Center for Independent Experts (CIE) Review of

Using model selection and model averaging to predict the response of Chinook salmon to dam removal.
S. T. Lindley and H. Davis

and

Forecasting the response of Klamath Basin Chinook populations to dam removal and restoration of anadromy versus no action.
N. Hendrix

John G Williams

**Executive Summary**

The Klamath Basin Restoration Agreement (KBRA) calls for the Secretary of the Interior to make a finding by 12 March 2012 whether four dams on the Klamath River should be removed. The two studies under review are intended to inform this decision. In particular, they addess the question whether and by how much removing the dams will increase the production of Klamath Basin Chinook salmon over the coming fifty years; the answer, reached by two different modeling approches, is "Probably, but it is hard to say how much."

The Lindley and Davis study deals only with production from habitat above the dams, and is "based on the simple assumption that we can extrapolate the relationship between the levels of escapement in other watersheds in the region and the characteristics of those watersheds, especially their size" (p. 12). This study is relatively easy to understand for non-specialists, at least on a superficial level.

The Hendrix model deals with the complete life history and the entire basin, and uses a hierarchical Bayesian approach that is more opaque to non-specialists, since it involves unfamiliar concepts and jargon. Moreover, the language in the report assumes specialist readers. Nevertheless, the Hendrix model provides a more useful frame-Basin work for future work on Klamath Chinook and for management of the basin.

Both models give highly uncertain estimates of future production of Klamath Basin Chinook, but that should be expected, and one of the strengths of these models is that they deal explicitly with uncertainty. To understand why the estimates should be so uncertain, consider that even pre-fishing season forecasts of age 3 Klamath Chinook over the last twenty years have differed from post-season estimates by almost an order of magnitude (Hendrix, p. 18). Not much can be expected of population forecasts for future decades.

Both models ignore a good deal of detailed information about the basin, which may make the models seem simplistic and unrealistic, and will upset the people who have developed the information. However, given the compexity and non-linearity of the system and the uneven understanding of different parts of it, trying to incorporate this information into predictive models such as these generally would not help (RSRP 2000; May 2004). More might be done to incorporate this information in the "priors" of the Hendrx model, but given the context and purpose of the modeling, the choice to use non-informative priors is certainly defensible.

Both studies fail to take account of two important factors: global warming, and interactions between hatchery and naturally produced salmon. Regional climate forecasts are more uncertain than global forecasts, and the extent of warming will depend on future human activity, so accounting for climate change would substantially increase the uncertainty in the forecasts. Nevertheless, if global warming approaches the higher end of the plausible range, then the Klamath Basin Chinook population in fifty years will be zero with high probability.

Although the details remain uncertain, there is compelling evidence that hatchery salmon have a negative effect on naturally spawning salmon. A recent study (Chilcote et al. 2011) using an approach and data set similar to that of Lindely and Davis found that the proportion of hatchery fish in basins has a strong negative effect on the intrinsic productity of naturally spawning Chinook, as well as coho and steelhead.

Models are tools of science, not science itself. The two models reviewed here incorporate the best available modeling approaches, but, in my assessment, to meet the standard of "best available science," the models need to deal with the effects of climate change and interactions with hatchery fish.

**Background**

The work under review arises from the Klamath Basin Restoration Agreement (KBRA). According to the summary provided:

> The Restoration Agreement is intended to result in effective and durable solutions which will: 1) restore and sustain natural fish production and provide for full participation in ocean and river harvest opportunities of fish species throughout the Klamath Basin; 2) establish reliable water and power supplies which sustain agricultural uses, communities, and National Wildlife Refuges; and 3) contribute to the public welfare and the sustainability of all Klamath Basin communities.

More specifically, the goals of the Fisheries Program established by the KBRA are to:

> 1) restore and maintain ecological functionality and connectivity of historic fish habitats; 2) re-establish and maintain naturally sustainable and viable populations of fish to the full capacity of restored habitats; and 3) provide for full participation in harvest opportunities for fish species.

