MEMORANDUM

To: John Hamilton, U.S. Fish and Wildlife Service

From: John Hefner, Senior Scientist, Raleigh, NC

CC:

Date: November 2, 2010

Subject: Expert Review of **Stillwater Sciences. 2009. Effects of sediment release following dam removal on the aquatic biota of the Klamath River.**

This memorandum presents comments submitted to PBS&J by two independent expert reviewers of *Stillwater Sciences. 2009. Effects of sediment release following dam removal on the aquatic biota of the Klamath River. Technical Report. Prepared by Stillwater Sciences, Arcata, California for State Coastal Conservancy, Oakland, California. January. 185 pp.*

The two reviewers are eminently qualified to provide expert evaluations of the subject document. One of the reviewers is a fisheries biologist with over 35 years experience evaluating the impacts of suspended sediments and other toxic materials on salmonid fishes in the western portion of North America and has published extensively on the subject. The second reviewer is a water resource engineer who has participated in over 150 dam removal and fish passage projects. Having reviewers from different disciplines, in our opinion, adds to the credibility of the overall comments.

General Comments

The expert reviewers were of the opinion that the report was thorough, very well written, and easily understood; that the research that went into the report was exhaustive; and that conclusions presented were well founded and logical. Taken in their entirety, the reviews were positive and suggestions for improving the report were minor. Minor suggestions from the reviewers included providing some additional information on the quantity and quality of sediments behind the dams and to provide estimates of the deposition of sediments within the channel once the dams are removed. It was also suggested that baseline information regarding the current levels of suspended sediments and water clarity might be useful for reference purposes as the dam removal project progresses.

The verbatim comments from the two reviewers follow.

Comments from Reviewer 1:

1. **Peer Review Evaluation**.

Further to the requirements of this contract (Scope of Work for Peer Review) as established by the Office of Management and Budget's Final Information Quality Bulletin for Peer Review (16-December 2004), here are my opinions in each of the *eight* required categories (Table 1):

Table 1. Reviewer's evaluation[<Δ>].		
'Final Information Quality' Category		Remark(s)
1	Clarity of hypothesis;	Clear.
2	Validity of the research design;	Valid.
3	Quality of the research design;	Excellent.
4	Quality of the data collection procedures;	Excellent.
5	Robustness of the methods employed;	Very robust.
6	Appropriateness of the methods for the hypothesis being tested;	Highly appropriate.
7	The extent to which the conclusions follow from the analysis;	Conclusions follow logically.
8	Strengths and limitations of the overall product.	The product is very well done.
[<Δ>] A review done in accordance with the Office of Management and Budget's Final Information Quality Bulletin for Peer Review (dated 16-December 2004).		

In the remainder of this report I explain my opinions, beginning with a brief background from outside sources to establish useful context for the general reader.

2. **Background**:

An agreement in 2008 involving the U.S. federal government, and two states – California and Oregon – could result in the removal of four hydro-electric dams in the Klamath river basin: Iron Gate Dam, Copco Dam 1, Copco Dam 2, and John C. Boyle Dam. The purpose in removing these dams is, among other things, to improve salmon fisheries. Projects on this scale are rare, and there is no routine approach known to guarantee the desired result. In an effort to optimize the operational aspects of the project, resource managers must try to demonstrate how the ecological benefits of removing these dams will outweigh the costs. Removal of the first dam apparently will not occur until some time after 2012, and removal of the fourth dam apparently will not occur until 2020. None of this information exists in the Final Technical Report, which is perhaps an oversight as context provides important insight.

3. **Summary Evaluation:**

(a) *Endorsement of Conclusions*. Conclusions of this Final Technical Report (2009) appear well-reasoned and sound. Local knowledge of fisheries populations is excellent; the simulated sediment pollution episodes are convincingly realistic; and the authors and their numerous advisers have used these two areas of expertise with great care and skill. They have missed nothing important that I can see; and they have produced a nuanced response to an exciting proposal.

