetation in long lowland reaches. Riparian vegetation has also been removed through browsing by cattle. Fencing cattle away from the stream banks is expected to lead to sufficient recovery of grassy riparian vegetation to reduce sediment input to streams, which will reduce phosphorous inputs to Upper Klamath Lake. Reduction of sediment input will probably also allow flows to deepen the pools and remove fines from existing gravel bars, but the limitation on this process is likely to be the shortage of gravel in the channels and the resulting low amplitude of bars, which force high-velocity water across channels and increase the scouring of pools. There is significant potential for improving bar-pool habitat through gravel augmentation after careful quantitative analysis and project design. Also, it is not clear from the assessment reports how much recruitment of riparian woody vegetation is expected or needed to restore fish rearing habitat.

Huntington et al. (2006) made qualitative field assessments in general agreement with the descriptions above, and then utilized model-based predictions of the extent and quality of existing potential spawning and rearing habitat for various anadromous species. The areas predicted to be of relatively high quality were somewhat larger than the spawning areas described by Fortune et al. (1966) from field measurements, but the distributions of the two sets of predicted areas are similar. However, Huntington et al (2006) repeatedly stressed that even the limited favorable reaches would require significant habitat improvements in order to support returning fish populations. An important part of these planned improvements is the reversal of past streamflow reductions through the restoration of 30,000 acre-feet of summer flows in as-yet-unspecified locations within the Upper Klamath Lake tributaries. Our own review of the Huntington pictures of reaches along the Wood, Williamson and Sprague rivers indicated that apart from the lower reaches there is very little spawning gravel, pool habitat, in-stream wood, or riparian shade over most of the networks, especially in the Sprague River downstream of the headwater tributaries where most of the high-quality habitat was predicted to be. It is important to assess the effectiveness of recent investments in channel restoration in these tributaries, and to intensify the planning of which restoration activities would yield quantitative improvements in habitat quality and extent.

2.4.4 Channel Habitat Downstream of Keno Dam

After passing out of Upper Klamath Lake, the Klamath River flows between Keno and Iron Gate dams through reservoirs impounded by J.C. Boyle, Copco 1, Copco 2, and Iron Gate dams. In this reach, the river traverses the southern extension of the Western Cascade Volcanic Province, which consists of extensive lava-based terrain that is steeper than the upstream High Cascade Province, but resistant to erosion. This 43 mi (69.2 km) reach of the Klamath between Keno and Iron Gate dams is generally steep (gradient is ~0.005-0.025), extensively confined by bedrock canyon walls, and has a sediment supply much lower than the river's transporting capacity. Stillwater Sciences (2010) estimated from various sources that the sediment supplied to this reach comprised only 24,000 tons(t) of sand-gravel per year and 127,000t of silt-clay. Thus, gravel bed-material storage on the free-flowing reaches between reservoirs is sparse, being confined to generally lower-gradient reaches such as the Frain Ranch area (RM 218) and the mouths of the few tributaries. However, most of this bed material is in the 100-500 mm (3.94-19.69 in) range, and only the finer 15-20 percent of it is in the range 10-100 mm (0.39-3.94 in). Before impoundment, there was a distinctively low-gradient reach at the site of the Copco 1 reservoir where the river flowed in a valley–wide meander belt through a floodplain containing old channel scars with varying degrees of connection to the current channel. Elsewhere, the free-flowing reach comprises long rapids, runs, and pools among large boulders. There was also a low-gradient reach at the site of J. C. Boyle reservoir, but the sediment supply to this reach was very low.

Between the quiescent impoundments, the free flowing reaches, especially the one between J.C. Boyle dam and Copco reservoir have generally high velocities with rapid fluctuations of discharge and velocity during summer because of peak power production. These fluctuations inundate the substrate with fast-flowing water and then dry it out on a daily basis. The Iron Gate reservoir re-regulates these flows into a hydrograph that propagates some minor fluctuation several miles downstream during summer low flows, but is dominated by unreliable and highly variable late-winter peaks of 5,000-30,000 cfs and extended low flows regulated to at least 700-1,300 cfs during the rest of the year (Hardy et al. 2006).

Downstream of Iron Gate reservoir the river has a gradient of ~0.0025 and a cobbly surface with a subsurface median grain size in the 10-20 mm (0.39-0.79 in) range. The mainstream has a wandering habit with broad, irregular bends and occasional anastomosing side channels. The average annual sediment supply to this reach increases slowly with increasing distance downstream of Iron Gate as the river enters more erodible terrain, so some riffles and bars form in the relatively low-gradient reach downstream of Iron Gate fish hatchery. However, the sediment supply remains low until it is strongly augmented at the Scott, Salmon and Trinity confluences, which although they are heavily impacted by water withdrawals and other management actions provide large sediment supplies the Klamath River. The sediment supply favors the development of more extensive pool and riffle habitat. However, the channel downstream of Iron Gate Dam is simple in form and wide enough to be essentially unshaded. High water temperatures result from reduced summer flows and a lack of shade.

In the absence of dam removal, the habitat conditions described above will persist with only subtle changes due to foreseeable hydrological changes. For example, some habitat improvements such as local gravel augmentation are already planned in a general way (no details on amounts or locations) in both the Middle Klamath and in reaches between the reservoirs. Other habitat improvements are also planned in a general way under the KBRA program that may gradually extend small areas of both spawning and rearing conditions for resident fish in the sediment-starved impounded reach and spawning conditions in the lower river.

2.4.5 Future Habitat under the Proposed Action: Short-Term and 50-Year Prospect

The immediate and simplest change in habitat resulting from Conditions without Dams and with KBRA will be the opening of approximately 69 mi (111 km) of channel habitat in the Klamath mainstem and the lower reaches of several tributaries between the Iron Gate site and Keno dam. An important characteristic of this expanded range is the potential for thermal refuges (e.g., Shovel Creek, Fall Creek) resulting from the presence of large, reliable springs with excellent water quality. The reach will continue to receive only a very small amount of sediment because of the resistant rocks and the proximity of Keno dam and Upper Klamath

Lake, which will continue to interrupt sediment supplies. The sediment supply will continue to be far less than the river's sediment transport capacity, and only the cobbles and coarsest gravel will travel slowly enough and intermittently so that it will be stored temporarily to provide a discontinuous substrate on the channel bed and some bars. Currently, the material on the bed in these reaches between reservoirs is mainly in the cobble-boulder range (Greimann PPT Presentation). The most likely sites for significant sediment storage will be the several tributary junctions and about four miles around the current site of Copco Reservoir, where a floodplain with active and abandoned meanders had created significant sediment storage and morphological complexity before impoundment. Both kinds of sites will probably also temporarily store small amounts of fine–grained sediment. Gravel augmentation, planned for some sites, will provide some expansion of gravel bars, but the river will continue to have a high capacity for transporting that gravel away from augmentation sites. Selection of low-gradient sites, such as the bed of the J.C. Boyle reservoir, which currently receives almost no sediment might be a favorable site for such gravel augmentation.

The extent of habitat downstream of the Iron Gate site will not be strongly affected by dam removal. However, several dramatic short- and subtle long-term changes resulting from sediment release will be evaluated below. The changes are likely to be dominated by sediment supply changes, rather than by changes in flood regime.

2.4.6 Flow Regimes under the Proposed Action: Short-Term and Long-Term

Dam removal resulting from Conditions without Dams and with KBRA will put an end to rapid fluctuations of flow for peaking of power production in the impounded reach. Halting of the peaking will remove the frequent alternation of hours of high flow velocities followed by rapid dewatering of channel margins. Total annual and seasonal flows are unlikely to be affected by removal of these small reservoirs, although there will probably be only a slight increase in the magnitude of flood peaks that are currently modulated slightly by the small attenuation capacity of the reservoirs. Low flows are currently fixed by mandated instream flow requirements, but simulations for planning scenarios under the KBRA envision important seasonal shifts in average monthly flows during summer and fall (e.g., Figure 4 below). Under this scenario, flows will be increased slightly during late June-September and diminished during October-December.

Figure 4. Average monthly flows and Upper Klamath Lake elevations (upper graph) for No-Action (Current Conditions) and Dam Removal Alternatives (Conditions without Dams and with KBRA) (Source: B. Greimann PPT 12/13/10).

2.4.7 Short-term Effects of Sediment Release

Geotechnical surveys of the magnitude and grain size of sediments stored behind the four dams have documented approximately 8.1 million tons of impounded sediment, approximately 84 percent of which is in the silt-clay size range. Only 0.26 million tons are behind J.C. Boyle Dam and the rest is distributed evenly between Copco 1 and Iron Gate reservoirs. Stillwater Sciences (2008; 2009a; 2009b; and, 2010) and the Bureau of Reclamation (Greimann PPT Presentation) have estimated the fraction of this sediment that will be eroded out of the impoundment sites under various conditions of flow and reservoir management.

Although there are important differences between the timing of the sediment releases between the various simulations that both groups have made and in their separate preferred release strategies based on engineering logistics and fish protection, the major results are consistent and in agreement with the qualitative interpretations made by earlier consultants (Ayres Associates 1999; Shannon and Wilson 2006).

Stillwater Sciences (2008) predict that a channel with assigned dimensions will cut down through the deposits in each reservoir at a rate that will depend on the inflow rate and the rate of reservoir lowering (to be managed, but vulnerable to unpredictable flood flows) and the rather low concentration of sand and gravel in the deposit in each reservoir. Sediment from J.C. Boyle reservoir will be flushed earlier and more completely than sediment from the lower reservoirs. It is likely that within the first year (or two if drought intervenes) 1.4-3.2 million tons of the sediment (biased toward the finer component) will be flushed downstream of Iron Gate. This would leave 60-83 percent of the sediment in place along the margins of the new channel that would require rapid revegetation under adverse soil and moisture conditions in order to avoid problems with invasive weeds and dust, as well as chronic erosion of fine sediment into the river. The predicted first-year total of flushed sediment is smaller than the total amount transported during major floods on the river, although the transport would occur over a much larger number of consecutive days and at much lower discharges in the dam removal case. The amount of sand-gravel flushed from the reservoirs in the first year is predicted to be in the range 300,000-600,000 t.

This Stillwater modeling of deposit erosion predicts that winter concentrations of sediment downstream of Iron Gate will range up to 10,000 mg/L at Iron Gate (3,000 mg/L at Orleans), declining to 2,000 mg/L at Iron Gate (500 mg/L at Orleans). The concentrations are computed to remain chronically within a range of several thousand to several hundred mg/L for periods of up to six weeks for two seasons at least (Nov-Dec and May-June) between periods of reservoir filling. This silt-clay fraction is not represented in the channel bed downstream of Iron Gate Dam. It expected that this "washload" will be transported far downstream by even low flows, and will be flushed rapidly to the ocean by typical annual and larger floods. This reasonable approximation was used in the simulation model runs by Stillwater Sciences (2008; 2009a; 2009b; and, 2010), who also interpreted that there will also be some deposition of this fine sediment along the channel margins and in the floodplain that was not represented in the model simulations. The amount of this sediment storage will be greatest in low-gradient, sinuous reaches of the Lower Klamath.

Within the impounded reach the bed of J.C. Boyle reservoir should be flushed more effectively and sooner than the beds of the other reservoirs. The buried floodplain on the bed of Copco 1 reservoir may need some dredging to recover former meanders and floodplain channels.

2.4.8 Long-term Effects of Sediment Release

After the first year or two, the chronically high suspended sediment concentrations will decline to much lower levels, fed by slow erosion of the floodplain and banks of the new channels through the reservoir sites along with the natural sediment supply from the terrain downstream of Keno reservoir. As the dams are removed, there will no longer be reservoir filling periods to interrupt sediment flushing, which will thus be driven by the seasonal and storm runoff regime. It is likely that there will have been some fining of the channel bed by sand and fine gravel during the initial sediment release and that tendency may continue for a decade or more as the sediment supply from the reservoir is gradually stabilized. Calculations of the likely frequency of bed mobilization by Klamath River flows predict bed mobilization every few years in the reach between the Iron Gate site and the Salmon River confluence (Ayres Associates 1999). The gravel in the reservoirs at the upper end of the project reach will be flushed out of the upper project reach rapidly in the first few years, with some fraction of the coarser gravels/cobbles being stored temporarily on bars. In the channel between Copco and Iron Gate reservoirs the enhanced transport of gravel from the reservoir deposits will take much longer to decrease and will be augmented by restoration of natural gravel supplies from the tributaries. These enhanced supplies will support increased gravel storage, and therefore trout habitat, especially in the low-gradient Copco reach, during the extended period of flushing.

The wave of coarser bed material will attenuate strongly during its passage down river, and it is unlikely to be recognizable morphologically after a decade without regular detailed cross-section surveys. However, it will contribute subtly to the mobile store of gravel that will maintain spawning habitat for resident fish in the generally sediment-starved reach between Iron Gate and the Salmon River. Its role in bar augmentation will also contribute to remobilizing bend growth and migration with its attendant undercut banks, causing a minor enrichment of the quality of rearing habitat for resident fish and other species.

The fine silt and clay sediment that is likely to be stored along the channel margins and floodplains of the Middle and Lower Klamath River channel during the first couple of years of sediment flushing will gradually be remobilized and flushed to the ocean. Sand emanating from the reservoir deposits is also likely to be flushed downstream, but less efficiently than the silt and clay. Some of it will be stored temporarily in the bed and pools of the Middle Klamath, causing some degradation of spawning habitat quality. However, the major sources of sediment in the Lower Klamath have always been the Trinity, Scott, and Salmon Rivers, and this fact will dominate the availability of spawning habitat in the Lower Klamath.

2.5 Temperature Regime and Water Quality

2.5.1 Water Quality Upstream of Keno Dam

Upper Klamath Lake waters contain only moderate levels of dissolved solids and alkalinity, but high concentrations of phosphorus, which in the warm, sunny conditions of the lake during summer support high production of phytoplankton, and especially of the cyanobacteria *Aphanizomenon flos-aquae* (AFA). The growth, senescence and decay of massive amounts of the organism result in high pH and ammonia and low DO concentrations. Water quality in Upper Klamath Lake is adequate for fish rearing during October through mid-June, but is poor from mid-June through September.

Dissolved phosphorous concentrations have repeatedly been implicated in favoring the growth of algae in the lake. Geologically controlled background inputs of dissolved inorganic phosphorous are high enough to have supported frequent algal blooms, but at lower concentrations than those observed in the past half-century (NRC 2004, p.104). Current average concentrations entering the lake today are two-thirds higher than background. Concentrations in lake water peak in mid-summer at about six times background level (NRC 2004, pp. 104-105), probably as a result of phosphorous recruitment from pore waters of sediments on the lake bed. High concentrations of algae and intermittent stratification of the warm lake waters eventually cause algal death and depletion of DO. (NRC 2004, pp. 117-122.)

These poor water quality conditions, aggravated by a clockwise wind-driven circulation of the surface water that concentrates oxygen-depleted water in the northern portion of the lake (U. S. Geological Survey website www.usgs.gov/projs_dir/klamath_ltmon/), have been implicated in mass mortality of both endangered species of suckers. However, the details of these developments are complex and options for solving the problem are still not agreed upon. Reduction of phosphorous inputs to the lake through erosion control and re-establishment of interception mechanisms in wetlands is currently the favored strategy. It is not clear, however, whether the internal source of phosphorous already in the lake sediments would vitiate any such control strategy. An alternative hypothesis is that the decline of limnohumic acids from the formerly extensive wetlands of the basin has favored the explosive growth of blue-green algae (NRC 2004, pp. 123-125). Restoration of lakeside wetlands is one restoration activity that could partially compensate for the more extensive loss of wetlands, which were diked and drained for agricultural purposes, and further eliminated as a result of pumping of groundwater and lowered water tables in some areas. However, the National Research Council report on endangered and threatened fishes in the basin (NRC 2004, p. 128) concluded their discussion of this problem with the statement: "Current proposals for improvement of water quality in Upper Klamath Lake, even if implemented fully, cannot be counted on to achieve the desired improvements in water quality. Thus, it would be unjustified to rely heavily on future improvements in the water quality of Upper Klamath Lake as a means of increasing the viability of the sucker populations." However, it may not be necessary to see overall improvement in lake-wide water quality to have improvements in productivity and health of resident fish, particularly the endangered suckers. During periods of poor water quality during the late summer, adult suckers move to water quality refugia near tributaries especially at Pelican Bay. Under KBRA, up to 30,000 acre-feet of additional tributary inflow is expected during the summer. These additions could increase the size of water quality refugia potentially providing more area for suckers to hold.

2.5.2 Water Quality Downstream of Keno Dam

Water quality conditions downstream of Keno under Current Conditions are substantially impacted by the four mainstem dams. Current project reservoirs contribute to low DO, downstream thermal phase shift, nutrient effects on algal abundance and exacerbation of algal toxins (Hamilton et al. 2010b). Inputs of important coldwater tributaries and springs would continue to be overwhelmed by thermal mass and long hydraulic residence time in the reservoirs. The thermal regime of the river downstream of the reservoirs would continue to be out of phase with the natural temperature regime, i.e., existing temperatures are cooler in spring and warmer in fall than those if dams were removed. The effects of ongoing and future upstream water quality improvements under TMDL would likely improve water quality over the period of analysis, but there is uncertainty as to when TMDL targets would be achieved above IGD. Removal of the four dams would decrease the residence time of water in the project reach from several weeks to less than one day (Hamilton et al. 2010b). Removal of project reservoirs would allow coldwater tributaries and springs to directly flow down the mainstem Klamath River, thereby providing thermal diversity in the river in the form of intermittently-spaced patches of thermal refugia (i.e. specific areas within the water column that provide fishes with suitable water temperatures). Thermal diversity will benefit resident fish during warm summer months. Without the dams, the thermal regime of the river downstream of the reservoirs would be more in phase with the natural temperature regime.

The restored channel and thermal regime will play a major role in nutrient dynamics as will other natural riverine processes; most notably re-aeration of water provided by a turbulent, well-mixed river. Under Conditions without Dams and with KBRA, an additional 23 mi or 37 km of free-flowing river would have an increased capacity to assimilate nutrients. The additional assimilative capacity for nutrients of the Klamath River would likely be further elevated over the current regime because of increased flows in the bypassed reaches where flows are now minimal.

Under Conditions without Dams and with KBRA, toxic cyanobacteria that currently flourish in the reservoirs below Keno Dam will no longer exist, resulting in better water quality conditions. High cyanobacteria levels will largely remain in Keno reservoir, although KBRA activities will attempt to reduce cyanobacteria levels by some, as-yet-to-be-specified, means.

2.6 Climate Change

Warming of global climate during the past century or more is unequivocal. During 1995-2006, eleven of the twelve years ranked among the warmest years in the instrumental record of global surface temperature since 1850 (IPCC 2007 in ISAB 2007). Global average air and ocean temperatures have increased, leading to widespread melting of snow and ice. The Pacific Northwest has warmed about 1.0°C since 1900, or about 50 percent more than the global average warming over the same period (Mote 2003). Water temperature in the Klamath River has increased 0.5°C per decade in response to warming trends in the region and to anthropogenic uses of the watershed (Bartholow 2005 in Hamilton et al. 2010a). Snow water equivalent (April 1) in the Klamath Basin has declined significantly since 1950, especially at elevations less than 6,000 ft (Mayer and Naman 2010a, and Mayer and Naman 2010b in Hamilton et al. 2010a). A somewhat abrupt decline in annual flows into Upper Klamath Lake (Greimann PPT Presentation) occurred in 1977, corresponding with the 1976/1977 ocean regime shift and the shift in the PDO. The effect of climate shifts on local precipitation during the past 80 years is shown by records at Keno and Tule Lake weather stations, whereby annual precipitation during the period of 1927-1936 was approximately 20 percent to 26 percent less, respectively, than precipitation during 2000-2009 (unpublished analysis of data; http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?orklam).

The warming rate of air temperatures for the Pacific Northwest over the next century is projected to be approximately 0.1-0.6°C per decade (ISAB 2007). The warming trend should translate to correspondingly warmer stream and lake temperatures in the Klamath Basin. Likewise, since temperature of spring and groundwater input to rivers are roughly related to the average air temperature during the recharge season, spring and groundwater inputs to rivers and streams are expected to rise correspondingly. However, the springs will continue to provide important thermal refugia in Upper Klamath Lake and along the Project Reach downstream of Keno Reservoir.

The future precipitation regime is essentially unknown, with projected changes by 2030-2060 for the Klamath basin ranging from -4 percent to +9 percent. Much uncertainty in the effect of climate change on precipitation results from the inability of models to capture the influence of local topographical features on precipitation.

Given the anticipated warming trend, a more significant and more secure prediction for the Klamath region is for a decrease in the proportion of snow fall and snow storage relative to total annual precipitation. The projected trend in declining snowpack relative to precipitation has been documented over the past 50 years by several studies across western North America (e.g., Service 2004). The result has been earlier peak stream flows in spring and lower minimum flows in summer (e.g., Leung and Wigmosta 1999). This climate effect on flows is expected for the small tributaries of the Klamath basin downstream of Keno Dam where runoff occurs relatively quickly from the less permeable volcanic soils.

The hydrology model predictions by Greimann (PPT Presentation) for the reach downstream of Iron Gate Dam, however, do not show a decline in summer flows because it was assumed that the mandated July through September flows (NMFS Biological Opinion for coho salmon) would be maintained during future climate scenarios. Likewise, during October to June, flows downstream of Iron Gate Dam were projected to equal or exceed those without climate change because of the expected increase in precipitation and intensified snowmelt under some climate scenarios. The timing of peak flows in the Klamath River did not change, apparently because the reservoirs, lakes, groundwater, and intentional management of flows buffer fluctuations in flows near Iron Gate Dam. For the 50-year time scale, there is no basis for confident predictions of channel-altering changes in the flood regime in response to climate scenarios.

In contrast, the Upper Klamath watershed has several geographical characteristics that will tend to buffer the effects of earlier snowmelt and increased evapotranspiration. A large fraction of the watershed is underlain by deep, permeable volcanic deposits. Fall and winter precipitation and snowmelt recharge these deep aquifers. This water is protected from evapotranspiration because much of the storage is deep underground and because the low temperatures at high elevation and thin soils with sparse vegetation keep evapotranspiration rates low during the spring and summer. Thus, the effect of climate change on peak timing of flows in the Upper Klamath Basin will likely be smaller than in most hydrogeological environments of the western region. However, Tague and Grant (2008) have recently pointed out that in basins with this kind of hydrogeological conditions (specifically the McKenzie River basin in Oregon) the effect of earlier snowmelt on late-summer low flows has some counter-intuitive characteristics. For a given amount of groundwater recharge, the reduction in late-August flows due to earlier melting would be smaller than in most Oregon mountain river basins in relative terms but larger in absolute terms (because these local streams maintain relatively high flows in summer in response to groundwater storage).

2.6.1 Climate Change Impacts

Climate change may influence productivity and abundance of resident fish including suckers and redband/rainbow trout. The climate change scenarios that were chosen by the BOR illustrated the potential for both higher and lower inflows into Upper Klamath Lake (Greimann PPT presentation, 8/2/2010).

Climate Change Impacts Downstream of Keno Dam

The key question is the extent to which climate change will differentially influence redband/rainbow trout and other resident fish under the current Conditions with Dams, versus the Conditions without Dams and with KBRA alternative. In response to climate change, the Panel expects the Conditions without Dams and with KBRA to have a positive effect on redband/rainbow trout habitat downstream of Keno Dam because fish would have unrestricted access to groundwater and thermal refugia areas throughout the reach between Iron Gate and Keno dams.

Climate Change Impacts Upstream of Keno Dam

Climate change will influence resident fish in Upper Klamath Lake and its tributaries. In this region, the Conditions without Dams and with KBRA alternative primarily involves habitat restoration and reduced agricultural diversion activities provided by KBRA. As discussed below, this alternative might provide a small additional benefit for resident fish including suckers and redband/rainbow trout under projected warming associated with climate scenarios.

Climate change is expected to lead to higher summer water temperatures in shallow Upper Klamath Lake. However, because much of the inflow to Upper Klamath Lake can be attributed to ground-water discharge to streams and major spring complexes within a dozen or so miles from the lake, this will buffer the lake somewhat from climate cycles (Gannett et al. 2007). These springs with travel times that average about 8-30 years (Manga 1999) are also supplied with far-travelled flow in the deepest parts of the aquifer (Gannett et al. 2007, Figure 6) that probably has travel times of up to a century or more. Such long travel times, on the order of decades to centuries, can be expected to dampen climatic temperature variations. Under the Conditions without Dams and with KBRA, voluntary water purchase programs that are expected to increase inflow to Upper Klamath Lake by up to 30,000 acre-feet per year may provide larger water quality refugia, including Pelican Bay and Williamson River Delta. Additionally, and under the Conditions without Dams and with KBRA, the proposed KBRA activities may also conserve irrigation water through better delivery systems by acquiring covered canals instead of open ditches, and purchasing irrigation pipe for irrigators to use instead of flood irrigation. Saved water could be transferred to instream flows. These areas provide important refugia for adult suckers in Upper Klamath Lake when water quality conditions degrade during late summer. Water quality conditions in the open waters of Upper Klamath Lake may be further degraded under climate change if the warmer temperatures lead to increases in duration and magnitude of AFA blooms. This may result in decreases in fish health by suppressing growth, reducing resistance to disease and parasitism, and increasing mortality. Other resident fish are likely to be similarly impacted with the exception of redband/rainbow trout that move out of the lake during the summer. Under the Conditions without Dams and with KBRA, substantial restoration of lakeside wetlands are proposed for the Agency Lake area. These restored habitats are also located where tributaries enter providing better water quality conditions. These habitat improvements should provide good habitat for juvenile suckers leading to increased survival. Although, juvenile suckers that do not use water quality refugia and restored lakeshore wetlands adjacent to Agency Lake will continue to be exposed to poor water quality during the summer (i.e., high water temperatures and pH, broad daily shifts in DO and high ammonia) (Wood et al. 1996; NRC 2004), overall sucker survival should be higher than under the Conditions with Dams alternative.

Under climate change, late summer low base flow conditions and higher water temperatures will likely increase in frequency, further restricting the suitable rearing habitat of redband/rainbow trout rearing in the tributaries. However, the large amounts of cool groundwater discharge in tributaries to Upper Klamath Lake will to some extent mitigate climate change effects in later summer for resident fish. Increased temperature in streams during summer may also be slightly moderated under the Conditions without Dams and with KBRA Alternative to the extent that planting of riparian vegetation reduces water temperature in the streams, and removal of cool water springs for irrigation declines. Nevertheless, access to abundant cool spring water is likely a key habitat characteristic supporting redband/rainbow trout and to a lesser extent suckers in the upper basin, especially during the projected warming climate scenarios.

3.0 Impacts on Resident Fishes Upstream of Keno Dam

3.1 Suckers

3.1.1 Hydrology Effects

Historically, February through June was the peak runoff period and high lake elevations were inherent. This hydrologic regime directly corresponds with the timing of the spawning migration of adult LRS and SNS to shoreline habitats near the eastside spring areas in Upper Klamath Lake and to tributary spawning streams, particularly the Williamson and Sprague Rivers. Spawning generally occurs from February to June and peaks in April and May. Filling the lake early in the water year ensures access to suitable lakeshore spawning habitats in addition to increasing the probability of achieving adequate lake levels through the summer.

Larval suckers begin to appear in Upper Klamath Lake in late March to early April, with peak abundance occurring in mid-May to mid-June. Larvae transform to juveniles by mid to late July. Lake fringe emergent vegetation is the primary habitat used by larval suckers and to a lesser degree by juvenile suckers. Juvenile suckers also utilize non-vegetated near-shore and offshore areas with a variety of substrate types. Target elevations specified under Conditions without Dams and with KBRA are designed to keep lake levels from falling too quickly in June and July and to meet a minimum lake level of 4,140 ft (1,261.9 m) at the end of July. When lake levels drop below about 4,140 ft (1,261.9 m), vegetated habitats preferred by larval suckers and juvenile suckers become dewatered and they must move to less desirable habitats. In late summer, the elevation of Upper Klamath Lake at or above 4,138 ft (1,261.3 m) allows juvenile suckers access to near shore non-vegetated habitat and sub-adults and adult suckers to offshore open water habitat with adequate depth (>6 ft or 1.8 m deep) and water quality refuge areas, particularly Pelican Bay, which typically has better water quality that the main body of the lake, at this time of the year. This also facilitates the likelihood of refilling the lake by the following winter/spring.

As lake elevations proposed under Conditions without Dams and with KBRA are targets rather than requirements, a certain degree of flexibility exists that will provide opportunities to strategically use basin storage to the benefit of aquatic species in both the lake and Klamath River. Up to 30,000 acre-feet of additional water will reportedly flow into Upper Klamath Lake from tributaries annually, which may provide a small increase in the amount of sucker habitat in Upper Klamath Lake. This action will also lead to higher base flows during the summer in the Sprague and Williamson rivers. These higher flows should result in more habitat for those juvenile and adult LRS and KLS in these streams. Habitat restoration may improve quantity and quality of spawning habitat. This combined with other major instream and riparian habitat restoration actions should increase the sucker populations and diversity of life history strategies leading to resiliency to stochastic events.

Under Conditions without Dams and with KBRA, improvements in the quality and quantity of spawning and larval/juvenile rearing habitat may lead to better survival and recruitment during the wetter water years ameliorating impacts of declining water supplies and increased drought. Under the no action alternative, lake level management is the primary strategy of protection and enhancement of sucker populations and this strategy has not been successful over the last decade as lake levels have been managed to support all life stages.

Based on modeling simulations of the two scenarios, lake levels under Conditions without Dams and with KBRA were generally higher particularly during dry years (Figure 5, Section 2.4.6). The higher lake levels lead to increased habitat including:

- emergent vegetation used by rearing larva/juvenile,
- unvegetated shoreline used by rearing juveniles, and
- sub-adult and adult offshore rearing and water quality refuge habitat.

Increasing the potential for higher sucker survival should increase recruitment of adults.

3.1.2 Water Quality Effects

Upper Klamath Lake and Keno Reservoir

In general, LRS and SNS are relatively tolerant of degraded water quality conditions. They tolerate higher pH, temperature, and un-ionized ammonia concentrations, and lower DO concentrations than many other fishes (Saiki et al. 1999; Meyer and Hansen 2002; NRC 2004). Nevertheless, despite their relatively high tolerance for poor water quality, both species are adversely affected by poor summer water quality in Upper Klamath Lake and the Lost River Basin (NRC 2004).

Most water bodies currently occupied by LRS and SNS do not meet water quality standards for nutrients, DO, temperature, and pH set by the States of Oregon and California (ODEQ 2002; NCRWQCB 2006). These conditions (primarily in summer) have caused several incidents of mass adult mortality, which appears to be a consequence of inadequate amounts of DO. Mortality is particularly severe in Upper Klamath Lake where all sucker life stages are mostly confined to the lake during the summer when water quality is poor.

Water quality conditions in Upper Klamath Lake are mostly attributed to nutrient loading. The lake was highly productive or "eutrophic" prior to settlement by Europeans in the mid-19th century, but it has become "hypereutrophic" from loading attributed to external (pumping of diked wetlands, farm/ranch run-off, timber harvest and roads) and internal (lake sediments) sources (Snyder and Morace 1997; ODEQ 2002; IMST 2003; Bradbury et al. 2004; Eilers et al. 2004; NRC 2004). Phosphorus is the primary nutrient responsible for this hypereutrophic condition, and it is borne by and stored in sediments (ODEQ 2002; Graham et al. 2005). Sediment accumulation rates dramatically increased during the 20th century, and these "modern" sediments are higher in nitrogen and phosphorus than pre-settlement sediment (Eilers et al. 2001).

Most of the pollutant load entering Upper Klamath Lake comes from non-point sources (ODEQ 2002). An annual average of approximately 60 percent of the phosphorus available to the water column is derived from lake sediment. Because the source of phosphorus is the naturally occurring sediments, some authors have expressed pessimism regarding prospects for remediation (NRC 2004). However, ODEQ (2002) believes that reduction in total phosphorus loading can improve water quality to the point that standards are eventually attained.

Poor water quality in Upper Klamath Lake is particularly associated with high abundance of the cyanobacteria *Aphanizomenon flos-aque* (AFA). Core samples of bottom sediments indicate that AFA was not present in Upper Klamath Lake prior to the 1900s (Eilers et al. 2004; Bradbury et al. 2004). Its appearance is believed to be associated with increases in productivity of the lake (NRC 2004). AFA now dominates the phytoplankton community from June to November, and because of the high concentrations of nutrients available, is able to reach seasonally high biomass levels that lead to highly degraded water quality (ODEQ 2002). These conditions affect LRS and SNS because rapid algal decay depletes DO and creates anoxic conditions (Perkins et al. 2000b; ODEQ 2002; IMST 2003; NRC 2004; Wood et al. 2006). Such events not only kill thousands of suckers, but they can reduce the reproductive capacity of the populations by eliminating the larger and more fecund females. Adverse water quality may also affect young suckers, but information is lacking regarding such effects.

