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TECHNICAL MEMORANDUM

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TO: Ben Swann

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SUBJECT: Qualitative assessment of prolonged facility removal for the Klamath River dams

1 INTRODUCTION

The U.S. Department of the Interior (DOI), as the National Environmental Policy Act (NEPA) lead agency, and the California Department of Fish and Game (DFG), as the California Environmental Quality Act (CEQA) lead agency, are currently developing an Environmental Impact Statement/ Environmental Impact Report (EIS/EIR) for the Klamath Hydroelectric Settlement Agreement (KHSA) and the Klamath Basin Restoration Agreement (KBRA). The EIS/EIR will evaluate the environmental and social effects of a set of alternatives that may include removing all or portions of J.C. Boyle, Copco 1 and 2, and Iron Gate dams on the Klamath River, which would provide volitional fish passage to aid in restoring salmonid fisheries.

The current plan for removing the four dams calls for reservoir drawdown during the winter of 2019 in a controlled manner, releasing the majority of the erodible sediments to the middle and lower Klamath River prior to the summer of 2020. This approach would limit the major fisheries impacts to the winter of 2019 and spring of 2020. Based upon a recent fisheries impacts analysis that considered predicted suspended sediment concentration and duration as well as geographic distribution and life-history traits of focal fish species in the downstream river reaches, suspended sediment impacts would be sub-lethal for most species and life stages, while some species and life stages would experience lethal impacts (Stillwater Sciences 2011).

Some stakeholders involved in the EIS/EIR and Secretarial Determination process have questioned the current dam removal plan and have asked if impacts to aquatic species could be reduced by prolonging the release of erodible sediments over multiple years. A prolonged release period can potentially decrease suspended sediment concentrations at any given point in time but would extend the number of years of relatively high concentrations in the river downstream of the dams. In general, a dam removal scenario that was prolonged over two or more years would involve either 1) staged removal of the dam structures, 2) sequenced removal of individual dams across multiple years, or 3) slower, simultaneous drawdown of the four reservoirs. This memorandum explores each of these potential dam removal strategies in a qualitative manner and provides a basic rationale for the anticipated biological impacts of prolonged dam removal. Among the four Klamath River dams considered, Copco 2 does not possess a sediment deposit and its removal will not affect the rate of sediment release for the project. J.C. Boyle contains relatively small amount of sediment (roughly 7.5% of the total deposits in all the reservoirs in question), and thus, sediment release due to J.C. Boyle Dam removal is minor compared to the release of sediment from Copco 1 and Iron Gate reservoirs. As a result, we focus our discussions only on Iron Gate and Copco 1 dams.

2 STAGED DAM REMOVAL

Dam removal can be accomplished through the physical removal of dam structures in a staged or progressive manner. For example, the Elwha River, Washington, dam removal project has adopted a staged deconstruction alternative as a way to control the rate of sediment released to downstream reaches. The two Dams on the Wlwha River will be gradually notched from the top by cutting and removing different sections of the dam, moving progressively lower in the dam crest to allow sequential fractions of the reservoir sediment deposit to be eroded downstream over a long time period. (Randle et al. 1996)

For the Klamath River dam removal project, staged dam removal for one or more of the four dams has been considered by the Lead Agencies; however, the physical configurations of the Klamath River dams are quite different from that of the Elwha River Dam. In each of the two Elwha River dams, there is no bottom outlet to allow for a controlled sediment release, and construction of bottom outlets is either technically or economically infeasible. As a result, notching the dams is practically the only feasible way of releasing the reservoir deposits in a controlled manner. In the Klamath River project, Iron Gate is equipped with bottom outlets that allow the reservoir to be drawdown in a controlled manner, thus, gradually release its sediment deposit. As a result, there is no need to seek other techniques of controlled sediment release for Iron Gate Dam removal. In addition, Iron Gate Dam is an earth-and-rock-fill dam, and a staged notching of this structure is not possible. Similarly for Copco 1 Dam, a diversion tunnel originally used during dam construction exists, which is currently plugged but can be opened and modified as a low-level outlet for controlled sediment release, eliminating the need for a staged deconstruction of the dam face for this purpose. As a result, there is no need to use staged removal technique as a way of controlling sediment release in the Klamath River dam removal project.

