Compilation of Information to Inform USFWS Principals on Technical Aspects of the Klamath Basin Restoration Agreement Relating to Fish and Fish Habitat Conditions

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Executive Summary

This document is a compilation and summarization of various modeling exercises, analyses, and relevant information relating to the potential effects of implementing the proposed Klamath Basin Restoration Agreement (Agreement) on fish and fish habitat conditions in the Klamath Basin. The Agreement includes a water management regime, programs for fish habitat restoration, fish reintroduction, and an assumption that a separate agreement will be reached with PacifiCorp regarding dam removal. The full text of the proposed Agreement is available for review at:

http://www.edsheets.com/Klamathdocs.html.

This report also provides the U.S. Fish and Wildlife Service (Service) Principals involved in finalizing the Agreement with supporting information and documentation of the technical staff analyses, data interpretations, and professional opinions relating to anticipated changes in fish production and fish habitat conditions that would occur as a result of implementing the Agreement. Information included in this document is not comprehensive due to the short time frame that accompanied this assignment, but may prove useful to initiate development of the Fisheries Restoration Plan to guide implementation of the Agreement. The summary below describes key points contained in this report with regard to the technical effects of the Agreement on fish and fish habitat conditions.

Water Quality

Potential changes in water quality conditions in the pre dam removal period are anticipated to be minor as the continued operation of the PacifiCorp dam complex has the greatest single influence on water quality dynamics in the Klamath River below IGD. Removal of project reservoirs and the restoration of the river channel in current hydropower reaches, in combination with attendant stream flows, are expected to contribute positively to restoring the physical, chemical, and biological interactions that are critical to a functioning river ecosystem, primarily through nutrient assimilation, re-aeration and shifts in the thermal regime. Following removal of the PacifiCorp dam complex, restoration efforts to improve water quality within and upstream of the Keno reach would be fully realized in the former hydropower reaches and below IGD.

- In the interim period leading up to dam removal, water quality conditions in the Klamath River may improve slightly in response to on-going regulatory and

restoration actions, including the Total Maximum Daily Load (TMDL) assessment, FERC relicensing of PacifiCorp's hydroelectric project, Clean Water Act Section 401 Certification, and wetland restoration projects (e.g. dike removal on Upper Klamath Lake). Benefits would be achieved primarily through reductions in nutrient loading.

- With removal of the Klamath River dams, water would not be retained in reservoirs for power generation. In the absence of project dams, hydraulic residence time through reaches occupied by the PacifiCorp dam complex would decrease from several weeks to less than a day, with the added benefit of nutrient assimilation (river versus reservoirs) - thereby improving water quality.
- Benefits of restoration efforts to improve water quality upstream of the PacifiCorp dam complex prior to and following dam removal would, after dam removal, be fully realized in the former hydropower reaches and below IGD. With the reservoirs in place, water quality improvements within and upstream of the Keno reach provided by the Agreement will be altered in the existing reservoirs and therefore, may not be fully realized below IGD.
- Evaporation from the large surface area of existing reservoirs would be greatly reduced to that occurring on the new river channel and this volume of water would flow down the river.
- Water temperatures will change dramatically with removal of the dams, resulting in a thermal regime that exhibits natural diurnal and seasonal fluctuations rather than the phase shift in thermal regimes that exists today with the project reservoirs in place. Temperature reductions ranging between 2 and 10 ° C would occur from mid- to late August through mid-November, which will have a positive influence on adult salmon migration, holding, and spawning in reaches upstream of Seiad Valley.
- Removal of project reservoirs would allow important coldwater tributaries (e.g. Fall Creek, Shovel Creek Spencer Creek, Jenny Creek) and springs, such as the coldwater inflow to the JC Boyle bypassed reach, to directly enter and flow unobstructed down the mainstem Klamath River, thereby providing thermal diversity in the river in the form of intermittently-spaced patches of thermal refugia. Thermal diversity will benefit a variety of aquatic biota during warm summer months and warmer periods during adult fall and juvenile spring-summer fish migrations.
- The restored thermal regime will play a significant role in nutrient dynamics as will other natural riverine processes; most notably re-aeration of water provided by a turbulent well-mixed river. In spite of the continued release of eutrophic water from Keno Dam, natural riverine processes below Keno are expected to reduce nutrient concentrations and prevent low dissolved oxygen concentrations and high pH events from occurring.
- Water quality modeling performed by PacifiCorp and USGS for the without project dams alternative suggest that dissolved oxygen concentrations are likely to improve and be suitable for aquatic biota in restored river reaches previously inundated by project reservoirs, and below IGD. We do not expect pH to reach levels that are detrimental to river biota because of the high degree of mixing that would occur and its associated positive influence on limiting algae production