Stream hydrographs, would clarify the report. Proposed sediment releases seem to mimic natural patterns. Mid-November to mid-February likely is the time of peak stream flow and peak suspended sediment load. It is also the time of minimum water temperatures. Fish populations exposed to excess suspended sediment survive best under these conditions.

Specifically, the proposed removal of the four hydro-electric dams seems unlikely to pose any threat of permanent harm any fish species or any life-history phase examined. There is good reason to believe that not one of the seven focal species will be extirpated, though all will likely experience short-term reduction in population size. One life-stage of one species, steelhead trout 'half-pounder', is at particular risk. This life stage might experience nearly 100% mortality in some parts of the river basin, though not high mortality at all places at the same time. This much is evident because of the high degree of overlap of the timing of this life-history phase and the timing of peak suspended sediment pollution episodes. However, local extirpation of steelhead 'half-pounders' is unlikely to cause permanent loss at the population level, for reasons discussed below. Migrant phases in the steelhead population are also at risk but less so. Migrants are *en-route* to spawning tributaries and might seek shelter at the margins of the mainstem river, or in small rain-fed tributaries even if these are unsuitable for spawning activity, and even if these offer nothing but clear water and cover.

This worst-case scenario in the report – steelhead 'half-pounders' – is supported by good local knowledge of the timing and distribution and abundance of steelhead life-history phases. However, re-population seems inevitable, and extirpation very unlikely. Survivors, whether they emerge from the pollution zone or elsewhere in the basin, and resident populations of steelhead unaffected by sediment pollution in adjacent basins would likely re-occupy vacant or underutilized habitat. This pattern might mask losses by direct mortality but would offset the inevitable harm of the sediment pollution. Mitigation measures for steelhead trout might limit these risks; and the steelhead themselves – 'half-pounders' in particular – might exhibit survival strategies that preserve more of their number than the simulations lead us to believe.

Analysis of the available information, as presented in this report, provides a solid rationale on which to act. If or when a dam is actually removed, there will be an opportunity for real-time impact assessment. Experience gained from the removal of the first dam would allow resource managers to adapt their methods to reduce harm in high-risk scenarios. Quantitative knowledge of fisheries resources and their life history phases in the Klamath river basin is excellent and has been used skillfully. Without these historical data on distribution and abundance of fish life-history phases, the task of predicting impacts would have been much more difficult. The amount of work that has gone into making these predictions is impressive.

(b) *Reasons for Concern and Optimism*. Because suspended sediment is a natural part of the hydrological cycle in salmon streams, it is often difficult to accept that increasing the sediment load is necessarily a harmful thing. Excessive suspended sediment can be harmful to fisheries at any time of year, but summer low-flow is the worst possible time. Fortunately, estimated total suspended sediment load in the Klamath river basin in summer in *dry* years is nil. In the wettest years -- in the summer months -- some simulations (though not all of them) indicate that sediment transport *resumes* in early May and continues – ranging from less than 100 ppm most of the time to 300 ppm max (not including a couple of spikes that are less than 1000 ppm) – until the end of September.

Summer suspended sediments events are generally more harmful to fishes in warmer water than in cold winter months. So, summer suspended sediment is cause for concern. Optimistically, since summer flood events capable of causing suspended sediments events are smaller than winter flood events, the particles in suspension during summer floods will likely be smaller (clay-sized and smaller) and less capable of harm. Where this is so, and if suspended sand-sized particles can be ruled out, perhaps the major effect in these 'wettest year' summer floods will be excessive water cloudiness. Under these conditions, where visual range for hunting is reduced, fish will have less success feeding; and primary production will be reduced.

Only three months are predicted to be free of excess suspended sediments: October, most of March, and all of April (including the first week in May). These clear water periods are important for two reasons: many important fish life history phases coincide in part with these periods, so there are no direct impacts during these periods; and fishes that have experienced harm – loss of feeding opportunity or gill abrasion, for example – may partially recover during clear water phases. These remarks are based on the simulations, and actual patterns might differ depending on the patterns of stream discharge.