3 SLOW RESERVOIR DRAWDOWN

To use the low level outlets for controlled sediment release for Iron Gate and Copco 1 reservoirs, which contain mostly silt and clay, the duration and magnitude of sediment release are functions of how quickly the reservoir pool level is reduced. Each time the reservoir water levels are lowered, sediment is eroded from the reservoir deposits and released downstream. The faster the drawdown, the higher the concentration of suspended sediment in the release water, and the shorter the overall duration of release. A slow reservoir drawdown approach through the control of the bottom outlets in Iron Gate and Copco 2 dams could extend the erosion period across multiple years.

The current Klamath River dam removal plan involves a relatively rapid reservoir drawdown period (constrained by concerns for slope instability) to release the majority of fine sediment during the first year in association with winter high flows. This approach is consistent with the natural timing of high turbidity events in the watershed, allows the released sediment to be diluted by high winter flows from tributaries, and coincides with relatively lower use of the mainstem Klamath River by focal fish species. However, it is theoretically possible to slow the reservoir drawdown through the low-level outlets such that fine sediments could be released across multiple years. The slow drawdown scenario could take place during two or more winters to coincide with high flow periods and the relatively low presence of focal fish species in the mainstem Klamath River. The technical feasibility of a multiple year drawdown has not been fully assessed. The anticipated biological impacts of prolonged dam removal using a slow reservoir drawdown approach are discussed in Section 5.

4 SEQUENCED DAM REMOVAL

Sequenced dam removal refers to the deconstruction of the four dams one-by-one, with little to no overlap in the timing of individual dam removal. There are two possible approaches to a sequenced removal of Iron Gate and Copco 1 dams: 1) remove the upstream Copco 1 Dam first while Iron Gate Dam is still intact, using Iron Gate Reservoir as a trap for sediments transported downstream; or 2) remove Iron Gate Dam first, followed by the removal of Copco 1 Dam. Both of these approaches to sequenced dam removal are technically feasible for the Klamath River dams. However, with regard to the first approach, Stillwater Sciences (2007) demonstrated that a large fraction of the fine sediment released during the removal of Copco 1 Dam would not settle in Iron Gate Reservoir, but would instead remain suspended and result in high water column concentrations downstream of Iron Gate Dam. Therefore, it is anticipated that removing Copco 1 Dam first would result in two periods of very high suspended sediment concentrations in the middle and lower Klamath River, similar to a multi-year slow reservoir drawdown scenario (above). Removing Iron Gate Dam prior to removing Copco 1 Dam would also be expected to produce two high suspended sediment events similar to a slow drawdown sediment release across two years. The anticipated biological impacts of prolonged dam removal using a sequenced dam removal approach are discussed in Section 5.

5 BIOLOGICAL CONSIDERATIONS

As described above, it is technically feasible to conduct a slow drawdown of, Copco 1, and Iron Gate reservoirs over a period of two or more years, or to sequence the removal of these four dams, such that the total amount of sediment released downstream is distributed across multiple years. For both of these approaches, the suspended sediment impacts could be generally constrained to a desired season (i.e., winter). However, the impacts to fisheries resources due to suspended sediments are not linearly related to the amount of sediment released (Figure 1). A recent analysis of the impacts of high suspended sediment concentrations on focal fish species in the middle and lower Klamath River demonstrated that reducing the magnitude of sediment release by approximately 44–45% through mechanical dredging would result in a minimal reduction of impacts to fish (Stillwater Sciences 2011). This implies that releasing sediment across two years would likely produce similar impacts during each of the two years and would negatively affect fish in consecutive year classes. For example, if extending reservoir drawdown across two years resulted in 50% of the total volume of sediment released during each year, predicted mortality would be 100% for spawning fall-run Chinook salmon in the mainstem

Klamath River in both of the two years[1]. Based on this reasoning it would be detrimental to prolong the sediment release over a two-year period.