- In the absence of project reservoirs, conditions under which blue green algae (BGA) thrive will be greatly diminished, resulting in fewer nutrients and a decrease in the alteration of water chemistry (pH and DO) associated with BGA blooms. Again, turbulent river conditions would prevent such blooms from occurring.
- Algae blooms in the reservoirs serve as an added source of nutrients (through nitrogen fixation with atmospheric nitrogen) to the already eutrophic water of the Klamath River.
- BGA can release toxins that have been found to be harmful to fish and invertebrates; dam removal will virtually eliminate this additional stressor to the biotic community.

Geomorphology and Channel Maintenance

- Lack of sediment input below IGD has created a sediment-starved system, which has caused negative changes in the quantity and quality of spawning gravels in the Klamath River, particularly in the reach below IGD.
- Information in the literature suggest that flows from IGD have been adequate for channel maintenance in most years and that fine sediments are regularly flushed from riffles and pools during average water years and under normal flow conditions.
- Low flows over extended period of drought have increased deposition of silt and fine organics, allowing rooted aquatic vegetation to become well established. These conditions provide habitats preferred by polychaete worms, the intermediate host of myxosporean parasites of salmonids in the Klamath River.
- Conflicting information exists regarding the extent of the effects that dam operations have had on the geomorphology of the river below IGD. However, geomorphic features important to aquatic organisms have been degraded due to fine sediment accumulations and establishment of dense beds of rooted aquatic macrophytes, which are the primary habitats for polychaete worms.
- While the coarse sediment deficit is anticipated to be alleviated with dam removal, flood flows to restore fluvial processes are necessary for the rehabilitation of the channel and associated riparian community. To address concerns relating to substrate conditions in the mainstem Klamath River, the Service has contracted with USGS to determine flow volumes and durations and bedload amounts and composition necessary to maintain dynamic alluvial processes, bank full and flood (timing, magnitude, frequency, and duration) events needed to improve and maintain quality spawning and rearing habitats for salmonids and to reduce abundance of preferred habitats of the polychaete worm. Results of this on-going study, when they become available, will be useful in guiding channel restoration actions in the interim period leading up to dam removal.

Water Quantity

The Water Resources Program in the Agreement consists of schedules, plans, and other provisions that will substantially change the management of delivered water supply for irrigation and related uses in the Klamath Reclamation Project, upper Klamath Basin, and the National Wildlife Refuges:

Upper Klamath Lake Wetlands Reconnection - Measures to increase water supply in Upper Klamath Lake include completion of the breaching of levees in the Williamson River Delta to add approximately 28,800 acre feet of storage; reconnecting Barnes

Ranch and Agency Lake Ranch to Agency Lake to add approximately 63,700 acre feet of storage; and reconnecting BLM's Wood River Wetlands to Agency Lake to provide approximately 16,000 acre feet of storage.

Federal Klamath Irrigation Project - The Agreement establishes limitations on the quantity of water diverted from Upper Klamath Lake and the Klamath River for use in the Klamath Reclamation Project. The limitation will result in the availability of water for irrigation being about 100,000 acre feet less than current demand in the driest years, with irrigation water availability increasing on a sliding scale with increasingly wet conditions. The pattern of agricultural deliveries being higher in dry years than in wet years would be reversed.

Off Project Program - The Agreement establishes a process to increase inflow to Upper Klamath Lake by 30,000 acre feet.

Real Time Water Management - The Agreement includes additional information sources and administrative structures to allow for real time scientific adaptive management by fish managers for the lake and river. The Agreement establishes a Technical Advisory Team that will develop an Annual Water Management Plan that will provide recommendations to the Secretary of the Interior. During each water year, the Technical Advisory Team will also recommend ongoing, real-time operations to adjust for changing environmental and biological conditions.