The important difference between the simulations for winter (wettest *and* driest years) and wettest-year summer simulations is that the mass of suspended sediment being transported by the stream is much greater in winter than in summer. I am guessing also that the maximum particle size-fraction transported in winter events will be significantly larger than the maximum in summer events. These two differences are significant, if they can be verified, because summer sediment events would be less harmful than they might otherwise be. Even so, summer sediment events are likely to be problematic.

Sediment character and amount vary as a function of time within individual flood events. Sediment transport is a general function of stream discharge, but the amount of sediment and the particle size distribution may be different on the rising limb of the hydrograph as compared with the descending limb. Daily averages mask peaks. For this reason it might be useful to study the discharge-concentration relationship in greater detail and to characterize the degree of hysteresis. My guess is that harm to fishes by suspended sediments is greater on the rising limb of the hydrograph than on the descending limb. How to use this information to protect fisheries resources is not clear, but it is important to be aware of the phenomenon.

As each of these dams is removed (consistent with the proposal), large amounts of fine sediment will be put into suspension and transported downstream – almost all of it in cold weather months. Although suspended sediment is a natural component of the stream environment, and although fish populations are adapted to seasonal variations as a function of natural fluctuations in streamflow, excessive suspended sediment is a source of concern, and it is the focus of this report.

The report ignores other stressors for good reason. Some chronic environmental stressors such as water pollution by domestic and agricultural sources, and land use patterns that reduce the integrity of the natural stream, have not been included in this analysis, nor need they be. While the dams are operating, and after the dams have been removed, these influences are relevant to fisheries management. But, because of the nearly cataclysmic scale of the proposed sediment releases occasioned by the removal of the dams, chronic environmental problems – harmful over the long-term – are almost irrelevant on the short-term.

Assessing sediment impacts and managing these will be a challenge. When an existing dam is removed, a large volume of deposited sediment is re-mobilized, causing dramatic increases in bed-load and suspended sediment. The report is silent on changes in streambed texture, except to indicate that deep pools will likely be well scoured and therefore not fill with fine sediment.

However, fine sediment will almost certainly infiltrate the stream bed, causing many changes: armoring and loss of primary and secondary productivity.

Excessive sediment movement of this kind causes fisheries impacts over a period of years. Since the removal of a dam causes short term impacts and long term benefits, the task of fisheries managers – responsible for seven focal fisheries – is to limit harm to the extent possible.

Collapse of a fishery is a possible consequence, but this is unlikely. Although excessive rates of sediment transport do harm fishes and their environment, there is little reason to be concerned about the extirpation of any species. In the history of sediment pollution events there are few if any examples. Real concerns of this kind – extirpation – are more likely to arise as a result of chronic, long-term, man-made change (soil erosion, or storm-water runoff, or domestic and agricultural pollution); or where climate change reduces annual stream discharge, or increases stream temperature, or both. Serious fisheries problems in a river basin are caused by phenomena that are beyond our ability to control. By contrast, removal of river dams is a task that invites a nuanced response designed to achieve the best possible outcome. Mainly the challenge is about finding the best time (week and month) in the hydrological cycle, and the best time (hydrological year) and the best time in the rhythm of the natural history of key fisheries. A delicate balance.

Careful and exhaustive simulations have been done. Fisheries scientists and stream hydrologists have worked together to forecast the suspended sediment climate in worst case and best case scenarios for each of the four Klamath River dams. They have predicted probable impacts using high quality information about the life history phases of seven carefully selected fish species, populations of which exist in the Klamath river basin. Based on this assessment they have proposed strategies to manage impacts for each identified fish species. Most of these strategies involve simulation of fisheries impacts during dry years and wet years for each life-history phase of each of the seven species. These simulations reveal that few of the identified fish species are at risk; and only one sub-population (fall and winter run steelhead trout, including 'half-pounders'; *Oncorhynchus mykiss*) is at significant risk of localized extirpation. Proposed mitigations reduce this risk to an acceptable level; and resident populations of these steelhead in nearby river basins would soon re-occupy a vacant niche in the Klamath river basin.

