RESPONSE TO PEER REVIEW COMMENTS ON AQUATIC ECOLOGY METHODOLOGIES AND RESULTS PRESENTED IN THE GLEN CANYON DAM LONG-TERM ENVIRONMENTAL AND MANAGEMENT PLAN DRAFT ENVIRONMENTAL IMPACT STATEMENT

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1. INTRODUCTION

This report addresses peer review comments pertaining to the modeling approaches and the evaluations presented in of Appendix F (*Aquatic Resources Technical Information and Analysis*) of the Glen Canyon Dam Long-Term Experimental and Management Plan (LTEMP) Draft Environmental Impact Statement (DEIS). The reviews covered the modeling approaches used and the resulting evaluations of the potential impacts of LTEMP alternatives and associated long-term strategies on the aquatic food base, rainbow trout (*Oncorhynchus mykiss*), endangered humpback chub (*Gila cypha*), other native fish, nonnative fish, and fish parasites.

Peer reviews of the methodologies for the models and for the material presented in Appendix F of the LTEMP DEIS were led by Scott VanderKooi (Chief, U.S. Geological Survey's Grand Canyon Monitoring and Research Center [GCMRC]). The integrated rainbow trout-humpback chub model was developed by Dr. Charles Yackulic (Research Statistician, GCMRC), Dr. Lew Coggins (Fishery Biologist, U.S. Fish and Wildlife Service), and Dr. Josh Korman (Ecometric Research Inc.) to evaluate potential population-level effects of alternatives (and associated long-term strategies) for the LTEMP EIS on humpback chub and rainbow trout. Models to evaluate effects of the LTEMP alternatives on temperature suitability for native (including humpback chub) and nonnative fishes (including trout) and for fish parasites was developed by Dr. John W. Hayse (Aquatic Ecologist, Argonne National Laboratory).

Sections 2, 3, and 4 summarize peer-review comments and responses provided by the authors for (1) the overview of the rainbow trout-humpback chub model, (2) the description of the temperature suitability model, and (3) Appendix F of the LTEMP DEIS, respectively.

2. OVERVIEW OF THE RAINBOW TROUT – HUMPBACK CHUB MODEL

An overview of the rainbow trout-humpback chub model, which identified assumptions and the modeling approach, was reviewed by two anonymous reviewers. A revised overview document that addressed the reviewer comments was completed in July 2014 and was used to prepare descriptions of the modeling approach in Appendix F of the LTEMP DEIS. Major and minor comments from the peer review of the overview document are summarized below, along with comment responses.

2.1 Major Comments

Comment: Both reviewers requested more information on how simulations would be undertaken.

Response: A new section (Part IV: Simulation Process) explaining the simulation design was added to the revised description document. The added section also identifies how various sources of uncertainty were included in simulations.

Comment: Reviewer 1 suggested a need for bioenergetics modeling to support the Lees Ferry trout component of the rainbow trout-humpback chub model.

Response: Scientists at GCMRC have been working to develop this sort of modeling. However bioenergetics-based models are not yet ready and it would require considerably more research to incorporate these models into the trout population component of the model. Furthermore, it is unclear whether such work will be funded or completed at any point in the near future.

Comment: Both reviewers raised concerns about whether the modeling would address potential influences of climate change.

Response: For the final analysis, potential influences of climate change was addressed (outside of the fish population model) by reweighting the probability of the various hydrologic traces used when developing the hydrologic conditions used as inputs for the model.

Comment: Reviewer 1 asked whether the assumption in the trout movement component of the model that emigration is constant across all months was realistic.

Response: Emigration rates are probably not constant across all months, but there were no data available to support more complexity. As identified by the commenting reviewer, the trout movement model represented gross patterns of emigration well when compared to historic observations.

Comment: Reviewer 1 asked what the rationale was for modeling growth as a temperature-dependent process in the Colorado River and not in the Little Colorado River.

Response: Although temperatures in the mainstem Colorado River could be affected by the operations of Glen Canyon Dam, there is no reason to suspect that temperatures in the Little Colorado River will systematically change over the next twenty years due to the operations of the dam. In addition, the implemented approach sufficiently approximated observed growth rates in this part of the ecosystem.

Comment: Reviewer 1 asked whether or not the form of the von Bertalanffy relationship used in the trout component of the model was the same as the version presented in Korman et al. (2012).

The reviewer also stated that the model should be characterized as a “length-at-age” model instead of a “size-at-age model.”