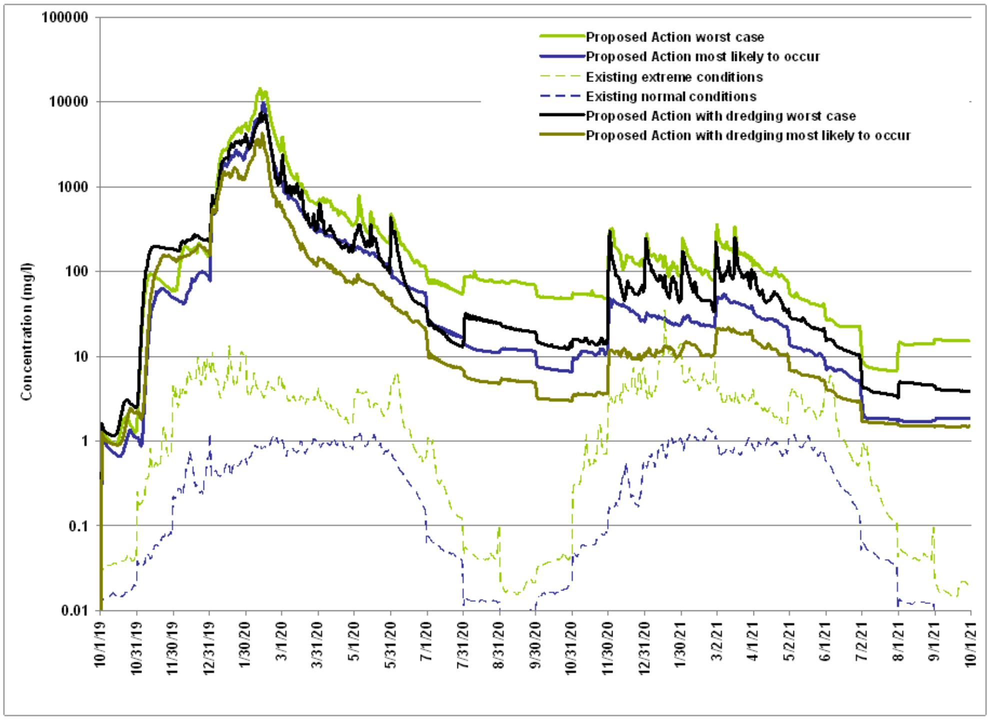

Figure 1. Comparison of SSCs under Proposed Action and Proposed Action with Dredging at Iron Gate Dam, as Predicted Using SRH-1D Model.

Alternatively, water levels in the reservoirs could be lowered a small amount each year for more than two years, releasing a small amount of sediment each winter until the reservoirs were fully flushed of erodible sediment. Although the feasibility of this approach has not been fully evaluated (see Section 3), if it were possible it could result in lower impacts to fish within each year. However, the effects to fish from multiple years of impacts, even if impacts in individual years are sublethal, could be significant. The cumulative long-term effects on a population of sublethal impacts to successive cohorts are difficult to predict. Under existing conditions salmon smolts outmigrating from Klamath River tributaries downstream of Iron Gate Dam have high mortality (35 to 70 percent) (Beeman et al. 2007, 2008), which, in conjunction with sublethal physiological stress and reduced growth from released SCC, could result in even higher mortality within each successive year that sediment were released. In addition, sublethal impacts associated with elevated suspended sediment concentrations, such as major physiological stress and reduced or no growth (Newcombe and Jensen 1996), results in smaller smolt size of outmigrants which can reduce marine survival (Bilton et al. 1982, Bilton 1984).