Much of the simulation in the Klamath Final Technical Report (2009) is based on mathematical models available in the peer reviewed scientific literature (notably those of Newcombe and MacDonald 1991; and Newcombe and Jensen 1996). These models are based on a large number of pollution events where the sediment particle size range includes sand, silt and clay, in varying proportions. Although these models ought to apply to the Klamath suspended sediment

simulations unmodified, a decision was made by the technical committee to underestimate the impacts predicted by these models in the belief that the Klamath simulation differs from the available science. While it is perhaps true that the Klamath situation differs from the main body of available research, this is unlikely to be the case. Clay is probably the predominant particle size in most *long-term or chronic* pollution episodes on which the models are based; and clay is believed to be the predominant form of suspended sediment affecting fisheries resources in the Klamath dam removal project. Even so, this decision to underestimate predictions made by the published models makes little difference in the final analysis. It is unlikely that any fish population will be extirpated: this is the major finding of the technical report. The report is in every other way rigorous, methodical and systematic, and it embodies a precautionary approach as an added level of safety.

One notable omission in the science used in this Klamath final technical report (January 2009) is a model developed expressly to predict fisheries impacts of excessive water cloudiness in the absence of coarser sediment fractions in suspension (Newcombe 2003). Very likely this water cloudiness paper was published *after* the initial literature review on which the Klamath simulations are based. Although this model might have added something of value to the understanding of the impacts of chronic fine-sediment pollution, the conclusions of the Klamath report remain beyond reproach. Pollution episodes occasioned by the proposed removal of the four Klamath dams will be enormous by any standard; enormous, but not cataclysmic. Perhaps this water cloudiness model would be more useful in the decade of stream restoration, after the major pollution events have taken place.

4. **Remarks on Specific Aspects of the Report.**

(a) Simulations of suspended sediment concentrations (various, and depicted in the figures) are convincing and have the look of real data with perhaps daily averaging. My guess is that the actual pattern in the streams will be characterized by countless brief spikes and dips that are detected only in hourly sampling. These spikes represent extremes not used in the simulations, but I doubt this makes any practical difference to fisheries impacts based on the existing models. With data of this type (suspended sediments concentration as a function of time) it might be helpful to see a representation of the area under the curve. This would allow people to compare the scale of various sediment pollution episodes.

(b) The Final Technical Report (January 2009) might benefit from the inclusion of some real-world data from the streams as an indication of existing conditions. Real stream data for suspended sediments and water cloudiness (*e.g.*, black disk sighting range for reaches and runs, or perhaps *Secchi* disk depth for pools) would have provided a useful baseline as

a reference. Perhaps these data exist elsewhere in a parallel water quality report. If these data *do* exist elsewhere in useable form, perhaps some future document could reference a source.

(c) Black disk sighting range is a particularly useful variable to measure as it is directly related to visual clarity and the natural history of fishes.

(d) Throughout the document, the text is uniformly well written and easily understood.

(e) Although parts per million is used as the unit of measure for total suspended sediments in this report, *milligrams per litre* is more generally used. Engineers will find the latter (mg/L) more useful than the former (ppm)

(f) Although the report does not reference water clarity directly – visual clarity and black disk sighting range being the accepted measures – it avoids mention of the much less useful variable 'turbidity' -- a poor substitute for the accepted, biologically relevant, measures.