Response: Text was added to clarify that the von Bertalanffy relationship used in the model is the same version used in Korman et al. 2012 and that the von Bertalanffy model predicts length-at-age.

Comment: Reviewer 1 noted that the model did not do a very good job of replicating observed angling success during the middle of the time series presented in the model description.

Response: The reason for the lack of fit of the simulated results to observed angling success in some portion of the traces to the observed data is unknown but could be the result of differences in how the catchability coefficient (q) varies in response to fish density and flows. For example, recent mark-recapture efforts suggest that trout density has a strong effect on capture probability via electroshocking such that the assumption of a constant value for the catchability coefficient (q) will lead to estimates that are biased low when fish densities are high and biased high when fish densities are low. Unfortunately, there are not yet sufficient data to refine the relationship further and q for angling in the model was calculated as a scalar. To estimate q, the simulation model was run using the recruitment estimates from the stock synthesis model to predict age-specific abundance between 1990 and 2010. The value for q was then calculated from the back-transformed average of the log of the ratio of the observed catch per effort (CPE) values to the estimates of the vulnerable population each year. Thus, q represents the average scalar required to convert predicted vulnerable abundance to the observed CPE. Overall, the fit to observed data when using this approach was considered adequate for evaluating the effects of the alternatives. Note that the model does not track the number of fish relative to wetted area (which would be a true fish density estimate). Rather, the model just estimates the number of fish present in the system.

Comment: Reviewer 2 had questions regarding the need for an age-structured model and recommended justification or explanation in the document. The reviewer also commented that the assumption in the trout movement component of the model that only age-0 trout emigrated from Glen Canyon into Marble Canyon should be justified.

Response: An age-specific approach was used for the modeling component that estimated population aspects for Lees Ferry, but not for the modeling component that estimated movement (emigration) of trout into Marble Canyon and locations further downstream. The model was set up in this fashion because a number of the performance metrics specific to Lees Ferry trout required some consideration of size (growth) and because there were data available to support this modeling approach for Lees Ferry. Age-specific data suitable for modeling population processes were not available for Marble Canyon, although there is ongoing research seeking to better understand such processes in Marble Canyon.

Comment: Reviewer 2 suggested that the Cauchy distribution was used in the trout movement component of the model to restrict movement.

Response: This is incorrect; the Cauchy distribution has a fatter tail, allowing for more long-term movement. Cauchy, and similar fat-tailed distributions, are frequently used in spatial modelling. We chose this distribution because it outperformed alternative forms considered (i.e., normal and exponential declines) in terms of fit to available data.

Comment: Reviewer 2 requested information regarding model selection for the humpback chub component of the model.

Response: Additional information regarding model selection was added into the narrative.

Comment: Reviewer 2 suggested that a range of recruitment patterns should be considered.

Response: Text was added to section 4 of the overview document to clarify that high, medium and low humpback chub recruitment levels were modeled.

Comment: Reviewer 2 suggested that differences in spawning frequency by different humpback chub size classes was not represented in the humpback chub life history diagram.

Response: By estimating ω_9 and ω_10 separately (movement from the mainstem into the LCR for adult size class 4 and adult size class 5) the model implicitly allows for different movement rates for fish in the different spawning size classes, which affects spawning frequency. Additional information is provided in Yackulic et al. (2014).

2.2. Minor comments

A typographic error in the equation for predicting the abundance of age-1 fish following out-migration was identified by one reviewer; the equation was corrected.

3. DESCRIPTION OF THERMAL SUITABILITY MODELING FOR LTEMP EIS ALTERNATIVES

A description of the temperature suitability models was reviewed by Scott VanderKooi (Chief, GCMRC) in January 2014; a revised description that addressed the reviewer comments was incorporated into Appendix F of the LTEMP DEIS. Major and minor comments from the peer review are summarized below, along with comment responses.

3.1. Major comments

Comment: The approach is scientifically sound and appropriate for evaluating the LTEMP EIS alternatives for their potential to produce thermal conditions suitable for the establishment and maintenance of populations of native and nonnative fishes and invasive parasite species.

Response: Comment noted.

Comment: The basis for the relationship used in the models is species-specific and comes directly from values in the published literature. These include the minimum, maximum, and optimum temperatures reported for successful spawning, incubation, and growth of key native and nonnative fish species and for host activity and rate of infestation for four parasite species of concern. The application of these values to estimate the timing, location, and duration of suitable conditions for the key life history components of interest is logical and relatively straightforward.