Degraded water quality conditions may also weaken fish and increase their susceptibility to disease and parasites (Holt 1997; Perkins et al. 2000b; ISRP 2005). New information indicates that pathogens substantially affect sucker survival, especially during adverse water quality events. Although fish die-offs that occurred in Upper Klamath Lake in the 1990s were likely a response to hypoxia (low levels of DO), disease outbreaks also probably contributed to mortality during these events (Perkins et al. 2000b; NRC 2004).

A number of pathogens have been identified from moribund (dying) suckers, but *Columnaris* disease or "gill rot" seems to be the primary organism involved (Foott 1997; Holt 1997). It is caused by the bacterium *Flavobacterium columnare,* which can damage gills, produce body lesions, which leads to respiratory problems, an imbalance of internal salt concentrations, and provides an entry route for lethal systemic pathogens (ISRP 2005).

Parasites were not identified as a threat at the time of listing, but recent information indicates they could be a threat to the suckers. Parasites can lead to direct mortality, provide a route for pathogens to enter fish, since they create a wound, and can make fish more susceptible to predation (Robinson et al. 1998). *Lernaea* sp., a parasitic copepod or "anchor worm," which feeds on fish tissues by puncturing the skin of its host (Briggs 1971) is a common parasite on suckers in the Upper Klamath Basin.

Lernaea parasitism rates on juvenile suckers appear to be increasing in Upper Klamath Lake (Carlson et al. 2002; ISRP 2005). From 1994-1996, the percent of juvenile suckers parasitized by *Lernaea* sp. ranged from 0-7 percent, but by 1997-2000 it had increased to 9-40 percent. *Lernaea* now infects about half of juvenile SNS (D. Markle, OSU, pers. comm. 2005).

Some cyanobacteria such as *Microcystis aerginosa* which is present in Upper Klamath Lake (VanderKooi et al. 2010) produce biotoxins that may result in mortality. Recent studies by

USGS provide preliminary support for a hypothesis that juvenile suckers in Upper Klamath Lake are exposed to biotoxins at concentrations that are much higher than those considered safe for drinking water and nearly 50 percent of juveniles collected in Upper Klamath Lake during 2007 had liver damage consistent with exposure to microcystin (VanderKooi et al. 2010). It appears that the route of exposure to toxins was through the food chain where suckers consumed chironomids that had eaten the toxic algae.

Under Conditions without Dams and with KBRA, water quality conditions in Upper Klamath Lake are likely to improve particularly in restored wetlands and open water areas adjacent to wetlands so that growth and survival of the suckers in Upper Klamath Lake increases. It is also anticipated that levels of parasitism and disease will be lower with better water quality because fish will have lower stress levels and stronger immune systems. Water quality has already improved in larval and juvenile sucker rearing areas with the reconnection of the Williamson River Delta where high quality Williamson River water mixes with Upper Klamath Lake water (H. Hendrixson, TNC, pers. comm.). With the reconnection of the Agency Lake Ranch, Barnes Ranch, and Wood River Wetlands additional emergent wetland and shallow shoreline habitat will immediately have better water quality because of the influence of mixing of high quality tributary inflows from Wood River and Sevenmile Creek.

Currently, many adult suckers move to tributary inflow areas when water quality conditions degrade in Upper Klamath Lake particularly Pelican Bay (Banish et al. 2008). Under Conditions without Dams and with KBRA, additional water quality refuge areas are likely to be created with the reconnection of historic Agency Lake wetlands at the mouths of the Wood River, Crooked Creek, and Sevenmile Creek.

Water quality improvements in Upper Klamath Lake are generally aimed at suppression of algal abundance (NRC 2004). The Upper Klamath Lake TMDL calls for a 40 percent reduction in total external P loading for long-term improvement in water quality (ODEQ 2002). Restoration activities proposed under KBRA particularly wetland and riparian restoration in the Upper Klamath Lake watershed are expected to result in a total external P load reduction approximately 40 percent (M. Barry, USFWS, PPT Presentation 8/2/2010). However, water quality improvements in the main body of Upper Klamath Lake are less certain because of the high internal loading (nutrients coming from the sediments) and other factors (NRC 2004). Furthermore, high abundances of AFA in Upper Klamath Lake may be related to loss of wetland habitat and Upper Klamath Lake levels. A drastic decrease in mobilization of humic substances (produced from decomposition of wetland plants) by alteration of wetlands and hydrology, fits historical observations more satisfactorily than a phosphorus-based hypothesis. Upper Klamath Lake has apparently always had very low nitrogen:phosphorus ratios that set the stage for dominance by a nitrogen fixer, such as AFA. Recent laboratory and lake microcosm studies indicate humic substances suppress AFA growth (ASR 2005). There are also other mechanisms associated with wetlands that may reduce AFA productivity like reducing light penetration. Under KBRA, restoration of wetlands in Upper Klamath Lake is likely to be accelerated. Although this may not significantly improve water quality throughout Upper

Klamath Lake, substantial areas in and adjacent to the wetlands should have improved water quality supporting all life stages of suckers.

Water quality conditions in Keno Reservoir is extremely poor particularly during the summer, with heavy AFA growth and die-off, low DO concentrations, and high pH and water temperature (Deas and Vaughn 2006). Large numbers of larval and juvenile suckers move downstream into Keno Reservoir from Upper Klamath Lake annually although most perish (USFWS 2008). Also, hundreds of adult LRS, SNS, and KLS have been documented in the upper portion of this reservoir where water quality is better but many die during the summer (Piaskowski 2003). Conditions are not likely to change under current management. Conditions without Dams and with KBRA, major actions are proposed to reduce nutrients and organic matter to improve water quality and habitat conditions. If water quality conditions improve, survival of suckers moving downstream from Upper Klamath Lake into Keno Reservoir should increase and then the fish may be able to migrate back to Upper Klamath Lake as sub-adults or adults and contribute to the Upper Klamath Lake populations as spawners. No sucker spawning habitat exists between Link River and Keno dams.

Tributaries

LRS and SNS utilize the tributaries to Upper Klamath Lake, primarily the Sprague and Williamson rivers for spawning and some larval and juvenile rearing. There is also evidence of a small population of adult LRS residing in the upper Sprague River. All life stages of KLS use the tributaries for habitat (Buettner and Scoppettone 1990). The Sprague River under current conditions has poor water quality particularly during the summer and is listed as water quality impaired for nutrients, temperature, sediment, pH, and DO (ODEQ 2002).

Since the early 1990s, the Sprague River has been a major focus area for habitat restoration including riparian fencing and channel reconstruction. However, the overall impact on water quality, riparian and instream habitat benefiting resident fish has been relatively small due to limited resources. Under Conditions without Dams and with KBRA, large-scale habitat restoration will occur enhancing water quality particularly sediment and nutrient loading because of reduced erosion, and localized reductions in summer temperature due to spring improvement, enhancement and reconnection and increased flows from acquisition of 30,000 acre-feet of water, riparian vegetation restoration and reductions in warm and high nutrient agricultural return flows. Water quality improvements are likely to increase survival of juvenile LRS and SNS that rear in the river. Klamath largescale sucker populations, which are currently fairly abundant in the Sprague River, are also likely to increase in abundance and productivity with water quality improvements under Conditions without Dams and with KBRA.

3.1.3 Habitat Quantity Effects

LRS and SNS spawn in the Sprague and Williamson rivers. LRS also spawn at shoreline springs in Upper Klamath Lake. Under current conditions, suckers have access to approximately 85 miles of riverine habitat for spawning and rearing (Ellsworth et al. 2007). Much of this habitat was reconnected with removal of Chiloquin Dam in 2008 (USFWS 2008). A small amount of SNS spawning occurs in the lower Wood River (USFWS 2008). In Upper Klamath Lake, LRS spawn at four shoreline spring areas (Hayes et al. 2002). The amount of spawning habitat under current conditions is not likely to change.

Upper Klamath Lake is the primary rearing habitat for all life stages of LRS and SNS in the Upper Klamath Basin. Emergent wetlands are important rearing habitat for larval and juvenile suckers. Approximately 70 percent of the original 20,400 hectares (hec) (50,000 ac) of wetlands surrounding Upper Klamath Lake was diked and drained between 1889 and 1971 (Geiger 2001). Until recently, approximately 6,500 hec (16,000 ac) of wetlands remained connected to the lake (Snyder and Morace 1997; ASR 2005). In 2007-2008, an additional 2,600 acres of emergent wetlands were restored at the Williamson River Delta by The Nature Conservancy to benefit the listed suckers (USFWS 2008). Under Conditions without Dams and with KBRA, restoration actions are identified to increase wetland and open water habitat in Upper Klamath Lake particularly Agency Lake Ranch, Barnes Ranch, and Wood River Wetlands (up to 13,000 acres). With reconnection and restoration of these properties, approximately 1,000 acres of fringe wetlands would be available for larval and juvenile sucker rearing and 12,000 acres for sub-adult and adult rearing. Without KBRA, these properties will continue to be managed for off-stream storage (Agency Lake and Barnes Ranch) and wetlands disconnected from Upper Klamath Lake (Wood River Wetlands) providing no habitat for suckers.

The habitat provided by restored emergent wetlands in Agency Lake may reduce the number of larvae moving downstream through the lake to be entrained at A Canal and Link River Dam and lost to the population. Also, many juvenile suckers move toward the lower end of Upper Klamath Lake throughout the summer and large numbers are entrained at Link River Dam and end up in Keno Reservoir where they likely perish. A fish screen at A Canal reduces the number of larvae and excludes all juvenile suckers. Additional fringe emergent wetland development is planned in Keno Reservoir which will provide habitat for larval and juvenile suckers moving down from Upper Klamath Lake.

Substantial habitat restoration is planned under Conditions without Dams and with KBRA in the Sprague River to enhance water quality, river channel form and function, and riparian areas. These actions should substantially increase the quantity of spawning and larval and juvenile rearing habitat resulting in more larval and juvenile sucker production; monitoring and evaluation will be needed to document changes in habitat quantity and quality following restoration activities.

3.1.4 Habitat Quality Effects

In Upper Klamath Lake, the eastside shoreline springs used by LRS for spawning have been impacted by construction of a variety of projects including a railroad, highway, and park that were built along the edge of the lake. These activities restricted access to one major spring complex (Barkley Springs) and altered the physical configuration and supply of coarse substrates for others. Other spring habitat on the west side of Upper Klamath Lake at Harriman Springs was also degraded by private resort development. Small gravel enhancement projects have been conducted in recent years to benefit spawning suckers and a major spawning habitat restoration project at Barkley Springs is underway. Under the current conditions, efforts to restore shoreline spring spawning habitats are uncertain. Under KBRA, restoration of all degraded spring habitats in Upper Klamath Lake is proposed leading to higher sucker spawning success for lake spawning LRS.

Tributaries to Upper Klamath Lake, particularly the Williamson and Sprague rivers are important spawning and rearing areas for LRS and SNS. These habitats are degraded because of seasonal water withdrawals for agriculture, channelization modifications for flood control, and annual grazing of riparian areas. Sucker spawning substrate has become armored and filled with fine sediment reducing sucker egg survival, and rearing areas for larval and juvenile suckers particularly off-channel wetlands and backwater areas are lacking. To the degree that suckers benefit from restoration, suckers will benefit more under the KBRA than under current conditions because of the greater resources made available. Restoration actions under KBRA particularly in the Sprague River are substantial and should improve the quality of spawning and rearing habitat for suckers leading to higher survival and increased numbers of fish.

3.1.5 Non-Native and Re-Introduced Species Effects

Approximately 20 fish species have been accidentally or deliberately introduced into the upper basin (Logan and Markle 1993; Moyle 2002). Non-native fish species most likely to affect LRS and SNS are the fathead minnow *(Pimephales promelas)* and yellow perch *(Perca flavescens)*. These fishes prey on young suckers and compete with them for food or space (Dunsmoor and Markle 2007).

Fathead minnows were first documented in the Klamath Basin in the 1970s and are now the numerically dominant fish in Upper Klamath Lake (Andreasen 1975; Simon and Markle 1997). Laboratory studies have demonstrated that adult fathead minnows feed on sucker larvae, and that predation rates decrease with increased vegetative cover and water depth (Markle and Dunsmoor 2007). Field studies in Upper Klamath Lake by the same authors found negative relationships between fathead population size and larval sucker survival rates; and that higher larval survival rates were also associated with greater water depth and shoreline vegetative cover, factors which help larvae avoid predation (Markle and Dunsmoor 2007). These studies indicate that predation by the abundant introduced fathead minnows is an important factor in larval sucker mortality rates, and that loss of emergent wetland habitat may have exacerbated this predation.

Under Conditions without Dams and with KBRA, wetland restoration at Agency Lake Ranch/Barnes Ranch/Wood River Wetlands will likely result in hundreds of acres of fringe wetland habitat and higher survival of larval suckers because of the cover provided to protect them from predation. Juvenile suckers may be displaced from near-shore areas by competition for food and space by high summer densities of non-native fish (USFWS 2008). Competition with non-native fish and other factors could contribute to an overall loss of body condition and fitness going into fall and winter and may leave juvenile suckers without adequate energy stores to survive their first winter, more vulnerable to opportunistic infections, or more sensitive to changing environmental conditions (Foott and Stone 2005). Wetland restoration may also provide additional habitat for non-native fish particularly near inflow tributaries. However, increased survival of larval and juvenile suckers related to restoration actions is likely to exceed any negative non-native species impacts. Lake levels are higher during the larval and early juvenile rearing period under the KBRA alternative particularly during dry years resulting in greater inundation of emergent vegetation and shoreline rearing habitat for larval and juvenile suckers and reduced interaction with non-natives leading to increased survival of these life stages. Under the Conditions with Dams, non-native species would continue to negatively impact larval and juvenile sucker survival through predation and competition associated with less shoreline wetland habitat and lower dry year lake levels.

Under the Conditions without Dams and with KBRA, there probably would be minimal interaction between adult anadromous salmon and suckers because the salmon will quickly move through lake habitats occupied by LRS and SNS and will not be feeding. If recolonization is successful, spring Chinook salmon would be migrating up the Sprague and Williamson rivers about the same time as spawning LRS and SNS. However, they would likely be seeking holding habitat in cold tributaries and springs including the Williamson River near Spring Creek and the North Fork of the Sprague River. Suckers would generally spawn further downstream in the mainstem Sprague River and the Williamson River below the confluence with the Sprague River.

Endangered suckers generally do not generally occupy riverine habitats during the fall. Therefore, there is little opportunity for interaction with fall Chinook salmon, which would migrate through Upper Klamath Lake to spawn in tributaries during that time.

Progeny of spring and fall Chinook salmon will rear in the river habitats up to a year before migrating to the ocean. There may be small numbers of juvenile suckers rearing in the tributaries at the same time as juvenile salmon. Young salmon may prey on larval and small juvenile suckers. However, other fish species including dace, minnows, sculpins, redband/rainbow trout, and a number of non-native species (including fathead minnows and yellow perch) are much more numerous than the suckers and would be the more accessible prey. Unlike the salmon juveniles that would be associated primarily with moving water, sucker larvae and juveniles occupy the shallow areas with low velocity (Buettner and Scoppettone 1990). Currently, salmonid species in the Sprague River, which is where most sucker spawning and larval rearing occurs, become restricted to spring inflow areas and colder tributaries during the summer (W. Tinniswood, ODFW, pers. comm.). Suckers also occupy the cold water inflow areas but to a greater extent prefer the warmer mainstem habitats. Therefore, there would be less opportunity for overlap. However, if extensive habitat restoration occurs and summer water temperatures decrease in the Sprague River, there could be more interaction and potential predation by salmon juveniles on small suckers.

If salmon juveniles rear in Upper Klamath Lake, there is more potential for interaction with suckers. However, Upper Klamath Lake is a highly productive environment with extremely large populations of fish including native species such as blue chub, tui chub, sculpins, and redband/rainbow trout, as well as non-native species (fathead minnows, yellow perch, brown bullhead, and pumpkinseed). The numbers and biomass of these other species that are potential prey for salmon juveniles is enormous. Juvenile suckers currently constitute far less than 0.1 percent of the fish numerically in Upper Klamath Lake. Even when robust populations of LRS and SNS are restored, other fish species would far outnumber the suckers. Also, juvenile suckers are bottom oriented while juvenile salmon are more likely to be water column oriented. Their different spatial distributions would reduce interactions.

Food interactions between juvenile salmon and juvenile suckers are also not considered to be a major impact. Because of the tremendous productivity of Upper Klamath Lake, it is unlikely that food resources would be limiting for suckers or salmon. While the juvenile salmon feed on benthic macroinvertebrates and small fish; suckers feed on zooplankton, benthic macroinvertebrates, and algae. In tributaries like the Sprague River, where both suckers and salmon may co-occur, productivity is very high. This suggests that there would be plenty of food for both suckers and salmon.

Reintroduction of salmon will likely not increase the risk of introducing pathogens that are not currently present in the Upper Klamath River Basin (J.S. Foott, USFWS, pers. comm.). While the viral pathogen, Infectious Hematopoietic Necrosis (IHNV), and the bacteria *Renibacterium salmoninarum,* have been documented in Chinook salmon in the Lower Klamath River Basin, IHNV is rare and is not virulent to trout and non-salmonid resident fishes in the Upper Klamath system. *R. salmoninarum* is present in low levels in juvenile and adult Chinook salmon in the Klamath River basin but does not appear to induce significant disease (J.S. Foott, USFWS, pers. comm.). The qualitative risk of introducing a non-native or highly virulent pathogen into the upper basin by anadromous fish can be categorized as low (J.S. Foott, USFWS, pers. comm.). Generally, both anadromous and upper basin resident fish share the same suite of pathogens. As mentioned previously, *Columnaris* disease or "gill rot" seems to be the primary disease involved on sucker die offs (Foott 1997; Holt 1997). *Columnaris* disease is ubiquitous in freshwater systems, and present throughout the Klamath River system above and below Iron Gate Dam (J.S. Foott, USFWS, pers. comm.; Administrative Law Judge 2006). Because anadromous fish were present in the upper basin for thousands of years, it is likely that Pacific Northwest fish pathogens would be present in the resident fish populations including LRS and SNS.

3.2 Headwater Redband/Rainbow Trout

Removal of the dams themselves would not be expected to directly affect populations of redband/rainbow trout in the headwater streams. Because of this, the following discussion focuses on the implementation of the KBRA and the effects this could have on these fish.

3.2.1 Hydrology Effects

Small scattered populations of redband/rainbow trout inhabit small streams in the headwaters of the Williamson-Sprague system. The upper Sprague River area also contains six very small populations of federally-threatened bull trout which are discussed separately below (see Sections 2.1.3 and 3.4).

Although they occupy a limited area, the headwater trout populations are relatively stable at this time. Implementation of KBRA would include numerous actions in the upper basin that could influence hydrology and therefore resident fish. Many of the KBRA implementation details are unclear at this time. When developing the KBRA plan for resident trout in the headwater areas of the Upper Klamath Lake basin, managers should consider enhancement plans that improve local hydrology where headwater trout are presently distributed and areas immediately downstream. Extending the immediate downstream trout distribution through KBRA should not endanger the genetic resources and uniqueness of these headwater trout populations (see Genetic and Disease sections). Fencing out livestock and riparian restoration activities proposed under KBRA should improve the habitat quality and hydrologic function of the stream channel. Groundwater spring improvements and use of the proposed KBRA increase of 30,000 acre-feet of instream summer flow should enhance habitat quality for redband/rainbow trout depending on where the water is acquired. More benefits would come if acquisition of cool water and selected reaches where it is most needed was prioritized for instream aquatic habitat purposes.

3.2.2 Water Quality Effects

Temperature can be the greatest limiting water quality issue for both redband/rainbow trout and bull trout in small headwater streams (Buchanan and Gregory 1997).

Impacts of elevated temperature were demonstrated in upper Deming Creek (tributary of the upper South Fork of the Sprague River) in 1994 where bull trout and redband/rainbow trout were present and the water temperature was 17.4°C, while in a treeless, degraded habitat section of lower Deming Creek located only a few miles downstream, the maximum summer temperature increased to 29.3°C and no trout were present (Buchanan et al. 1994). Degraded headwater reaches that lack sufficient riparian canopy and other constituent elements under current conditions limit resident trout use.

KBRA activities that fence livestock and wildlife away from the headwater streams should, with associated KBRA restoration of the riparian areas, reduce the temperature extremes in these small headwater streams where shade from trees may extend over the water surface. Both redband/rainbow trout and bull trout distributions would be expected to increase and extend downstream with the remediation of water temperatures.

Successful riparian restoration will take years before measureable reductions in water temperature are achieved. Specifics of how KBRA would be implemented on a site-level are not available at this time. The Panel suggests that KBRA activities include both livestock exclusion fencing and individual collars and cage fencing around each planted tree to improve success of planting. Watering during the dry season may also be required. Fenced corridors and newly planted riparian areas should be far enough away from the stream banks to allow for the natural changes in stream sinuosity. A period of extended care may be required for several years to restore riparian areas in the Upper Klamath Lake basin. Assuming that such care is provided, there could be positive affects to redband/rainbow trout as instream conditions gradually improve.

3.2.3 Habitat Effects

Habitat for resident redband/rainbow trout in the headwater streams is limited and highly fragmented. Light et al. (1996) reported that major impacts on resident trout habitat in the Upper Klamath Lake basin come from channelization, water withdrawals, removal of streamside vegetation, and elevated sedimentation.

Projected restoration actions associated with the KBRA should greatly improve the riparian habitat and reduce sedimentation and erosion in these headwater tributaries of the Upper Klamath Lake basin. The KBRA activities include (KBRA 2010):

1) fence construction and offstream water sources for livestock
2) maintenance of existing fences
3) riparian corridor management agreements
4) groundwater spring improvements

These activities should fence livestock and wildlife away from headwater streams and begin the long process of riparian restoration (see Water Quality, Proposed Action above). Riparian restoration and livestock removal will increase shade, undercut banks, large wood, riffle stability and reduce sedimentation and erosion as described in Dambacher and Jones (1997).

Habitat improvements in headwater streams will increase abundance and distribution of resident trout populations. These improvements would help protect long-term resiliency and enhance harvest potentials for redband/rainbow trout.

3.2.4 Population Level Effects

Information on the current population levels of redband/rainbow trout in the headwater streams is limited. Projected restoration from KBRA actions should enhance mixed stock and downstream populations of native, co-evolved redband/rainbow populations. Effective implementation of proposed fencing projects, riparian projects, and groundwater spring improvements should increase the abundance and distribution of redband/rainbow trout populations by several fold in these headwater streams.

3.2.5 Genetic Effects

Redband/rainbow trout from the headwater streams of the Upper Klamath Basin are genetically separate and unique from the lake/river redband/rainbow trout found in lower parts of the Upper Klamath Basin (see Section 2.1.2 Genetics). It is likely that headwater populations of trout have never been exposed to *C. shasta* (See Sections 2.12 Genetics and Disease). Potential long-term effects to headwater trout by *C. shasta* has been suggested to be negligible, as populations of the polychaete host for *C. shasta* has not been found in the upper headwaters, therefore preventing *C. shasta* from completing its life cycle and persisting in headwater areas (J. Bartholomew, OSU, pers. comm.). Documentation of anadromous steelhead migrating to the headwater area prior to dam construction is not readily apparent (Hamilton et al. 2005). Spawning locations of anadromous steelhead and other anadromous salmonids should be monitored after dam removal to evaluate potential adverse effects to headwater redband/rainbow trout.

3.3 Lake/River Redband/Rainbow Trout

3.3.1 Hydrology Effects

Because of summertime irrigation withdrawals and evapotranspiration at the Klamath Marsh, the Williamson River above Kirk Springs commonly goes dry (R. Smith and W. Tinniswood, ODFW, pers. comm.). This represents a temporary impediment for resident redband/rainbow trout moving to and from Upper Klamath Lake and the upper Williamson River and a reduction of instream habitat for rearing salmonids. KBRA efforts to voluntarily purchase water from irrigators, or improve irrigation delivery systems by purchasing covered canals or piped systems, could add instream flows to this important area. Summer inflow into the lower Williamson River is currently provided by the Sprague River and groundwater flow from Kirk Springs and Spring Creek near Collier Memorial State Park.

As discussed above for sucker species, lake levels within Upper Klamath Lake during certain portions of the year are critical for providing lake-fringe wetland and other shallow water refugia. Similar to sucker species, these shallow water habitats are important for juvenile redband/rainbow trout drifting or out-migrating from the Williamson, Sprague, and Wood rivers. Under current conditions when Upper Klamath Lake levels are low, these shallow water habitats are limited and there is less available cover in Upper Klamath Lake for resident redband/rainbow juvenile trout during spring and summer.

A proposed increase in 30,000 acre-feet of summer flow (roughly 170 cfs over a 90-day period) is planned by the KBRA activities under the Proposed Action. The actual sites for this are yet to be determined. Nevertheless, it is expected that these increases will improve resident redband/rainbow trout habitat during summer months in the Sprague and Williamson rivers if implemented in conjunction with other KBRA activities to establish and maintain habitat connectivity and rearing for trout.

3.3.2 Water Quality Effects

Many of the factors affecting water quality in Upper Klamath Lake and its tributaries have already been described above for sucker species. The combination of high nutrient loading, ammonia, phosphorous, high water temperatures, proliferation of cyanobacteria, toxins, high pH, and low DO together represent adverse conditions and substantial stresses to resident fishes in the system, including resident redband/rainbow trout. Fortunately, similar to sucker species, redband/rainbow trout have a high tolerance to degraded water quality conditions (see Section 2.1.2, Trout Downstream of Keno Dam). However, redband/rainbow trout subject to excessively poor conditions during the summertime months, when refugia is limited, move to more suitable locations within Upper Klamath Lake and its tributaries. Perhaps more so than sucker species, resident redband/rainbow trout within Upper Klamath Lake and its tributaries have greater opportunities to move and hold within more suitable water quality and thermal refugia due to their ability to persist well in both lake and riverine environments.

In the summertime, water quality conditions in Upper Klamath Lake have been characterized as being representative of a hypereutrophic environment. Similar to that which was described above for sucker species, resident redband/rainbow trout move from areas experiencing poor water quality to seek the cool oxygenated waters of springs in the lake. Unlike sucker species, which seek refugia at spring margins and within the mixing zones, redband/rainbow trout prefer deeper pools that occur within or immediately adjacent to the spring discharge. Adults and juveniles will move into these areas, congregate, and hold until conditions improve. Because of the limited number of springs that exist within the lake, it is anticipated that this behavior and association would continue to persist over the 50 year period of interest, with the only limiting factor being capacity and availability of space and resources at lake spring locations.

Therefore, assuming water quality conditions remain relatively unchanged from the current conditions over the 50 year period of interest, resident redband/rainbow trout using Upper Klamath Lake will likely continue to hold within these areas, and populations will continue to be limited by capacity and habitat availability. In conclusion, under current conditions, resident redband/rainbow trout have open access to and use of a limited amount of thermally adequate deep pool and spring habitats in Upper Klamath Lake. Poor water quality conditions in Upper Klamath Lake during the summertime are temporarily displacing and positioning resident redband/rainbow trout at spring locations, of which, there are limited space and resources. This could represent a limiting factor on current redband/rainbow trout populations that reside or move through Upper Klamath Lake during portions of the year.

Water quality in the Williamson, Sprague, and Wood rivers, as well as Sevenmile Creek is much higher than Upper Klamath Lake, and these tributaries provide a vital source of good water quality and thermal refugia for resident fish. Although compromised within certain reaches from agriculture and grazing activities, these tributary waters contain approximately 1,130 cfs of groundwater contributions from active springs.

Of the tributary waters to Upper Klamath Lake, the mainstem of the Sprague River currently represents the most water quality compromised and/or in need of remediation (Hamilton et al. 2010b). Under current conditions, agricultural operations and grazing along the mainstem of the Sprague River have resulted in groundwater and surface water withdrawals, nutrient loading, habitat removal and degradation, and streambank erosion, among others.

This is not necessarily the case for the Williamson and Wood rivers, or Sevenmile Creek. Current access to, and use of, thermally adequate habitats within the lower Williamson River and tributaries is limited by dry season instream barriers above Kirk Springs and Collier State Park as a result of irrigation withdrawals and evapotranspiration of the Klamath Marsh.

Over the 50-year period of interest, the anticipated water quality improvements resulting from successful implementation of KBRA are expected to increase redband/rainbow trout populations and improve the sport fishery in Upper Klamath Lake and its tributaries.

Under the Proposed Action, it is anticipated that improvements in Upper Klamath Lake will supplement spring function and provide alternative water quality and thermal refugia for resident redband/rainbow trout during important times of the year. It is expected that areas within and immediately surrounding the existing lake springs will continue to be used by resident redband/rainbow trout. Under the Proposed Action, water quality at existing lake-fringe wetlands and nearshore areas adjacent to wetlands in Upper Klamath Lake would continue to improve, and in combination with additional efforts, growth and survival of the redband/rainbow trout in Upper Klamath Lake might increase.

The recent restoration efforts at the Williamson River Delta represent a positive example of wetland restoration at Upper Klamath Lake. These efforts may help improve the local water quality and provide rearing and other habitat opportunities for resident fish, including redband/rainbow trout (H. Hendrixson, TNC, pers. comm.). Similar wetland creation, restoration, and enhancement efforts are targeted by KBRA under the Proposed Action, and with proper maintenance and monitoring over the 50-year period of interest, these efforts should assist in improving water quality and habitat suitability and availability for redband/rainbow trout populations and the sport fishery in Upper Klamath Lake.

Also under the Proposed Action, it is anticipated that improvements targeted in the Williamson, Sprague, and Wood rivers, and their tributaries, will improve water quality and supplement spring function, enhancing the health of and expanding live-in and migratory habitat for resident redband/rainbow trout. The majority of planned efforts for these tributaries to Upper

Klamath Lake are targeted on the mainstem Sprague River (Table 4). Under current conditions, intensive cattle grazing along the mainstem has resulted in degradation to water quality, among other impairments, the adverse effects of which are apparent at the local and watershed level. KBRA targeted on the mainstem Sprague River would help manage cattle grazing and restore the functions and values of in-stream, riparian, wetland, and upland habitats associated with the mainstem corridor.

The proposed 30,000 acre-feet of additional water purchased voluntarily from irrigators or by purchasing improved delivery systems during the summer irrigation season, combined with the decommissioning of existing diversions and water pumps at or near spring locations, are expected to provide for higher volume flows and better water quality conveyed through the tributaries and ultimately discharged into Upper Klamath Lake. These KBRA activities could have a strong beneficial effect on redband/rainbow trout populations and sport fisheries (see Section 5.2) in the tributaries.

3.3.3 Habitat Effects

The activities proposed within Upper Klamath Lake focus on lake fringe wetland restoration, including the removal of levee material and re-use for habitat features such as raised channels or island habitats (Table 4). A total of 10 mi (16.1 km) of lakeshore area is proposed for restoration under the KBRA. These activities are particularly important for resident redband/rainbow trout because they will provide key rearing opportunities for juveniles entering Upper Klamath Lake from the tributaries.

3.3.4 Population Level Effects

Under existing conditions, populations of redband/rainbow trout in Upper Klamath Lake would continue to be subject to the stresses related to water quality and limited access to degraded habitat in the tributaries to the lake. Depending on how fast conditions either continue to degrade in the lake or how fast they improve, these populations could show either declines or increases respectively. Redband/rainbow in the river would continue to exist within areas of suitable habitat.

The Proposed Action with KBRA would include a number of elements as discussed above that when successfully combined could result in improved habitat for redband/rainbow trout. Improved water supply would increase access to thermal refugia and spawning habitats. Riparian fencing and restoration actions should reduce water temperatures, sediment loads, and improve instream habitat. Lake fringe restoration actions could help improve water quality in Upper Klamath Lake and increase edge habitat available for fish. All of these combined could result in increases in redband/rainbow trout.

3.3.5 Genetic Effects

Anadromous steelhead trout in the Upper Klamath Basin historically migrated up the Klamath River between Iron Gate Dam and Upper Klamath Lake. They also migrated into river tributaries upstream of Upper Klamath Lake (Fortune et al. 1966; Huntington et al. 2006; Butler and Stevenson 2010). Anadromy is another successful life history form of Upper Klamath Lake redband/rainbow and has historically co-adapted naturally with the resident form. There is close genetic similarity of redband/rainbow trout in Spring Creek on the lower Williamson River, Spencer Creek and the Klamath River downstream of Upper Klamath Lake to redband/rainbow steelhead from Bogus Creek (see 2.1.2 Genetics). Removal of the dams would allow steelhead to access the historically occupied habitat. Because of the genetic similarity it is unlikely that re-introduction of anadromous steelhead, presumably from Bogus Creek stock, would have a deleterious effects on resident trout. Anadromous and resident forms of redband/rainbow trout have historically and naturally produced trophy fisheries and robust populations for each life history type, for example in the Deschutes, Yakima, and Babine rivers (Zimmerman and Reeves 2000; Pearsons et al. 2007) (see 2.1.2 Genetics). However, the genetic relationship between populations of anadromous and resident forms of redband/rainbow trout is still somewhat unclear.