The KBRA calls for the Secretary of the Interior to make a finding by 12 March 2012 "whether facilities removal: 1) will advance restoration of the salmonid fisheries of the Klamath Basin; and 2) is in the public interest, which includes but is not limited to consideration of potential impacts on affected local communities and tribes." The modeling studies reviewed here are intended to inform this decision. It follows from the goals of the KBRA that at least one of the models should address both natural production and harvest of Chinook.

Unfortunately, the sort of guidance that the Secretary probably desires may not be scientifically feasible. That is, estimating the production of Chinook over future decades under the two alternatives, one involving major changes in the riverine habitat, is arguably beyond science. Mike Healey, author of a widely cited review of Chinook life histories (Healey 1991), has argued that such problems are "transcientific;" that is, they "can be framed in the language of science but cannot be answered by the traditional means of science" (Healey 1998:667). In implicit recognition of this problem, the KBRA calls for adaptive implementation of the Fisheries Program.

Some history of the modeling efforts under review should also be considered. Another model, the Fall Chinook Life Cycle Production Model, was under development through 2010 (Hendrix et al. 2011). Following review in January 2011 by an expert panel, a decision was made that the model could not be completed in time for the Secretarial Determination, and the effort shifted to the models under review (M. Hampton, NMFS, pers. comm.).

In short, the developers of the models under review were given an arguably impossible task, and little time to accomplish it. My summary judgment is that they have given it a good go.

**Reviewer's Role**

This represents an independent review, without discusson or consultation with other reviewers. I reviewed the models and associated reports in light of their context, and restricted my comments to matters of significance; given the speed with which the modeling had to be done and the reports had to be written, various minor problems are inevitable. My suggestions for changes are restricted to matters that I think could be dealt with in time to meet the purpose of the exercise. I organized my review in terms of the Terms of Reference given in my scope of work, which is attached as Appendix A.

**Terms of Reference (ToRs)**

*Evaluation and recommendations of data quality*
Models should be appropriate for the data that are available. I am not highly knowledgeable regarding the data available on Chinook in the Klamath Basin, and if there is a review of monitoring programs there similar to Pipal's (2005) review of monitoring of listed Central Valley Chinook and steelhead, I did not find it. It seems that there has been considerable work done on sampling juveniles in the Klamath River (e.g., Chamberlain and Williamson 2006; True et al. 2011), but not so much as in the Trinity River (e.g., Phinnix et al. 2010), and my impression is the monitoring is rooted in what Bottom et al. (2005) called "production thinking." Relatively little attention has been given to the life-history patterns of naturally produced juveniles, such as the work on the Rogue River by Ewing et al. (2001). Moreover, Chamberlain and Williamson (2006) reported substantially different catches in frame and screw traps, and other reports suggest that even screw traps can be hard to operate early in the spring because of flow conditions, so I suspect that existing monitoring programs may not be effective for fry migrants. According to STT (2005), there were no data on the survival of naturally produced Chinook in the Klamath/Trinity, and this seems still to be so. There are survival estimates for tagged hatchery fish from release to age 2, or four months post-release, for the years 1979-2000, developed from a stock-reconstruction model (STT 2005). Probably these reflect ocean or estuarine rather than riverine conditions, because survival estimates for the hatcheries on the Klamath and Trinity rivers are highly correlated. Whether these survival estimates apply well to naturally produced fish is an open question. Given the goal of the KRBA regarding "naturally sustainable and viable populations," the incomplete data on naturally produced juveniles are a problem, and limit the kinds of models that are appropriate.

*Evaluation of strengths and weaknesses of, and recommendations to improve analytic methodologies*
The models under review use different approaches, but both properly generate estimates of the uncertinty in the modeling results, given the models and the data.