Refuges - The Agreement provides specific allocations and delivery obligations for water for the Lower Klamath and Tule Lake National Wildlife Refuges. It also increases water availability and reliability above historical levels.

Other (Drought, Emergency, Groundwater, Climate Change) - These programs will focus on investigations and development and implementation of specific management actions to that will give the Agreement the best chance of enduring through unforeseen circumstances and unintended consequences. The Agreement offers the structure and potential to implement a functional drought plan, which has been insufficient under recent management.

At the request of technical staff representing participants in the settlement negotiations, the Klamath Tribe performed iterative modeling simulations that incorporated differing flow and lake elevation targets, Klamath Irrigation Project delivery amounts, and model assumptions. Outputs of model runs were used to assess performance of model inputs and assumptions, determined by examination of deviations from model input targets. Comparisons between alternatives were conducted at a variety of exceedence year types (water year types) related to flow levels at the 10% (wetter) 30%, 50%, 70%, and 90% (dryer) exceedance levels. The model run that most closely reflects the water terms of the Agreement is labeled "WRIMS Run-32 Refuge." Model inputs and outputs of this run are compared to a number of alternatives, including recommendations from the Hardy Phase II habitat modeling study, which employed advanced field and modeling techniques to describe habitat-flow relationships for priority fish species and life stages in the Klamath River. Upper Klamath Lake elevation targets specified in the WRIMS Run-32 Refuge model simulation are referred to as the ALT-Y lake elevation schedule.

- In general, WRIMS Run-32 Refuge output flows exceed historical IGD flows and were similar to the Hardy Phase II recommendations for the 30% and greater

exceedences during the critical Chinook salmon fry rearing (March-April) and Chinook (May) and coho salmon (June) juvenile rearing months.

- At a 10% exceedence, WRIMS Run-32 Refuge model flow outputs and historic IGD flows were generally similar, but the difference varied between time steps within the March - June period. WRIMS Run-32 Refuge output flows for this period were considerably higher than the Hardy Phase II baseflow recommendations for a 10% exceedence, likely due to the Hardy baseflow recommendations not reflecting spill. We note that the Hardy Phase II flows were a baseflow regime target and that higher flows associated with pulse or overbank flows (i.e., spills) are also a component of the Hardy Phase II flow regime.
- Habitat values for WRIMS Run-32 Refuge model output flows were consistently higher than habitat values calculated for historic IGD flows for the March – June emergence and rearing life stages of Chinook and coho salmon for exceedences greater than 10%. At the 10% exceedence level, habitat values estimated for the WRIMS output were higher then historic IGD during the October, November spawning period and during March of the rearing period, but were similar to one another for April-June.
- WRIMS Run-32 Refuge model output flows were lower than the Hardy Phase II recommendations in the fall and winter for dryer water years to help insure that Upper Klamath Lake (UKL) would fill, as needed to meet lake elevations and the specified allocation to the Klamath Irrigation Project.
- October-November Chinook salmon spawning habitat values for the WRIMS Run-32 Refuge model outputs were generally higher for the 10% exceedence level, similar for the 30, 50, and 70% exceedences, and less at the 90% exceedence level than values calculated for historic IGD flows and the Hardy Phase II recommendations. However, habitat values calculated for the Hardy Phase II flow recommendations would be lower in wetter water years as result of higher flows associated with pulse or overbank flows (i.e., spills) that exceeds flows corresponding to the maximum habitat value.
- WRIMS Run-32 Refuge model simulations predicted the lake to fill to the targeted lake elevation (4,143 feet) for the majority of exceedence year types.
- There was a clear trend in the lake elevation outputs of the WRIMS Run-32 Refuge model run being higher than the proposed ALT-Y lake elevation targets throughout the fall and winter and during the majority of exceedences. This indicates that there is an opportunity to adaptively manage the lake and river on a real time basis.
- Outputs of the WRIMS Run-32 Refuge simulations also predicted that lake elevations would not drop below 4,139 feet during late summer/early fall with the exception of September and October for a 90% exceedence year. This should greatly facilitate refill of the lake by the following spring and provide listed suckers with unrestricted access to tributaries and spring refugia areas during periods of adverse water quality.