3.4 Bull Trout

In June 1997, in response to litigation, the USFWS proposed the Klamath Basin bull trout be listed as endangered under the ESA, while the Columbia Basin bull trout be listed as threatened (USFWS 1998). The Klamath Basin bull trout have since been downgraded to a threatened status. Although not part of the official request for inclusion in this Panel's review, the Panel decided that this species needed to be considered.

Bull trout are stenothermal, requiring a narrow range of colder temperature conditions to rear and reproduce (Buchanan and Gregory 1997). Water temperatures in excess of 15°C are thought to limit general bull trout distribution (Rieman and McIntyre 1993). Dambacher and Jones (1997) found juvenile bull trout only in areas of quality habitat characterized by high amounts of shade, undercut banks, large wood, gravel in riffles, and low levels of fine sediment and bank erosion. Weaver and Fraley (1991) found that any increase in fine sediment reduced survival of bull trout. Presently eight reduced and fragmented populations of bull trout can be found in the Upper Klamath Basin (USFWS 2002). Six of these groups are found in headwater streams of the upper Sprague and Sycan rivers and the other two in streams near Upper Klamath Lake. Detailed distribution surveys were conducted in the headwater streams for bull trout by the Oregon Chapter of the American Fisheries Society (1993) and Light et al. (1996). Only six fragmented resident bull trout populations were found in 16 mi (25.7 km) of streams. This distribution includes miles of bull trout in competition with non-native brook (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*). Only 9 mi (14.5 km) of bull trout distribution contained native bull trout without non-native competition (Buchanan et al. 1997). The small fragmented populations of bull trout in these limited areas are at a high risk of extinction compared to other areas. The current abundance and distribution of bull trout in the Upper Klamath Lake basin are greatly reduced from historical levels because of habitat loss and degradation caused by reduced water quality, timber harvest, livestock grazing, water diversions, roads, and non-native fishes (USFWS 2002; Hamilton et al. 2010a). If existing conditions continue to degrade, bull trout in these remnant populations could become extinct.

As discussed above for headwater trout, the proposed KBRA actions would enhance resident populations of headwater bull trout, and particularly in Threemile and Sun creeks, from which waters ultimately flow into Upper Klamath Lake. Both of these populations are listed as populations with a high risk of extinction (Buchanan et al. 1997), and implementation of KBRA could have a significant contribution toward recovery of these populations. Passage from Sun Creek to the Wood River may be improved by KBRA actions allowing for fluvial life history forms of bull trout in the Wood River system. The cold waters of the Wood River may successfully provide habitat for reintroductions of anadromous salmon and steelhead. Rearing anadromous juveniles could provide an increased prey base for fluvial bull trout and produce predator/prey interactions ecologically similar to historical conditions (Buchanan et al. 1997).

3.5 Other Resident Fish

The Upper Klamath Basin includes native fishes that are adapted to lakes or warmer streams and rivers of lower gradient (NRC 2004). In total, 16 native species representing five families of fishes currently exist in the Upper Klamath Basin. Most of the native fishes in the Upper Klamath Basin are endemic to the watershed. Relatively abundant or common species include Klamath tui chub (*Gila bicolor bicolor*), blue chub (*Gila coerulea*), Klamath speckled dace (*Rhinichthys osculus klamathensis*), Upper Klamath marbled sculpin (*Cottus klamathensis klamathensis*), and Klamath Lake sculpin (*Cottus princeps*). Some of the species are not common including Slender sculpin (*Cottus tenuis)* and Miller Lake lamprey (*Lampretra milleri)* and there is potential for them to be considered for protection under the ESA in the future (NRC 2004).

The Proposed Action has a greater probability of benefiting native fish populations compared with the Current Conditions. NRC (2004) concluded that restoration of habitats in the Upper Klamath Basin would be beneficial for most native fishes. According to NRC (2004), restoration of habitats may also be detrimental to non-native fishes, which adversely affect survival and abundance of native fishes. The Proposed Action includes KBRA, which is a major effort to restore habitat throughout the Upper Klamath Basin. Although efforts are ongoing to restore habitat, KBRA would accelerate and expand upon the ongoing efforts, thereby providing greater benefit to native fishes.

Climate change has the potential to adversely affect native fishes, leading to low population status and consideration for protection under the ESA. Given the potential adverse affect of climate change on native fishes, actions that increase habitat quantity and quality, such as the Proposed Action, are especially important as a means to reduce additional adverse effects to native fishes.

4.0 Impacts Downstream of Keno Dam

4.1 Suckers

4.1.1 Short-Term Effects of Dam Removal

Short-term impacts of dam removal on LRS and SNS are minimal because most adults currently found in all the reservoirs downstream of Keno Dam will be captured and relocated to Upper Klamath Lake. Dam removal would eliminate lake-like habitat and SNS and LRS not relocated to the Upper Basin would likely perish. There may be temporary displacement of reservoir populations of KSS and KLS to river reaches both upstream and downstream of the dams. Those fish in J.C. Boyle that move upstream during dam removal will not be exposed to the sediment issues. Within a couple of years KLS and KSS are likely to reoccupy the new river habitat.

4.1.2 Long-Term Effects of Dam Removal

Historically, the geographic range of SNS and LRS was restricted to the lakes and sluggish rivers of the Upper Klamath River Basin upstream of Keno Dam. Construction of J.C. Boyle, Copco No. 1, and Iron Gate Dams created lacustrine (lake-like) rearing habitat in which a small number of SNS could survive after being swept downstream from Upper Klamath Lake (Scoppettone and Vinyard 1991; Desjardins and Markle 2000; Buettner and Scoppettone 1991). It is highly unlikely that these species would occupy the riverine habitat downstream of Keno Dam under free-flowing conditions because they have not been documented in the Klamath River below Iron Gate Dam and are not known to reside in other similar habitat elsewhere. NRC (2004) noted that LRS and SNS populations in the Klamath River reservoirs do not have a high priority for recovery because they are not part of the original habitat complex of the suckers and probably are inherently unsuitable for completion of life cycles by suckers because of poor water quality, lack of larval habitat, and predation by large populations of non-native fish.

Under current conditions, there is unlikely to be substantial changes in the status of LRS and SNS populations in the reservoirs downstream of Keno Dam because there will still be a lack of suitable spawning and rearing habitat present in the reservoirs, and adverse water quality and completion and predation from non-natives will continue to be threats. KLS will continue to be rare downstream of Keno Dam. There are likely to be little change in KSS populations.

KLS are similar to SNS based on morphology (Markle et al. 2005) and cannot be distinguished from SNS genetically based on mtDNA and microsatellite studies (Dowling 2005; Tranah and May 2006). Analyses of morphological and molecular characters indicate that hybridization between KLS, SNS, and LRS has occurred through the evolutionary history of these suckers. KLS have a similar life history pattern to SNS and LRS they are likely to respond similarly to LRS and SNS if the dams are removed. Early life stages of SNS, LRS, and KLS are likely to be entrained or move downstream volitionally after dam removal. However, these fish are likely to perish or return to more suitable lacustrine habitats above Keno Dam.

KSS are common in the Klamath River downstream of Keno Dam (Desjardins and Markle 2000; PacifiCorp 2004; Buettner and Scoppettone 1991; Moyle 2002). An abundant population is found in J.C. Boyle Reservoir. Dam removal is not likely to change this species' range and abundance downstream of Keno Dam. However, dam removal would restore connectivity among disjunct populations. It is unlikely that KSS populations will increase upstream of Keno Dam because KLS currently fill a similar niche.

4.2 Redband/Rainbow Trout

4.2.1 Short-Term Effects of Dam Removal

The population of redband/rainbow trout found in the reach between Keno Dam and J. C. Boyle Reservoir would not be directly impacted by the short-term effects of dam removal because they are upstream of all proposed activities. Redband/rainbow trout found the free-flowing reaches between the other downstream reservoirs would be directly impacted during dam removal. Although there could be some minor direct impacts from dam removal itself, such as entrapment, harm or mortality of individuals at the dam (demolition) construction sites, the major effects would come through sediment flushing (see Section 2.4). The initial flush of sediment could have several effects on redband/rainbow trout (Waters 1995):

- Periods of high turbidity could impair visibility and therefore reduce foraging success of fish. This in turn requires more work to obtain adequate food and results in lower growth rates.
- Deposition of sediments in low-gradient reaches could bury populations of benthic macroinvertebrates upon which trout feed.
- High turbidity could impair normal respiration.
- Fish may move out of the area of high turbidity resulting in a stretch or river with very few fish.

The duration of the sediment plume would be the primary factor determining how large of an adverse effect this would have on the fish populations. The shorter the pulse, the sooner fish can return to the affected area. The relatively abundant population of trophy redband/rainbow trout in the reach below Keno Reservoir, including Spencer Creek, would provide the seed population from which the project reach would be re-colonized.

4.2.2 Long-Term Effects of Dam Removal

Removal of the four dams downstream of Keno Dam should create significant increases in the size, abundance, and distribution of resident trout in the 45 miles of the Klamath River between Keno Dam and Iron Gate Dam. The trophy trout fishery between the free flowing Keno Reach from Keno Dam down 5.9 mi (9.5 km) to the slack water of J.C. Boyle Reservoir is the only fishery downstream of Keno Dam that is not expected to be drastically increased by the removal of the four dams. Using this section as a control, we can predict changes in the 39.1 mi (62.9 km) of the Klamath River that would return to a free flowing condition under the Proposed Action. In addition to the mainstem channel, there are 4.2 mi (6.8 km) of tributaries that are currently inundated by the reservoirs, including portions of Spencer, Jenny, and Fall creeks.

Presently, with the four dams in place, there is only a limited number of resident trout using the 22-23 mi (35.4-37.0 km) of slack water between J.C. Boyle, Copco 1 and 2, and Iron Gate Dams (Cunanan 2009). These reservoirs do not provide trout habitat during the summer because of low DO and high temperatures (W. Tinniswood, ODFW, pers. comm.; Hamilton et al. 2010a).

Flow peaking within the reach between J.C. Boyle Powerhose and Copco Reservoir causes chronic stress to trout and results in mortality, stranding and entrainment of fry, juvenile, and adult redband/rainbow trout (W. Tinniswood, ODFW, pers. comm.; Hamilton et al. 2010a).

Macroinvertebrate densities are highest in the free flowing Keno reach and lowest in the bypass and peaking reaches (Addley 2005). J.C. Boyle Dam has a fishway for trout migration but the number of trout that successfully use this passageway has decreased up to 98 percent since 1959 when the fishway was first operated (Hemmingsen et al. 1992). Trout recruitment from Spencer Creek is hindered by infrequent spill events at J.C. Boyle Dam. Recruitment is further reduced by trout entrainment in the powerhouse diversion (W. Tinniswood, ODFW, pers. comm.). Copco 1, Copco 2, and Iron Gate Dams currently do not have fishways and block all upstream trout passage.

Water quality of the Project Reach could be enhanced by KBRA water quality measures to the Upper Klamath Lake and its upper tributaries and Keno Reservoir. Water in the Project Reach after the dams are removed will be enhanced by cold groundwater spring flow (285 cfs) located in the Bypass reach (e.g., Big Springs) (Turaski 2003; Tinniswood 2011). Additional high quality water will come from Spencer, Fall, and Shovel Creeks. Further, the lower Klamath River and Fall Creek contain substantial cold groundwater springs from the powerhouse to Iron Gate Dam (128 cfs) (See Table 3) (USGS 2007; Tinniswood 2010; Tinniswood 2011).

Water quality in the dam removal sections of the lower Klamath River would improve DO, pH, and nutrient concentrations due to KBRA implementation. Removal of the four dams would reduce or prevent further growth of the blue-green algal blooms in the 22-23 mi (35.4-37.0 km) of slack water in the reservoirs between J.C. Boyle and Iron Gate dams (Cunanan 2009, Hamilton et al. 2010a).

We estimate that 43 mi (69.2 km) of new free flowing water will be available to resident redband/rainbow trout after the removal of the four dams. This area will expand the total distribution of resident trophy trout in the fishery approximately seven times from below Keno Dam to the Iron Gate reach. This total reach should continue to produce large trout up to 23 in

(58.4 cm). With expanded area under the Proposed Action, it would be expected that the current non-statistical estimate of 6,700 angler-days (W. Tinniswood, ODFW, pers. comm.) in the Keno Reach would increase substantially.

4.3 Non-Native Fishes

Non-native fishes are recognized as a major threat to indigenous fishes in the Pacific Northwest. For example, Sanderson et al. (2009) concluded that non-native species have a major effect on salmonids protected by the Endangered Species Act. Of particular importance are non-native predators of indigenous fishes. Sanderson et al. (2009) reported that the construction of reservoirs associated with hydro-system projects has facilitated the spread and establishment of many aquatic non-native species, including key non-native piscivores such as smallmouth and largemouth bass (*Micropterus dolomieui* and *Micropterus salmoides*) that consume virtually any prey smaller than the size of their gape. In areas where freshwater bass have been introduced, predation by bass has contributed to the decline of native fishes, frogs, and salamanders (Moyle 2002).

Most of the watershed downstream of Iron Gate Dam is presently dominated by native anadromous fishes, but the reservoirs upstream of Iron Gate Dam have higher numbers of non-native fishes (NRC 2004; M. Pisano, CDFG, pers. comm.). Many of the non-native fishes are attracted to the warmer, lentic waters associated with reservoirs. The non-native fishes presumably invaded the area from the upper basin where non-native fishes are especially abundant or from bait-bucket introductions (NRC 2004). Overall, at least 17 species of non-native fishes inhabit the lower Klamath and Trinity rivers. Relatively abundant non-native fishes in the reservoirs upstream of Iron Gate Dam include yellow perch (*Perca flavescens*), largemouth bass, bluegill (*Lepomis macrochirus*), and brown bullhead (*Ameiurus nebulosus*) (NRC 2004). Yellow perch and largemouth bass support a recreational fishery. Of these fishes, yellow perch, largemouth bass, and brown bullhead may prey upon native fishes, depending on relative size of predator and prey. However, the degree of interaction between non-native and native fishes in the area is unknown. Under the Current Conditions, the assemblage of non-native fishes would continue to persist.

The Proposed Action would change reservoir habitat to free-flowing river, which would adversely affect non-native fishes in the lower Klamath basin between Keno Dam and Iron Gate Dam. Abundances of largemouth bass, yellow perch, bluegill, and brown bullhead would significantly decline or be eliminated because their preferred reservoir habitat would be gone. The decline of these non-native fishes could improve conditions for native fishes, including redband/rainbow trout, to the extent that there are adverse interactions at present. For example, elimination of largemouth bass in J.C. Boyle Reservoir would remove predation pressure by non-native fish on redband/rainbow trout. Many predator/prey vulnerability relationships change drastically when dammed, slack-water reservoir conditions are compared to free-flowing undammed river conditions. Northern pikeminnow (*Ptychocheilus oregonensis*) predation on juvenile salmonids in slack-water conditions of Columbia River reservoirs has been well documented in the literature (Rieman et al. 1991; Petersen et al. 1994; Friesen and Ward 1999). However, Buchanan et al. (1981) and Fresh et al. (2003) found that northern pikeminnow ate only small amounts of salmonids in free-flowing sections of the Willamette River (Oregon) and the Chehalis River (Washington) respectively.

Tabor et al. (2007) assessed the impact of predation by smallmouth and largemouth bass on juvenile Chinook salmon from February to June in Lake Washington, WA. They found that the overall predation on salmonids was generally low for both bass species; however, juvenile salmonids made up a substantial part of bass diets in June (up to 50 percent). They found that the vulnerability of juvenile salmonids can be attributed to their small size; their tendency to migrate when water temperatures exceed 15°C that coincides with greater bass activity; and juvenile salmonid use of nearshore areas where habitat usage overlap with bass is greatest. Juvenile redband/rainbow trout with peak migrations from May in Spencer Creek into the slack-water of J.C. Boyle Reservoir would match these vulnerability conditions.

Concern has been raised that the removal of dams could release piscivorous non-native fishes to the reach downstream of Iron Gate Dam where anadromous salmonids are present. Presently, some of these non-native fishes move through the reservoirs during spill events to areas below Iron Gate Dam, yet sampling of fishes with screw traps and boat electrofishing indicates these non-native fishes have not colonized the lower river (M. Pisano, CDFG, pers. comm.). If habitat downstream of Iron Gate Dam was suitable for the non-native fishes, then we would expect to see evidence of colonization because spill events and re-introductions of non-native fishes occur annually. The lack of non-native fishes in catches downstream of Iron Gate Dam provides evidence that non-native reservoir fishes would not become abundant in the free-flowing river and therefore they would not adversely affect native salmonids.

The Proposed Action alternative includes a variety of habitat restoration activities that would likely favor native fishes. Given that the abundance of non-native fishes is positively correlated with the degree of habitat disturbance (Moyle and Light 1996 in NRC 2004), the Proposed Action has additional benefits for reducing non-native fishes downstream of Keno Dam while improving habitat quality for native fishes.

4.4 Other Resident Fish

The Klamath Basin downstream of Keno Dam supports 19 species of native fishes. Four species are resident freshwater species, two are amphidromous (larval stages in salt water), and 13 species are anadromous (NRC 2004). The resident freshwater species show close taxonomic ties to fishes in the Upper Klamath Basin or adjacent basins. The Lower Klamath marbled sculpin (*Cottus klamathensis polyporous*) is endemic to the Klamath Basin. Relatively common resident fishes include Klamath speckled dace and Klamath river lamprey (*Lampetra similis*).

Resident fishes downstream of Keno Dam evolved under free-flowing river conditions and without piscivorous non-native fishes that presently inhabit the dam removal reach. The

Proposed Action alternative will restore approximately 43 mi (69.2 km) of mainstem reservoir and isolated river habitat to free-flowing river habitat. It will cause abundance of most non-native fishes to decline significantly. Removal of the dams will enable isolated populations of resident fishes to co-mingle and colonize mainstem reaches that are not presently utilized. In the long-term, the Proposed Action is likely to provide significant benefits for resident native fishes within the dam removal reach and immediately downstream of Iron Gate Dam. Immediately after dam removal, high suspended sediments may adversely affect resident species located below and near Iron Gate Dam, but the resident fish abundances are likely to quickly recover and increase as the resident fish population moves into the dam removal reach.

5.0 Harvest

5.1 Suckers

Before harvest can occur, populations need to recover sufficient numbers such that managers believe there is an adequate number of fish to support harvest without adversely impacting population trends. Long-lived species that reproduces multiple times over their lifespan are highly susceptible to overharvesting if the harvest focuses on larger individuals.

LRS and SNS reproductive populations in Upper Klamath Lake transformed from one dominated by old fish with little size diversity and consistently poor recruitment in the 1980s and early 1990s to a reproductive population dominated by smaller young adult fish and very few remaining large individuals by the late 1990s (Janney et al. 2008). In recent years, populations of both species exhibited a slight increasing trend in length, comprised of similarly aged individuals (18-20 years old), suggesting that recent substantial recruitment is lacking (Janney et al. 2008). Based on the number of fish tagged in recent years, adult populations of both species are likely in the low tens of thousands of individuals in Upper Klamath Lake.

Results of PIT tag studies from 2001-2007 show that abundances of male and female shoreline LRS in 2007 declined to 56 percent and 75 percent, respectively of their 2002 abundance (VanderKooi PPT Presentation). Male and female river-spawning SNS abundances have declined over the 2001-2007 period to 42 percent and 49 percent, respectively of their 2002 abundance (VanderKooi PPT Presentation). Similar data are not available for river-spawning LRS. These data show that both LRS and SNS are declining under current conditions (Figure 5 below - Line B).

Unless a recruitment event occurs soon, these populations could become extinct in the near future given their current annual mortality rates (Figure 5 – Line C). Major restoration efforts completed in recent years have been undertaken (e.g., Williamson River Delta, Chiloquin Dam removal) with the purpose of generating higher sucker survival and recruitment.

Under KBRA, restoration strategies used to recover suckers including lake level management, water quality improvement, and habitat restoration (wetlands and spawning and rearing habitat) are expected to increase spawning success, and larval, juvenile, and adult survival leading to larger populations and more frequent recruitment. With major restoration efforts occurring from 2012 to 2022, adult sucker populations are likely to start showing an upward trend by 2022 given that it takes 5-10 years for LRS and SNS to mature. A greater upward trend could occur after approximately 20 years (2032) due to the high reproductive potential of the suckers and full functionality of the restoration projects implemented during Phase 1 (Figure 5 – Line A).

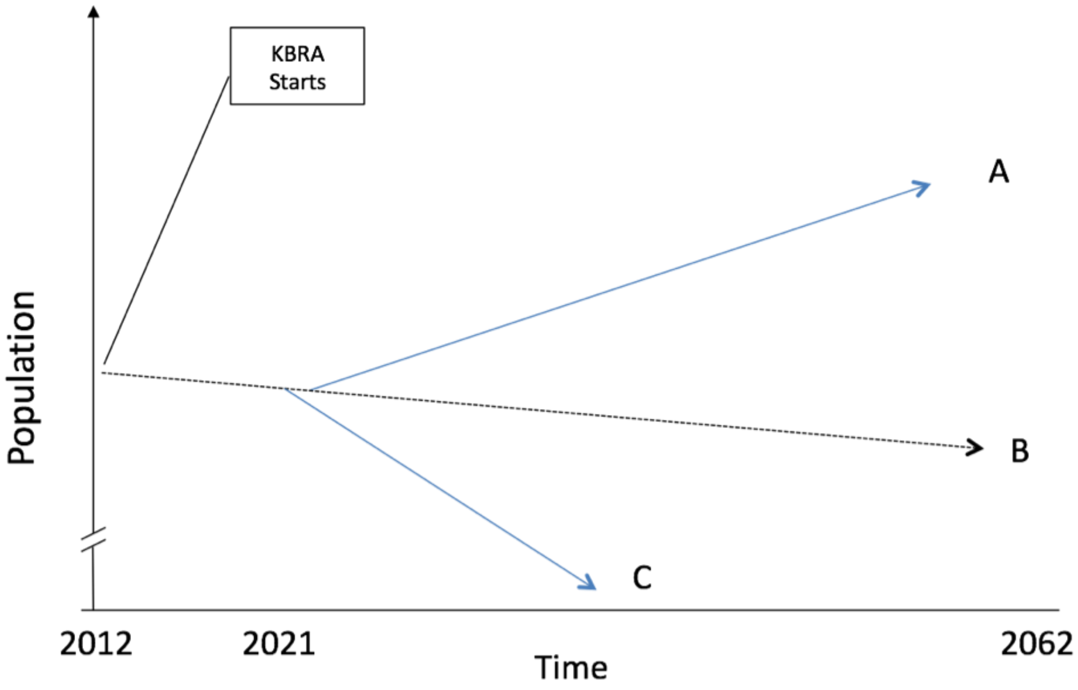

Figure 5. Potential sucker population trends following implementation of KBRA (A-Population trend with effective implementation of KBRA restoration projects, B-Current population trend, C-Potential population trend without a major recruitment event).

With declining populations under the current conditions, there are no opportunities for tribal or recreational harvest. Under KBRA, populations are likely to increase beginning about 2022 based on increasing survival of larval and juvenile suckers and recruitment of new adult year classes. However, until population monitoring indicates an upward trend in the population over at least a decade with major recruitment events and multiple age classes, harvest would reduce or negate population growth. Since suckers have high reproductive potential population numbers can increase rapidly if favorable conditions are reestablished. For example, from the late 1980s until the mid 1990s LRS and SNS populations increased from a few thousand to upwards of 100,000. However, if unfavorable conditions return, then numbers can crash to unsustainable levels as demonstrated in the 2002-2007 period. Therefore, these short-term rapid increases should not be used as a basis for establishing harvest of these species. Harvest other than ceremonial tribal harvest should only occur after a sustained population growth can be shown over a period of decades.

5.2 Redband/Rainbow Trout

Anglers travel from throughout the United States and internationally to fish large resident trout from Upper Klamath Lake, the lower Williamson River, the Wood River, and the Keno reach of the Klamath River (Messmer and Smith 2007; Tinniswood 2010). ODFW fishing regulations protect the large trophy redband/rainbow trout of the Upper Klamath Basin by permitting only one trout per day per angler in Upper Klamath Lake, the Williamson River, and the Keno reach. The Wood River recreational fishery is only open from April 24 to October 31 and is catch and release only. The Keno reach fishery is further restricted as it is open January 1 to June 15, then closes during high temperature stress conditions from June 16 to September 30 (3.5 months). The Keno Reach fishery then re-opens again from October 1 to December 31 (Oregon Sport Fishing Regulations 2010). The free-flowing (5.9 mi or 9.5 km) Keno Reach produces large redband/rainbow trout up to 23 in (58.4 cm) in length. A non-statistical sampling of anglers fishing the Keno reach in 2006 estimated 6,700 angler-days (W. Tinniswood ODFW, pers. comm). Trout can live successfully in the free flowing Keno Reach year-around, including under summertime conditions when DO can be as low as 5 to 6 mg/l; temperatures can be as high as 27°C; and, pH can be as high as 9.6 (Li et al. 2007). Klamath Tribal regulations on resident redband/rainbow trout allow subsistence take. Tribal individuals can catch up to five fish per day in the Williamson River system and up to ten fish per day in other systems.

Under the current Conditions with Dams, distribution and abundance of Lake/River redband/rainbow trout is expected to remain stable (Figure 6 – Line A). The Panel believe that distribution and abundance of headwater fluvial resident trout in the Williamson, Sprague, and Wood rivers and their tributaries will increase by successful implementation of KBRA activities (Figure 6 – Line B).

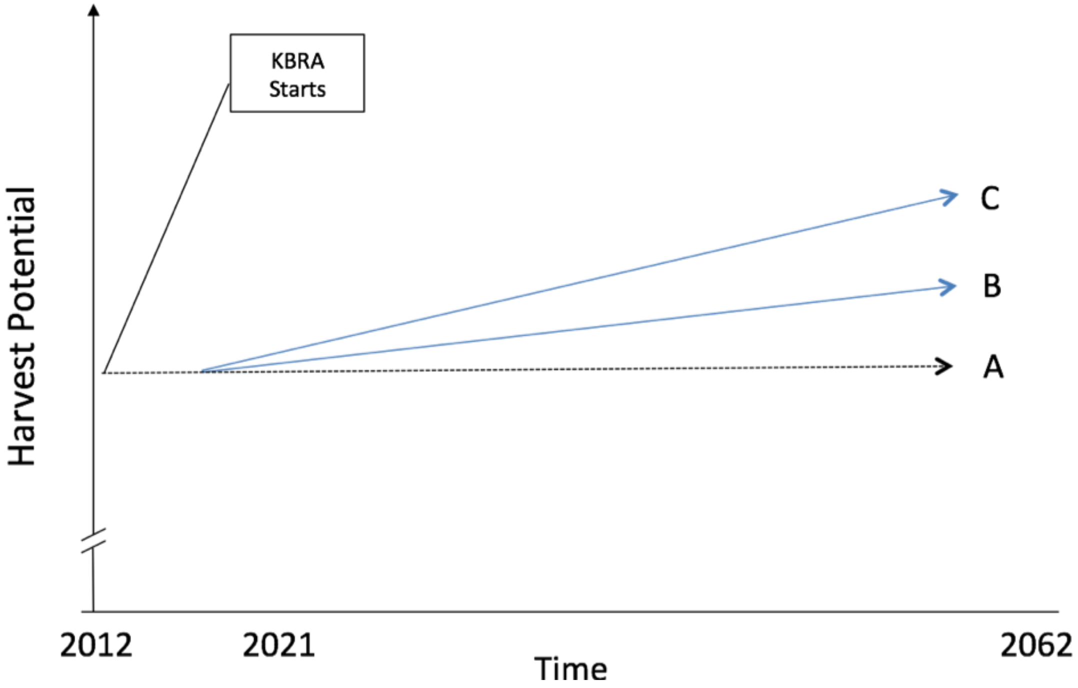

Figure 6. **Redband/Rainbow trout harvest potential upstream of Keno Dam (A-trout populations under Conditions with Dams, B-Headwater populations under Conditions without dams and with KBRA, C-Upper Klamath Lake populations under Conditions without dams and with KBRA).**

KBRA activities should expand abundance and distribution of headwater trout, but increases in the harvest potential will be dampened by the relative small size of these trout (Figure 6 – Line B). The distribution and abundance of resident adfluvial trout in Upper Klamath Lake, and the lower Williamson and Wood rivers, three very important areas for harvest, are also expected to expand (Figure 6 – Line C). For example, KBRA efforts to voluntarily purchase water from irrigators or improve irrigation delivery systems (such as covering or piping water in irrigation canals, or buying irrigation pipe for irrigators to replace out-dated flood irrigation) should add instream water flow to parts of the lower Williamson River above Kirk Springs. Under successful implementation of KBRA measures, the large size of resident trout within these areas is expected to remain stable.

Under current conditions the population of redband/rainbow trout, and therefore the harvest level, in the area immediately downstream of Keno Dam (in the free-flowing 5.9 mi or 9.5 km) is influenced by adverse water quality but the population appears to be stable (Figure 7 below – Line A). While there would be short-term adverse impacts from dam removal (Section 4.2), the Proposed Action would likely create significant increases in the size, abundance, and distribution of resident trout in the 43 mi (69.2 km) of the Klamath River between J.C. Boyle Reservoir and Iron Gate Dam.

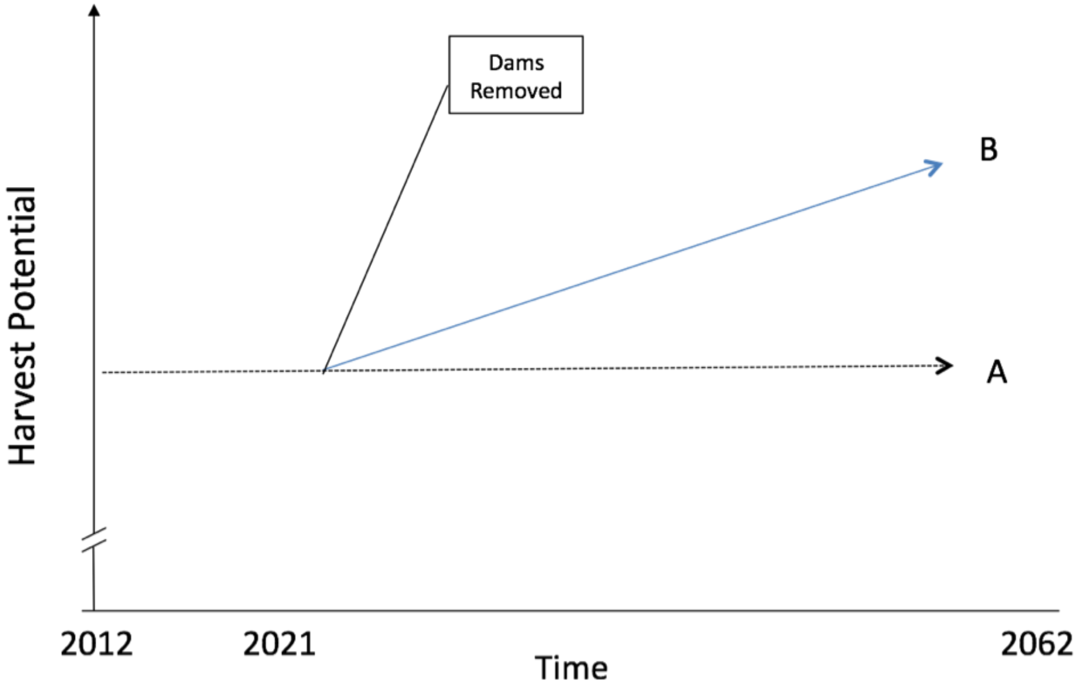

Figure 7. Redband/Rainbow trout harvest potential downstream of Keno Dam (A-Conditions with Dams, B- Conditions without dams and with KBRA).

The existing trophy trout fishery between the free flowing Keno Reach from Keno Dam downstream to J.C. Boyle Reservoir is the only fishery downstream of Keno Dam that is not expected to increase following the removal of the four dams. This population should provide a major source to repopulate the river downstream through the project reach.