The Hendix model, unhappily named the Evaluation of Dam Removal and Restoration of Anadromy[1] (EDRRA), is a Bayesian hierarchical (HB) model; such models are increasingly used for ecological analyses (Clark 2005; Cressie et al 2009; Webb et al. 2010). Use of the MCMC algorith allows for fitting a more complex model to the available data than be appropriate using

[1] Anadromy is an attribute of fish, not streams.

older methods. The EDRRA model covers the complete life cycle, and, with some exceptions noted below, and was fit to historical data for the Klamath River below Iron Gate to generate posterior distributions that were then used for simulating reference points for a stock-recruitment relationship under future conditions, using a Monte Carlo procedure. For the part of the watershed above Iron Gate, EDRRA used posterior distributions from Liermann et al. (2010) for the simulations. Probably because of the press of time, and to avoid the problem of modeling future management of the fishery, Hendrix patched in the Klamath Harvest Rate Model (KHRM) in EDRRA for the fishable part of the ocean life cycle, together with an estimate from the literature for the survival of hatchery fish between ages 2 and 3. These patches notwithstanding, an HB model such as EDRRA seems the best option for simulating Chinook productivity for the entire river under the two alternatives being considered. Moreover, the EDRRA model could also be used in the adaptive implementation of either alternative.

The Lindley and Davis (L&D) model (or models) is much simpler, and considers only the habitat above the dams. As they note, the model is "based on the simple assumption that we can extrapolate the relationship between the levels of escapement in other watersheds in the region and the characteristics of those watersheds, especially their size" (p. 12). First, L&D used multidimensional scaling on 77 watersheds California, Oregon, Washington, and Idaho, and found that the resulting ordination does a good job of separating watersheds supporting spring and fall Chinook. A large number of candidate log-linear models with various environmental covariates were then fit to data on fifth field hydrologic units (~50,000 ha) in the subset of watersheds that support spring-run, or to the complete data set. (This was done because Liermann et al. (2010) reported a clear separation in the productivity of populations of stream-type and ocean-type Chinook, and there are reasons to think that many of the populations in the upper Klamath Basin were spring Chinook, which are often stream-type.) The candidate models fit to both data sets were then compared using a standard method for model selection, and the results of the ten top-ranking models were combined as a weighted average.

The L&D models use appropriate analytical methods, and, although they produce a somewhat different result, nicely complement the EDRRA modeling. Models should be used to help people think, not to provide 'answers,' and having two good methods provide somewhat different results helps discourage undue reliance on either.

Importantly, the models under review are consistent with the recommendations of the Recovery Science Review Panel (RSRP), a group of outstanding scientists that was recruited by NMFS to provide scientific guidance for Pacific salmon recovery efforts coast-wide. In a discussion of modeling in the report of their December 2000 meeting, which is attached as Appendix C, the RSRP wrote that (RSRP 2000):

> The conclusions to be derived are that large-scale models that attempt to capture the dynamics of many species, or that rely upon the measurement of massive numbers of parameters, are doomed to failure. They substitute sledgehammer simulation for analytical investigation and efforts to identify the few key driving variables. Large models are bedeviled by problems of parameter estimation, the representation of key relationships, and error propagation. When the phenomena are fundamentally non-linear, this leads naturally to path dependence and to sensitivity of results to parameter estimates. As the number of parameters increases, the potential for mischief increases. Thus it is essential to rid models of irrelevant parameters, and

> to identify key relationships. It also emphasizes the importance of locating what aspects of the model are most likely to lead to the expansion of error, and to focus on representing these as accurately as possible. This can only be done reliably through data-driven methods, with attention to appropriate statistical methodology.
>
> When the data are not available for the needed estimates of parameter values, there is a tendency to insert values based on opinion or expert testimony. This practice is dangerous. The idea that opinion and "expert testimony" might substitute for rigorous scientific methodology is anathema to a serious modeler and clearly represents a dangerous trend. Indeed, there are limitations even to what can be done on the basis of data: the fact that relationships are often nonlinear, and further that interest often rests on understanding the behavior of populations beyond the range of variables that has been observed, creates vexing problems for the modeler. It provides a compelling argument for experimentation in order to elucidate underlying mechanisms, for the recognition of limits to predictability, and for the use of adaptive assessment and management (Ludwig and Hilborn 1983; Holling 1978).
>
> EDT is a case study of the problems just discussed. The current version which uses 45 habitat variables might be a useful list of things to consider, but the incorporation of so many variables into a formal model renders the predictions of such a model virtually useless. Even more vexing is that EDT depends upon a large number of functional relationships that are simply not known, (and cannot be known adequately) and yet they play key roles in model dynamics. The inclusion of so much detail may create an unjustified sense of accuracy; but actually it introduces sources of inaccuracy, uncertainty and error propagation. Subjective efforts to quantify these models with "expert opinion" compound these ills.