While significant short-term impacts to focal fish species are anticipated under the current, one-year dam removal approach, in the long-term all focal species are predicted to have a strong

[1] 100% mortality for spawning fall-run Chinook salmon in the mainstem Klamath River is approximately 8 percent of the total fall-run Chinook salmon in the Klamath River.

recovery. The principal reason for the broad-based recovery is that under the current dam removal plan none of the focal species would have an entire year-class exposed to multiple months of high suspended sediments as a result of dam removal. Adults, juveniles, and smolts from each year-class that can avoid the impacts will support population recovery (Stillwater Sciences 2011). Distribution and life-history traits that will allow focal fish species to avoid sediment related impacts in a one-year dam removal scenario vary, but in general they include the following:

- limited use of the mainstem Klamath River for spawning and rearing;
- variation in adult migration timing;
- variable outmigration timing;
- variable age at outmigration;
- mature adults remain in the Pacific Ocean rather than returning to spawn; and,
- repeat spawning of steelhead and sturgeon.

A multiple-year sediment release approach, either through slow reservoir drawdown or a sequenced dam removal, would reduce some of the natural protection that distribution and life-history traits afford each of the focal fish species, and it would result in the eventual exposure of multiple life-stages of each cohort to elevated suspended sediment concentrations downstream of Iron Gate Dam. For example, under the current, one-year dam removal scenario, by the time progeny of the 2019 year-class outmigrate from Klamath River tributaries as age-1 smolts, the concentrations of suspended sediment are predicted to be indistinguishable from existing conditions. As a result, only the adults of the 2019 year-class would be affected by dam removal and the year-class has a good chance of a strong recovery (Stillwater Sciences 2011). With a multiple year drawdown the adults would be affected during migration, and the progeny are also affected when they outmigrate in spring 2021. Further, within the Klamath River green sturgeon population only 25% of mature adults spawn within a given year, ensuring that a relatively small portion of the population would be exposed to sediment released during dam removal (Stillwater Sciences 2011). With a multiple year drawdown a much larger percentage of the mature adult population could be affected during their migration.

A final consideration regarding slow reservoir drawdown or sequenced dam removal where Iron Gate Dam is removed last, is that any extended period of dam removal will inevitably delay the opening of fish passage in the Klamath River upstream of Iron Gate Dam, further delaying the intended purpose for dam removal (i.e., to allow focal fish species access to historical habitat in the upper Klamath River basin).

6 REFERENCES

Bilton, H. T. 1984. Returns of Chinook salmon in relation to juvenile size at release. Canadian Technical Report of Fisheries and Aquatic Sciences 1245. Department of Fisheries and Oceans, Fisheries Research Branch, Pacific Biological Station, Nanaimo, British Columbia.

Bilton, H. T., D. F. Alderdice, and J. T. Schnute. 1982. Influence of time and size at release of juvenile coho salmon (*Oncorhynchus kisutch*) on returns at maturity. Canadian Journal of Fisheries and Aquatic Sciences 39: 426-447.

Greimann BP, Varyu D, Godaire J, Russell K, Lai G, and Talbot R. 2011. Hydrology, hydraulics and sediment transport studies for the Secretary's Determination on Klamath River dam removal and basin restoration, Klamath River, Oregon and California, Mid-Pacific Region. Draft Technical Report No. SRH-2011-02. Prepared for USDI Bureau of Reclamation, Mid-Pacific Region, Technical Service Center, Denver, Colorado.

Newcombe, C. P., and J. O. T. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16: 693-727.

Randle, T.J.; Young, C.A.; Melena, J.T.; Ouellette, E.M., October 1996, Sediment Analysis and Modeling of the River Erosion Alternative, Elwha Technical Series PN-95-9, U.S. Department of the Interior, Bureau of Reclamation, Boise, Idaho, 138 pages.

Stillwater Sciences. 2007. A first-order estimate of fine sediment trapping potential within Iron Gate Reservoir for upstream drawdown and dam removal. Technical memorandum prepared for Mr. Michael Bowen, Project Manager, California State Coastal Conservancy, September 6.

Stillwater Sciences. 2011. Suspended Sediment Concentrations and Potential Impacts on Focal Fish Species for Klamath Dam Removal under the Proposed Action Drawdown Scenario 8 with Mechanical Sediment Removal. Draft Technical Memorandum. Prepared by Stillwater Sciences, Berkeley for CDM, Sacramento, California.