Trout in the free-flowing Keno Reach are exposed to extremely high temperatures and pH stress conditions. Because these trout have evolved near and below an eutrophic system, Upper Klamath Lake, they have adapted to extreme conditions. Presently, Upper Klamath Lake has become hypereutrophic, which could further stress these trout by increasing susceptibility to ubiquitous secondary fish pathogens (*F. columnaris* and *Ich*) found throughout the Upper Klamath Lake basin. Removal of the dams and reservoirs would add water to the Bypass Reach, eliminate fluctuating flows in the Peaking Reach, and increase free flowing water. Also, KBRA implementation should maintain or improve overall water quality so that hypereutrophic conditions will not become more severe and lead to possible fishery collapse. However, quality of water flowing from Keno Reservoir into the free-flowing reach is not expected to improve markedly following upstream KBRA activities.

It is expected that eventually the entire reach downstream of Keno Dam would be capable of supporting a resident redband/rainbow trout fishery after the removal of the four dams. It is possible that the trophy fishery will expand seven times from below Keno Dam to the Iron Gate reach. Several factors contribute to the estimated 7-fold increase of redband/rainbow harvest.

The removal of 4 dams and their slack-water reservoirs would add 22-23 mi (35.4-37.0 km) of new free flowing waters (Cunanan 2009). Reservoir waters do not support significant redband/rainbow trout fisheries because there are a limited number of trout in the J.C. Boyle, Copco, and Iron Gate Reservoirs (Adm. Law Judge Orders 2006). Iron Gate, Copco I and Copco II dams do not have fishways and currently block all upstream fish passage (Adm. Law Judge Orders 2006). J.C. Boyle Dam has a fishway but trout passage in this fishway has declined up to 98% since its initial operation in 1959 (Hemmingsen et al. 1992; Adm. Law Judge Orders 2006). Approximately 3-4 mi (4.8-6.4 km) of the Klamath River below the J.C. Boyle Dam (Bypass Reach) is reduced to only 100 cfs of flow. An additional 17.3 mi or 37.8 km (Peaking Reach) of free flowing waters between the J.C. Boyle powerhouse outlet to the upper end of the Copco Reservoir experience daily fluctuating flows from about 350 cfs, where there is no power production, up to 1,850 cfs for only a few hours during peak power production (Adm. Law Judge Order 2006; Starcevich et al. 2006). Dewatered and daily fluctuating flows reduce redband/rainbow trout abundance and harvest (Adm. Law Judge Orders 2006; Starcevich et al. 2006; Tinniswood 2010).

Riffles and rapid areas in the proposed 43 mi (69.2 km) of natural free flowing waters between J.C. Boyle Reservoir and Iron Gate Dam should increase dissolved oxygen levels. Carlson (1991), a project hydrologist for the City of Klamath Falls, found that water temperatures at Big Springs (285 cfs) in the lower section of the Bypass Reach produces a constant year-around temperature of approximately 48°F. Nichols (1991) stated that during the summer months the Klamath River flows below Keno Dam are so reduced that the J.C. Boyle Powerhouse only generates one turbine for 6 to 10 hours of peaking per day. We calculate that the dilution of natural groundwater at Big Springs (285 cfs) into the Klamath River will make up 30-40 percent of the total flow. These groundwater springs should have positive effects on water quality and temperature and enhance rearing and harvest for redband/rainbow trout.

Another 128 cfs of natural groundwater enters the Klamath River below the Powerhouse Reach near Fall Creek (Table 3). These springs should also dilute and improve water quality and enhance trout rearing and harvest.

Limited spawning area below Keno Dam may affect redband/rainbow trout abundance and harvest. Trout spawning has been well-documented in Spencer and Shovel Creeks (see Section 2.1.2). Trout production from Spencer Creek should be benefited by a reduction in predation when migrating fry and juveniles move directly into free-flowing waters instead of the slack-water of J.C. Boyle Reservoir (see Section 4.3). Numbers of migrating trout from Spencer Creek should be enhanced by the removal of the four dams (see Section 2.1.2). Spawning and trout production from Shovel Creek could be enhanced by KBRA activities that would increase actual spawning areas and instream flows.

Trout spawning has been documented in the mainstem Klamath River below J.C. Boyle Dam in the Bypass Reach (see Section 2.1.2). In the 1950s, before J.C. Boyle Dam and Powerhouse were built, adult rainbow trout would actively spawn in the Klamath River near the Frain Ranch area of the Peaking Reach (Adm. Law Judge 2006). Also, groundwater springs may provide additional mainstem spawning.

A prediction of future harvest potential is difficult. Using the 5.9 mi (9.5 km) of the Keno Reach as a control for the harvest of the proposed 43 mi (69.2 km) of natural free flowing waters, and assuming that overall harvest would be similar within each mile of redband/rainbow trout distribution, we estimate a 7 fold increase assuming spawning habitat does not limit the population increase.

This new 43 mile reach should continue to produce large trout up to 23 in (58.4 cm). With expanded area under the Proposed Action, it is possible that this new stretch of river could support a substantial population of fish and therefore a major trout fishery (Figure 7 – Line B).

5.3 Other Fish Species

There are no other native resident harvestable species that would be affected by the Proposed Action. Downstream of Keno Dam, the existing harvestable populations of non-native species would remain under current Conditions with Dams and be completely removed by the Proposed Action.

6.0 Conclusions

6.1 Suckers

Available data show that both LRS and SNS are declining under current conditions and that they could become extinct in the near future unless a major recruitment event occurs soon. The Proposed Action provides greater promise for preventing extinction of these species and for increasing overall population abundance and productivity. The key benefits of the Proposed Action to LRS and SNS stem from major habitat improvement activities in the Upper Klamath Lake and its tributaries that support these fishes. Specific details of most activities are not yet available, therefore this assessment is qualitative in nature and it assumes subsequent planning activities will target actions for each species and life stage. In general, habitat improvement activities will include lake level management, water quality improvements, and habitat restorations (wetlands and spawning and rearing habitat). Water quality in streams is expected to improve in response to greater instream flows (purchase of water rights) and to revegetation of the degraded riparian corridors. Water quality should increase in lake fringe areas adjacent to improved wetlands, which are important for survival of larval and juvenile suckers. Water quality of open water areas such as Agency Lake may improve, but the Panel does not anticipate improvement in water quality in most open water areas of Upper Klamath Lake. Spring habitats in Upper Klamath Lake are critical for LRS and SNS, especially lake spawning fish, and habitat projects are expected to target these areas. The primary goal of actions should be the recovery and delisting of LRS and SNS from the Endangered Species Act. Harvest other than limited ceremonial tribal harvest should only occur after a sustained population growth can be shown over a period of decades.

6.2 Redband/Rainbow Trout

Redband/rainbow trout currently support trophy recreational fisheries in tributaries of Upper Klamath Lake, the lake itself, and in free-flowing sections of the Keno Reach between Keno Dam and J.C. Boyle Reservoir. The Proposed Action is expected to increase trout populations in all areas.

Proposed habitat improvements, including water quality and quantity and riparian corridor improvements and protection, are anticipated to increase trout productivity in headwater and lower tributary areas of the Upper Klamath Lake basin. However, the level of improvement is uncertain in part because details of most activities have not been described. Recreational fishing opportunities would be expected to increase in proportion to the increase in trout abundance in all areas.

Following dam removal, the abundance of redband/rainbow trout in the free-flowing reach between Keno Dam and Iron Gate Dam could increase significantly. The amount of habitat with free flowing waters would increase by 43 mi (69.2 km) following dam removal but the quality of this habitat for supporting each life stage of redband/rainbow trout has not been carefully evaluated because 22-23 mi (35.4-37.0 km) of habitat remains under the reservoirs (Cunanen 2009); approximately 4 mi (6.4 km) of habitat has been adversely affected by the dewatered (100 cfs) flows in the bypass reach; and 17 mi (27.4 km) of habitat has been adversely affected by the daily fluctuating flows in the peaking reach (Adm. Law Judge Orders 2006). Existing trout and colonizing anadromous steelhead are expected to co-exist, as they do in other watersheds, although there may be shifts in abundance related to competition for space and food. An increase in abundance for redband/rainbow trout in the project reach could provide significantly more recreational fishing opportunities than the current trophy trout fisheries.

6.3 Bull Trout

The Proposed Action provides promise for preventing extinction of this species and for increasing overall population abundance and distribution. The primary goal of actions should be the recovery and delisting of bull trout from a threatened status under the federal ESA.

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APPENDIX A
Panelists' Resumes

RESUME

Mark Buettner
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Employment Overview

- Supervisory Fish Biologist for U.S. Fish and Wildlife Service, Ecosystem Restoration Office, Klamath Falls, Oregon 2003-2009 (GS-482-13)
- Senior Fish Biologist for Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, Oregon 1992-2003 (GS-482-12)
- Fish Biologist with U.S. Fish and Wildlife Service, Great Basin Complex Office, Reno Nevada 1980-1992 (GS-482-11)
- Research Associate with Colorado State University, Reno, Nevada 1978-1980
- Biological Technician with U.S. Forest Service, Shasta Trinity National Forest, Redding, California 1977-1978
- Graduate Student Assistant with California Department of Fish and Game, Weaverville, California 1976-1977
- Seasonal Aid with California Department of Fish and Game, Napa, California 1974

Education

- MS in Fishery Biology from Humboldt State University, Arcata CA (1978)
- BS in Fishery Biology from Humboldt State University (1976)
- Vista High School, Vista CA (1971)

Employment Profile

Supervisory Fish Biologist

2003-2009
Klamath Falls Fish and Wildlife Office
Klamath Falls, Oregon

Provide biological technical expertise to all operational aspects of investigations, consultations, and documentation relating to listed fish, fish and wildlife habitat and water quality in the upper Klamath River Basin. Developed an aquatic monitoring program for the Klamath Falls FWO to assess current status of key ecological indicators in the Upper Klamath watershed and evaluate the effectiveness of a watershed restoration program. FWS representative on a multidisciplinary/multiagency Science Team that developed a 5-Year action plan for aquatic habitat restoration and research critical uncertainties in the Upper Klamath Basin focused on listed fish recovery. Assisted with the development of and selection of ecosystem restoration proposals for funding through the FWS's Fish Passage, Hatfield and Partners for Fish and Wildlife Restoration Programs. The Klamath Falls FWO receives $1-3 million per year under these programs. Supervise the Monitoring Division (up to 5 employees) and serve as acting Field Supervisor of the office when the supervisor is out of the office.Primary technical lead for a complex biological opinion on the effects of operation of the Klamath Irrigation Project on listed fish species (Lost River sucker, shortnose sucker, coho salmon). Provided technical review of a NOAA Fisheries biological opinion on the effects of operation of the Klamath Project on threatened coho salmon. Provided technical input to FWS managers working with stakeholders on the Klamath River Restoration Agreement which proposes a $1 billion aquatic restoration program, removal of 4 hydroelectric dams, and reintroduction of anadromous fish into the upper Klamath Basin. Assisted the Forest Service and Oregon Department of Fish and Wildlife with population monitoring of threatened bull trout and non-native fish control. Over the last 10 years, worked with agencies and stakeholders to implement major projects to aid in the recovery of listed fish including removal of Chiloquin Dam ($14 million), purchase and restoration of the Williamson River Delta by TNC (6,000 acres; $10 million), construction of a new fishway at Link Dam ($3 million), and installation of a major fish screen complex ($14 million). FWS lead for revising the Lost River and Shortnose Sucker Recovery Plan.

Senior Fish Biologist
1992-2003
Bureau of Reclamation
Klamath Basin Area Office
Klamath Falls, Oregon

Served as Reclamation's technical expert for fisheries, aquatic habitat management and water quality in the Klamath Basin Area Office. Helped develop, design, and implement investigations on the status and effects of the Klamath Irrigation Project operations on endangered fish and their habitat including water quality. Served as a Contracting Officer Technical Representative for $1 million per year in listed fish, fish habitat and water quality research and monitoring projects. Prepared Endangered Species Act section 7 biological assessments on the effects of irrigation project operations on listed suckers and coho salmon, supervised up to 4 lower grade biologists and technicians, and served as a team member for a multi-agency ecosystem restoration program. Conducted and supervised annual endangered fish salvage activities in irrigation canals. Analyzed data and prepared technical reports on field investigation.

Fish Biologist
1980-1992
U.S. Fish and Wildlife Service
Great Basin Complex Office
Reno, Nevada

Coordinated research activities including cui-ui population dynamics, Ash Meadows endangered fish status surveys, Lost River and shortnose sucker life history investigations, and endangered Borax Lake chub population status surveys. Led a field study in Klamath Falls, Oregon to determine life history of endangered suckers in the upper Klamath River Basin. Principal investigator in status surveys of endangered sucker populations in California. Responsible for evaluation of the effect of old age on the viability of cui-ui eggs and larvae. Responsible for evaluation of the FWS Lahontan Cutthroat trout stocking program at Pyramid Lake, Nevada. Supervised crews that tagged juvenile trout at Lahontan National Fish Hatchery and recovered tags through a systematic creel census program and adult spawn run monitoring. Monitored trout and cui-ui spawning runs at the Marble Bluff Fishway Facility and evaluated fish passage success and made modifications with different ladder designs. Coordinated with the Pyramid Lake Paiute Tribe Fisheries Program for spawning of fish at the Marble Bluff Fishway Facility. Conducted life history research on the endangered cui-ui including radio and sonic telemetry, spawning habitat requirements, larval emigration, food habits, aging, and population dynamics. Supervised 1-4 biologists and technicians and analyzed data and wrote technical reports including peer reviewed journal articles.

Research Associate
1978-1980
Colorado State University
Cooperative Fishery Unit
Fort Collins, Colorado

Conducted microcosm studies at Pyramid Lake, Nevada to assess the impacts of increased salinity on the aquatic ecosystem. Monitored primary productivity, plant and animal community structure, bacterial activity and fish production in microcosms with 1, 1.5, and 2 times the salinity of Pyramid Lake water. Major responsibility was to monitor phytoplankton, periphyton, zooplankton, and macro-invertebrates in the microcosms. Analyzed data and wrote reports summarizing the research results. Co-authored several peer reviewed journal articles related to this research.

Training

Contract Officer Technical Representative
Fish Passage and Fishways
Fish Genetics and Conservation
Stream Corridor Restoration
Applying the NEPA process
Department of Interior Boat Operator Training
Electrofishing Certification
Basic Aviation Safety
Rotenone and Antimycin Use in Fish Management
Scuba certified
Larval Fishes Short Course
Investigating Fish Kills

Instream Flow Incremental Methodology (IFIM)
Creating and Using Wetlands for water quality improvement

Affiliations
American Fisheries Society
Audubon
The Nature Conservancy
Klamath Bird Observatory

Additional Information
Proficient in computer use including word processing, spreadsheets, data base, statistics, and email. Extensive experience in collaboration, technical writing, oral communication, interacting with managers, scientists, stakeholders, and the public. Operate 4-wheel drive vehicles, boats, ATVs.

Awards
Fishery Worker of the Year – Oregon Chapter of the American Fishery Society
Star Performance Awards for superior performance
    Bureau of Reclamation 1992-2002
    Fish and Wildlife Service 2003-2009

Publications
Buettner, M. 1978. Seasonal and Spatial Distribution of Zooplankton in Trinity Lake, California and associated environmental variables. MS Thesis. Humboldt State University, Arcata, CA.

Buettner, M. 1981. Evaluation of Lahontan National Fish Hatchery stocking program in Pyramid Lake, Nevada. Completion Report. U.S. Fish and Wildlife Service, Fishery Assistance Office, Reno, Nevada.

Buettner, M. 1985. Fish spawning run monitoring at the Marble Bluff Fishway from 1982-1986, Pyramid Lake, Nevada. Completion Report. U.S. Fish and Wildlife Service, Reno, Nevada.

Buettner, M. 1986. Evaluation of spawning runs at the Marble Bluff Fish Facility, Nixon, Nevada, 1978-1985. Fisheries Resources Report FR1/FAO-86-11, Portland, OR.

Buettner, M. 1987. Spawning runs from Pyramid Lake in 1986 and studies of cui-ui life history. Completion Report. U.S. Fish and Wildlife Service, Great Basin Complex, Reno, Nevada.

Buettner, M. and A McGie. 1987. Evaluate causes for the decline of the shortnose and Lost River suckers in Klamath Lake, Oregon. Annual Progress Report. Oregon Department of Fish and Wildlife, Portland, OR.

Buettner, M. and K. Johnson. 1988. History of fish stocking and fish management in Pyramid Lake, Nevada. Journal of Fisheries Management.

Buettner, M., J. Kann, and G.G. Scoppettone. 1988. Life history and ecological investigations of catostomids from the Upper Klamath Basin, Oregon. Annual Report. U.S. Fish and Wildlife Service, National Fisheries Research Center, Seattle Washington.

Buettner, M., M. Falter, and G. Scoppettone. 1989. Ecological investigations of catostomids from the Upper Klamath Lake basin, Oregon. Annual Report. U.S. Fish and Wildlife Service, National Fisheries Research Center, Seattle, Washington.

Buettner, M. and C. Scoppettone. 1990. Life history and status of Catostomids in Upper Klamath Lake, Oregon. U.S. Fish and Wildlife Service, National Fisheries Research Center, Reno Field Station, Nevada. Completion report.

Buettner, M., P. Rissler, and G. Scoppettone. 1990. Cui-ui embryo and yolk-sac larvae development and survival under different simulated fluctuating temperature regimes. Completion Report. U.S. Fish and Wildlife Service, National Fisheries Research Center, Seattle, Washington.

Buettner, M. and C. Scoppettone. 1991. Distribution and information on the taxonomic status of the Shortnose sucker, *Chasmistes brevirostris*, and Lost River sucker, *Deltistes luxatus*, in the Klamath River Basin, California. Completion report. CDFG Contract FC-8304. U.S. Fish and Wildlife Service, Seattle National Fishery Research Center, Reno Substation, Nevada.

Buettner, M. 1992. Potential refugial habitat for suckers in Upper Klamath Lake and Agency Lakes at different lake elevations. Letter to the Files. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, Oregon. 7 p.

Buettner, M. 1997. Upper Klamath Lake fish die-off, 3rd consecutive year-1997. Completion Report. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, OR. 7 p.

Buettner, M. 1998. Lost River and shortnose sucker spawning in the lower Lost River, Oregon. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, OR. 14 p.

Buettner, M. 2000. Link River Dam fish passage project scoping report. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, OR. 14 p.

Buettner, M. 2000. Analysis of Tule Lake water quality and sucker telemetry, 1992-1995. U.S. Bureau of Reclamation, Mid-Pacific Region, Klamath Basin Area Office. March 30, 2000.

Buettner, M. 2001. Inventory of water diversions in the Klamath Project service area that potentially entrain endangered Lost River and shortnose suckers. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, OR. 19 p.

Buettner, M. 2001. A-Canal entrainment reduction alternative assessment – decision support document. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, OR.

Buettner, M. 2002. Agency Lake Ranch operations report. U.S. Bureau of Reclamation, Mid-Pacific Region, Klamath Basin Area Office.

Buettner, M. 2005. Contributions of the Lost River to the recovery of federally listed Lost River and shortnose suckers. U.S. Bureau of Reclamation, Mid-Pacific Region, Klamath Basin Area Office. April 6, 2005.

Buettner, M., R. Larson, J. Hamilton, and G. Curtis. 2006. Contributions of Klamath reservoirs to federally listed sucker habitat and populations. Unpublished report. U.S. Fish and Wildlife Service, Klamath Falls and Yreka Fish and Wildlife Offices.

Buettner, M. 2007. Juvenile fish monitoring in the Sprague and Sycan rivers, Oregon 2005-2006. Completion Report. U.S. Fish and Wildlife Service, Klamath Falls Fish and Wildlife Office, Klamath Falls, OR. 20 p.

Buettner, M. 2008. Fish monitoring at habitat restoration sites on the Sprague and Sycan rivers, Oregon 2003-2004. U.S. Fish and Wildlife Service, Klamath Falls Fish and Wildlife Office, Klamath Falls, OR. 6 p.

Buettner, M. 2008. Klamath Project entrainment analysis for Upper Klamath Lake. Unpublished report. U.S. Fish and Wildlife Service. Klamath Falls Fish and Wildlife Office. April 2, 2008.

Buettner, M., J. Murphy, and R. Parrish. 2009. Juvenile fish emigration in the Wood, Williamson, and Sprague rivers, Oregon. Completion Report. U.S. Fish and Wildlife Service, Klamath Falls Fish and Wildlife Office, Klamath Falls, OR. 35 p.

Hodge, J. and M. Buettner. 2007. Sucker population monitoring in Tule Lake and Lower Lost River - 2006. Annual Report. U.S. Fish and Wildlife Service. Klamath Falls Fish and Wildlife Office, Klamath Falls, OR. 25 p.

Hodge, J. and M. Buettner. 2008. Sucker population monitoring in Tule Lake and the Lower Lost River – 2007. Annual Report. U.S. Fish and Wildlife Service. Klamath Falls Fish and Wildlife Office, Klamath Falls, OR. 17 p.

Hodge, J. and M. Buettner. 2009. Sucker population monitoring in Tule Lake and the Lower Lost River – 2008. Annual Report. U.S. Fish and Wildlife Service. Klamath Falls Fish and Wildlife Office, Klamath Falls, OR. 35 p.

Larson, R. and M. Buettner. 2009. Introgression of Lost River and shortnose suckers and how it might affect their conservation status under the ESA. Completion Report. U.S. Fish and Wildlife Service, Klamath Falls Fish and Wildlife Office, Klamath Falls, OR. 24 p.

Peck, B. and M. Buettner. 2000. Radio telemetry studies of adult shortnose and Lost River suckers in Upper Klamath Lake and tributaries, Oregon. Completion Report. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, OR.

Perkins, D.L. and G.G. Scoppettone and M. Buettner. 2000. Reproductive biology and demographics of endangered Lost River and Shortnose suckers in Upper Klamath Lake, Oregon. Completion Report. U.S. Geological Survey, Biological Resources Division, Western Fisheries Science Center, Reno Field Station, Reno, Nevada. 42 pp.

Piaskowski, R. and M.E. Buettner. 2003. Review of water quality and fisheries sampling conducted in Gerber Reservoir, OR with emphasis on the shortnose sucker and its habitat needs. Unpublished Report. US Bureau of Reclamation. Klamath Basin Area Office. Klamath Falls, OR. 82 p.

Scoppettone, G.G., M.E. Buettner, and G.A. Wedemeyer. 1986. Life history and status of the endangered cui-ui of Pyramid Lake, Nevada. U.S. Fish and Wildlife Service Research 1. 23 pp.

Scoppettone, G.G., S. Shea, and M.E. Buettner. 1995. Information on population dynamics of shortnose suckers and Lost River suckers in Tule and Clear Lakes. Completion Report. National Biological Service, Northwest Biological Science Center, Reno Field Station. 79 pp.

Scoppettone, G.G., M. Buettner, and P.H. Rissler. 1993. Effect of four fluctuating temperature regimes on cui-ui, *Chasmistes cujus,* survival from egg fertilization to swim-up, and size of larvae produced. Environmental Biology of Fishes 38:373-378.

Scoppettone, G.G., P.H. Rissler, and M.E. Buettner. 2000. Reproductive longevity and fecundity associated with nonannual spawning in cui-ui. Transactions of the American Fisheries Society 129:658-669.

Scoppettone, G.G., G.A. Wedemeyer, M.E. Buettner and H. Burge. 1983. Reproduction by the endangered cui-ui in the lower Truckee River. Transactions of the American Fisheries Society 112: 788-793.

U.S. Bureau of Reclamation. 1994. Biological assessment on long-term operations of the Klamath Project with special emphasis on Clear Lake operations. U.S. Bureau of Reclamation, Mid-Pacific Region, Klamath Basin Area Office, Klamath Falls, Or.

U.S. Bureau of Reclamation. 1996. Biological assessment on PacifiCorp and The New Earth Company Operations associated with the Klamath Project. U.S. Bureau of Reclamation, Mid-Pacific Region, Klamath Basin Area Office, June 14, 1996.

U.S. Bureau of Reclamation. 2001. A-Canal entrainment reduction alternative assessment: decision support document. U.S. Bureau of Reclamation, Mid-Pacific Region, Klamath Basin Area Office, December 6, 2001.

U.S. Bureau of Reclamation. 2001. Biological assessment of Klamath Project's continued operations on endangered Lost River and shortnose sucker. U.S. Bureau of Reclamation, Mid-Pacific Region, Klamath Basin Area Office, February 13, 2001.

U.S. Bureau of Reclamation. 2002. Final biological assessment. The effects of the proposed actions related to Klamath Project operation (April 1, 2002 - March 31, 2012) on federally-listed threatened and endangered species. U.S. Bureau of Reclamation, Mid-Pacific Region, Klamath Basin Area Office, February 25, 2002.

U.S. Fish and Wildlife Service. 2007. Formal consultation on the proposed relicensing of the Klamath hydroelectric project, FERC Project No. 2082, Klamath River, Klamath County, Oregon and Siskiyou County, California. Klamath Falls and Yreka Fish and Wildlife Offices. December 3, 2007.

U.S. Fish and Wildlife Service. 2008. Biological/Conference Opinion regarding the effects of the U.S. Bureau of Reclamation's Proposed 10-year Operation Plan (April 1, 2008 – March 31, 2018) for the Klamath Project and its effects on the endangered Lost River and shortnose suckers. Klamath Falls Fish and Wildlife Office and Yreka Fish and Wildlife Office. April 2, 2008.

Scientific Presentations

1978 – Pacific Fishery Biologist Annual Meeting
Distribution and abundance of zooplankton in Ruth and Trinity Reservoirs, Trinity County, California

1987 – Western Division of American Fisheries Society
History of Stocking and Lahontan Cutthroat Trout Management in Pyramid Lake, NV

1988 – Lost River and Shortnose Sucker Working Group
Life history and status of endangered Lost River and shortnose suckers in Upper Klamath Lake, Oregon

1993 – Oregon Chapter of American Fisheries Society
Effects of Klamath Project Operations on Endangered Lost River and shortnose suckers

1995 – Desert Fishes Council
Lost River and Shortnose sucker life history studies in the Upper Klamath Basin.

1998 – Oregon Chapter of American Fisheries Society
Adult Sucker Radio Telemetry Study on Upper Klamath Lake, Oregon

2000 – Oregon Chapter of American Fisheries Society
Update on Lost River and Shortnose Sucker Status

2002 – Upper Klamath Basin Sucker Summit
Review of Lost River and Shortnose sucker status

2004 – Upper Klamath Basin Science Workshop
Overview of Lost River and shortnose sucker spawning habitat

2007 – Upper Klamath Basin Sucker Summit
Fish Population Monitoring in the Sprague River, Oregon

2008 – Western Division of the American Fisheries Society
Sucker Recovery –Where are we and where do we need to go?

THOMAS DUNNE: CURRICULUM VITAE

ADDRESS

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tdunne@bren.ucsb.edu

PROFESSIONAL PREPARATION:

Cambridge Univ., Geography, B.A. 1964
Johns Hopkins University, Geography, Ph.D. 1969

APPOINTMENTS:

1995- Professor, Donald Bren School of Environmental Science and Management, and Department of Earth Science, University of California, Santa Barbara
1973-1995 Asst. Prof. to Professor, Dept. of Geological Sciences, Univ. of Washington (Chair 1984-1989)
1971-1973 Assistant Professor, Department of Geography, McGill University, Canada,
1969-1971 Visiting Professor, Department of Geography, University of Nairobi, Kenya.
1968-73 (WAE) Research Hydrologist, Water Resources Division, US Geological Survey, Washington DC
1966-1968 Research Associate, Agricultural Research Service, US Department of Agriculture, Vermont

CURRENT RESEARCH INTERESTS IN HYDROLOGY AND GEOMORPHOLOGY

1. Field and theoretical studies of drainage basin and hillslope evolution

2. Hydrology, sediment transport, and sedimentation in river channels and floodplains

3. Sediment transport, channel migration, and oxbow lake sedimentation in rivers of the Central Valley, California.

Thomas Dunne is a Professor of Environmental Science and Management, and of Earth Science at the University of California Santa Barbara. He conducts field and theoretical studies of drainage-basin, hillslope, and fluvial geomorphology, and in the application of hydrology, sediment transport, and geomorphology to landscape management and hazard analysis.

While working for the USDA Agricultural Research Service (1966-1969) and McGill University (1971-1973), he conducted research on the effects of topography, soil characteristics, and vegetation on runoff processes under rainfall and snowmelt in Vermont and Canada. While teaching at the University of Nairobi, Kenya (1969-1971), he initiated a long-running research interest in African environments, including experimental studies of runoff and erosion processes, and statistical studies and field surveys of the effects of land use on hillslope erosion and river-basin sediment yields. He continues to use data from the experimental studies to model sediment transport and hillslope evolution, one of his long-term research interests. He also conducted occasional studies of reservoir sedimentation, water quality, and erosion due to charcoal production and grazing. This work was supported by the Rockefeller, Guggenheim, and Beijer Foundations, the United Nations Development Programme, U.S. National Science Foundation, and Kenya government agencies between 1969 and 1991.

While teaching in the Department of Geological Sciences at the University of Washington (1973-1995), he studied landsliding and debris flows; drainage-basin sediment budgets in natural and managed forests; tephra erosion and debris-flow sedimentation on active volcanoes; and sediment transport and channel morphology in sand-bed and gravel-bed river channels. He also conducted several studies related to resource management, such as the impacts of gravel harvesting on the river-channel sedimentation and morphology; impacts of timber harvest on erosion and sedimentation; and effects of flow diversion and reservoir management on sedimentation. The work was funded by NSF, and various state agencies (Depts. of Ecology and of Natural Resources), and federal agencies (USFS, USGS, FEMA).

Since moving to California he has studied hydrology, sediment transport, and floodplain sedimentation in the Amazon River of Brazil and in the Andes Range and adjacent floodplains of eastern Bolivia. His work, funded by NSF and NASA, involved studies of runoff processes in forest and pastures, modeling of the runoff response of the Amazon River, channel and bed material surveys, floodplain coring to measure rates of sediment accumulation with isotopes, measurement and interpretation of channel change and floodplain features from satellite images, flow and sediment transport modeling in channels and floodplains, and erosion of the Andes Range and sedimentation in the adjacent foreland basin with meteoric and cosmogenic isotopes.

He and his students have studied runoff and erosion on rangeland hillslopes and small wildland and urbanized watersheds around Santa Barbara, and as well as sediment transport, channel change and oxbow lake sedimentation along the Sacramento River and its floodplain. With five biologist colleagues in the Bren School, his group now studies how physical and biological processes interact to create and maintain habitat for fish and their food sources in the Merced and San Joaquin Rivers, CA. Funds are provided by the California Bay-Delta Restoration Science Program and the California Department of Water Resources.

He has gained experience with geomorphic and hydrologic processes through research and consultation in many parts of the world, and has expressed some of that experience in teaching courses, advising government and international agencies, publishing journal articles, and co-authoring two textbooks.

HONORS

Fulbright Scholar, 1964
Robert E. Horton Award, American Geophysical Union, 1987
Member, National Academy of Sciences, 1988
Fellow, American Geophysical Union, 1989
Guggenheim Fellowship, 1989
Fellow, American Academy of Arts and Sciences, 1993
Fellow, California Academy of Sciences, 1996
National Research Council Wolman Distinguished Lecturer, 1997
National Academy of Sciences Warren Prize for Fluviatile Geology, 1998
Bren School Distinguished Teaching Award, 2002, 2008
American Geophysical Union Langbein Lecturer, 2003
Geological Society of America Easterbrook Distinguished Scientist Award, 2003
Borland Distinguished Lecturer in Hydraulics, Colorado State University, 2007
Linton Award, British Society for Geomorphology, 2008.
Elected Honorary Member, Japanese Geomorphological Union, 2009

SOME RECENT PUBLICATIONS

T. Dunne, J. A. Constantine, and M. B. Singer, The Role of Sediment Transport and Sediment Supply in the Evolution of River Channel Complexity and Floodplain Evolution, **Transactions Japanese Geomorphological Union**, 2010.

T. Dunne, D. V. Malmon, and S. M. Mudd, A rainsplash transport equation assimilating field and laboratory measurements, **Journal of Geophysical Research – Earth Surface,** 2009.

J. A. Constantine, T. Dunne, H. Piégay, and G. M. Kondolf, Controls on the alluviation of oxbow lakes by bed-material load along the Sacramento River, California, **Sedimentology**, 2009.

J. A. Constantine, S. R. McLean, T. Dunne, A Mechanism of Chute Cutoff along Large Meandering Rivers with Uniform Floodplain Topography, **Geological Society of America Bulletin**, 2009.

C. R. Constantine, T. Dunne, and G. J. Hanson, Examining the physical meaning of the bank erosion coefficient used in meander migration modeling, **Geomorphology**, 106, 242-252, 2009.

R. E. Beighley, K. G. Eggert, T. Dunne, Y. He, V. Gummadi and K. L. Verdin, Simulating Hydrologic and Hydraulic Processes Throughout the Amazon River Basin, **Hydrological Processes,** 23, 1221-1235, DOI: 10.1002/hyp.7252, 2009

J. A. Constantine and T. Dunne, Meander Cutoff and the Controls on the Production of Oxbow Lakes, **Geology**, 2008.

R. E. Beighley, T. Dunne and J.M. Melack**,** Impacts of climate variability and land use alterations on frequency distributions of terrestrial runoff loading to coastal waters in southern California, **Journal of the American Water Resources Association**, 44(1), 62-71, 2008.