(g) Somewhere in this report it would be helpful to see a complete description of particle size distribution of the deposited sediments in the reservoirs behind the dams. Also, because the distribution of suspended sediment particle size of changes as a function of the amount of time the particles have been in suspension, the effect of differential settling rates as a function of particle size is a useful variable to be aware of. The coarsest particles tend to settle at the greatest rate leaving the finer, less damaging particles in suspension. The upside of this pattern is that flowing water becomes less aggressively harmful to aquatic organisms (less scouring of fishes and bio-film and aquatic invertebrates); the downside is that differential settling causes deposition of sand and silt on the stream bed, particularly on the margins, with predictable, harmful, changes in stream bed texture.

(h) Figures are exceptionally well done, and integrate daily average suspended sediment data with fish life-history data is a highly useable format. Quantitative graphic data (timing of TSS data) and qualitative data (timing of fish life history phases) are juxtaposed for maximum utility, clearly representing the nature of the predicted impacts being. Text and figures agree in every relevant way.

(i) Removal of dams in the Klamath river basin is a unique opportunity to understand better the effects of suspended sediments pollution. Significant effort already is devoted to routine monitoring of fisheries in the Klamath river basin, and for this reason there is a large

amount of useful fisheries life-history data. Presumably there also is a large volume of stream discharge data and some kinds of water quality data. I note however, that long-term data on background TSS in the Klamath river basin are not available and presumably do not exist.

(j) Monitoring and Research. The proposed removal of any hydro-electric dam in the Klamath river basin presents a rare, unique, opportunity to measure suspended sediments loads, natural stream discharge, and fisheries impacts associated with excessive stream sediment and water cloudiness. This is a research opportunity best exploited with the benefit of careful pre-planning, interagency collaboration, and adequate funding. Removal of the dams will turn the Klamath river basin into a natural laboratory. It offers endless scope for research. When the dams are removed, it will be essential for fisheries managers to have reliable data on sediment transport (bed-load/wash-load, and suspended; and comprehensive data on particle size distribution).

(k) During my reading I began to wonder whether it might be possible to explore some alternative to the current scenario in which sediment pollution episodes (after a dam is removed? or after the reservoir is drawn down, but before the dam is removed?) seem to be driven by natural rainfall events.

If the sediment pollution events take place as a result of reservoir draw-down, and before the dam is actually removed, I can see that managers should be able to regulate the surface level of the low water level behind the dam, and should therefore be able to determine *how much sediment* will be exposed to wave action, and to some extent the *size and duration* of sediment pollution events.

Managers have no such discretion if the dam is removed immediately after the reservoir is drawn down. In this scenario sediment pollution episodes will be driven by rainfall events and surface runoff.

Details of how the operation is planned to proceed are not included in the report, and perhaps it is not my role to ask for this level of detail. Nevertheless, I did wonder (a) about the scenario where draw-down precedes dam removal by one or more hydrological years; and (b) about a scenario where a floating suction dredge is used to pump deposited sediments over the dam for a period of years (as many years as is reasonable to prevent massive sediment pulses envisaged in the existing scenario), whether the reservoir is drawn down or not.

I know that hydro-electric reservoirs are very large and that human-scale interventions in such settings might seem ineffectual; but even if the suction dredge did not actually move sediments downstream, it perhaps could be used as a water-jet to re-suspend deposited sediment, dispersing it into the water column such that spill water from the dam could be used to transport moderate amounts of sediment downstream for as many years as desired before the dam is removed.

These two scenarios -- controlled draw-down; and managed re-suspension of deposited sediment (by discharge from a suction dredge; or by force of water jet) – might give managers better control over fisheries impacts than the scenario where the dam is simply removed and natural rainfall events wash the silty deposits downstream.

One downside of this proposal, even if it happens to be practicable, is that hydro-electric dams must be managed for power production while they remain in service. Any plan to flush re-suspended sediments downstream would entail changes to the operation of the dam which would make it less efficient for power production. Water spilled for sediment transport could not be used for power generation.