Chinook Salmon Production

Prior to dam removal, production potential of fall Chinook salmon would significantly improve in years resembling historic low and average production years in response to implementing the water allocation proposed in the Agreement. In years where modeled historic production was high, potential for improvement under both Run-32 Refuge and

Hardy Phase II flow schedules was consistently low as habitat availability modeled in SALMOD was at or near the maximum values. Conversely, years where modeled historic production of fall Chinook salmon was low provided the greatest opportunity for improvement under any of the alternative flow schedules.

While opportunity exists to improve Chinook salmon production prior to dam removal, removal of Klamath River dams has potential to greatly increase production over that experienced even in the historically highest production years. Expansion of accessible habitats resulting from removal of Klamath River dams will greatly increase production potential over that which exists with the dams in place and augmented flows provided by the Agreement. In general, gains in habitat availability and associated production potential that would result from removal of the Klamath River dams, including the reestablishment of spring Chinook salmon in the upper basin, far exceed gains that could be achieved below IGD through manipulation of flows alone.

Pre Dam Removal

- In general, years where modeled historic production of fall Chinook salmon was low provided the greatest opportunity for improvement under any of the alternative flow schedules. Conversely, in years were modeled historic production was high, there was little difference in the change in production for the alternatives.
- Percent change in production from the historic baseline for the Run-32 Refuge and Hardy Phase II simulations for the 10 highest historic production years (upper 25th percentile) averaged about +6 % and -7% and for the 10 lowest historic production years (lower 25th percentile), about +45 % and +51 %.
- In years when modeled fish production increased significantly over historic baseline predictions (>±10 % over baseline), improvements in production often occurred as a result of increased flows in the spring and/or reduction in intensity and/or frequency of fall spills. Early fall spills reduced estimates of adult spawning habitat availability, while increases in spring flows over historical baseline conditions resulted in increased fry and juvenile rearing habitat availability.
- Implementing either the WRIM Run-32 Refuge model outputs or Hardy Phase II flow recommendations was predicted to cut poor production years by about 2/3 in the future. Reducing the average occurrence of low production years from 1 out of every 4 years downward to 1 out of every 10 years is significant given the dominant 3 to 4 year life cycle of fall Chinook salmon in the Klamath Basin.
- SIAM simulations predicted Upper Klamath Lake water surface elevations to be substantially lower under the Hardy Phase II simulation than elevations predicted from the WRIMS Run-32 Refuge model outputs. This, however, should be expected as Hardy et al. (2006) characterize their flow recommendations as being "*made based on the ecological needs of the Lower Klamath River and anadromous fish in particular"* and that the Hardy Phase II study was *"not commissioned to undertake any 'optimization' or flow balancing to meet competing water demands*".

Post Dam Removal

- About 350 miles of stream and associated anadromous fish habitat, much of which has been lost since 1918 with the construction of Copco 1 Dam, would become available for spring and fall Chinook and coho salmon, steelhead, and lamprey in the Klamath Basin as a result of dam removal proposed under the Agreement.

The return of these anadromous fishes to their historic range would provide a wider diversity of occupied fish habitats, such as intermittent streams and thermal refugia, than is currently present in the Klamath River system. This added diversity in fish habitats will be of benefit to various life stages and species of anadromous fishes and will contribute to the ability of these species to thrive in variable and challenging environments by providing opportunities to maintain greater genetic variation.

- Changes in water temperatures that more closely resemble the historic thermal regime are anticipated to increase the average size of juveniles at ocean entry, which has been widely shown in the literature to increase estuary/ocean survival. Adult salmon would also benefit from a colder thermal regime in the late summer and fall in the upper river, which may reduce disease incidence, increase swimming performance and increase gamete viability.
- Dam removal would provide access to additional spawning habitats that would disperse spawning. This would minimize the unnaturally high levels of redd superimposition that currently occurs below IGD, even in years of low escapement, thereby increasing adult to juvenile production ratios.
- Minimizing the high spawning and fry and juvenile densities that can occur below IGD may also benefit outmigrant fishes from the Shasta and Scott rivers, through reduced competition for food and space.
- Following removal of the Klamath dams, key historical spawning areas would become available in mainstem reaches such as Iron Gate and Copco and in numerous tributaries such as the Williamson and Sprague River, Jenny Creek, Fall Creek, Shovel Creek, etc.
- Dam removal provides a high potential for spring Chinook salmon to become established in the upper Klamath River and potentially become the dominant Chinook salmon run in the Basin once again. Under the Agreement, suitable stocks will be identified and a reintroduction plan will be implemented, with harvest of returning adults possible within several return cycles after supplementation begins.