T. W. Biggs, T. Dunne, D. Roberts, and E. Matricardi, The rate and extent of deforestation in watersheds of the southwestern Amazon basin: implications for regional stream biogeochemistry, **Ecological Applications**, 18(1), 31–48, 2008.

L. A. K. Mertes and T. Dunne, The effects of tectonics, climatic history, and sea-level history on the form and behavior of the modern Amazon River, In: **Large Rivers** (ed. A. Gupta), Wiley & Sons, pp. 115-144, 2007

D. Alsdorf, P. Bates, J. Melack, M. Wilson, and T. Dunne, Spatial and temporal complexity of the Amazon flood measured from space, **Geophysical Research Letters**, 34, L08402, doi:10.1029/2007GL029447, 2007

E. B. Safran, A. Blythe, T. Dunne, Spatially Variable Exhumation Rates in Orogenic Belts: An Andean Example, **Journal of Geology**, 114, 665-681, 2006.

R. E. Aalto, T. Dunne, and J-L Guyot, Geomorphic controls on Andean denudation, **Journal of Geology,** 114, 85-99, 2006.

J. M. de Moraes, A. E. Schuler, T. Dunne, R. O. Figueiredo, and R. L. Victoria, Water storage and runoff processes in plinthic soils under forest and pasture in Eastern Amazonia, **Hydrological Processes**, 20 (12), 2509-2526, 2006

M. B. Singer and T. Dunne, Modeling the decadal influence of river rehabilitation scenarios on flow and sediment transport in large, lowland river basins, **Water Resources Research**, 42, W12415, doi:10.1029/2006WR004894, 2006

E. B. Safran, P. Bierman, R. Aalto, T. Dunne, K. X Whipple, and M. Caffee, Erosion rates driven by channel network incision in the Bolivian Andes, **Earth Surface Processes and Landforms**, 30 (8):1007-1024, 2005.

D. V. Malmon,S. L. Reneau, T. Dunne, D. Katzman, and P. G. Drakos, Influence of sediment storage on downstream delivery of contaminated sediment, **Water Resources Research,** 41, W05008, doi:10.1029/2004WR003288, 2005

D. V. Malmon, S. L. Reneau, and T. Dunne, Sediment sorting by flash floods, **Journal of Geophysical Research – Earth Surface**, 109(F2), 2004**.**

E. J. Gabet and T. Dunne, A stochastic sediment delivery model for a steep, Mediterranean landscape, **Water Resour. Res.,** 39, doi:10.1029/2003 R00234, 2003.

OTHER PROFESSIONAL ACTIVITIES

National Research Council Committees
- Environmental Aspects of National Materials Policy, 1972-73
- International Environmental Programs, 1979-82
- Working Group on Managemt of Renewable Natural Resources in Nepal, Kathmandu, 1981
- U. S. Army Basic Research, 1983-88
- U. S. Geological Survey Water Resources Research, 1987-89
- Opportunities in the Hydrological Sciences, 1987-89
- Alluvial Fan Flooding, 1994-96
- Future Roles, Challenges, and Opportunities for the U.S. Geological Survey, 1998-2000
- Water Resources Activities of the U.S. Geological Survey, 2006-2009
- Challenges and Opportunities in Earth Surface Processes, 2007-2009

Missouri River Recovery and Associated Sediment Management Issues, 2008-2010
U.S. National Committee for the International Union of Geological Sciences, 2009-13
Sustainable Water and Environmental Management in the California Bay-Delta, 2010-2013

United Nations

UNESCO Research team on Nzoia R., Kenya, 1970-71
FAO Consultant on Soil Erosion and Desertification in Kajiado District, Kenya, 1976
FAO Committee on Soil Erosion and Soil Conservation in Developing Countries, Rome, 1976
FAO/UNEP Committee on a Methodology for Assessing World Soil Degradation, Rome, 1978

Other Committees

Kenya National Committee on the Human Environment, Nairobi, 1970-71
Washington State Governor's Commission on Snohomish R. Basin, 1975
International Geographical Union, Commission on Field Experiments in Geomorphology, 1976-84 (Secretary, 1980-84).
Geological Society of America, Committee on the Penrose Medal, 1988-1990; Co-chair of Program Committee for 1994 Annual Meeting.
American Geophysical Union, Committee on the Horton Medal, 1990-1994, (Chair 1992-1994); Union Committee of Fellows (1992-1994)
Oregon State Legislature, Blue Ribbon Panel on Anadromous Fish Populations and Forest Practices, 1993-1995.
State of California Bay-Delta Ecosystem Restoration Program, Scientific Review Panel, 1997.
MEDEA Project on the Use of Remote Sensing in Environmental Analysis, 1997-2000
California Department of Forestry and Fire Protection/Univ. of California Committee on the Scientific Basis on the Prediction of Cumulative Watershed Effects (chair), 1998-2001.
State of Washington Panel on Salmon Conservation Validation Monitoring, 2000.
State of California Bay-Delta Ecosystem Restoration Program Science Board, 2000-2005.
U.S. Fish and Wildlife Service, Adaptive Management Forum for San Joaquin River Restoration, 2001-2003.
Sustainable Ecosystems Institute, Portland, Scientific Panel on the Columbia River Channel Improvement Project, 2001.
State of California Bay-Delta Program Independent Science Board, 2003- 2005(Chair).
Iraq Foundation, Eden Again Project, Technical Advisory Panel on Restoration of the Mesopotamian Marshlands, 2003.
National Academy of Sciences Warren Award Committee (Chair 2004, 2006)
American Institute of Hydrology Award Committees (Theis Award 2006; Linsley Award 2007)
Sustainable Ecosystems Institute, Portland, Scientific Panel to Review the Missouri River Pallid Sturgeon Restoration Project (2008)
National Science Foundation Steering Committee for the Community Surface Dynamics Modeling System (2007-2009)
National Science Foundation, Steering Committee for MARGINS (2008-2009).
National Science Foundation, Review Committee for the Hydrological Synthesis Project (2008-2011)
California Bay-Delta Conservation Program -- Independent Science Advisor on Adaptive Management (2008-2009)
US Department of the Navy, Naval Research Laboratory, Marine Geosciences Division, External Review of Research Program on Battlespace Environments and Undersea Warfare Technology (2009)

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CURRICULUM VITAE

GREGORY T. RUGGERONE

EDUCATION

Ph.D.	Fisheries, University of Washington, 1989.
M.S.	Fisheries, University of Washington, 1981.
B.S.	Biological Sciences, University of California, Irvine, 1978.

EXPERIENCE

1993-present	Vice-President, Fisheries Scientist, Natural Resources Consultants, Inc. Responsible for salmon investigations in the Pacific Northwest and Alaska. Affiliated research scientist, Alaska Salmon Program, School of Fisheries, University of Washington.
1990-1993.	Principal Fisheries Biologist. University of Washington, Fisheries Research Institute. Project Leader/ Co-PI, Alaska Salmon Program. Responsible for directing several research projects at FRI's Alaska field stations and supervision of graduate students.
1989-1990.	Senior Fisheries Biologist. University of Washington, Fisheries Research Institute. Project Leader for the Alaska Salmon Program (see above responsibilities).
1984-1989.	Predoctoral Research Associate. University of Washington, Fisheries Research Institute. Project Leader for the Chignik Lakes Salmon Research Program. Responsible for directing research projects and supervision of students.
1982-1984.	Fisheries Biologist. Jones & Stokes Associates, Inc. Responsible for environmental studies related to fish and fisheries in Alaska, Washington and California.
1982.	Consultant. BioSonics, Inc. Examined juvenile salmon migration at a Columbia River dam using hydroacoustic techniques.
1979-1981.	Research Assistant. University of Washington, Fisheries Research Institute. Field research on salmon at the Wood River lakes, Alaska.

1978-1979. Biologist. California Department of Fish and Game. Assisted several marine fisheries projects, including the annual CALCOFI anchovy survey.

1978. Biologist. University of California, Irvine. Department of Ecology and Evolutionary Biology. Received Student-Originated-Studies grant from the National Science Foundation to examine the effects of groundwater removal on natural spring communities in the Owens Valley, CA.

1977-1978. Lab Technician. University of California, Irvine. Department of Ecology and Evolutionary Biology. Field biologist for rocky intertidal studies.

PROFESSIONAL SERVICE

Society Memberships

American Institute of Fishery Research Biologists, NW District Director (1993-1994), Regional Director (1994-1995)
American Fisheries Society

Scientific Referee

Aquatic Living Resources
Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative
American Fisheries Society
Canadian Journal of Fisheries and Aquatic Sciences
First International Symposium on GIS in Fishery Science
Fisheries Oceanography
Fishery Bulletin
Fourth World Fisheries Congress, American Fisheries Society
Gulf of Alaska Ecosystem Monitoring Program (GEM)
Gut Shop 1993
Marine Stewardship Council
National Science Foundation
Nature
North American Journal of Fisheries Management
North Pacific Research Board
North Pacific Anadromous Fish Commission
Marine Stewardship Council
Ohio Sea Grant College Program
Pacific Salmon and Their Ecosystems: Status and Future Options
PICES
Reviews in Fish Biology and Fisheries
Transactions of the American Fisheries Society
West Coast National Undersea Research Center, NOAA

Committees

Science Technical Committee, Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative
Chignik Regional Aquaculture Association, Scientific Advisor
Independent Scientific Advisory Board, Columbia River, Ad Hoc member

AWARDS AND SCHOLARSHIPS

American Institute Fisheries Research Biologists, Research Award, 1992 (Visiting scientist in Russia)
John Cobb Memorial Scholarship, 1989
American Institute Fisheries Research Biologists, Research Award, 1988
Seattle Poggie Club (Fisheries) Scholarship, 1986
National Science Foundation Student-Originated-Studies Grant, 1978
University of California, Irvine President's Council Grant, 1977
Dean's Honor List: 1974, 1975, 1976, 1977

SUPERVISION OF GRADUATE STUDENT RESEARCH

Griffiths, J. 2009. Assessing the implications of changing geomorphology and climate on the habitat characteristics of Black Lake, Alaska. M.S. Thesis. University of Washington, Seattle.

Westley, P. 2007. Biocomplexity and rapid natural habitat change in the Chignik Lake system, Alaska. M.S. Thesis. University of Washington, Seattle.

Chasco, B. 2004. Inseason run size forecasting of Chignik sockeye salmon. M.S. Thesis. University of Washington, Seattle.

Harvey, C.J. 1994. Upstream migration of fishes in Black River, Chignik Lakes, Alaska. M.S. Thesis. University of Washington, Seattle. 154 p.

Bumgarner, J.D. 1993. Long-term trends in the growth of sockeye salmon from the Chignik Lakes, Alaska. M.S. Thesis. University of Washington, Seattle. 86 p.

Hanson, R. 1992. Brown bear (*Ursus arctos*) predation on sockeye salmon spawners in two tributaries of the Wood River Lake system, Bristol Bay, Alaska. M.S. Thesis. University of Washington, Seattle. 124 p.

Berejikian, Barry A.. 1992. Feeding Ecology of Rainbow Trout with Comparisons to Arctic Char in Iliamna Lake, Alaska. M.S. Thesis. University of Washington, Seattle. 72 p.

Zimmermann, M. 1991. Trends in the freshwater growth of sockeye salmon from the Wood River Lakes and Nushagak Bay, Alaska. M.S. Thesis. University of Washington, Seattle. 119 p.

PUBLICATIONS

Journals and Book Chapters

Ruggerone, G.T., J.L. Nielsen, and B.A. Agler. 2009. Linking marine and freshwater growth in western Alaska Chinook salmon, *Oncorhynchus tshawytscha*. Journal of Fish Biology 75: In press.

Ruggerone, G.T., J.L. Nielsen, and B.A. Agler. 2009. Climate, growth and population dynamics of Yukon River Chinook salmon. North Pacific Anadromous Fisheries Commission Bulletin. In Press.

Ruggerone, G.T., and J.L. Nielsen. 2009. A review of growth and survival of salmon at sea in response to competition and climate change. American Fisheries Society Symposium 70: In press.

Ruggerone, G.T., R.M. Peterman, B. Dorner, and K.W. Myers. 2009. Magnitude and trends in abundance of hatchery and wild pink, chum, and sockeye salmon in the North Pacific Ocean. In review.

Ruggerone, G.T., S. Goodman, and R. Miner. 2009. Behavioral response and survival of juvenile coho salmon to pile driving sounds. In review.

Westley, P.A.H., R. Hilborn, T.P. Quinn, G.T. Ruggerone, and D.E. Schindler. 2008. Long-term changes in rearing habitat and downstream movement by juvenile sockeye salmon (*Oncorhynchus nerka*) in an interconnected Alaska lake system. Ecology of Freshwater Fish 17:443-454.

Ruggerone, G.T., J.L. Nielsen, and J. Bumgarner. 2007. Linkages between Alaskan sockeye salmon abundance, growth at sea, and climate, 1955-2002. Deep Sea Research II 54:2776-2793.

Rand, P.S., C.P. Kellon, X. Augerot, M. Goslin, J.R. Irvine, and G.T. Ruggerone. 2007. Comparison of sockeye salmon (*Oncorhynchus nerka*) monitoring in the Fraser River basin, British Columbia, Canada and Bristol Bay, Alaska. North Pacific Anadromous Fish Commission Bulletin 4:271-284.

Nielsen, J.L. and G.T. Ruggerone. 2007. Climate Change and a Dynamic Ocean Carrying Capacity: Growth and Survival of Pacific Salmon at Sea. *Proceedings Pacific Salmon Environment and Life History Models: Advancing Science for Sustainable Salmon.* American Fisheries Society Symposium, Anchorage, AK. September, 2005. In press.

Ruggerone, G.T. and F. Goetz. 2004. Survival of Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*) in response to climate-induced competition with pink salmon (*O. gorbuscha*). Canadian Journal Fisheries and Aquatic Sciences 61:1756-1770.

Ruggerone, G.T., and J.L. Nielsen. 2004. Evidence for competitive dominance of pink salmon (*Oncorhynchus gorbuscha*) over other salmonids in the North Pacific Ocean. Reviews in Fish Biology and Fisheries. 14:371-390.

Ruggerone, G.T., M. Zimmermann, K.W. Myers, J.L. Nielsen, and D.E. Rogers. 2003. Competition between Asian pink salmon (*Oncorhynchus gorbuscha*) and Alaskan sockeye salmon (*O. nerka*) in the North Pacific Ocean. Fisheries Oceanography. 12:3:209-219.

Nielsen, J. L. and G. T. Ruggerone. 2005. Global change, anthropomorphic effects and nonlinearity in Bering Sea sockeye salmon populations. *In* V.R. Burkett, D. A. Wilcox, R. Stottlemyer, W. C. Barrow, D. B. Fagre, J. Barton, J. Price, J. L. Nielsen, C. Allen, D. L. Peterson, G. Ruggerone, and T. Doyle. Nonlinear dynamics in ecosystem response to climate change: Case studies and resource management implications. Ecological Complexity 2: 357-394.

Ruggerone, G.T., E. Farley, J. Nielsen, and P. Hagen. 2005. Seasonal marine growth of Bristol Bay sockeye salmon (*Oncorhynchus nerka*) in relation to competition with Asian pink salmon (*O. gorbuscha*) and the 1977 ocean regime shift. Fishery Bulletin 103:2:355-370.

Ruggerone, G.T., and D. Rogers. 2003. Multi-year effects of high densities of sockeye salmon spawners on juvenile salmon growth and survival: a case study from the *Exxon Valdez* oil spill. Fisheries Research. 6:379-392.

Quinn, T.P., S.M. Gende, G.T. Ruggerone and D.E. Rogers. 2003. Density dependent predation by brown bears (*Ursus arctos*) on sockeye salmon (*Oncorhynchus nerka*). Canadian Journal of Fisheries and Aquatic Sciences 60: 553-562.

Ruggerone, G.T., J. Nielsen, E. Farley, S. Ignell, P. Hagen, B. Agler, D. Rogers, J. Bumgarner. 2002. Long-term trends in annual Bristol Bay sockeye salmon scale growth at sea in relation to sockeye abundance and environmental trends, 1955-2000. North Pacific Anadromous Fish Commission Tech. Rept. 4:56-58.

Ruggerone, G.T., R. Hansen and D. Rogers. 2000. Selective predation by brown bears (*Ursus arctos*) foraging on spawning sockeye salmon. Canadian Journal of Zoology 78:6:974-981.

Ruggerone, G.T. 2000. Differential survival of juvenile sockeye and coho salmon exposed to low dissolved oxygen during winter. Journal Fish Biology 56:1013-1016.

Mahnken, C., G. Ruggerone, W. Waknitz, and T. Flagg. 1998. A historical perspective on salmonid production from Pacific rim hatcheries. North Pacific Anadromous Fish Commission Bulletin 1:38-53.

Harvey, C.J., G.T. Ruggerone, and D.E. Rogers. 1997. Migrations of three-spined stickleback, nine-spined stickleback, and pond smelt in the Chignik catchment, Alaska. Journal of Fish Biology. 50: 1133-1137.

Ruggerone, G.T and C.J. Harvey. 1995. Age-specific use of habitat by juvenile coho salmon and other salmonids in the Chignik Lakes Watershed, Alaska. Pages 45-60 *in* Salmon Ecosystem Restoration: Myth and Reality (M.L. Keefe, ed.). Proceedings of the 1994 Northeast Pacific Chinook and Coho Salmon Workshop. American Fisheries Society. Eugene, OR.

Rogers, D.E. and G.T. Ruggerone. 1993. Factors affecting the marine growth of Bristol Bay sockeye salmon. Fisheries Research 18: 89-103.

Ruggerone, G.T and D.E. Rogers. 1992. Predation of sockeye salmon fry by juvenile coho salmon in the Chignik Lakes, Alaska: implications for salmon management. North American Journal of Fisheries Management. 12: 87-102.

Ruggerone, G.T. 1992. Threespine stickleback aggregations create potential predation refuge for sockeye salmon fry. Canadian Journal of Zoology 70: 1052-1056.

Ruggerone, G.T. 1992. Predation on sockeye salmon by fish and wildlife in Alaska. Pp. 20-21. In C.D. Levings and G.A. Hunter (eds), An Account of a Workshop on Research Approaches to Predation/Competition Questions in River Fish Communities. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2150.

Rogers, D.E., and G.T. Ruggerone. 1992. FRI forecasts of the 1992 sockeye run to Bristol Bay. Pp. 13-16 *in* 1992 Alaska Salmon Markets, G. Knapp (ed.). University of Alaska, Fairbanks.

Ruggerone, G.T. 1991. Salmon redux (salmon population resilience and habitat in Alaska). BioScience 41: 284.

Ruggerone, G.T. 1991. Partial xanthism in an adult chum salmon (*Oncorhynchus keta*) near Chignik, Alaska. California Fish and Game 77: 55-56.

Ruggerone, G.T, T.P. Quinn, I. McGregor and T.D. Wilkinson. 1990. Horizontal and vertical movements of maturing steelhead trout, *Oncorhynchus mykiss*, in Dean and Fisher channels, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 47: 1963-1969.

Ruggerone, G.T. 1989. Coho salmon predation on juvenile sockeye salmon in the Chignik Lakes, Alaska. Ph.D. Dissertation. University of Washington, Seattle. 151 p.

Ruggerone, G.T. 1989. Gastric evacuation of single and multiple meals by piscivorous coho salmon, *Oncorhynchus kisutch*. Environmental Biology of Fishes 26: 143-147.

Ruggerone, G.T. 1989. Gastric evacuation rates and daily ration of piscivorous coho salmon (*Oncorhynchus kisutch*) Walbaum. Journal of Fish Biology 34: 451-463.

Ruggerone, G.T. 1986. Consumption of migrating juvenile salmonids by gulls foraging below a Columbia River dam. Transactions of the American Fisheries Society 115: 736-742.

Perkins, D.J., B.N. Carlsen, R.N. Miller, C.M. Rofer, G.T. Ruggerone, M.F. Fredstrom, and C.S. Wallace. 1984. Effects of groundwater removal on natural spring communities in the Owens Valley, CA. Pp. 515-527 *in* R. E. Warner and K.M. Hendrix, eds. California Riparian Systems: Ecology, Conservation, and Productive Management. University of California Press, Berkeley, CA.

Ruggerone, G.T. and D.E. Rogers. 1984. Arctic char predation on migrating sockeye smolts at Little Togiak River, Alaska. Fishery Bulletin 82: 401-410.

Technical Reports

Rogers, D.E. and G.T. Ruggerone. 1980. Alaska salmon studies: The study of red salmon in the Nushagak District. Ann. Rep. FRI-UW-8019. University of Washington, Seattle. 48 p.

Ruggerone, G.T. 1981. Arctic char predation on migrating sockeye smolts at Little Togiak River, Alaska. M.S. Thesis. Fisheries Research Institute, University of Washington, Seattle. 57 p.

Ruggerone, G.T. 1982. Salmonid habitat quality of 22 creeks in the Mt. Baker/Snoqualmie National Forest, Washington. Prepared for the U.S. Forest Service with Jones & Stokes Associates, Bellevue, WA. 40 p.

Ruggerone, G.T. and R. Denman. 1982. Salmonid spawning and rearing habitat survey: Illabot Creek. Prepared for Seattle City Light with Jones & Stokes Associates, Bellevue, WA. 15 p.

Ruggerone, G.T. 1983. Fishery enhancement potential of the Hanford Reach, Columbia River. Prepared for U.S. Army Corps Engineers, Seattle District, with Jones & Stokes Associates, Bellevue, WA. 64 p.

Van Veldhuizen, H. and G.T. Ruggerone. 1983. Analysis of Ocean Discharge Criteria Evaluation limitations for the St. George Basin (Lease Sale 70, southeastern Bering Sea). Prepared for the Environmental Protection Agency with Jones & Stokes Associates, Bellevue, WA.

Van Veldhuizen, H. and G.T. Ruggerone. 1983. Analysis of Ocean Discharge Criteria Evaluation limitations for Navarin Basin (Lease Sale 83, Bering Sea). Prepared for the Environmental Protection Agency with Jones & Stokes Associates, Bellevue, WA. 37 p.

Van Veldhuizen, H., J. Cabreza, G.T. Ruggerone and others. 1983. Ocean Discharge Criteria Evaluation: Diapir Field OCS Lease Sale 71 (Arctic Ocean). Prepared for the Environmental Protection Agency with Jones & Stokes Associates, Bellevue, WA. 175 p.

Ruggerone, G.T., and M. Green. 1984. San Antonio Creek hydroelectric project: Exhibit E. Application for exemption for a small hydroelectric project from licensing. Prepared for Jones & Stokes Associates, Sacramento, CA. 22 p. 1984.

Ruggerone, G.T. 1984. Review of the Draft EIS (fisheries section) for the Susitna River, Alaska, hydroelectric project. Prepared for the Environmental Protection Agency with Jones & Stokes Associates, Bellevue, WA. 41 p.

Van Veldhuizen, H., R. Denman, G.T. Ruggerone and A. Godbey. 1984. Environmental assessment of alternative seafood waste disposal methods at Akutan Harbor, Alaska. Prepared for the Environmental Protection Agency with Jones & Stokes Associates, Bellevue, WA. 97 p.

Van Veldhuizen, H., J. Cabreza, G.T. Ruggerone and others. 1984. Ocean Discharge Criteria Evaluation: Gulf of Alaska- Cook Inlet OCS Lease Sale 88 and state lease sales located in Cook Inlet. Prepared for the Environmental Protection Agency with Jones & Stokes Associates, Bellevue, WA. 230 p.

Conrad, R.H., and G.T. Ruggerone. 1985. Stock composition of the 1984 sockeye salmon run to the Chignik Lakes estimated using scale patterns and linear discriminant functions. Alaska Dept. Fish and Game Technical Report No. 151. 43 p.

Ruggerone, G.T., and D.E. Rogers. 1986. Chignik Sockeye Studies: Aerial survey of spawning coho salmon along the southern Alaska Peninsula. FRI-UW-8607. University of Washington, Seattle. 40 p.

Ruggerone, G.T., Q. Stober and H. Senn. 1986. An environmental assessment of the resident trout hatchery on the Colville Indian Reservation. Prepared for the Bonneville Power Administration with Jones & Stokes Associates, Bellevue, WA. 59 p. + appendices.

Ruggerone, G.T., B. Smith and S.B. Mathews. 1986. Effects of water flow fluctuations caused by hydropower operations on sport catches of steelhead trout in the Cowlitz River, Washington. Data report prepared for the City of Tacoma.

Van Veldhuizen, H., G.T. Ruggerone and others. 1988. A best professional judgment on Quartz Hill mine tailings disposal in Boca de Quadra, Alaska with reference to Ocean Discharge

Criteria. Final Report. Prepared for the Environmental Protection Agency with Jones & Stokes Associates, Bellevue, WA. 125 pp. + appendices.

Ruggerone, G.T., and D.E. Rogers. 1988. Chignik Sockeye Studies: gastric evacuation rates and daily ration of juvenile coho salmon. FRI-UW-8810. University of Washington, Seattle. 27 p.

Ruggerone, G.T., and D.E. Rogers. 1989. Chignik Sockeye Studies: consumption of sockeye salmon fry by juvenile coho salmon in the Chignik Lakes, Alaska: implications for salmon management.. Ann. Rept. to Nat. Mar. Fish. Serv. FRI-UW-8914. University of Washington, Seattle. 31 p.

Ruggerone, G.T., S.B. Mathews, T. Iverson and R.W. Tyler. 1989. Annotated bibliography: predator control programs and methods for capturing northern squawfish. Pp. 319-354 *in* A.A. Nigro, ed. Developing a predation index and evaluating ways to reduce salmonid losses to predation in the Columbia River Basin. Bonneville Power Administration, Portland, OR.

Mathews, S.B., T. Iverson and R.W. Tyler and G.T. Ruggerone. 1989. Evaluation of harvesting technology for potential northern squawfish commercial fisheries in Columbia River reservoirs. Pp. 278-318 *in* A.A. Nigro, ed. Developing a predation index and evaluating ways to reduce salmonid losses to predation in the Columbia River Basin. Bonneville Power Administration, Portland, OR.

Rogers, D.E., and G.T. Ruggerone. 1989. Bristol Bay salmon forecasts for 1990 and statistics of North American salmon. Annual Report to Pacific Seafood Processors Association. University of Washington, Seattle. 21 p.

Ruggerone, G.T., and R. Denman. 1990. Hydrological characterization of lower Alec River and Black Lake near Chignik, Alaska. Progress report to the Chignik Seiners Association. 10 p.

Alverson, D.L., D.E. Rogers, J.A. Crutchfield, D.W. McNair, J.A. June, J.B. Suomala and G.T. Ruggerone. 1990. Preliminary 1987 Cook Inlet oil spill studies. Prepared with Natural Resources Consultants for Faegre and Benson. 136 p.

June, J.A., G.T. Ruggerone and D.E. Rogers. 1990. Report on the upper Cook Inlet 1987 sockeye salmon season. Prepared with Natural Resources Consultants for Faegre and Benson. 56 p.

Rogers, D.E., and G.T. Ruggerone. 1990. Bristol Bay salmon forecasts for 1991 and statistics of North American salmon. Annual Report to Pacific Seafood Processors Association. University of Washington, Seattle. 21 p.

Rogers, D.E., B. Rogers, G. Ruggerone, D. Helton, L. Patterson and M. Zimmermann. 1990. Alaska salmon research. Annual Report (1989) to Pacific Seafood Processors Association. FRI-UW-9002. University of Washington, Seattle. 27 p.

June, J.A., G.T. Ruggerone and D.E. Rogers. 1991. Report on the upper Cook Inlet 1989 sockeye salmon season. Prepared with Natural Resources Consultants for Faegre and Benson. 97 p.

Rogers, D.E., B. Rogers, G. Ruggerone, L. Patterson and M. Zimmermann. 1991. Alaska salmon research. Annual Report (1990) to Pacific Seafood Processors Association. FRI-UW-9101. University of Washington, Seattle. 31 p.

Ruggerone, G.T. 1991. Evidence for morphological and behavioral responses of juvenile sockeye salmon to size-biased predation. Ann. Rept. to Nat. Mar. Fish. Serv. FRI-UW-9107. University of Washington, Seattle. 18 p.

Ruggerone, G.T., D. Helton and D.E. Rogers. 1991. Potential factors influencing the large annual fluctuations of adult sockeye salmon returning to Black Lake, Alaska. FRI-UW-9117. University of Washington, Seattle. 15 p.

Rogers, D.E., and G.T. Ruggerone. 1991. Bristol Bay salmon forecasts for 1992. Annual Report to Pacific Seafood Processors Association. University of Washington, Seattle. 27 p.

Ruggerone, G.T., C. Harvey, J. Bumgarner. and D.E. Rogers. 1992. Investigations of salmon populations, hydrology, and limnology of the Chignik Lakes, Alaska. FRI-UW-9211. University of Washington, Seattle. 30 p.

Ruggerone, G.T. 1992. Winter ecology of sockeye salmon in the Chignik Lakes, Alaska. FRI-UW-9214. University of Washington, Seattle. 33 p.

Ruggerone, G.T. 1993. 1989 Chignik salmon harvest had there been no *Exxon Valdez* oil spill. Prepared for Exxon Plaintiff's Litigation Joint Venture by Natural Resources Consultants, Inc.

Ruggerone, G.T. 1993. 1989 Balboa-Stepovak harvest had there been no *Exxon Valdez* oil spill. Prepared for Exxon Plaintiff's Litigation Joint Venture by Natural Resources Consultants, Inc.

Ruggerone, G.T., C. Harvey, J. Bumgarner. and D.E. Rogers. 1993. Investigations of salmon populations, hydrology, and limnology of the Chignik Lakes, Alaska, during 1992. FRI-UW-9302. University of Washington, Seattle. 59 p.

Rogers, D.E., T. Quinn, B. Rogers, and G. Ruggerone. 1993. Alaska salmon research in 1992: Bristol Bay. FRI-UW-9303. University of Washington, Seattle. 36 p.

Ruggerone, G.T. 1993. Winter investigations of salmon in the Chignik Lakes, Alaska, during 1993. Prepared for the Chignik Regional Aquaculture Association by Natural Resources Consultants, Inc. 41 p.

Ruggerone, G.T., and J. June. 1994. Effects of the *Braer* oil spill on the marine resources of the Shetland Islands. Prepared for the Shetland Seafood Consortium by Natural Resources Consultants, Inc. 120 p.

Denman, R.A., and G.T. Ruggerone. 1994. Effects of beaver colonization on the hydrology and spawning habitat of sockeye salmon in the Chignik Lakes, Alaska. Prepared for the Chignik Regional Aquaculture Association by Natural Resources Consultants, Inc. 56 p.

Ruggerone, G.T., and D.E. Rogers. 1994. Harvest rates of Upper Cook Inlet-bound sockeye salmon in the Kodiak Management Area's commercial salmon fishery. Prepared for the Kodiak Island Borough Salmon Working Group by Natural Resources Consultants, Inc. 46 p.

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Ruggerone, G.T. and S. Ralph. 1994. Initial water quality assessment of the Upper Hood Canal Watershed. Prepared for Kitsap County Department of Community Development, Port Orchard, WA. Natural Resources Consultants, Inc. 54 p + appendix.

Ruggerone, G.T., S. Kuchta, D. Bregar, and H. Senn, and G. Morishima. 1995. Database of propagated anadromous Pacific salmon, steelhead and cutthroat trout, 1950-1993. Prepared for the Northwest and Alaska Fisheries Science Center, National Marine Fisheries Service, Seattle, WA.

Ruggerone, G.T. 1995. Investigation of salmon at Enatai Beach Park, Lake Washington. Prepared for the City of Bellevue by Natural Resources Consultants, Seattle, WA. 45 p.

Simpson, P.K., G.T. Ruggerone, M. Freeberg. 1995. Fish return forecasting with neural networks. Phase I Final Report prepared by Scientific Fishery Systems and Natural Resources Consultants for Small Business Innovative Research Program (SBIR), National Science Foundation (DMI-9461197). 29 p.

Ruggerone, G.T. 1995. Preseason forecast of sockeye salmon run timing in Bristol Bay, Alaska, 1995. Prepared for Pacific Seafood Processors Association by Natural Resources Consultants, Seattle, WA. 16 p.

Ruggerone, G.T. 1995. Winter investigations of salmon in the Chignik Lakes, Alaska, during 1995. Prepared for the Chignik Regional Aquaculture Association by Natural Resources Consultants, Seattle, WA. 51 p.