For such reasons, the eminent mathematical ecologist Robert May wrote in an article in Science, entitled “Uses and abuses of mathematics in biology,” that “It makes no sense to convey a beguiling sense of ‘reality’ with irrelevant detail, when other equally important factors can only be guessed at” May (2004:793).

Evidently this conclusion is counterintuitive to many, and despite the rather strong guidance from the RSRP, NMFS has continued to use EDT for recovery planning. Reportedly this is because the EDT provides a way for the various participants in the recovery planning to contribute their knowledge and information, and see how it matters in EDT simulations. However, this is a political rather than a scientific virtue.

*Evaluation of and recommendations to improve model assumptions, estimates, and characterization of uncertainty*

Both models explicitly estimate the uncertainty in their results, in statistical terms. However, both could be improved by taking account of existing information on climate change, hatchery effects, and, to a lesser extent, the role of winter temperatures in determining whether spring Chinook follow an ocean-type or a stream-type life history.

The evidence for negative interactions between hatchery and naturally produced salmon is too strong to be ignored, and a recent paper by Chilcote et al. (2011) suggests an approach by which they can be taken into account, especially in the L&M models. Chilcote et al. (2011) reported that the percentage of hatchery fish among natural spawners is an important predictor of the intrinsic productivity ($\alpha$ in the Ricker model) of Chinook from 35 watersheds in Oregon, Washington, and Idaho. There must be considerable overlap between the data sets that they and L&D used, in which case it should be practicable for L&D to incorporate the percentage of hatchery as a covariate in some of their candidate models, at least for data from those watersheds. Although it would be harder, because it would entail re-doing the Liermann et al. modeling for watersheds with hatchery fish, the same basic approach could be taken with the EDRRA.

August temperature is already a covariate in the L&D approach, so a crude analysis of the effects of climate change probably could be made simply by looking at the effects of an appropriate range of values on the model estimates. However, this would entail extrapolating beyond the data, which is perilous, because the negative effects of high temperatures on Chinook are approximately threshold effects. Nevertheless, the exercise seems worth doing, providing that the results are qualified appropriately. Alternatively, a threshold temperature or temperature range, especially for holding adult spring Chinook, could be indentified from the literature, and the probability that it will be exceeded could be estimated from existing temperature forecasts in a separate analysis, with the results combined in a qualitative way in the discussion.

L&D note that many populations of spring Chinook in the southern part of their range exhibit ocean-type juvenile life history patterns. Populations of stream-type fish are generally less productive, because the availability of freshwater habitat limits the number of juveniles that can rear there, and this seems the most likely explanation for the lower productivity of stream-type populations reported by Liermann et al. (2011). Clarke et al. (1992) showed that naturally stream-type Chinook from a river in British Columbia would follow an ocean-type juvenile life history if they were exposed to a short-day photoperiod at emergence. Because these fish naturally incubate in cold water, they normally do not emerge until days are too long to trigger the ocean-type pattern. As far as I know, this photoperiodic effect has not been shown directly for spring Chinook farther south, but the life history patterns of juvenile spring Chinook in the Central Valley seem consistent with it (Williams 2006). The relationship between water temperature and time to emergence is well known, and water temperature is more predictable than most aspects of Chinook habitat, so it should be possible to take this into account, at least in the discussion of the results. This matters because of the potentially greater productivity of ocean-type populations.

Both models depend on relationships between watershed attributes and Chinook abundance or productivity that are parameterized with data from other watershed. However, the morphology of the Klamath Basin is unusal, with low gradient habitat high in the watershed and a steeper, more confined channel below, which suggests that the "simple assumption" articulated by L&D may be less satisfactory for the Klamath than for other basins. I do not have a good suggestion for dealing with this problem, except for disclosing it.