Implementing the Water Allocation in Real Time

Under the Agreement, a Technical Advisory Team will develop an Annual Water Management Plan that will provide recommendations to the Secretary of the Interior. During each water year, the Technical Advisory Team will also recommend ongoing, real-time operations to adjust for changing environmental and biological conditions. Water management would become a transparent process, with flow release decisions made using an adaptive management process with stakeholder involvement. In this report, we provide an example of real time management (RTM) application that may serve as a viable approach for water management under the Agreement. The goals of the RTM application are 1) to provide a feasible method for implementing the water allocation proposed in the Agreement and 2) to reestablish important processes and function of the natural hydrograph, including the timing, frequency, magnitude, duration, and rate of change in flows. The RTM process eliminates the need for water years and fixed flow schedules by using real-time daily discharge for an unregulated reference stream (Williamson River) to inform daily flows at IGD, as recommended by the NRC (2007). This concept was at the root of the Hardy Phase II flow regime and is strongly supported by instream flow practitioners and stream ecologists because it results in flow patterns that mimic the shape and function of the natural hydrograph under which the

aquatic biota evolved.

- The RTM process would restore the natural flow paradigm under which aquatic biota evolved and that is inherent in unregulated, natural river systems.
- The RTM process proposed in this report has been demonstrated to be a viable tool for implementing the water allocation proposed in the Agreement.
- The division of water between the lake and the river could be modified using an adaptive management approach to provide flexibility in implementing river flows and maintaining lake elevations; a progressive approach new to Klamath water management.

Fish Health

Fish diseases are widespread in the mainstem Klamath River during certain periods and there is increasing evidence to suggest that disease levels, in some years, are adversely affecting the freshwater production of Chinook salmon. In recent years, the Service working collaboratively with its Tribal and Agency partners, has documented high infection rates in emigrating juvenile Chinook and coho salmon, primarily by one or both myxosporean parasites – *Ceratomxya shasta*, and *Parvicapsula minibicornis*. Fish health studies conducted from 1995 to present have consistently documented high infection incidence (up to 44% of natural origin juvenile fall Chinook salmon) in the Klamath River during the spring and summer. Abnormally high infection prevalence within the native salmon population indicates that a host-parasite imbalance exists below IGD.

- Polychaetes, the intermediate host for *C. shasta*, and *P. minibicornis,* are found throughout the mainstem Klamath River but are most prevalent in low velocity areas such as runs, pools, and riffle edge habitats In addition, inflow zones of Klamath River reservoirs have exceptionally high densities of polychaetes, which is consistent with published literature. Converting the existing reservoir complex to a riverine system will eliminate these densely colonized areas.
- Restoration of the hydrologic function of the river system is vital in creating habitat diversity and maintaining biophysical attributes of a river system. Flexibility to change flows to respond to real-time climatic and biological conditions, made possible by the Agreement, will create diversity in flows and resulting habitat conditions as well as instability and disturbance in microhabitat conditions that will diminish polychaete populations and presumably, reduce infection rates within polychaete populations.
- Stable, monotypic, nutrient- and diatom-rich flows that occur below IGD provide an optimal environment for production of filter-feeding benthic invertebrates like polychaete worms. Fluctuating flows that mimic, albeit to a lesser degree, conditions experienced under a natural flow regime, will eliminate the monotypic stable flow conditions in which polychaetes are known to proliferate.
- The greater thermal diversity that will be experienced following removal of the Klamath River dams and reservoirs is likely to result in greater invertebrate diversity and less favorable environmental conditions for production and survival of a single species such as the polychaete worms.
- Removal of the project dams is likely to alter the distribution of myxospores, an intermediate life stage of myxozoan parasites that are released from salmonids, by

dispersing concentrations of adult salmon and resident trout found below IGD. The passage barrier created by IGD and the shared location of the Iron Gate Fish Hatchery has concentrated the density of spawning adult salmon in the IGD to Scott River reach, thereby exacerbating release of infectious myxospores within this reach. The greater abundance myxospores released by dense concentrations of spawning salmon within this reach results in higher infection rates in polychaetes, which proliferate in this relatively hydrologic stable reach.