(l) It will be helpful to know as much as possible about the particle size distribution of suspended sediment loads at all stages of the annual hydrograph. However, because of the costs involved, a decision will have to be made about the finest size-fraction of interest. Coarse size fractions tend to cause acute harm, scouring of biofilm and gills for example; whereas the finest size fractions, not always problematic in these ways, tend to contribute to chronic problems such as low stream productivity. A cost-effective strategy might be to specify a particle size fraction equal to and smaller than clay-sized (e.g., $\geq$ 5 microns) and to treat it as a single size class. Coarser size-fractions are much easier to measure using standard lab methods. The full range of size classes greater than 5 microns will be useful to know; and the amount of material in each size class.

It will also be useful to know something of the superficial geology, source of water-borne sediments in the Klamath river basin. Biological effects of fine suspended sediment particles is a function of their size, angularity and hardness. Also, some species of fishes – some minnows for example – might be more sensitive to excess suspended sediment than any of the seven focal species used in the modelling exercise (see Sutherland and Meyer 2007). This possibility (that there might be an ultra-sensitive species of fish in the Klamath river basin) does not negate reliance on the focal species for decision-making.

5. **Detailed Remarks**.

P	¶	L	Comments
i - vi			Executive summary is comprehensive and useful.
2	2	19	Gauging is the conventional spelling; “gaging” is perhaps a misspelling?
3,4			Table 1 and Table 2 provide a useful summary of suspended sediments concentration.
19			Table 7 and numerous others like it are comprehensive and useful.
21			Biological interpretation of suspended sediments impacts in this report is logical and consistent with what is known. For this reason, the congruence between what is believed will happen and what actually happens will be a function of how well the sediment transport models worked.
23	3	5	3.1.4.1. “ ... there will be *fewer* fish in the ocean ...”
27			The life-history tables (Table 9 and numerous others like it) are very well done. They are authoritative (based on published sources), and therefore a useful basis for modelling.
32	3		3.2.4. These recommendations (here and in other sections of this report) for reducing impacts seem sound; and the decision to not trap and to not transport fish (here and in other sections of this report) is reasonable, noting one reasonable exception.
41	1	3	.... pers. comm. 2007 ... ”
43	1		Reference to landscape management issues and habitat enhancement efforts is relevant and useful, if not in relation to the anticipated sediment pollution but in relation to stream stewardship in the recovery phase, and beyond.
46	3		3.4.3. To some extent summer steelhead 'runbacks' may be protected from the worst of he harmful effects of suspended sediments to the extent that they remain, if they do, near the estuary. If 'runbacks' migrate upstream closer to the source of sediment pollution, their exposure to the harmful effects will be correspondingly greater. Concentrations of TSS will likely be greater further upstream, and particle size distribution in suspension likely will be coarser. Coarse sediments in suspension are much more harmful than clay-sized particles.
48	1, 2		Starvation and gill damage are likely scenarios. One British Columbia fisheries biologist reports, informally, that some salmon and trout species (and some life-history phases) protect themselves from harmful concentrations of suspended sediment by burying themselves in the gravel. Once buried they can breathe water that is partially filtered by the stream bed.
49	1	12	“..... anticipated to be greatly harmed (by excessive suspended sediment concentrations) .... ”
50	2	20	“.... fall steelhead adults can potentially hold in the mainstem ...” *Question*: do these fishes continue to eat stream invertebrates while holding?