Ruggerone, G.T. 1996. Evaluation of escapement levels to maximize returns of Kenai River sockeye salmon and maintain habitat quality. Prepared for Kenai River Sportfishing Association, Inc. by Natural Resources Consultants, Seattle, WA. 43 p.

Rogers, D.E., B. Rogers, J. Miller, D. Peterson, and G. Ruggerone. 1996. Chignik Lakes Research: Data summary of historical research. FRI-UW-9608. University of Washington, Seattle. 29 p.

Ruggerone, G.T. and J. June. 1996. Pilot Study: survival of chinook salmon captured and released by a purse seine vessel in Southeast Alaska. Prepared for Southeast Alaska Seiners Association and Purse Seine Vessel Owners' Association. Natural Resources Consultants, Inc. 10 p.

Ruggerone, G.T. 1996. Preseason forecast of sockeye salmon run timing in Bristol Bay, Alaska, 1996. Prepared for Bristol Bay salmon processors by Natural Resources Consultants, Seattle, WA. 18 p.

Ruggerone, G.T. 1997. Straying of coho salmon from hatcheries and net pens to streams in Hood Canal and Grays Harbor, Washington. Prepared for Pacific States Marine Fisheries Commission by Natural Resources Consultants, Seattle, WA. 75 p.

Ruggerone, G.T. 1996. Winter investigations of salmon in the Chignik Lakes, Alaska, during 1996. Prepared for the Chignik Regional Aquaculture Association by Natural Resources Consultants, Seattle, WA. 46 p.

Ruggerone, G.T. and D.L. Alverson. 1996. Technical review of sockeye salmon studies associated with water diversion in the Nechako River, Fraser River Basin, British Columbia. Prepared for Private Client. Natural Resources Consultants, Inc. 20 p.

Ruggerone, G.T. 1997. Winter investigations of salmon in the Chignik Lakes, Alaska, during 1997. Prepared for the Chignik Regional Aquaculture Association by Natural Resources Consultants, Seattle, WA.

Ruggerone, G.T. 1997. Preseason forecast of sockeye salmon run timing in Bristol Bay, Alaska, 1997. Prepared for Bristol Bay salmon processors by Natural Resources Consultants, Seattle, WA.

Alverson, D.L., and G.T. Ruggerone. 1997. Escaped farm salmon: environmental and ecological concerns. Prepared for the Environmental Assessment Office, Government of British Columbia, by Natural Resources Consultants, Seattle, WA. 100 p.

Ruggerone, G.T. and J. June. 1997. Pilot Study: survival of chinook salmon captured and released by a purse seine vessel near Sitka, Southeast Alaska. Prepared for Southeast Alaska Seiners Association and Purse Seine Vessel Owners' Association. Natural Resources Consultants, Inc. 15 p.

Ruggerone, G.T. 1997. Genetic Baseline Investigation of Chignik Sockeye Salmon: Operational Plan and Fish Sampling. Prepared for the Chignik Regional Aquaculture Association by Natural Resources Consultants, Seattle, WA. 15 p.

Ruggerone, G.T. and D.L. Alverson. 1997. Technical review of chinook salmon studies associated with water diversion in the Nechako River, Fraser River Basin, British Columbia. Prepared for Private client. Natural Resources Consultants, Inc. 20 p.

Ruggerone, G.T., and D.E. Rogers. 1998. Historical analysis of sockeye salmon growth among populations affected by large escapements associated with the *Exxon Valdez* oil spill. *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Project 96048-BAA), Natural Resources Consultants, Seattle, WA.

Ruggerone, G.T., J. June, and J. Crutchfield. 1998. Reconstruction of chinook and steelhead runs to the Clearwater River, Idaho, during 1910-1995 and estimated lost tribal harvests associated with Lewiston and Harpster Dams. Prepared for Bogle and Gates by Natural Resources Consultants, Inc.

Ruggerone, G.T. 1998. Preseason forecast of the 1999 Bristol Bay sockeye salmon run adjusted for 1997 and 1998 marine survival conditions. Pp 1-4 *in* The 1999 FRI preseason forecast of the Bristol Bay sockeye run using an alternative approach. FRI-UW-9819. Fisheries Research Institute, University of Washington, Seattle.

Ruggerone, G.T. 1999. Winter investigations of salmon in the Chignik Lakes, Alaska, during 1998. Prepared for the Chignik Regional Aquaculture Association by Natural Resources Consultants, Seattle, WA.

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Growth and Survival of Salmon in Response to Competition and Climate Change: Implications for Interactions of Wild and Hatchery Salmon. Symposium: Population Growth, Climate Change and Fish Habitat in the Columbia River Basin. American Fisheries Society Western Division Conference, May 4-9, 2008; Portland, OR.

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Growth and Survival of Salmon in Response to Competition and Climate Change. AYK SSI Symposium on the Sustainability of the AYK Salmon Fisheries. February 6-9, 2007; Anchorage, AK.

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Hatchery Versus Wild Salmon Production in the North Pacific Ocean. American Fisheries Society North Pacific International Chapter Annual Meeting. Tacoma, WA. June 6-8, 2007.

Hatchery Versus Wild Salmon Production in the North Pacific Ocean. 9th Salmon Ocean Ecology Meeting. Newport, OR. March 14-16, 2007.

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Differential Marine Growth of Sockeye Salmon During Odd and Even Years: Evidence for Density-Dependent Effects of Pink Salmon Abundance on Nushagak Bay and Chignik Sockeye Salmon, 1955-1997. Pink and Chum Salmon Workshop. University of Washington, Seattle. March 2001.

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Historical analysis of sockeye salmon growth among populations affected by large escapements associated with the Exxon Valdez oil spill. Legacy of an oil spill: ten years after the Exxon Valdez oil spill. Anchorage, AK. March 1999.

A historical perspective on salmonid production from Pacific rim hatcheries. First Symposium of the North Pacific Anadromous Fish Commission. Hokkaido, Japan. w/ C. Mahnken, NMFS. October 1996.

Factors influencing the survival of salmon in Alaska and the Pacific Northwest. Visitation Retreat & Cultural Center, City of Federal Way, WA. October 1995.

The application of remotely-sensed data to salmon harvest management and operational planning of the salmon industry in Alaska. Third Thematic Conference: Remote Sensing for Marine and Coastal Environments. Seattle, WA. September 1995.

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Investigations of salmon populations, hydrology, and limnology of the Chignik Lakes, Alaska, during 1993. Chignik Regional Planning Team. Anchorage, Alaska. December 1993.

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Sockeye salmon run fluctuations and winter habitat quality of Black Lake, Ak. Chignik Regional Planning Team. Anchorage, AK. April 1992.

Habitat and sockeye salmon dynamics in a unique Alaskan lake. The 54th Annual Meeting of Pacific Fishery Biologists. Semi-am-hoo Resort, Blaine, WA. March 1992.

Responses of juvenile salmon to low oxygen levels in Black Lake during February 1992 and the forecast of adult sockeye returning to Chignik in 1992. Chignik Seiners Association, Shilshole Marina, Seattle, WA. March 1992.

The Alaska Salmon Program of the Fisheries Research Institute, University of Washington. Poster presentation at FISH EXPO 1991. Seattle, WA. October 1991.

Enhancing harvests of Chignik salmon through predator control and habitat rehabilitation: a cost-benefit analysis. Chignik Seiners Association. Seattle, WA. January 1991.

Rehabilitation and enhancement of sockeye salmon returning to Black Lake, Alaska. Chignik Regional Aquaculture Association. Seattle, WA. November 1990.

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Salmon projects of the Fisheries Research Institute in Alaska. Annual Meeting of the National Food Processors Association. Seattle, WA. March 1990.

Predator impacts on salmon populations. Annual Meeting of the National Food Processors Association. Seattle, WA. March 1989.

Threespine stickleback (Gasterosteus aculeatus) *aggregations as a refuge from predation for sockeye salmon fry* (Oncorhynchus nerka). National meeting of the Animal Behavior Society. Missoula, MO. August 1988.

Forecasts of Chignik salmon and the effects of predation by coho on sockeye survival in the Chignik Lakes, Alaska. Presentation to the Chignik Seiners Association and salmon processors. Chignik, AK. June 1988.

Salmon forecasts and research activities of the Fisheries Research Institute in the Chignik Lakes, Alaska. Presentation to the Chignik Seiners Association and salmon processors. Chignik, AK. June 1987.

Evaluation of the fisheries monitoring program to determine effects of the proposed Navy Home Port, Everett, WA. Presentation to Engineers and Navy personnel. Federal Way, WA. Oct. 1987.

Salmon forecasts and research activities of the Fisheries Research Institute in the Chignik Lakes, Alaska. Presentation to the Chignik Seiners Association and salmon processors. Chignik, AK. June 1986.

Consumption of migrating juvenile salmonids by gulls foraging below a Columbia River dam. Meeting of the Northwest Chapter, American Fisheries Society. Bellingham, WA. March 1986.

Alaska salmon research by the University of Washington. Seattle Poggie Club. Seattle, WA. April 1986.

Predator-prey interactions of piscivorous coho salmon and juvenile sockeye salmon in the Chignik Lakes, Alaska. Fisheries Research Institute Seminar, University of Washington. October 1986.

Salmon Research in Alaska: Past, Present, and Future. Organized seminar series at Fisheries Research Institute, University of Washington. October- December, 1986.

Salmon forecasts and research activities of the Fisheries Research Institute in the Chignik Lakes, Alaska. Presentation to the Chignik Seiners Association and salmon processors. Chignik, AK. June 1985.

EXPERT WITNESS TESTIMONY

Dam effects on salmon	Reconstructed salmon harvests by Tulalip Tribe had Sultan Diversion Dam not been built in 1916. Estimated fish passage through high gradient cascades. (case mediated & settled, 2005).
Exxon Valdez Oil Spill	Effects of oil spill on salmon tenders in Alaska (deposition, case settled) 2003.
Skokomish Tribe v. Tacoma Power	Tribal harvests had the dams not been built, 1926-1998. Ability of salmon to pass Big Falls prior to inundation by reservoir. (report, deposition, case removed in summary judgment) 2001.
Salmon Forecast Accuracy	Preseason and inseason run size forecast accuracy; insurance claim for 1998 Bristol Bay run failure (report, case settled) 2000.
Calkins v. Burger King	Probability of biotoxin accumulation in pollock from the Bering Sea (report, case settled) 2000-2001.
Proposed Cross Cascade Pipeline	Effects of refined oil pipeline on salmon and habitat (report, deposition, pipeline explosion ended proposed pipeline) 1999.
Dam Effects on Salmon	Chinook and steelhead runs reconstructed to estimate historical (85 yr) runs and harvests had dams not been built. (report, mediation settlement) 1998.
Exxon Valdez Oil Spill	Effects of oil spill on salmon harvests in Alaska (reports, deposition, trial testimony) 1994.
Glacier Bay Oil Spill	Effects of oil spill on salmon harvests in Cook Inlet, Alaska (report, deposition) 1989.
Touchet River Chemical Spill:	Effects of ammonia spill on salmonids in Touchet River, WA (deposition) 1983.

APPENDIX B
Panel Review Questions

June 25, 2010

General Questions for Klamath Review Panels

As part of the Secretarial Determination on the removal of four lower dams on the Klamath River, expert panels will be asked to conduct a scientific assessment. The panels will be asked to determine the most likely effects of the two proposed alternatives on the harvest of selected fish species, mostly salmonids. The two alternatives are:

No Action: No change from current management conditions, which includes ongoing programs under existing laws and authorities that contribute to the continued existence of listed threatened and endangered species and Tribal Trust species. This Alternative would be realized if a negative determination is made. This Alternative is referred to herein as the Current Conditions Alternative (Hamilton et al. 2010).

Proposed Action: Removal of the lower four Klamath River dams and the full range of actions/programs to implement the Klamath Basin Restoration Agreement (KBRA). This Alternative would be realized if a positive determination is made. This Alternative is referred to herein as the Dams-out Alternative.

The products or opinions from the panels will be used by the Economic Sub Team to evaluate the economics of the fisheries. In response to the needs for economic evaluation, the Biological Sub Team included questions of a quantitative nature that would be useful in the evaluation of salmonid fisheries enhancement as required in the Klamath Hydropower Settlement Agreement (KHSA). Inasmuch as the KBRA is part of an alternative under review, we used the broad definition of fish from the KBRA to mean: “the historic complement of species (including races) of fish that naturally occupied the Klamath River Basin”. Furthermore, the KBRA defined harvest opportunities to mean: full participation in Tribal, ceremonial, and commercial, ocean-commercial and recreational harvest; and inriver recreational harvest opportunities for anadromous fish species. The time period for the evaluation of the alternatives is 50 years from 2012 to 2062.

We will pose general questions and species-specific questions to the panels. The species specific questions might address a life history attribute or habitat requirement unique to that species. General questions fall into two themes. The first theme examines future habitat conditions and the second theme the viability of fish populations associated with those habitat conditions. Selected questions on habitat address hydrology, water quality, habitat, habitat restoration, ecosystem function, and climate change. The second theme is the biological viability of fish populations as indicated by criteria such as those proposed by Williams et al. (2008): 1) abundance, 2) productivity, 3) diversity, and 4) spatial structure. We propose to use these criteria because they are a conceptually intuitive link to salmonid population size, to the recovery of ESA listed species, and to the potential for harvest resulting in an economic or cultural benefit.

The signatories to the KBRA acknowledged the federal ESA listed status of coho salmon, Lost River and shortnose suckers, and bull trout and the Biological Sub Team recognizes those species have been subject to prior ESA reviews. While the earlier reviews create a data rich record, we encourage the panels to conduct a diligent review of the best available information on each of the species with respect to the two alternatives and the 50 year time horizon which are unique to this review process. Furthermore, we recognize the incongruous nature of the current listing status and the request of projections of future harvest opportunities, but do the best you can.

Ideally, each projection of the fish population abundance, harvestable fraction, and spawning escapement would be provided on an annual basis over the 50 year analytical horizon with some estimate of uncertainty. While such a quantitative estimate may be ideal for economic analysis, the Biological Sub Team and Economics Sub Team recognize projection of fish population abundance may be largely unachievable for most of the species reviewed. Our expectations are that in lieu of quantitative estimates, ranked value of abundance or an expression of change such as "two fold increase" could be used. Also useful is the trajectory of population abundance over time, such as declining or increasing under each of the proposed alternatives. Furthermore, if mileposts along the 50 year timeline marking significant events such as the salmonid populations reaching self-sustaining status, a harvestable surplus, or escapement goals can be identified, then these can be applied to further analysis. Because all ecosystem components can not be quantified, the review panels are encouraged to express qualitative values when predicting quantitative values is not prudent.

Questions:

1) Geomorphology: The two alternatives will result in very different geomorphic dynamics of the Klamath River down stream of Keno Dam. We recognize that the dams are associated with bed starvation of gravels and removal of dams may mobilize sediments over the short-term and over decades. How will alternatives affect geomorphology in the short-term (1-2 years) and over the 50 year period of interest? Included in this question are the potential effects of KBRA restoration activities on geomorphology of tributaries throughout the Klamath Basin and subsequent effects on harvestable populations of fish. What are the expected short-term effects of dam removal on the fish abundance and how long will it take these populations to return to baseline levels?

2) Water quality: The panels will be provided with information on numerous water quality issues from throughout the basin including dissolved oxygen, pH, ammonia, blue green algae, microsystin toxin, phosphorus loading, and Total Maximum Daily Loads (TMDL). Water quality in the Klamath Basin presents a multiplicity of challenges to restoration of fish populations. The Stakeholders and Water Quality Subgroup will provide some insight concerning the likely trends in water quality during the 50 year period of interest. Under these water quality scenerios, how will the two alternatives differ in reaching the goal of harvestable fish populations?

3) Water temperature: If reviewers consider the broad distribution of salmonids, salmonids in the Klamath River Basin are at the southern limit of their range. Furthermore, the removal of dams is predicted to alter the seasonal pattern of water temperatures with higher spring and summer temperatures and cooler fall water temperatures. What are the likely effects of the water temperature regimes under the two alternatives on rearing, spawning, and use of thermal refugia by native salmonids that might be manifest in harvestable fish?

4) Habitat and restoration (KBRA): Habitat is essential to productive fish populations and the stakeholders have recognized this critical linkage in the crafting of the Klamath Basin Restoration Agreement. The review panel will receive information on the use of Ecosystem Diagnosis and Treatment (EDT) method for tributaries above Upper Klamath Lake and the 2-D model of mesohabitats in the project reach to estimate aquatic habitat under the two alternatives. In addition, the panel will be provided a description of KBRA effects on habitat in the Klamath River Basin. The two proposed alternatives will result in different paths and timelines for habitat management. What are the likely effects of the two alternative habitat management paths on the recovery of ESA-listed fish or in the level of harvest of fish populations?

5) Climate change: We recognize a high level of uncertainty is associated with climate change during the 50 year period we are studying for the Secretarial Determination. The review panel will receive information on predicted hydrology and temperature for several climate change scenarios that have been downscaled for the Klamath River Basin. To what extent might potential changes in habitat, the hydrograph, and thermal refugia mitigate the effects of climate change under the two alternatives? What are the likely effects of climate change on the harvest levels of fish under the two alternatives.

6) Abundance: How will the two alternatives affect abundance of the fish population and what are the expectations for the enhancement of the fisheries? This question may have several milestones along a timeline or population trajectory. For example, inasmuch as some fish populations have been extirpated from the upper Klamath Basin for more than 90 years, when might fish be available for tribal ceremonial use within the upper Klamath Basin? Using a time trajectory, when will a sustainable fishery start and at what levels? We recommend the Panel consider abundance at different time scales ranging from seasonal, inter-annual, and to decadal trends. Economic concerns are that extreme variation in fish populations can affect economic stability of fisheries and fishing communities or slow recovery of fish populations and will delay any economic benefits.

7) Productivity: The metrics of productivity of fish populations may be measured several different ways. These methods include: 1) number of recruit spawners produced per parent spawner at low abundance, 2) juvenile outmigrants per adult spawner, or 3) redd counts per redd count of the previous generation. Each of these examples may be expressed through commonly used stock-recruitment models, such as the Beverton-Holt or Ricker curves. We recognize that conditions resulting from the proposed alternatives may not restore fish productivity to levels associated with historical pristine conditions.

What are the most likely expectations for productivity over time and what is the effect of productivity on the number of harvestable fish? (role of hatcheries and productivity?)

8) Diversity: Diversity refers to the variation in phenotypic characteristics such as individual size, fecundity, run timing, and life history patterns of fishes. Collective diversity of groups of subpopulations will reflect the diversity in the selective environments across the range of a fish species. The diversity enables the individuals to respond to changes resulting from subtle to catastrophic events across space and time. For populations lacking diversity the seasonal availability of adult (harvestable) fish to fisheries might result in very short and highly regulated harvest seasons. Historically, diversity of the salmonid populations may have been an important determinant of the seasonal patterns of harvest, the range in size of harvestable adults, and perhaps other characteristics of the fisheries. What will the effect of the two alternatives be on diversity of fish populations? How will the resulting diversity be manifest in the harvestable population of fish? How will potentially low baseline populations and/or introductions of hatchery fish affect diversity under the two alternatives?

9) Spatial structure: Spatial structure of the fish populations refers to the distribution of fish in various habitats used throughout their life history. Spatial structure enables fish populations to respond to localized catastrophic events across the landscape or to long-term changes in the environment. For a fishery, spatial structure of the population may stabilize the opportunity to produce harvestable fish. Will the two alternatives result in improved spatial structure of fish populations and to what extent is that improved structure likely to result in harvestable fish?

10) Ecosystem restoration: Numerous small dams across the U.S. have already been removed and several large dams in the West such as the Elwha Dam (105 ft) and Glines Canyon Dam (210 ft) in Washington State are scheduled for removal in the future. The goals of these dam removal projects range from restoring volitional movement of fish to restoration of entire ecosystems. One of the goals of the KBRA is to restore and maintain ecological functionality and connectivity of historic fish habitats. However, in most drainages, in addition to dams, widespread degradation of habitat and other forms of human perturbations have contributed to the decline of harvestable populations of salmonids. The signatories to the KHSA recognized that dam removal on the Klamath River is perhaps not a panacea for restoration of fisheries, and therefore also proposed the restoration activities of KBRA in an attempt to provide participation in harvest opportunities for fish species. How do the proposed alternatives address ecosystem function and connectivity sufficiently to recover the lost harvest opportunities of fish populations?

July 23, 2010

Questions for Review Panel on Lost River and Shortnose Suckers

The following questions were prepared for the Secretarial Determination to serve as guidance to the review panel on resident fishes of the Klamath River Basin. The questions may be considered along with a set of general questions provided to each of the four panels convened for the Secretarial Determination. The following questions are not in order of priority and are not intended to constrain the discussion by the review panel or limit the scope of the final product.

1) Sucker Restoration: The Lost River and shortnose suckers (*Deltistes luxatus* and *Chasmistes brevirostris*, respectively) are listed under the Endangered Species Act (ESA) as endangered. One of the goals of the ESA is to restore listed species so they no longer need federal protection. Three of the strategies used to recover the suckers are water level management in Upper Klamath Lake (UKL), water quality improvement, and restoration of wetlands that may serve as nursery areas. How might the two proposed alternatives affect the primary restoration strategies for the Lost River and shortnose suckers during the 50 year period being considered? Given that there will likely be lake level effects to sucker habitat, which of the two alternatives before the Expert Panel is likely to be most beneficial to sucker populations considering competing demands for water?

2) Water Quality: Owing to historical land management practices around and upstream of UKL, as well as naturally high phosphorus concentrations in lake inflows, UKL is currently classified as hypereutrophic and supports large summer and fall populations of cyanobacteria (blue-green algae). Draining and farming over 25,000 acres of former wetlands around UKL over the last century has contributed large loads of phosphorus and nitrogen to the lake. The cyanobacteria populations produce algal toxins that have been shown to be detrimental to the survival of juvenile suckers. Crashes of the algal blooms produce hypoxia in large parts of UKL, periodically contributing to large adult fish die-offs. How might actions identified in KBRA aimed at improving water quality (e.g., reestablishing functions of former wetlands around UKL, repairing riparian areas, and reducing input of nutrients from agricultural/grazing land) potentially influence water quality in UKL and the health of suckers populations over the next 50 years?

3) Tribal Harvest: Harvest of Lost River suckers “c’waam” and shortnose suckers “qapdo” historically played an important part in the ceremonial and subsistence harvest by the Klamath Tribes (Howe 1968). Since the 1980s, the only suckers taken by the Klamath Tribe have been for scientific or ceremonial purposes. After the first snow in March, the return of the c’waam ceremony is held by the Klamath Tribe on the banks of the Sprague River to ensure the well being of the fish. The Klamath Basin Restoration Agreement (KBRA) defined harvest opportunities to mean: full participation in Tribal, ceremonial, and commercial, ocean-commercial and recreational harvest. What is the most likely effect of the two proposed alternatives during the 50 year period on having harvestable populations of suckers?

4) Climate Change: Downscaled projections from three climate models predict average increases in annual Klamath Basin air temperatures of 2.1 to 3.6º C by 2035-2045 and June-

August increases of 2.2 to 4.8º C (Koopman et al. 2009). Bartholow (2005) found evidence of a 0.5º C increase in water temperatures per decade in the lower Klamath Basin, suggesting that effects of climate change may already be present in the Basin. Changes in total precipitation could occur as a result of climate change but with less certainty; however, it is likely that there will be a reduced snowpack at mid- and low-elevations (Koopman et al. 2009). As a result of temperature increases, possible changes in precipitation, and other effects, there will be a range of possible impacts to aquatic ecosystem and species that depend on them including the endangered suckers. How might climate change affect major processes such as watershed function, water quality, primary production, trophic interactions, and other processes that could affect suckers? To what degree do you think the adverse effects of climate change will be mitigated under the two alternatives being considered?

5) Non-native and Reintroduced Species: Non-native aquatic species are associated with the decline of threatened and endangered species in many areas (Sanderson et al. 2009) and have been implicated as being a threat to Lost River and shortnose suckers (Markle and Dunsmoor 2009). In Upper Klamath Lake the shoreline abundance of the introduced fathead minnow (*Pimephales promelas*) has a negative relationship with annual larval sucker survival (Markle and Dunsmoor 2009). What is the likely effect of the two proposed alternatives on non-native species and reintroduced species, including their predatory and competitive interactions with suckers? What effect will the two alternatives have on non-native species, lake level management, wetland restoration, and the restoration of suckers?

6) Drought and Declining Water Supplies: Analysis of Upper Klamath Lake net inflows shows that baseflows have declined significantly (p=0.003) during the period 1961 to 2006 (Mayer 2008). The decline equates to a total reduction of ~63,000 acre-feet, or roughly 50 percent, in the July-September net inflows to the lake over the 46-year period. While the reduction in baseflow is only statistically significant in the summer period, it is likely that a similar reduction in baseflows has occurred over the entire water year (Mayer 2008). Also, substantial water shortages have recently occurred in the upper basin in 2001 and 2010 during droughts, suggesting that future droughts are likely. During drought conditions how would the alternatives affect the three primary restoration strategies for suckers during the 50 year period?

7) Uncertainty: The resident fishes review panel has been asked to consider the possible effects of two alternatives over a 50-year period. There is considerable uncertainty in what will happen to Lost River and shortnose suckers under each of the two alternatives over that period. Important among the many variables that could alter the outcomes are how climate change will affect water quality and quantity and to what degree will restoration under the KBRA mitigate these effects. Droughts, toxic algae, and invasive species are other examples of factors whose effects on suckers are uncertain over the 50-year period. How might this uncertainty affect the sucker populations under the two alternatives?

References Cited

Bartholow, J.M. 2005. Recent water temperature trends in the lower Klamath River, California. North American Journal of Fisheries Management 25:152-162.

Howe, C.W. 1968. Ancient Tribes of the Klamath County. Binford and Morts, Publishers. Portland Oregon. 254 p.

Koopman, M.E., R.S. Nauman, B.R. Barr, S.J. Vynne, and G.R. Hamilton. 2009. Projected Future Conditions in the Klamath Basin of Southern Oregon and Northern California. The National Center for Conservation Science and Policy and the Climate Leadership Initiative, University of Oregon. 28 p.

Markle, D.F., and L.K. Dunsmoor. 2007. Effects of habitat volume and fathead minnow introduction on larval survival of two endangered sucker species in Upper Klamath Lake. Transactions of the American Fisheries Society 136: 567-579.

Mayer, T. 2008. Analysis of trends and changes in Upper Klamath Lake hydroclimatology. Unpublished report. U.S. Fish and Wildlife Service, Portland, Oregon. 31 p.

Sanderson, B.L., K.A. Barnas, and A.M. Wargo Rub. 2009. Nonindigenous species of Pacific Northwest: An overlooked risk to endangered salmon? BioScience 59:245-256

July 21, 2010

Questions for Review Panel on Redband Trout in the Klamath River Basin

The following questions were prepared for the Secretarial Determination to serve as guidance to the review panel on redband/rainbow trout of the Klamath River Basin. The questions may be considered along with a set of general questions provided to each of the four panels convened for the Secretarial Determination. The questions are not in order of priority and are not intended to constrain the discussion by the review panel or limit the final product. We did not distinguish between redband trout and resident rainbow trout in the questions below.

1) The four dam Project Reach (PR): In the PR under the current conditions several fish passage issues exist including entrainment at the four dams, passage of fry and juveniles through reservoirs, and upstream passage of adult redband/rainbow trout. The conditions result in fragmentation of habitat for fluvial redband/rainbow trout populations that are adapted to take advantage of habitat connectivity to complete their life history. Some populations of redband/rainbow trout in the PR have declined progressively in size over recent decades, possibly as a result of a combination of inadequate fish passage and instream growth conditions for redband/rainbow. Please identify the activities associated with the two alternatives that would increase or decrease potential size, growth, and abundance of redband/rainbow trout.

2) Water quality: Above Iron Gate Dam, water quality issues include pH, dissolved oxygen, ammonia, algae blooms, toxic microcystins, nutrients, and water temperature. Continued operation of the four dams in this review or the removal of those dams will have a minimum effect on the Upper Klamath Lake and tributaries, but the Klamath Basin Restoration Agreement (KBRA) associated with the action alternative, as well as climate change, may have some effects on the Lake and tributaries. Over the 50 year period of interest, what are the likely effects of water quality changes on redband/rainbow trout populations and the sport fishery in Upper Klamath Lake and the tributaries?

3) Fishery for redband/rainbow trout: Upper Klamath Lake and the Williamson and Wood Rivers have a redband trout sport fishery that is recognized for the catch of trophy size fish. ODFW's Klamath Basin Fish Management Plan indicates that the Klamath River (including the PR), Upper Klamath Lake, Williamson River, and Wood River will be managed for natural reproduction under the trophy management option with limited harvest. How might fish size and abundance in each of these areas be affected by the two alternatives?

4) Genetics of redband, rainbow, and steelhead trout: The relationship between redband, rainbow, and steelhead trout is complex and the fish apparently have considerable plasticity. They often use freshwater habitats that are similar, but do not necessarily use the same niche. The productive capacity for redband/rainbow/steelhead has many determinants and KBRA may have some effect on that capacity under the action alternative. Will the restoration of anadromous steelhead to the PR and above Upper Klamath Lake have deleterious effects on capacity to produce trophy redband/rainbow?

Under the two alternatives, what are the likely scenarios for redband/rainbow trout harvest over the 50 year time period?

5) Thermal conditions for redband trout: Redband/rainbow trout are well known for their ability to survive in relatively harsh environments. Redband Trout can apparently survive daily maximum water temperatures exceeding 29 C and diel water temperature fluctuations of 8-12 C (Gamperl et al. 2002). Rainbow trout in the Klamath River below Keno Dam can experience water temperatures up to 27 degrees. In the Klamath River Basin the conditions are characterized by widely fluctuating flows and temperatures in the PR, poor summer-time water quality in Upper Klamath Lake, and diverse flows and temperatures in tributaries to Upper Klamath Lake. Please describe the extent to which the two alternatives differ in terms of redband access to and use of thermally adequate habitats, and how such differences might influence the resilience of Upper Basin redband populations, and the harvest opportunities they might provide.

References Cited

Gamperl, A.K. and Others. 2002. Metabolism, swimming performance, and tissue biochemistry of high desert redband trout (*Oncorhynchus mykiss* ssp.): Evidence for phenotypic differences in physiological function. Physiological and Biochemical Zoology 75 (5) 413-431.

Literature Cited:

Hamilton, J., R. Quinones, D. Rondorf, K. Schultz, J. Simondet, S. Stressor. 2010. Biological synthesis for the Secretarial Determination on potential removal of the lower four dams on the Klamath River. Biological Subgroup for Secretarial Determination. Draft May 27, 2010. 128 pp.

Williams, T.H., et al. 2008. Framework for assessing viability of threatened coho salmon in the Southern Oregon/Northern California Coast Evolutionary Significant Unit. NOAA-TM-NMFS-SWFSC-432 NOAA Technical Memorandum NMFS:113.

APPENDIX C
Comments and Responses on Draft Report

April 11, 2011

Note: In the following text, the major peer review points were responded to by the Panel. The responses are indicated in **bold font** indented below the main comment.

Review of:

Klamath River Expert Panel Draft Report
Scientific Assessment of Two Dam Removal Alternatives on Resident Fish

Summary of Comments Received from Peer Reviewers and Expert Panel Responses

General Comments Received from Peer Reviewers:

One of the reviewers responded favorably to the overall content and general quality of the report. The reviewer commented that he found "the report to be accurate and to reflect the available science on this system and these species." He went on to say that he believed that "the panel has made predictions within the scope of the available data," and that he saw "no problems with interpretation of the data or coverage of the literature."

The second reviewer was silent on the overall report content, quality, and the conclusions of the authors. On the other hand, he provided detailed recommendations for reformatting the report into a much more logical and coherent document. He specifically suggested compiling the report into five major sections. The first section would describe the panel and the questions it was to address. The second section would provide extensive background information. The third section would describe the alternatives. The fourth section would describe the effects of the alternatives and how the panel members reached their conclusions. The fifth and last section would summarize the findings of the expert panel. Following this format would result in a much more readable report.

Both reviewers suggested that many statements in the report lacked the necessary references from the scientific literature to support them. As with other Klamath reports related to the Secretarial Determination, one of the reviewers suggested adding citations about how similar dam removals had affected streams. The reviewers noted that in some cases the references used in the report were incomplete or in inconsistent formats making them difficult to locate and evaluate. The reviewers noted as well that units of measure were applied inconsistently throughout the report. The authors should decide to use either English and metric units of measure. Cases of undefined or inappropriate terminology were also identified.

Both reviewers provided paragraph-specific and line-by-line recommendations which should be considered by reviewing their verbatim comments. Among the most important are suggestions to include a section on the genetics of suckers as was done for rainbow trout; to be more specific about the vulnerability of suckers to overharvest; to provide estimates of error on the observed and predicted flows and lake elevations; to provide more detail regarding the Hetrick 2009 report; and to introduce bull trout earlier in the report.