*Determine whether the science reviewed is considered to be the best scientific information available.*

Models are tools of science, not science itself, so it is less clear how to make this assessment than to say whether, for example, a Biological Opinion is based on the best available science. That said, the approaches embodied in the models under review are up-to-date and appropriate for the situation. However, in my judgement, the application of the models needs to take account of two additional factors, climate change and hatchery effects, before it would meet this standard.

*Recommendations for further improvements*

Several recommendations are given above. I have also suggested that HB models such as EDRRA are appropriate as a framework for adaptive management in implementation of whatever course of action is selected for the Klamath/Trinity. In conjunction with this, Bayesian Networks could also be considered for this purpose. These reportedly work well with stakeholder processes (Marcot et al. 2001; Steventon), and can deal with large numbers of variables in a way that feeds naturally into HB modeling. That is, Bayesian Networks may be able to play the same political role as EDT, but do so in a way that produces approximate posterior distributions. These could be used to select and paramaterize distributions that could be used for HB, either in the same way that Hendrix used posterior distributions from Liermann et al. (2011) to run EDRRA in simulation mode, or as priors when the model or an extension of it is used for estimation.

*Brief description on panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations*

This ToR does not seem relevant for an individual review (and was in fact dropped after consultation with the CIE and the office that requested the review).

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# Attachment A: Statement of Work for Dr. John Williams

### External Independent Peer Review by the Center for Independent Experts

### Klamath River Fall Chinook salmon production model and final report

**Scope of Work and CIE Process:** The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

**Project Description:** The United States, the States of California and Oregon, the Klamath, Karuk, and Yurok Tribes, Klamath Project Water Users, and other Klamath River Basin stakeholders negotiated the Klamath Basin Restoration Agreement (KBRA) and the Klamath Hydroelectric Settlement Agreement (KHSA), thereby proposing the largest dam removal restoration action in US history. In 2012 it is anticipated that a determination will be made by the Secretary of the Interior, in consultation with the Secretary of Commerce regarding removal of four hydroelectric dams on the Klamath. A benefit-cost (BC) analysis is needed to inform this determination. The BC analysis will compare two alternatives: (1) dam removal and implementation of the KBRA; and (2) current conditions projected into the future. To inform the BC analysis and environmental compliance documents, two Klamath River Chinook fish production models (Option A and B) has been developed. Option A is capable of providing annual forecasts of stage specific abundances under the two alternatives over a 50 year time period. A written technical report will be completed and available for the CIE review on 16 May 2011 including: the assumptions incorporated into the fish production model, mathematical equations used to define reproduction, growth, and mortality for all phases of the fish production model, and definition of model coefficients described based on how they were derived. This model and report will inform a landmark federal action with a recent litigious history. The results of this model have large potential implications on the economy of California and Oregon, commercial, tribal and recreational fisheries in California and Oregon, and tribal and public trust resources. The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**.

**Requirements for CIE Reviewers:** Three CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. CIE reviewers shall possess a combination of expertise with working knowledge and recent experience in the application of fish production modeling, Bayesian methodologies, hydrology, climatology, river restoration, and Pacific salmon life history. Each CIE reviewer's duties shall not exceed a maximum of 10 days to complete all work tasks of the peer review described herein.

**Location of Peer Review:** Each CIE reviewer shall conduct an independent peer review as a desk review, therefore no travel is required.

**Statement of Tasks:** Each CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Prior to the Peer Review: Upon completion of the CIE reviewer selection by the CIE Steering Committee, the CIE shall provide the CIE reviewer information (full name, title, affiliation, country, address, email) to the COTR, who forwards this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers. The NMFS Project Contact is responsible for providing the CIE reviewers with the background documents, reports, and other pertinent information. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to the CIE reviewers the necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE Lead Coordinator on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for the peer review.