			Remark: (a) fishes in cold water require less oxygen because their metabolic rate is reduced; and (b) cold water holds more dissolved oxygen than warm water. For these two reasons, fishes in cold water are less vulnerable to gill damage than fishes in warm water during a suspended sediments pollution event. Optimum water temperature for the protection of salmon and trout exposed to excessive suspended sediment is around 6ºC (*probably* Servizi and Martens 1991). Seasonal differences in the response of juvenile Atlantic salmon to suspended sediments have been observed and may be explained by temperature-related changes in *diel* activity patterns (Robertson *et. al.* 1997).
62	1		3.7.4.1. Notwithstanding appropriate restrictions on the harvest of Pacific lamprey, the 'condition' of individuals (whether harvested or not) might be inferior as compared with Pacific lamprey in nearby fisheries unaffected by excessive suspended sediments pollution.
63	1	2	It ... is ... believed ...
64	1		There is anecdotal information that young sturgeon survive and grow better in cloudy water. The cloudiness provides protection from predation and it allows them to get closer to their prey. Downstream from dams the water tends to be excessively clear, and excessive water clarity works to the disadvantage of young sturgeon for these reasons. I have heard but not seen personally of efforts in British Columbia to mix clay in the water upstream of juvenile sturgeon rearing reaches for the purpose of providing 'cover'.
66	2	7	The apparent absence of physiological stress might indicate the the suspended sediments in this instance are very fine (clay-sized, colloidal).
66	3		Would it make sense to recommend a fishing ban on green sturgeon for as long as necessary to overcome the impacts of excessive suspended sediment?
68	4	7	Properties of suspended sediment discharged by streams into estuaries may differ from what we are accustomed to in freshwater. A marine chemist might be able to comment on the rate (perhaps increased by the phenomenon of flocculation) at which suspended sediments are deposited in estuaries, where fresh water and salt water mix.
69	1	11	Brook stickleback (*Culaea* ....); italics missing.
Fig 2.			'Focal species' vetting process very clear to follow.
Fig. 47			This figure clearly shows how, in November and December and half of January, conditions for 'half-pounder' residence (*Oncorhynchus mykiss*) would be challenging unless these fishes have strategies for avoiding the worst of the suspended sediment pulses (estimated to range from >100 ppm to about 8000 ppm). My guess is that these fishes will hold very close to the stream bank and avoid the worst of the sediment pulses. This is only a guess, and the pattern is not universal (see Robertson *et. al.* 2007). Also, since this is the time of year when stream temperatures are possibly very cool (4º to 6º Centigrade?) it is also the time when the fishes' rate of respiration is at its minimum. For these reasons, I am guessing that 'half-pounders' might fare somewhat better than predicted.

Fig. 49			Suspended sediment concentrations are excessively, unavoidably, elevated for summer steelhead from mid-November to mid-February. It seems that adult upstream migrants can not avoid excessive exposure. And 'half-pounders' reside in the stream for all of the worst times of the year, notwithstanding that water temperatures are at or near their annual minimum – a condition (naturally cold water) that confers some level of protection by virtue of high concentrations of dissolved oxygen and low respiration rate of fishes.
Other (a)			The report contains no data or graph depicting the annual hydrograph at any station in the Klamath river basin. While it is not essential to general understanding, it would have added detail to the context of various scenarios.
Other (b)			With rare exceptions (noted above) there was no need to copy-edit the report as it has been carefully edited already.

References Cited:

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Servizi, J.A. and D.W. Martens. 1991. Effect of temperature, season and fish size on acute lethality of suspended sediments to coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences. 48:493-497.

Sutherland, A.B, and J.L. Meyer. 2007. Effects of increased suspended sediment on growth rate and gill condition of two southern Appalachian minnows Environmental Biology of Fishes. 80(4): 389-403.

Comments from Reviewer 2:

Dear Mr. Hefner,

I have completed a peer review of Stillwater Sciences' 2009 final technical report entitled "Effects of sediment release following dam removal on the aquatic biota of the Klamath River". I found the document to be clearly organized and well written. The Stillwater Sciences report appears to represent sound science, and provides significant and appropriate detail.

I have organized the peer review into five (5) subject areas for clarity of presentation and to ensure compliance with the critical elements outlined in the scope of work provided by PBS&J for this peer review process.

Completeness:

The report is thorough and complete. Stillwater Sciences has arranged the report in an easy to follow manner and has included the necessary citations and figures. They have included an executive summary, introduction, approach to analysis, results of analysis, a summary of their recommendations, and references. References were made to previous reports that described the modeling processes in more detail. I did not review any of the earlier reports for the project as of the date of this report.