Comments Received from Peer Reviewers and Expert Panel Responses:

Reviewer 1

1. Page 73 – The third and fourth paragraphs under section 4.1.2 don't seem to reflect the newest work on the genetics of suckers in this system. Check with Tom Dowling to see if statements square with his genetic data. To make a statement like "…cannot be distinguished from SNS genetically…" based on one cited study is unacceptable. Whether a species can be distinguished or not depends on the type of genetic information used. Was this study based on mtDNA, nuclear genes, microsatellites, or genetic data from a common environment experiment? If one conclusion from these data is that the species cannot be differentiated then that takes away the justification for trying to restore populations of the endangered "species". You must be careful about making such pronouncements with limited data. Curiously, there is no "genetics" section for the suckers in the life history section of the report. There is for the rainbow trout. Why not for the suckers? This is an odd place to give a little bit of genetic information for the suckers.

    a. **Section 2.1.1 has been revised to include a discussion of the genetics of Klamath Basin suckers. Section 4.1.2 has also been revised in response to this comment.**

2. Page 79-80 – Pertaining to possible harvest of suckers – I think it would be useful here to be more specific. Even if populations recovered to the several hundred thousand level, and there were multiple age classes represented, a sustainable harvest will be much smaller than historic harvests on these populations. You could figure this out mathematically, but roughly speaking if individuals live and spawn for up to thirty years after maturation, then a harvest of more than a couple percent of the adult population biomass would not be sustainable. So, if the population numbers 100,000 and adults weigh 1kg on average, you may be able to take, say 1000 kg annually -a very small number compared to historic harvests. I think readers should clearly understand that the life history of long-lived lake suckers makes them especially vulnerable to overharvest. Recruitment of suckers is always low (compared to the millions of eggs spawned), even in the best of years, and thus there is only a small harvestable portion available every year. No restoration scheme will ever be able to provide a massive sustainable harvest similar to historic harvests.

a. **This comment is noted. Background information is presented within Section 2.1.1 regarding the life history and longevity of suckers. Section 5.1 states that long-lived species, such as suckers, that reproduce multiple times over their lifespan are highly susceptible to overharvesting if the harvest focuses on larger individuals. With successful implementation of KBRA activities, lake level management, water quality improvement, and habitat restoration (wetlands and spawning and rearing habitat) are expected to increase spawning success, and larval, juvenile, and adult survival leading to larger populations and more frequent recruitment. The Panel assert that, with declining populations under the current conditions, there are no opportunities for tribal or recreational harvest, and harvest, other than ceremonial tribal harvest, should only occur after a sustained population growth can be shown over a period of decades.**

3. Pages 38, 44 – Figures 3 and 4. Is there no way to get estimates of error on the observed and predicted flows and lake elevations? Without estimates of error surrounding the lines we really don't know if flows differ under different scenarios. The point is made that flows in July are higher and in November-December lower under the dam removal scenario. How do we know if they are really different? Although there is a bigger difference in the observed lines before and after dam construction, it is still instructive to see estimates of error.

   a. **It was not the Panel's specific task to determine estimates of error for the data depicted in Figures 3 and 4. The trends depicted for each scenario, supplemented by the literature reviewed, provided the Panel with the information necessary to formulate the findings and conclusions presented in the report.**

4. Page 40 – Probably need to say something more about the Hetrick 2009 report. What data did they use? Were their methods different and were they scientifically valid? This is a big discrepancy, and the readers should be given some information on which to make a judgment about the utility of the Hetrick 2009 report.

   a. **The report has been revised to include clarification in response to this comment. A statement of the utility of the Hetrick 2009 report is provided in the context of whether recent restoration and livestock and water management have had any effect on the extent of favorable aquatic habitat documented forty years ago. Specific information regarding the methodologies used in Hetrick 2009 can be found within the source document.**

5. Page 29 – This is the first time bull trout have been mentioned. I find this odd given that they are listed at some level. I realize that the directive may not have included bull trout and I am pleased to see that the panel treated bull trout anyway. I think you may want to introduce it earlier with the explanation that it will be influenced by the proposed changes.

a. **The report has been revised to introduce bull trout in Section 1.4. In addition, the discussions of bull trout in the report, including genetics of bull trout, have been elaborated upon.**

6. Page 24 – How can you determine movement from scale analysis? The authors need to provide details from the Borgerson 1992 report to allow readers to judge the validity of the results. Add some supporting details to the paragraph.

   a. **The report has been revised to include clarification in response to this comment. The observed changes in scale growth patterns determine what environmental conditions the individual had been exposed to during a growing period or year, which can then help determine the general locations within a particular system (e.g., Spencer Creek) in which the individual had migrated or temporarily resided. Specific information regarding the methodologies used in Borgerson 1992 report can be found within the source document.**

7. Page 72 – "Some of the species are not common and declining in abundance…" Be specific here. Which species are declining? Where is the data to back up this claim? All of section 3.5 seems to be unnecessarily vague and general. You have listed the common species by name, but then lumped the declining species into one group. It should be the other way around.

   a. **This comment is noted. Reference to NRC (2004) is provided in support of the statement that the slender sculpin and Miller Lake lamprey are believed to be in decline.**

8. Page 73 – What does it mean to be "inherently unsuitable for completion of life cycles by suckers." Is this a comment about the fish themselves or about the reservoirs? The sentence should be reworded to avoid confusion.

   a. **The statement is provided with respect to the Klamath River reservoirs. The text has been revised to include clarification in response to this comment.**

9. Page 24 – "However, some errors? may account for the discrepancy…" in reference to the Beyer 1984 report. You had better fully explain the errors so readers can make a judgment about the utility of the data presented.

   a. **The text has been revised to include clarification in response to this comment. Specific information regarding the Beyer 1984 can be found within the source document.**

10. Page 29 – what does "internal lake sediment sources…" mean in this context and how can this be a contributing factor to hypereutrophication. If the nutrients have always been internal to the lake how can they all of a sudden produce hypereutrophic conditions. This

may be referring to recently trapped sediments that are stirred up by wind and wave action. If so, that should be carefully explained. As is, it sounds like the lake, not the external degraded conditions, is the main contributing factor to this abnormally high nutrient level.

   a. **The text has been revised to include clarification in response to this comment.**

11. Page 37 – 60% and 25% makes 85%, where does the rest come from? You should mention the other sources here.

    a. **The text has been revised to include clarification in response to this comment.**

12. Page 20 – "…key factors of decline for lake suckers are in the lake." I am not so sure about this interpretation and logic. At least you should explain the chain of logic better. The streams and the lake are both degraded and they are inherently connected, so why try to shift the blame to the lake only. I would just take this statement out.

    a. **The text has been revised to include clarification in response to this comment.**

13. Page 70 – reference to the Deschutes, Yakima, and Babine river systems and their steelhead populations is unclear. Is this an example of both life histories coexisting in other systems? If so, the information should contain a citation and it should be clear that it is an example. The final sentence in the paragraph is unclear as to what it references (i.e., what is meant by "these populations"?).

    a. **The text has been revised to include citation and clarification in response to this comment.**

14. Page 84-96 – Many of the references are not in acceptable form. A reference should allow a person to find the information cited. For example, see the citation for Scoppetone et al., 1995 – a title with nothing else (?) – Starcevich et al., 2006, what is this? – Vanderkooi 2010, Fact Sheet (what is that?). References should be clearly traceable to 1) a published paper in a peer-reviewed journal, 2) a report that is accessible upon request from the agency or organization cited (gray literature), or 3) personal communication, complete with date of communication and persons full name and position. A couple more examples Bartholowmew 2008 (maybe a typo on the name, but no information on what type of document this is.), Beyer 1984 – a M.S. thesis?

    a. **The references in the report are clearly traceable and have been formatted in response to this comment.**

15. Be consistent with English and metric units throughout. Choose one or the other (preferably metric) and stick to it. Currently it is a mishmash.

   a. **The report has been revised to include clarification in response to this comment. Certain values are presented in either English or metric units according to their respective source documents from which the information was extracted.**

16. Page 6 – Figure legend not accurate, only 4 of 6 dams shown are to be removed.

   a. **The text has been revised to include clarification in response to this comment.**

17. Page 15 – What does “sucker food from the bottom” mean

   a. **The text has been revised to include clarification in response to this comment.**

18. Page 15 – Can’t find Terwilliger 2010 in references.

   a. **The text has been revised to include the correct reference to Terwilliger et al. 2010.**

19. Page 23, Table 3 – Typos, “RM xxx”? – Powerhose to Powerhouse?

   a. **Table 3 has been revised to reference RM 219. The spelling of Powerhouse has been corrected accordingly.**

20. Page 24 – Beyer 1884?

   a. **The text has been revised to include the correct reference to Beyer 1984.**

21. Page 24 – First full paragraph – move “respectively” up near “in 1990 and 1991”

   a. **The text has been revised accordingly in response to this comment.**

22. Page 25 – does JC Boyle have a fish passage structure?

   a. **The text has been revised to include reference to the existing fish passage facilities.**

23. Page 54 – Last paragraph of 3.1.1, typo “may ‘be’ more important…”

   a. **The report has been revised to remove this statement in response to this and other comments received.**

24. Page 76 – Need citation for the effects of bass.

  a. **The report has been revised to include reference to Moyle 2002. Additional changes with respect to bass have been made to the report.**

Reviewer 2

1. On page 4 in the last paragraph, I recommend changing the phrase “expert fish panels” to “panel of scientists” or “panel of experts.” I don’t believe that you had a panel of fishes. Similarly, use the same phrasing elsewhere in the document.

    a. **The report has been revised to include clarification in response to this comment.**

2. On page 4 in the last paragraph, I recommend adding the word “hereinafter” before “Panel.”

    a. **The report has been revised accordingly in response to this comment.**

3. On pages 5 and 6, I recommend that at least one legal locator, such as a latitude and longitude, be included inside the maps or figures. That is because the irregular shape on the small California-Oregon map does not match the rectangles pictured in the maps or figures.

    a. **This comment is noted.**

4. On page 8 in the last paragraph, I recommend deleting the phrase “for an in-person.”

    a. **The report has been revised accordingly in response to this comment.**

5. On page 9 in the first paragraph the “Technical Management Team” is introduced. Their relationship to this document should be described and their role needs to be defined.

    a. **The report has been revised to include clarification in response to this comment.**

6. On page 9 in the next to last paragraph it says, “before creating this draft version” but the next paragraph identifies that the version that I am reading was revised. The two paragraphs need to be reconciled.

    a. **The report has been revised to include clarification in response to this comment.**

7. On page 10 the “Panel Role” is described. This would be better just before a summary of the authors’ resumes.

    a. **This comment is noted. No changes were made to the report in response to this comment.**

8. On page 11 in the first paragraph, there is reference to a "prized sport fish." This is better left to a description of the background information on fisheries. There is no scientific definition of "prized." What is "prized" is a value judgement on the authors' part.

    a. **The report has been revised to include clarification in response to this comment.**

9. On page 12 in the first paragraph, there is a phrase, "there is a fundamental disagreement regarding" but there is no description of what that means. Define the "fundament disagreement."

    a. **The report has been revised to include clarification in response to this comment.**

10. On page 12 in the last paragraph, the phrase "inadequate for a rigorous scientific assessment" is used. This calls into question the integrity of the whole document. I recommend that the phrase be stricken or the title have the word "scientific" stricken. If the author's want to qualify the quality of the science, then they should use less damning language.

    a. **The report has been revised to include clarification in response to this comment. The phrase is intended to emphasize the time and resource constraints presented to the Panel in conducting their assessment.**

11. On page 13 a section called "Background" begins, but this section appears to mostly be fish life history. I recommend writing a full background including all relevant geology, hydrology and biology.

    a. **This comment is noted. No changes were made to the report in response to this comment.**

12. On page 13 in the first paragraph the phrase "feeding-related structures" should be replaced with "mouth parts."

    a. **The report has been revised accordingly.**

13. On page 14 in the last paragraph the word "desiccation" is used. If this means water development then use that wording.

    a. **The report has been revised to include clarification in response to this comment.**

14. On page 21 the next to the last paragraph starts “Phenotypic and life history...” but there is not any supporting scientific reference. There should be one cited that specifically supports this for the Klamath Basin.

    a. **The report has been revised to include reference to Li et al. 2007.**

15. On page 22 in the first paragraph, it says that “limited habitat in the smaller, shallower streams limits growth” but no scientific reference is given. A reference should be supplied.

    a. **The report has been revised to include reference to Buchanan et al. 1990 and R. French, ODFW, pers. comm.**

16. On page 22 in the second paragraph, it says “Much of the spawning occurs” but “much” is not quantified or objectively described. It should be.

    a. **The report has been revised to include clarification in response to this comment. The majority of individuals that spawn in those systems are known to spawn at the cold groundwater discharge areas associated with those systems.**

17. On page 22 in Table 3, a citation is not given for the source of the data. A source should be cited.

    a. **The data source is cited below the table in the draft report. The report has been revised to include reference to USGS 2007, Tinniswood 2010, and Tinniswood 2011.**

18. On page 23 in the first paragraph references are not given for the second sentence. It needs a reference.

    a. **The report has been revised to include reference to W. Tinniswood, ODFW, pers. comm.**

19. On page 24 in the next to the last paragraph, it says “dammed or exposed.” Should this say “dammed and exposed?” The last sentence of this paragraph does not make sense and needs to be rewritten.

    a. **The report has been revised to include clarification in response to this comment.**

20. On page 25, the first sentence says “is difficult to detect” but it is not clear why this is relevant or what causes the difficulty. This should be rewritten.

a. **The report has been revised to include clarification in response to this comment.**

21. On page 25 in the second paragraph, a causal statement is made between creating a dam and an "unusual life history." It is not clear that the dam created this life history or that the life history did not exist before the dam was created. This type of life history is common in bull trout based on tracking studies, but few redband trout tracking studies have been done and the species may have similar life history diversity. The sentence should be rewritten.

    a. **The report has been revised to include clarification in response to this comment.**

22. On page 25 in the next to the last paragraph, the first sentence says that there are "unique stocks" but no scientific reference is given. The statement needs a scientific reference.

    a. **The report has been revised to include reference to Buchanan et al. 1994.**

23. On page 25 in the last paragraph, it says that "migration is suggested" but who is suggesting it? The statement needs a scientific reference.

    a. **The report has been revised to include reference and clarification in response to this comment.**

24. On page 26, the second and third paragraphs discuss steelhead stocks in other river basins. A statement is needed to say why this information is relevant to the Klamath.

    a. **The report has been revised to include clarification in response to this comment.**

25. On page 26 in the fourth paragraph, the first sentence needs a scientific reference.

    a. **The report has been revised to include reference in response to this comment.**

26. On page 27 in the next to the last paragraph, the information needs scientific reference.

    a. **The report has been revised to include reference in response to this comment.**

27. On page 28 in the first paragraph, there is reference to "trophy sizes" but the relevance is not defined. It should be.

    a. **This comment is noted.**

28. On page 28 in the second paragraph, the sentence stating "Almost all of the stocked fish...." needs a scientific reference.

a. **The report has been revised to include reference in response to this comment.**

29. On page 28 in the third sentence it is stated that “hatchery rainbow trout...could survive” but the relevance is not clear. It should be clarified.

    a. **The report has been revised to include clarification in response to this comment.**

30. On page 29, the first sentence needs a scientific reference, as does the first sentence in the fourth paragraph.

    a. **This comment is noted.**

31. On page 29 in the last paragraph, the statement is made that “redband/rainbow have adapted.” That is not an apparent fact, but a conclusion, so this sentence should be reworded. In the same paragraph reference is made to a “world class trophy fisheries”; this is not a scientific statement and should be rewritten.

    a. **The report has been revised to include clarification in response to this comment.**

32. On page 30 in the second paragraph, “Tribal trust species” is introduced. This needs to be defined as part of the background. What are “Tribal trust species”?

    a. **The report has been revised to include clarification in response to this comment.**

33. On page 31 under item 2, reference is made to Table 4. It is not clear to me why some of these actions cannot be a part of any alternative. Please clarify that in the text.

    a. **This comment is noted.**

34. Starting on page 36, a section on “Hydrology and Geomorphology” begins. Most of this is appropriate background information.

    a. **This comment is noted.**

35. On page 39 in the second paragraph, there is a statement about “favorable rearing habitat” that seems out of place. Appropriate scientific references are needed and this kind of statement belongs with the description appropriate to a species.

    a. **The report has been revised to include reference in response to this comment.**

36. On page 40 in the third paragraph, there is a statement about “supporting a world class fishery” that seems out of place. Appropriate scientific references are needed and this kind of statement belongs with the description appropriate to a species. “World class” is

not a scientific description of a fishery. These types of statements belong in Sports Illustrated or a similar venue, not in a scientific assessment.

a. **This comment is noted.**

37. On page 40 in the third paragraph, there is a statement that "The Panel could not confirm..." The relevance of confirmation is obscure. If this discussion is necessary, then it should be rewritten.

a. **The report has been revised to include clarification in response to this comment.**

38. On page 41 in the first sentence, there is discussion of a "functional level" and "habitat are not obviously positive". This sentence needs to be rewritten to identify what "functional level" means scientifically and say what "obviously positive" would mean as opposed to obviously negative. This whole paragraph needs scientific references, or needs to be written so that it is obvious that these are the conclusions of the panel based on relevant facts.

a. **This comment is noted.**

39. On page 41, the last sentence in the second paragraph is an excellent example of how to write the authors' conclusions.

a. **This comment is noted.**

40. On page 42, all paragraphs need scientific references added.

a. **This comment is noted. References are provided for Stillwater Sciences (2010) and Hardy et al. 2006.**

41. On page 43 in the third paragraph, there is reference to "channel habitat". Habitat is for organisms not channels. What does the phrase mean? Is this statement about a certain species gaining 69 miles of river channel as habitat? If it is, then say so and identify the species.

a. **This comment is noted.**

42. On page 45, the first two sentences need scientific references.

a. **This comment is noted. Reference is provided to Stillwater Sciences (2008, 2009a, 2009b, 2010) and the Bureau of Reclamation (Greimann PPT Presentation).**

43. On page 45 in the third paragraph, there is reference to “adverse soil and moisture conditions.” What does this mean scientifically? What is adverse? Rewrite this to be explicit.

    a. **This comment is noted. Adverse is used in the context of riparian and other non-invasive vegetation recruitment and establishment.**

44. On page 45 and in general, the text mixes metric and English units of measure. This is not appropriate in a scientific document. All units should be either English, or metric, or expressed as both.

    a. **The report has been revised to include clarification in response to this comment. Certain values are presented in either English or metric units according to their respective source documents from which the information was extracted.**

45. On page 46, the first two sentences need scientific references, as does the beginning to the third paragraph.

    a. **This comment is noted.**

46. On page 47, more scientific references are needed where they are not included with various sentences.

    a. **This comment is noted.**

47. On page 48 in the first paragraph, there is a statement that “details...are complex and options for solving the problem are still not agreed upon” but the relevance is not explained clearly. Why is agreement desirable or even necessary?

    a. **This comment is noted.**

48. On page 48, the last paragraph needs scientific references.

    a. **Scientific references have been added.**

49. On page 49, a section on “Climate Change” begins. Most of this is appropriate to a discussion of background conditions. The last sentence states that there is “no basis” to conclude something, but there probably are no bases to conclude lots of other things too. Is this statement necessary? Clarify or delete it.

    a. **This comment is noted. The Panel has elected to retain the information in this section.**

50. On page 51, the first sentence needs scientific references.

a. **This comment is noted.**

51. On page 55, most of the text describes background conditions not effects and should be moved to an appropriate section.

    a. **This comment is noted. The Panel has elected to retain the information in this section.**

52. On page 56, most of the text describes background conditions not effects and should be moved to an appropriate section.

    a. **This comment is noted. The Panel has elected to retain the information in this section.**

53. On page 58, most of the text describes background conditions not effects and should be moved to an appropriate section.

    a. **This comment is noted. The Panel has elected to retain the information in this section.**

54. On page 59 in the third paragraph, most of the first part of the text describes background conditions not effects and should be moved to an appropriate section.

    a. **This comment is noted. The Panel has elected to retain the information in this section.**

55. On page 60 in the second paragraph, most of the first part of the text describes background conditions not effects and should be moved to an appropriate section. The same is true of the last paragraph.

    a. **This comment is noted. The Panel has elected to retain the information in this section.**

56. On page 61 in the first paragraph, most of the first part of the text describes background conditions not effects and should be moved to an appropriate section. The second paragraph contains too much speculative wording, like “may be displaced”, “surmise”, “unconfirmed”, and “It is also possible”. Rather than write this way, I recommend merely stating what possibilities are.

    a. **The report has been revised in response to this comment.**

57. On page 61 in the last paragraph, there is a statement there “would be minimal interaction between adult anadromous salmon and suckers.” There is an abundant literature on nutrient import to streams by anadromous salmonid populations. Nutrient import should have some effects on other species. I recommend that the authors cite appropriate

research and describe potential effects rather than use an unscientific description like "minimal."

a. **This comment is noted.**

58. On page 62 in the third paragraph, the authors discuss potential salmonid predation on suckers. I recommend that the authors use the abundant literature on diets of juvenile salmon to support their conclusions.

a. **This comment is noted.**

59. On page 63, the next to the last paragraph introduces bull trout to the text. The introduction should be part of the background and introduced earlier.

a. **The report has been revised to include clarification in response to this comment.**

60. On page 64, in the first paragraph there is discussion of a "prudent plan". Prudence is a value judgement, not a scientific one. This should be reworded.

a. **The report has been revised to include clarification in response to this comment.**

61. On page 64 in the second paragraph, scientific reference is needed.

a. **Scientific reference has been added.**

62. On page 64, the third paragraph is background information and should be moved to an appropriate section.

a. **This comment is noted. The Panel has elected to retain the information in this section.**

63. On page 65, the second paragraph is background and should be moved to an appropriate section. The third paragraph is a description of the action and should be moved to an appropriate section. The next to the last paragraph, should cite other studies from the abundant literature about the effects of riparian management.

a. **This comment is noted. The Panel has elected to retain the information in this section.**

64. On page 68 in the fifth paragraph there is reference to "benefit redband/rainbow trout populations". Benefit is a value judgement not a scientific statement. If populations will increase, then say that. If growth rates will increase then say so.

   a. **The report has been revised to include clarification in response to this comment.**

65. On page 69 in the third paragraph, there is reference to “sport fisheries” but there was not a background description. It is needed.

   a. **The report has been revised to refer the reader to Section 5.2 for additional information on the redband/rainbow sport fishery.**

66. On page 69, there is a “3.3.4 Effects of Population Levels”. It looks like this should be worded “Effects on Population Levels.”

   a. **The title of Section 3.3.4 has been revised to “Population Level Effects”.**

67. On page 70, A section on “Bull Trout” begins. Most of it is background and should be in an appropriate section. In the last paragraph “McIntrye” is cited but his name is incorrectly spelled “Mcintrye” on page 94.

   a. **This comment is noted. The Panel has elected to retain the information in this section. The spelling of McIntrye has been corrected.**

68. On page 71 in the first paragraph, there is a statement that ”bull trout in these limited areas are not sustainable.” This should be worded consistently with other text to say that they are at a high risk of extinction compared to other areas. The last sentence in the second paragraph needs scientific reference.

   a. **The report has been revised accordingly and reference has been added.**

69. On page 71, the section “3.5 Other Resident Fish” starts, most of which is background and should be moved to an appropriate section.

   a. **This comment is noted. The Panel has elected to retain the information in this section.**

70. On page 72 in the first paragraph, “redband trout” are listed but should probably be deleted because they have their own sections and are not “other species.”

   a. **This comment is noted. The report has been revised accordingly.**

71. On page 73, the sentence in the first paragraph that starts, “It is highly likely...” is a good model for how to write conclusions. Other parts of the text could benefit from a parallel style.

   a. **This comment is noted.**

72. On page 74 in the first paragraph, "minor direct" impacts are identified. Define the direct effects.

    a. **The report has been revised to include an example of such potential direct effects.**

73. On page 74 in the next to the last paragraph, the sentence that starts "Using this section as a control..." is a good model for how to write conclusions. Other parts of the text could benefit from a parallel style.

    a. **This comment is noted.**

74. On page 75, most of the first two paragraphs are background and should be moved to an appropriate section. The fifth paragraph is a good conclusion, but there was not background section about the amount of fishing.

    a. **This comment is noted. The Panel has elected to retain the information in this paragraph.**

75. On page 76, most of the first two paragraphs are background and should be moved to an appropriate section. The second sentence in the last paragraph, that starts "Abundances of..." is a good model for how to write conclusions. Other parts of the text could benefit from a parallel style. The next to the last sentence should have some scientific reference added.

    a. **This comment is noted. The Panel has elected to retain the information in this paragraph. References have been added in response to this comment.**

76. On page 77, most of the next to the last paragraph is background and should be moved to an appropriate section.

    a. **This comment is noted. The Panel has elected to retain the information in this paragraph.**

77. On page 78, most of the "Harvest" section is background and should be moved to an appropriate section.

    a. **This comment is noted. The Panel has elected to retain background information relevant to harvest.**

78. On page 80, the first sentence in the second paragraph starting "Anglers travel..." is background and should be moved to an appropriate section. In addition, scientific references should be added.

a. **The Panel has elected to retain the sentence in Section 5.2, as this background information is relevant to harvest. The report has been revised to include scientific references in response to this comment.**

79. On page 81 in the last paragraph, the first sentence says “reduced but stable”. Reduced compared to what? A comparative statement needs to be added.

a. **The report has been revised to include clarification in response to this comment.**

80. On page 82, the conclusions are pretty well worded compared to others. I would expect a conclusions section to read mostly like this.

a. **This comment is noted. No revisions to the report were implemented in response to this comment.**

81. On page 83, the section on “Conclusions” appears to be a summary of earlier thoughts. Perhaps it should be called a “Summary.”

a. **This comment is noted. The Panel has elected not to change the title of Section 6.0.**

April 11, 2011

Klamath River Expert Panel
Scientific Assessment of Two Dam Removal Alternatives on Resident Fish
Response to Comments on the Draft Report dated January 13, 2011

Comment Number	Comment Author	Page, Paragraph	Comment	Panel Response
1	M. Armstrong Siskiyou Co.	Page 76-77	The fish most important to the Siskiyou County above the dams are bass and golden perch as a sports fishery. They are an important economic engine for that area. The report gives short shrift to them. The golden perch are important to the Southeast Asian population in Siskiyou County as a dietary staple (they take them out in buckets) and the bass fishery is a tournament fishery. Anecdotal reports by retired DFG Rightmeir is that the perch can survive if the dams are removed and there are hundreds of thousands of them. They are also predatory on salmonid juveniles. Indications are that some have escaped the reservoir and have already taken up residence in the Shasta River. This was all previously reported by the County is its EIR/EIS comments.	This comment is noted. The commenter is referred to Section 4.3 of the report for the Panel's discussion regarding non-native fishes.
2	D. Lynch	48, 1	I think the panel may have underestimated the potential value of several KBRA line items in appendix C-2 on water quality in Upper Klamath Lake (UKL). Line 11 in KBRA Appendix C-2 specifically identifies an expenditure of $50 million dollars to study and remediate the water quality issues in Keno reach. Because water quality issues in the 20 mile Keno reach come from organic matter and nutrients generated just upstream in Upper Klamath Lake (UKL), this expenditure of $50 million dollar is	This comment is noted. The Panel has reviewed KBRA Appendix C-2. The information provided in this comment regarding KBRA has been considered by the Panel.

Comment Number	Comment Author	Page, Paragraph	Comment	Panel Response
			targeted at controlling or treating this supply of nutrients and organic matter from Upper Klamath Lake. There will be workshops conducted very soon to explore what remediation efforts make the most sense for Upper Klamath Lake and Keno reach. Restoration measures could range from: chemical additions to UKL (e.g. alum) to prevent nutrient releases from bottom sediments, sediment dredging, physically removing algae (Aphanizomenon) from UKL, which would remove organic matter and nutrients, restoration of wetlands around UKL that continue to be a nutrient source rather than sink for the lake, construction of wetlands in the Keno reach to retain nutrients and organic matter, etc. The workshops and available research will inform what measures are feasible, should be researched and tested, and ultimately implemented. So there is a lot of focus on this water quality issue in UKL, but not a lot of detail yet. Lines 46 -51 in the KBRA Appendix C-2 all focus on monitoring and studying the water quality issues in UKL to help inform the water quality remediation that needs to be done. It totals about $22 million dollars. It focuses on understanding the algal dynamics in the lake, quantifying and controlling internal and external loads to the lake, etc. Over 70 million dollars of research and remediation programs for UKL in KBRA is in part a response to the NRC review's recognition of how important UKL is for suckers and downstream species. The NRC quote was well before significant remediation of wetlands around the lake had occurred by TNC on the Williamson River delta, or before this 70 million dollar KBRA program was envisioned, or before new wetlands around UKL are targeted for additional restoration in KBRA that will improve water storage and water quality in UKL (see lines 76 and 77 in Appendix C-2 in KBRA dealing with restoration of Barnes/Agency/Wood River wetland areas).	

Comment Number	Comment Author	Page, Paragraph	Comment	Panel Response
3	M. Pisano	General	An Executive Summary would be very helpful	This comment is noted. The Panel elected not to include an Executive Summary.
4	M. Pisano	General	Since so much emphasis is placed on developing an additional 30k AF of water to benefit resident fish in the upper basin through the KBRA, an explanation of where this water could/would come from is needed to help inform the reader. Further, does the panel feel this water could realistically materialize?	There are no specifics in KBRA at this time about where this water would come from. The likelihood of actually obtaining this water depends on willing sellers and available funding. Nor is it clear whether landowners who sell their surface water rights will compensate by pumping more ground water.
5	Klamath Falls Fish and Wildlife Office	6, Figure 2	The Link River Dam is incorrectly placed on the map and should be located closer to Upper Klamath Lake	Figures 1 and 2 have been revised to depict the correct approximate location of the Link River Dam.
6	Klamath Falls Fish and Wildlife Office	14, last	The two statements about the pre-historical and historical ranges of the suckers are somewhat contradictory because one says it was uncertain and the other says they were widely distributed. Perhaps what was meant was that the exact distribution is unknown but based on the current distribution the range was extensive.	The statements have been revised for clarification.
7	Klamath Falls Fish and Wildlife Office	15,1	The statement regarding upwelling associated with the springs is unclear. For the eastside spawning springs, most of them originate above the lake.	The statement has been revised for clarification.
8	Klamath Falls	15,5	Degree sign is needed in two places.	The report has been revised to

Comment Number	Comment Author	Page, Paragraph	Comment	Panel Response
	Fish and Wildlife Office			include this edit.
9	Klamath Falls Fish and Wildlife Office	16,2	Degree sign is needed in three places.	The report has been revised to include this edit.
10	Klamath Falls Fish and Wildlife Office	19,1	A comma is needed between surface and juveniles in line 6.	The report has been revised to include this edit.
11	Klamath Falls Fish and Wildlife Office	21,1	A degree symbol is needed in two locations.	The report has been revised to include this edit.
12	Klamath Falls Fish and Wildlife Office	23,1	A lower case c is needed in Comm.	The report has been revised to include this edit.
13	Klamath Falls Fish and Wildlife Office	24,2	Close up ( ) around (range 2-4)	The report has been revised to include this edit.
14	Klamath Falls Fish and Wildlife Office	24,4	What is error? We suspect something was to be added.	The report has been revised to include this edit.
15	Klamath Falls Fish and Wildlife Office	27,2	A semicolon is needed between authors.	This comment is noted.
16	Klamath Falls Fish and Wildlife Office	37,1	Statements made here suggest that groundwater pumping has led to "…extensive lowering of the water table." It is not clear if this applies to the entire basin or subbasins, but Gannett et al. (2007) state that this has only occurred in the Lost River subbasin. Also, there may be other causes of reduced water tables besides pumping.	The report has been revised for clarification based on the following two sources. Gannett et al (2007, pp. 59-60) say "Pumping in the upper Klamath Basin increased an estimated 50 percent starting in 2001 in response to changes in water management and a prolonged

Comment Number	Comment Author	Page, Paragraph	Comment	Panel Response
				drought. The ground-water system has responded to the increased pumping with water levels showing acute, seasonal, and long-term effects … Seasonal effects reflect the general lowering of the water table over a broad area (several square miles to tens of square miles) in response to the combined seasonal pumping of multiple wells and, in some places, seasonal variations in recharge. These effects typically build up over the irrigation season and largely recover over the following winter … Water levels declined more than 10 ft over more than 130 mi2 and more than 20 ft over about 20 mi2 during the 2004 irrigation season. Declines of 10–20 ft are apparent in an area extending from north of the Klamath Hills, through the Klamath Valley, into the northern and eastern parts of the Tulelake subbasin. Smaller areas in the Klamath Valley and the southeastern part of the Tulelake subbasin show seasonal water-level declines exceeding 20 ft in some wells. Seasonal

Comment Number	Comment Author	Page, Paragraph	Comment	Panel Response
				water-level declines of 1–3 ft were measured in most wells distant from pumping centers. These widespread declines are due to natural seasonal fluctuation, possibly amplified by dispersed pumping and ongoing drought. Although a general decline in water levels was measured during this period, levels in some wells that are hydraulically connected to the shallow aquifer system in the basin-fill sediments rose between spring and fall, ranging from a fraction of a foot to as much as 3 ft. This is an annual occurrence entirely due to artificial recharge to the shallow system by canal leakage and deep percolation of irrigation." Long-term pumping effects refer to the lowering of the water table for more than a season, often years. Long-term effects can be caused by both climate and pumping stresses. Long-term water level declines typically occur over broad regions, such as an entire subbasin. Long-term decline generally is measured by

Comment Number	Comment Author	Page, Paragraph	Comment	Panel Response
				comparing the spring high water levels each year. Such lowering of the water table has been observed over most of the upper Klamath Basin since about 2000 because of ongoing drought. The only exception is in shallow aquifers in the Klamath Project area, where water levels are maintained by recharge from canal leakage and deep percolation of irrigation water. Long-term declines due to pumping have occurred locally in addition to this drought-related decline. Distinguishing pumping related declines from drought related declines in the basin is difficult because of the scarcity of data from previous drought cycles. However, near the town of Tulelake, where long-term water-level data exist, the rate of the year-to-year decline observed in the present drought cycle in well 48N/04E-35L02 appears to be about twice that observed in the most recent previous drought, from the late 1980s through mid-1990s (Figure 39).