- Removal of project dams would facilitate the occurrence of higher peak flows and restoration of mid-sized (gravel) sediment input below Iron Gate Dam that could scour polychaete colonies and their habitats and reduce actinospore loads in the following spring.

Conclusion

Successful implementation of the Fisheries Program of the Agreement will necessitate a change in scientific process within the Klamath Basin. Scientific efforts and funding would shift from competing science, which has functioned in the Klamath Basin to preserve status quo, to restoration, reintroduction, and adaptive management. A unified approach to science in the Basin that aligns funding and technical efforts to meet a common purpose identified in and supported by the Agreement, will contribute immensely to fish recovery in the Basin. This unified approach will be well defined in the Fisheries Restoration Plan required under the Agreement, a concept supported by the NRC (2007).

As described in section 9.1.1. of the proposed Klamath River Restoration Agreement, the purpose of the Agreement's Fisheries Program is to restore and sustain natural production of fish species throughout the Klamath River Basin. Specifically, this program,

> *"...establishes conditions that, combined with effective implementation of the Water Resources Program in Part V, will contribute to the natural sustainability of fisheries and Full Participation in Harvest Opportunities, as well as the overall ecosystem health of the Klamath River Basin…"*

Based on information summarized in this report, in combination with various other technical documents provided to settlement participants by non-Service entities, the Technical Staff of the US Fish and Wildlife Service recommends that the Principals for the U. S. Fish and Wildlife Service support full implementation of the Klamath Basin Restoration Agreement. Implementing the water allocation proposed in the Agreement prior to dam removal would significantly improve production potential of fall Chinook salmon below IGD in years resembling historic low and average production years. However, the collective professional opinion of lead technical staff that contributed to this report concur that removal of the Iron Gate, J. C. Boyle, and Copco 1 and Copco 2 complex of dams will provide the single greatest contribution to the recovery of native anadromous fish populations, as needed to support full participation in ocean and in-river harvest opportunities. When viewed in combination with the suite restoration and management actions proposed under the Agreement (Table I-1), we anticipate that benefits to the Klamath River and its dependent fisheries will begin to be realized in the interim period leading up to dam removal, with a high probability of significant improvements occurring once the dams are removed. The timing and magnitude of improvements, however, will largely depend on the timing and degree to which the suite

of restoration and management actions identified in the Agreement are fulfilled (Table I-1).

Table I-1. Status of various activities that influence fish production in the Klamath River under current conditions, the FERC relicensing process, and under the Klamath Basin Restoration Agreement (no= will not occur, yes = will occur, ? = likelihood of occurrence unknown).

Activity	Status Quo	Dams Remain Fish Passage Installed	Restoration Agreement
Basin-wide Restoration Plan	?	?	Yes
Increased Funding, Scope, and Pace of Restoration Actions	No	No	Yes
Reintroduction Plan above IGD	No	Yes	Yes
Reintroduction of Anadromy to 350 Miles of Habitat	No	Yes	Yes
HCP Above UKL	No	?	Yes
Acquisition of Water Rights above UKL	No	No	Yes
Increased Storage and Restoration in UKL Wetlands	Yes	Yes	Yes
Capped Allocation of Water to KIP & Increased Environmental Water	No	No	Yes
No Adverse Impact from KIP Groundwater use	No	No	Yes
Drought Management Plan	?	?	Yes
Real-time Management of Environmental Water	No	?	Yes
Funding Water Quality Work in Keno Reservoir	No	No	Yes
Dams out	No	No	Yes
Anadromous Fish Habitat at Present Reservoir Sites	No	No	Yes
Improved Water Quality in Lower Klamath River	Limited	Limited	Yes