It would have been helpful to see photographs of the river, its tributaries and the impoundments as this review was limited to a "desk top" review. It is assumed that photographs were included in earlier reports for the project.

Scientific Approach:

It is my professional opinion that the Stillwater Sciences' scientific approach described in

the report was well thought out and thorough. The quantity and quality of references that they were able to gather and incorporate into the assessment, relating to the life histories, behavioral characteristics, and potential physiological impacts of increased total suspended sediment concentrations (TSS), greatly assisted in strengthening the conclusions of this report.

There were some data gaps, such as detailed information on total populations, specific distributions within the mainstream of the Klamath versus the tributaries, and specific data on the potential physiological impacts of increased TSS on some of the non-salmonid species, however these data gaps were recognized and clearly described by the author, along with the approaches and assumptions used to compensate for these gaps in the body of existing biological data.

I found the timing aspects of sediment modeling to be rather suspect due to the complexity of the variables involved, primarily the variability of hydrologic patterns, therefore I support Stillwater Sciences' use of a "worst case scenario" approach for this analysis.

Consistency of Thought:

The report was very consistent and did not contradict itself in any way. Each biological analysis section clearly laid out the life history, distribution, and potential responses to increased TSS. In addition, all but two sections (i.e. coastal cutthroat trout and other aquatic species) described recommendations for reducing impacts to each species, which I found useful and well reasoned. The executive summary and summary of recommendations were reflected and supported the body of the report.

Soundness of Conclusions:

The conclusions throughout the report were soundly made and well supported by the extensive biological references. All references were clearly cited.

My review of this document is based on my experience as a water resources engineer highly familiar with dam removals and associated sediment responses on the east coast. I am not a fisheries biologist with a detailed understanding of west coast diadromous and resident fish species, so I cannot comment as to the appropriateness of the specific biological data used as reference material to support the conclusions of the report.

General Comments:

In addition to my review to the reports completeness and consistency I offer the following comments:

1. It would have been valuable to have data on the total quantity of sediment impounded behind each dam and the portion of that quantity that is anticipated to be transported downstream. There was one reference to a total tonnage of fine sediment, but density of impounded sediment can vary significantly, and therefore, densities would have provided a clearer understanding of the volumetric quantity of material. In addition it would have been useful if a discussion of potential sediment deposition thicknesses within the downstream channel had been included, especially when discussing how sediment releases might impact egg incubation or burrowing lamprey ammocoetes. This information may have been described in previous reports on the sediment modeling, but a summary of such data in this report would have been valuable for the purpose of this review.

2. The report included a discussion of the fact that the anticipated range of TSS changes dramatically depending on whether it is a wet or dry year, and describes that this is due to the amount of sediment exposure in the impoundment during drawdown. Without photographs of the impoundments and river, it is unclear to me whether vegetation might play a role in quickly stabilizing the exposed sediment during drawdown as can typically be the case in more humid climates. I assume this was not included in the analysis because the researchers feel that the exposed sediments would not quickly re-vegetate during a drawdown in this region of the

United States.

3. The recommendations to reduce impacts to the focal species were well thought through and clear. In addition to the recommendations described in this report, I am curious if TSS, bed load, and biological response monitoring during the drawdown, is being proposed such that drawdown rates can be adjusted adaptively based on the monitoring data and biological responses observed.

Thank you for this opportunity to be involved in this peer review. In conclusion I found the Stillwater Science's 2009 final technical report entitled "Effects of sediment release following dam removal on the aquatic biota of the Klamath River" to be generally complete, well written, and well referenced. The conclusions in the report seem reasonable and based on the best available scientific information, thereby representing "sound science" in the prediction of the potential impacts of sediment releases on aquatic biota in the Klamath River following the removal of four dams.