Desk Review: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified herein. **Modifications to the SoW and ToRs must not be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COTR and CIE Lead Coordinator.** The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

**Specific Tasks for CIE Reviewers:** The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review.
2) Conduct an independent peer review in accordance with the ToRs (**Annex 2**).
3) No later than 2 June 2011, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Mr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and CIE Regional Coordinator, via email to David Die ddie@rsmas.miami.edu. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

**Schedule of Milestones and Deliverables:** CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

| | |
|---|---|
| *9 May 2011* | CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact |
| *16 May 2011* | NMFS Project Contact sends the CIE Reviewers the report and background documents |
| ***16-30 May 2011*** | Each reviewer conducts an independent peer review as a desk review |
| *2 June 2011* | CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator |
| *16 June 2011* | CIE submits the CIE independent peer review reports to the COTR |
| *20 June 2011* | The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director |

**Modifications to the Statement of Work:** Requests to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the COTR within 10 working days after receipt of all required information of the decision on substitutions. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToRs within the SoW as long as the role and ability of the CIE reviewers to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer review has begun.

**Acceptance of Deliverables:** Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

**Applicable Performance Standards:** The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards:
(1) each CIE report shall completed with the format and content in accordance with **Annex 1**,
(2) each CIE report shall address each ToR as specified in **Annex 2**,
(3) the CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

**Distribution of Approved Deliverables:** Upon acceptance by the COTR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COTR. The COTR will distribute the CIE reports to the NMFS Project Contact and Center Director.

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## Annex 1: Format and Contents of CIE Independent Peer Review Report

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the ToRs.

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Statement of Work

## Annex 2: Tentative Terms of Reference for the Peer Review

## Klamath River Fall Chinook salmon production model and final report

1. *Evaluation and recommendations of data quality*
2. *Evaluation of strengths and weaknesses of, and recommendations to improve analytic methodologies*
3. *Evaluation of and recommendations to improve model assumptions, estimates, and characterization of uncertainty*
4. *Determine whether the science reviewed is considered to be the best scientific information available.*
5. *Recommendations for further improvements*
6. *Brief description on panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations*

**Attachment B: Materials provided for Review**

Supporting Reference and Background Materials Included in the Packet

Reference Materials

Liermann, M. C., R. Sharma, and C. K. Parken. 2010. Using accessible watershed size to predict management parameters for Chinook salmon, Oncorhynchus tshawytscha, populations with little or no spawner-recruit data: a Bayesian hierarchical modelling approach. Fish Manag Ecol 17:40–51.

Parken, C. K., R. E. McNicol, and J. R. Irvine. 2006. Habitat-based methods to estimate escapement goals for data limited Chinook salmon stocks in British Columbia, 2004. Research Document 2006/083, Fisheries and Oceans Canada. URL http://www.dfo-mpo.gc.ca/csas/.

STT (Salmon Technical Team). 2005. Klamath River fall Chinook stock-recruitment analysis. Prepared by Salmon Technical Team, Pacific Fishery Management Council.

Klamath Background Materials

Hamilton, J. B., G. L. Curtis, S. M. Snedaker, and D. K. White. 2005. Distribution of Anadromous Fishes in the Upper Klamath River Watershed Prior to Hydropower Dams - A Synthesis of the Historical Evidence. Fisheries 30:10–20.

Hamilton, J., M. Hampton, R. Quinones, D. Rondorf, J. Simondet, and T. Smith. 2010. Synthesis of the effects of two management scenarios for the Secretarial Determination on removal of the lower four dams on the Klamath River, Final Draft dated November 23, 2010.

Hetrick, N. J., T. A. Shaw, P. Zedonis, J. C. Polos, and C. D. Chamberlain. 2009. Compilation of information to inform USFWS principals on the potential effects of the proposed Klamath Basin Restoration Agreement (Draft 11) on fish and fish habitat conditions in the Klamath Basin, with Emphasis on Fall Chinook Salmon. U. S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, CA.

Klamath Settlement Agreements

Summary of the Klamath Basin Settlement Agreements. 2010

Klamath Basin Restoration Agreement for the Sustainability of Public and Trust Resources and affected Communities (KBRA). February 18, 2010.

Klamath Hydroelectric Settlement Agreement (KHSA). February 18, 2010