Comment Number	Comment Author	Page, Paragraph	Comment	Panel Response
				Also, Leonard and Harris (1974, p. 56) state that "present pumping of ground water has had no detectable effect on water levels … Exceptions are in the southeast corner of Poe Valley and the west side of Swan Lake Valley, where a few wells have prennialklky declining water levels."
17	Klamath Falls Fish and Wildlife Office	40,2	When discussing the habitat and the differing opinions about habitat conditions in tributaries, it should be mentioned that the report by Fortune (1966) is over 40 years old and there have been improvements in land management as well as considerable restoration occurring, especially in the Williamson/Sprague River basin.	The report has been revised to address this comment. Panel also provides discussion for the 2009 report by Hetrick et al.
18	Klamath Falls Fish and Wildlife Office	40,3 and 41,1	The first sentence speaks to the extensive habitat degradation of the lowermost reaches of the Upper Klamath Lake tributaries and of the low prospects for spawning and rearing habitat to be restored. While we agree that the damage has been extensive, we are optimistic that fish habitat can be restored in those reaches where restoration is occurring. This is especially true for redband trout that quickly use spawning gravel when it is either provided or exposed by restoration activities.	The Panel reports the optimism stated by Huntington et al (2006) and Hetrick et al. (2009). The Panel has inserted a statement that the disparity between these optimistic statements and the results of the Fortune survey could be resolved easily and rapidly by a systematic field survey.
19	Klamath Falls Fish and Wildlife Office	41,1	There are several references in this section to a lack of gravel in the tributaries. We don't disagree with this statement in general, but in the Wood River, redbands spawn in pumice, indicating that gravel is	This comment is noted. The Panel's role is to state the problem. The Panel cannot

Comment Number	Comment Author	Page, Paragraph	Comment	Panel Response
			not always necessary for spawning to occur. Also, restoration projects in the tributaries have added gravel and more will be added by future projects because it is understood that gravel is sometime lacking. Additionally, Service restoration staff in Klamath Falls have found gravel in the Sprague River when the bed is exposed at low flow, and they have found gravel in several places under fine sediment, and they believe with future improvements in the channel, this sediment will be mobilized exposing the gravel and thereby adding channel complexity.	assess the appropriateness of optimism. The report has been revised to include a statement suggesting that the magnitude of the problem can be assessed rapidly.
20	Klamath Falls Fish and Wildlife Office	44, Figure 4	It is difficult to distinguish between the curves for the lake and river, so we recommend that a combination of solid and dashed lines or use of symbols, be used instead of the colored lines.	This comment is noted. The graphic used for Figure 4 cannot be revised, as it was extracted from its respective source (B. Greimann) and not created by the report authors.
21	Klamath Falls Fish and Wildlife Office	51,1	Should Montgomery River be changed to McKenzie River?	The report has been revised accordingly.
22	Klamath Falls Fish and Wildlife Office	52,1	The ground water travel times quoted seem unusually long and therefore we recommend that these figures be verified if possible.	This comment is noted. The ground water travel times are not unusually long, given that Manga (1999) calculated average ages of 8-30 years, and that Gannet's (2007) Figure 6 shows that some flow lines in the aquifer have much longer trajectories and therefore lower head gradients. The report has been revised for clarification.

Comment Number	Comment Author	Page, Paragraph	Comment	Panel Response
23	Klamath Falls Fish and Wildlife Office	52,2	Higher water temperatures in the tributaries as a result of climate change are unlikely to have much effect on suckers in the tributaries, because for the LRS and SNS, they primarily use the tributaries in the spring, and suckers are relatively tolerant of water temperatures compared to salmonids.	This comment is noted.
24	Klamath Falls Fish and Wildlife Office	56,3	Lernaea is the correct spelling.	The report has been revised accordingly.
25	Klamath Falls Fish and Wildlife Office	58,3	The second sentence mentions that the impact of restoration in the Sprague River has been small due to limited resources, but it does not say what impacts refers too, e.g., water quality, suckers, redbands, or others.	This section of the report addresses potential impacts of restoration with regard to water quality and suckers.
26	Klamath Falls Fish and Wildlife Office	59,3	The statement made here about A-canal entrainment should make it clear that currently no juvenile suckers are entrained and fewer larvae are likely entrained owing to the presence of the fish screen.	The report has been revised for clarification.
27	Klamath Falls Fish and Wildlife Office	60,3	The last sentence talks about current conditions unlikely to change the status of the endangered suckers. It might be more accurate to say that to the degree that suckers benefit from restoration, suckers will benefit more under the KBRA because of the greater resources made available for restoration.	The report has been revised for clarification.
28	Klamath Falls Fish and Wildlife Office	64,1	The authors emphasize the importance of the 30 TAF of additional instream summer flows depending on what kind of water is acquired and where the water comes from. This is a very important point and more detail here should emphasize that the most benefits would come if acquisition of cool water and selected reaches where it is most needed was prioritized for instream aquatic habitat purposes.	The report has been revised to address this comment.
29	Klamath Falls	78,4 and	Please reiterate that this discussion is for Upper Klamath Lake sucker	This comment is noted. The

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	Fish and Wildlife Office	83,2	populations only.	Panel reiterates that the discussion is for Upper Klamath Lake sucker populations, only.
30	Klamath Falls Fish and Wildlife Office	83,2	The first sentence states that Upper Klamath Lake suckers (LRS and SNS implied?) could go extinct in 10-15 years. While it is likely that the suckers in Upper Klamath Lake will go extinct without greater recruitment, the time frame for that to happen is less certain because some recruitment is occurring. We suggest that the "10-15 years" be removed and replaced with "in the near future" to make it clear that we don't know when extinction will occur.	The report has been revised to address this comment.
31	Klamath Falls Fish and Wildlife Office	83,2	The conclusion states that specific details of habitat restoration activities under the KBRA are not yet available. While additional planning is certainly needed to finalize KBRA restoration activities, there is a guidance document providing an extensive and detailed list of actions and associated cost estimates for aquatic habitat restoration in the Upper Klamath Basin. The document is: Projected Restoration Actions and Associated Costs Under the Klamath Basin Restoration Agreement for the Upper Klamath River Basin Above Keno, Oregon. USFWS Klamath Falls Office. July 30, 2010. That document is already being integrated into the Service's 2011, 5 year strategic plan for habitat restoration in the Upper Klamath Basin. All of the Service restoration offices in the Klamath Basin are developing these 5-year plans. We think it is important to cite these documents so the public or other policy decision makers are aware that we do have available information for specific planned actions.	This comment is noted.
32	Klamath Falls Fish and	83,2	Agency Ranch Lake should be changed to Agency Lake.	The report has been revised accordingly.

Comment Number	Comment Author	Page, Paragraph	Comment	Panel Response
	Wildlife Office			
33	J. Hamilton	4,1	The criteria for the Secretary's decision are not correct. 2) should be 'will advance salmonid fisheries.'	The report has been revised accordingly.
34	J. Hamilton	30,2, #7	The latest DRAFT hydrology and sediment report is at: ftp.usbr.gov/tsc/mdelcau/Klamath/Reports/Hydrology_Sediment Climate change is Chapter 11.	This comment is noted. The reference has been included.
35	J. Hamilton	40,1	Reference to the eastern and southern arc of the UKL basin is not clear.	The report has been revised for clarification.
36	J. Hamilton	42,1	The river miles between Keno and IGD are 43 miles, not 33 miles.	The report has been revised accordingly.
37	J. Hamilton	70,2	Steelhead upstream from UKL have also been documented by Butler et al. (Butler et al. 2010).	This comment is noted. The reference has been included.
38	J. Hamilton	80,1	Sucker harvest recommendations were not part of any questions or requests, and are beyond the scope of the tasks to the panel.	This comment is noted. The Panel has chosen to retain the statements regarding sucker harvest.
39	J. Hamilton	82,2	*"It is possible that the trophy fishery will expand at least seven times from below Keno Dam to the Iron Gate reach."* This statement has no citation or supporting information. If conjecture, it does not belong here. What is the basis for this claim?	The report has been revised to substantiate the statement.
40	J. Hamilton	84,2	*"The amount of habitat with free flowing waters would increase by 43 miles following dam removal…"* This needs to be rewritten. Without dams there would be 43 miles of free flowing habitat, but this alternative would not increase habitat by that amount. The amount of habitat under Project reservoirs is	The report has been revised accordingly.

<table>
<tr><th>Comment Number</th><th>Comment Author</th><th>Page, Paragraph</th><th>Comment</th><th>Panel Response</th></tr>
<tr><td></td><td></td><td></td><td>estimated to be 22-23 miles (Cunanan 2009).</td><td></td></tr>
<tr><td>41</td><td>J. Hamilton</td><td>84-86</td><td>Citations need to be checked for format and spacing.</td><td>This comment is noted. Format and spacing of citations have been confirmed, and where appropriate, revised.</td></tr>
<tr><td colspan="5">Citations used in J. Hamilton Comments:
Butler, V. L., et al. (2010). "The Use of Archaeological Fish Remains to Establish Pre-development Salmonid Biogeography in the Upper Klamath Basin. Final Report."
Cunanan, M. (2009). Historic anadromous fish habitat estimates for Klamath River mainstem and tributaries under Klamath Hydropower reservoirs. Arcata CA., U.S. Fish and Wildlife Service: 3 p + attachments.</td></tr>
<tr><td>43</td><td>R. Graham</td><td>i</td><td>The Table of Contents is well organized, and makes the report understandable and easy to follow.</td><td>This comment is noted.</td></tr>
<tr><td>44</td><td>R. Graham</td><td>24</td><td>Last line; correct year for reference is 1984, not 1884.</td><td>The report has been revised accordingly.</td></tr>
<tr><td>45</td><td>R. Graham</td><td>28</td><td>Population Trends paragraph #1: Has anyone looked at changes in fish populations once all stocking was discontinued in 1991, vs. the temperature trends and the water supply management choices? I am struck that it is possible that awareness of fish water quality characteristics may have decreased after stocking was discontinued, such that correlations with changes in management may have been missed. Given the emphasis on adaptive management, a critical review of the dynamic that occurred at this time may be warranted?</td><td>This comment is noted. The Panel was not specifically tasked with determining such correlations or testing such hypotheses.</td></tr>
<tr><td>46</td><td>R. Graham</td><td>29</td><td>Last paragraph, discussion of hypereutrophic trends: it is interesting that Upper Klamath Lake became hypereutrophic (extremely high nutrient levels) during the middle 1990s, which was right after stocking ceased (see comment #3 above), and “occurred rapidly over time”. This leads me to think that there was some kind of either</td><td>This comment is noted. The Panel was not specifically tasked with testing such hypotheses.</td></tr>
</table>

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			management change and/or environmental trend that began at this time, which was not noticed because stocking was discontinued, so there were fewer receptors to alert observers.	
47	R. Graham	39	2.4.2 Upper Klamath Lake Levels: add a reference for the process of tannic acids countering the growth of blue-green algae	Reference has been noted in the report.
48	R. Graham	39	2.4.2 Upper Klamath Lake Levels: If Conditions without Dams and with KBRA result in up to 1 ft higher level, but recent droughts cause 2-3 feet of drop below the minimum elevation needed for inundation of lakeshore wetlands, how is it that Conditions without Dams and with KBRA will result in increased inundation in drought years?	The commenter is misunderstanding the discussion. Conditions without Dams and with KBRA result in up to 1 feet higher level during drought years, the baseline of which already takes into account the 2-3 feet deficit.
49	R. Graham	45	2.4.7 Short-term Effects of Sediment Release: since sediment from J.C. Boyle reservoir will be flushed earlier and more completely than sediment from the lower reservoirs, does that imply that (1) dredging in J.C. Boyle to fully remove sediment is less likely to enhance sediment removal; and (2) that sediment contamination in sediments for this reservoir is more likely to be dispersed and diluted during dam removal?	This comment is noted. The Panel did not see and did not consider the value of dredging sediment from J.C. Boyle reservoir. The Panel was not provided with information on contaminants in the sediment.
50	R. Graham	46	2.4.7 Short-term Effects of Sediment Release: If dredging to recover former meanders and floodplain channels on the bed of Copco 1 reservoir could not occur without disturbing sensitive cultural sites, how much longer would the recovery take, or would it be unlikely to occur without the proposed dredging?	This comment is noted. The Panel has no way to estimate timing since they were not provided with the necessary geotechnical information on the site. It is likely that the river could be trained to reoccupy its former channel quickly as most

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				of the sediment that has accumulated in the reservoir is fine-grained.
51	R. Graham	50	Climate Change: I think that it is important to clearly state that climate change is both temperature and precipitation, and that temperature is more clearly predicted by models than by precipitation, so that the last sentence on this page is made understandable. [This is how I interpreted that sentence, but was unsure that my interpretation is accurate.]	This comment is noted. The two paragraphs on that page refer to temperature and precipitation separately.
52	R. Graham	51-52	I interpret the prose to show the following discrete climate change impacts that justify the statement in 3rd from bottom line on page 51—"…might provide a small additional benefit…"? (1) Springs with travel times on the order of decades to centuries will cause the impact to be <u>neutral</u>; (2) Upper Klamath Lake may be further degraded to be <u>negative</u>; (3) Restored habitats located where tributaries enter to be <u>positive</u>; (4) Increased frequency of late summer low base flow conditions and higher water temperatures mitigated by abundant cool spring water to be <u>neutral</u>. Is this an accurate assessment? Would the information make more sense in a table?	This comment is noted. The additional benefit is discussed clearly in the text.
53	R. Graham	53-54	3.1.1 Effect on Hydrology: The second sentence indicates that historically the timing of peak flows and high lake levels was a direct cause of spawning success for suckers. The last sentence of this section asserts that lake levels are not as important as water quality and habitat quality for suckers. Since habitat quality requires lake fringe vegetation submergence, how else could one affect the quality of habitat? Similarly, since water quality is better in submerged lake fringe vegetation, how else could one affect the water quality? I was following this section's logic until the last sentence (sorry). See also	The text has been revised for clarification.

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			pages 57-58, where it is stated, “Although this [restoration of wetlands in UKL] may not significantly improve water quality…substantial areas adjacent to the wetlands should have improved water quality supporting all life stages of suckers.” How can these wetlands be ‘wet’ without having higher lake elevations? Is the presumption that by reconnecting Agency Lake Ranch, Barnes Ranch, and Wood River Wetlands, an adequate supply to produce this wetted fringe would occur without raising the lake elevation in UKL, or are these separate wetland habitats that are not connected to UKL? See last sentence of 3.3.3 on page 69 regarding this statement.	
54	R. Graham	55	Last paragraph—did the start of AFA presence in Upper Klamath Lake coincide with using the lake for holding logs? Or, is there no correlation with any land use change in terms of AFA being post-1900s?	The Panel was not specifically tasked to determine the start of AFA presence in Upper Klamath Lake or identify correlations with changes in land use.
55	R. Graham	56	First full paragraph—did the low levels of DO in Upper Klamath Lake in the 1990s extend as far downstream as the area where fish stocking ceased (see my comment #3 above)?	The Panel was not specifically tasked to determine this.
56	R. Graham	60	3.1.4 Effects of Habitat Quality: how many springs are there to be restored under KBRA if all degraded spring habitats in Upper Klamath Lake are restored? Do any of these springs appear to be unlikely to flow during droughts, even if restored? What is the timeframe for seeing results of restoration? See page 65, first sentence of last paragraph, which states: “Successful riparian restoration will take years before measureable reductions in water quality are achieved.” It would be consistent to make the same determination for restoration of both springs and riparian zones.	The Panel was not provided with specific information to answer such questions.

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57	R. Graham	61,2	How many restoration actions need to occur for increased survival of larval and juvenile suckers to exceed any negative non-native species impacts? Is it 100% of what is proposed in KBRA?	The Panel was not provided with specific information to answer such questions.
58	R. Graham	70	Section 3.4 Bull Trout: does the panel anticipate that bull trout will be on the species list for our Biological Assessment?	The Panel believes that bull trout will be on the species list.
59	R. Graham	88	Was the Expert Panel aware of this 2007 reference, revised in 2010? Gannett, Marshall W., Kenneth E. Lite, Jr., Jonathan L. La Marche, Bruce J. Fisher, and Danial J. Polette. 2010. Ground- Water Hydrology of the Upper Klamath Basin, Oregon and California. U.S. Geological Survey Scientific Investigations Report 2007-5050. Version 1.1. Available at http://pubs.usgs.gov/sir/2007/5050. April 2010.	The Panel references this data throughout the document.
60	W. Tinniswood	23, bottom Table	Should read RM 219	The report has been revised accordingly.
61	W. Tinniswood	23, last	Recent calculations estimate the bypass springs at 285 cfs. A gauge was installed in 2010 below JC Boyle Dam by Pacificorp to ensure the release of 100 cfs. Therefore the gage reads 100 cfs at that location and 385 cfs at USGS 11510700 KLAMATH RIVER BLW JOHN C.BOYLE PWRPLNT, NR KENO,OR below the powerhouse when the turbines are not functioning. One minor tributary input of less than one cfs. 385-100= 285 cfs spring flow	The report has been revised accordingly. The Panel was very pleased to receive an accurate estimate for the amount of cfs from this commenter.
62	W. Tinniswood	37,2	Maximum depth of Upper Klamath Lake is 61 feet	The report has been revised accordingly.
63	W. Tinniswood	40,2	The lower portions of Fourmile and Sevenmile Creek have been channelized due to the construction of dykes at Agency and Barnes Ranches. Historically these stream channels were likely similar to	This comment is noted. The detailed information provided in this comment has been reviewed

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			Crystal and Recreation Creek to the east in the refuge. Most of Sevenmile Creek is unchannelized as only the last five miles are channelized. The lower portion of Threemile Creek is channelized. The channelized section of Crane Creek was restored to the historic channel in the years 2008-2010. The lower portion of Denny Creek, Cherry Creek, and Fourmile Creeks are channelized but most habitat is unchannelized. Fourmile Creek is unnaturally ephemeral due to all the water being diverted to Jackson County. Most streams and Rivers are not dyked and diverted. All of Fort Creek and tributaries are not dyked. Only 2 miles above the headwater springs at Klamath hatchery of Crooked Creek are channelized. Agency Creek is not channelized. The Wood River has been slightly channelized near the mouth at approximately five of 21 miles of habitat. Lower portion of Sun Creek and Annie Creek are channelized but the majority of habitat on ODF, USFS and Crater Lake National Park are not channelized. With the exception of Annie, Sun and the Wood River the remaining streams have little irrigation withdraw. Sevenmile Creek has a large irrigation diversion on the USFS but large springs (Blue Springs, Short Creek, Crane Creek recharge the creek but then more water is taken out of the creek downstream. Diversions in the Sevenmile Creek and Wood River valley were documented by Craven Consulting Group in 2004. Much of Sevenmile, Crooked and Crane Creek has been leased for instream flows. Google earth is a good tool to determine rate of channelization just remember those pictures were taken in 2005. Crooked Creek, Crane Creek, and Sevenmile Creek have had restoration projects to reduce channelization.	by the Panel.

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64	W. Tinniswood	40,3	ODFW has calculated that redband trout occupy 496 miles of stream in the possible distribution of steelhead. This does not include Upper Williamson or Jenny Creek. Another 137 miles of habitat in the possible range of steelhead and redband trout is dominated by brook trout and brown trout and redband trout do not occur but would likely occur without brown and brook trout. Fortune et al. (1966) underestimated spawning habitat for steelhead. Fortune et al (1966) performed his assessment after the 1964 flood and on the Klamath River that had significant impacts from the hydroelectric system. During the time little information was available on the use of habitat by steelhead, the size of steelhead adults and life history. Fortune (1966) only documented very large habitat stream segments 46 years ago. For example an average summer steelhead is 18 inches and can use much smaller habitat than Fortune estimated. For example Fortune estimated that Spencer Creek could only support 110 pair of steelhead. However egg take from 1948-1956 from *O. mykiss* averaged up to 17 inches with usually over 1200 females collected each year. Recent escapement estimates into Spencer Creek by O. mykiss have been a minimum of 1800 (Buchanan et al. 1991) Fortune et al. (1966) also did not document any spawning gravel in Spring Creek (Williamson River). Spring Creek is now used by at least 1000 female adfluvial O. mykiss spawners that are significantly larger (22”) (Buchanan et al. 1991) than a 1 salt summer steelhead (18”) Everest 1973. Many other areas of good habitat were not considered by Fortune that have had recent gravel placement with good success. Everest (1973) found that almost all spawning habitat in the Rogue River by summer steelhead occurred in areas of intermittent streams of small watersheds. Fortune et al (1966) did not estimate any of these stream types in his report. Many large productive streams were not in Fortune’s analysis	This comment is noted. The detailed information provided in this comment has been reviewed by the Panel. None of this information was presented to the Panel for the review, and the Fortune (1966) report was the only one provided that had any concrete information on habitat. The Panel has added a statement in the text that there needs to be an updating of assessments of habitat potential, based on systematic field surveys. At present, too much reliance is placed on these anecdotal reports of single places and references, and what one reviewer above called “optimism”. The Panel was not specifically tasked to perform a detailed habitat assessment during the short-term external review.

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			these include Fort Creek and tributaries, Crooked Creek and tributaries, Sevenmile tributaries, Trout Creek , Cherry Creek and numerous other streams. HERE	
65	W. Tinniswood	41,3	Most of the Williamson River and Wood River watershed are in typically good condition as well as large sections of the Sprague River (38 out of 85 miles). The Sevenmile Creek watershed is experiencing significant restoration activities and the trend in habitat conditions are upward. Most of the Sevenmile Creek watershed is fairly pristine with the only impacts coming from roads. The headwaters start in the Sky Lake Wilderness. Habitat in the upper basin produces the most abundant and largest adfluvial *O. mykiss* known in the species range. The 136 miles of thermal refuge predicted by ODFW has good habitat to support all life stages of steelhead, and winter and summer thermal refuge if needed. The panel description of habitat describes sections of the Sprague River for approximately 40 miles, The South Fork Sprague for 8 miles, all of Whiskey Creek, and small sections (3-4 miles) of the NF Sprague River, Sevenmile Creek, Wood River and other small streams.	The Panel refers the commenter to response to comment 65 above.
66	W. Tinniswood	43,1	ODFW’s goal for gravel augmentation from JC Boyle Dam (RM 223) to Frain Ranch (RM 214) is 1000 cubic yards of spawning gravel 3/8 to 4” per year from 2012- 2020 as part of the interim conditions. The panel also need to consider the amount of material that has been lost at the emergency spillway which continues to erode each time the spillway is used and the landslide that occurred just upstream of the emergency spillway when a rock hit the bypass channel and water eroded the hillside into the river.	This comment is noted. The detailed information provided in this comment has been reviewed by the Panel.
67	W. Tinniswood	54,4	“and habitat quality may more” insert be	The report has been revised to remove the text.

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68	PacifiCorp	General	While PacifiCorp recognizes the short time that the panel had to develop this report and appreciates the effort, it is apparent that a wealth of information regarding species present in the Klamath Hydroelectric Project (Project) area and the hydropower effects has been overlooked or ignored. Much of this information is in the Project License Application and the subsequent FERC EIS. In addition to these sources, results from recent Klamath nutrient assessments are also missing. Overlooking these important sources of information weakens the panel evaluation.	Given the limited time available, the Panel relied on the best available information provided to them during the preparation of the report. The FERC EIS and Klamath nutrient information was reviewed and is referenced throughout the document.
69	PacifiCorp	Pg 29; Para 5	The report states that Upper Klamath lake became hypereutrophic in the middle 1990's. Did the panel mean 1890's? It has been recognized the UKL has been hypereutrophic since the early 1900's.	The report has been revised for clarification.
70	PacifiCorp	Pg 30; 2.2.1	The panel should assume that the TMDL requirements in downstream tributaries (Shasta, Scott, etc) will also be met.	This comment is noted.
70	PacifiCorp	Pg 42; Para 1	The gradient range should be expanded to ~2.5% to account for the steep reaches downstream of JC Boyle Powerhouse	The report has been revised accordingly.
72	PacifiCorp	Pg 43; 2.4.5	At the top of page 43, the panel states that high water temperatures downstream of Iron Gate dam result from reduced summer flows and lack of shade. There is no mention of the fact that water temperatures at the headwaters is usually above 20 C in the summer which persist downstream. Even though there are springs in the JC Boyle bypass reach and a few cold water tributaries in the hydroproject reach, the amount of water from these sources is not enough to have a measurable impact of the incoming flux of warm water from Upper Klamath Lake. A definition of thermal refugia is required to determine which	The commenter is referred to water quality discussions in the report for information on water temperatures.

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			streams provide benefits to fish. Jenny Creek should be removed from the list of streams that may provide thermal refugia as stream temperatures are similar or higher than those observed in the mainstem during the summer. This stream is highly impacted by agricultural withdrawals and stream temperature data indicate that temperature exceed 23 degrees Celsius in the summer.	A general definition has been provided in the text. The report has been revised accordingly.
73	PacifiCorp	Pg 49; Para 2	The panel should describe just what the outcome of increased assimilation may be for the river channel downstream of Keno dam under dams out scenario. Asarian et al. (2010) estimated that Total Phosphorous concentrations will rise 2-12% and Total Nitrogen concentrations will rise 37-42% following dam removal. The authors stated that although nutrients are predicted to increase downstream of the dams following dam removal, the resulting effects on algal and macrophyte growth are unknown. We provide the following comment on this topic: In free flowing river reaches mechanical re-aeration provides a mechanism to oxidize these materials without driving DO to exceedingly low levels. Therefore assimilation of oxygen demanding substances is higher under free flowing river reaches. Note the oxidation of all that organic matter is a source of nutrients (N and P). Second, the nutrient end of the equation is quite a bit different. Although an oxygen rich environment (e.g., mechanical reaeration) will provide for nitrification (conversion of ammonium to nitrate) while not overly depressing DO, the end product is still an inorganic nutrient – nitrate. Thus, the only way you can "assimilate" inorganic nitrate and phosphorus is through sequestration in plant biomass – i.e. lots of vegetation. The large standing crop of aquatic vegetation produces diel DO and pH swings due to photosynthesis and	This comment is noted. The detailed information provided in this comment has been reviewed by the Panel.

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			respiration (DO) and carbon update (pH). Resulting in undesirable conditions in many cases. Also, the aquatic vegetation is a source of organic matter (and nutrients) through excretion and senescence. Thus, the river will most likely experience high productivity throughout the Project reach during the summer. Light will be the principal limiting factor in the upstream most reaches (reducing assimilation), coupled with high velocities and substrate conditions. It is therefore quite likely the river will have extensive growth from the JC Boyle springs all the way to the Scott River (similar to conditions observed between Iron Gate Dam and Scott River currently). This growth will provide excellent habitat for the polychaete which is the intermediate host for C. shasta. Asarian, E. J. Kann, and W. Walker. 2010. Klamath River Nutrient Loading and Retention Dynamics in Free-Flowing Reaches, 2005-2008. Final Technical Report to the Yurok tribe Environmental Program, Klamath, CA. 59pp+appendices.	
74		Pg 74; 4.2.2	The panel concludes that there is only a limited number of resident trout that use the 17 miles of slackwater habitat between the dams. Primarily because of high summer temperatures and low DO. However, trout may use the reservoirs during different parts of the year for rearing and feeding etc then leave these areas when habitat conditions become unfavorable. This would be similar to the behavior exhibited by upper Klamath River trout populations that migrate large distances to find thermal refugia when Klamath Lake temperatures get too high and DO too low in the summer. The presence of Copco reservoir may be one reason that fish populations upstream of this site are robust (i.e. trophy fishery); especially when the panel notes that fish inputs from above JC Boyle are limited due to the Project. Additionally, whether fish size would increase with	The information provided in this comment has been reviewed by the Panel. The report has been revised for clarification.

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			removal of the reservoirs does not seem supported by the data presented. While large fish are found in the low gradient reaches that exist above Upper Klamath Lake, it is not clear that fish size would increase substantially in the more high gradient reaches that exist from Keno dam to Iron Gate dam. One can simply look upstream to Upper Klamath Lake (and Keno) and see the outcome in regards to fish size for populations that have access to a large body of water. It is unclear if the panel was aware of the status of redband trout in the reach extending from JC Boyle Powerhouse to Copco reservoir. Data collected during FERC relicensing indicated that fish populations in this reach were abundant, and provided one of the best fisheries in Oregon and California (PacifiCorp 2004). PacifiCorp. 2004. Fisheries Resources. Final Technical Report for relicensing the Klamath Hydroelectric Project (FERC Project No. 2082). February. http://www.pacificorp.com/es/hydro/hl/kr.html#	
75		Pg 75; Para 3 and 5	The panel should note that water quality in the JC Boyle bypass reach will not improve with dam removal. Most of the water currently in this reach is from the spring inflows supplemented by a 100 cfs release from JC Boyle dam. If JC Boyle dam is removed, the full flow of the Klamath River will occur in this reach and water temperatures will increase (Bartholow and Heasley 2005). Flows into the reach from June-August are expected to be in the 500-1,000 cfs range in order to achieve flow targets identified below Iron Gate Dam for this period under dam removal. Table 3 in the cited report show that maximum water temperatures will be in the 18 to 21 °C range; average temperatures from 17 to 21 °C. Data presented in Table 12 of the report show that the number of kilometers of stream habitat with a mean daily water temperature of less than 16 °C is zero. In	The information provided in this comment has been reviewed by the Panel. This comment is noted.

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			contrast, under current condition 6.10 of the 7.22 kilometers of stream channel in this reach have a mean daily temperature of less than 16 °C. It is also likely that current DO conditions will likely degrade with increasing water temperatures in this reach because dissolved oxygen solubility decreases with increasing water temperature. Water temperatures leaving the mouths of Jenny and Spencer creeks are typically in the range of 20 C during the summer and should not be considered high water quality inputs. The panel should note that angler days for resident trout may increase, but this could be offset by a loss in angler days for fishers targeting reservoir fish communities such as yellow perch; a very popular fishery for this species exists in both Iron Gate and Copco reservoirs. Bartholow, J,, J. Heasley (2005). JC Boyle Bypass Segment Temperature Analysis. Administrative Report to the US Fish and Wildlife Service and Bureau of Land Management.	
76		Pg 77; Para 2	Dahl (1979) found that yellow perch were indeed inhabiting areas downstream of IGD. He also found that approximately 80 percent of the yellow perch stomachs they captured contained Chinook juveniles (1-5 per stomach sampled). The yellow perch were found in slack water areas…so total impact with the release of millions of yellow perch from dam removal would depend on the amount of this type of habitat (i.e. slackwater) present in the lower river. The river area downstream of the Trinity River may provide this type of habitat. Citation:	The information provided in this comment has been reviewed by the Panel. The citation could not be confirmed at this time. This comment is noted.

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			Dahl, Trygve. 1979. Observations of Fingerling Chinook Salmon in the Stomachs of Yellow Perch from the Klamath River, California. CDFG 1979.	
77		Pg. 82 last paragraph	The panel suggests that it is possible for the trophy redband trout fishery to expand at least 7 times from the Keno to Iron Gate reach following dam removal. Please give a short summary on rationale on how this scenario (i.e. The sevenfold increase) would occur.	The report has been revised for clarification.