Response: Comment noted.

Comment: There are uncertainties associated with this approach, however, which should be identified and discussed. The exact relationship between each variable of interest over the range of temperatures used (minimum to maximum) is not used (and may not always be known), but instead a linear fit among the minimum, maximum, and optimum temperatures is applied to create a triangular probability function.

Response: The reviewer is correct that a triangular relationship based on the minimum, optimum, and maximum reported suitable temperatures was used for the relevant life history aspects (spawning, egg incubation, and growth for fish; host activity and rate of infestation for parasites) for each species of concern Other relationships (e.g., uniform or normal distributions) were considered. Based on input from the aquatic ecology subject matter experts for the LTEMP EIS, it was decided that a triangular distribution would be used. Discussion regarding the uncertainties associated with the use of a triangular distribution was added to the model description in Appendix F of the DEIS.

Comment: A discussion of limitations of the approach and related uncertainties should be included.

Response: Assumptions and key uncertainties associated with the temperature suitability modeling approach are incorporated into the model description and presentation of results in Appendix F of the DEIS.

Comment: The reviewer suggested that there would not be any compounding uncertainty associated with the use of the Temperature Suitability Model since the suitability values generated only rely on a single temperature value (i.e., a daily mean). Any compounding uncertainty would instead result from those uncertainties associated with the hydrologic traces used to generate temperature estimates used by this model.

Response: Variability in the temperature suitability values calculated by the model reflects variability in predicted water temperatures among the hydrologic traces used as input values.

3.2. Minor comments

A number of text additions or changes were requested by the reviewer. Revisions incorporated into the model description provided in Appendix F of the DEIS included corrections of formatting errors and text changes such as rewording to improve clarification of meaning. Some repetitive text was modified to shorten the document and remove redundancy.

4. APPENDIX F OF THE LTEMP DEIS

Peer review of Appendix F for the LTEMP DEIS, which incorporated overviews of the modeling approaches and a presentation of modeling results, was provided by a reviewer from the U.S. Geological Survey, Western Fisheries Research Center in September 2015.

4.1. Major comments

Comment: Regarding the way in which uncertainty in the level of effectiveness of trout management flows (TMFs) was evaluated by using two different levels (i.e., reducing the number of young-of-year trout surviving to age-1 by either 10% or 50% after a TMF during each 20-year simulation period), the reviewer asked whether a uniform distribution bounded by the effectiveness values should have been used instead.

Response: That approach was considered. However, there was a desire to explicitly consider how modeled outcomes would differ under different assumptions (i.e., high vs low TMF effectiveness).

Comment: Present the value for asymptotic length (L_{inf}) in the description of the Glen Canyon trout submodel (Appendix F, Section 3.1.1)

Response: As presented in the description of the trout component of the rainbow trout-humpback chub model, The value for L_{inf} varies for each year in the simulation based upon the number of trout greater than 150 mm total length that are present in the modeled population. Later, in the paragraph the reviewer was commenting on, it is described how interannual variability in the L_{inf} value was simulated.

Comment: The reviewer had questions regarding the effect of trout density on the catchability coefficient used in the trout submodel and suggested providing additional support for the method used to estimate catchability.

Response: The reason for the lack of fit of the simulated results to observed angling success in some portion of the traces to the observed data is unknown but could be the result of differences in how actual q *varies in response to fish density and flows. For example, recent mark-recapture efforts suggest that trout density has a strong effect on capture probability via electroshocking such that the assumption of a constant value for the catchability coefficient* (q) *will lead to estimates that are biased low when fish densities are high and biased high when fish densities are low. Unfortunately, there are not yet sufficient data to refine the relationship further and* q *for angling in the model was calculated as a scalar. To estimate* q*, the simulation model was run using the recruitment estimates from the stock synthesis model to predict age-specific abundance between 1990 and 2010. The value for* q *was then calculated from the back-transformed average of the log of the ratio of the observed catch per effort (CPE) values to the estimates of the vulnerable population each year. Thus,* q *represents the average scalar required to convert* *predicted vulnerable abundance to the observed CPE. Overall, the fit to observed data when using this approach was considered adequate for evaluating the effects of the alternatives. Note that the model does not track the number of trout relative to wetted area (which would be a true fish density estimate). Rather, the model just estimates the number of rainbow trout present in the system.*

Comment*:* The presentation of the effect of alternatives on trout catch rates states that long-term strategies that have fewer high-flow experiments (HFEs), more variable flows, and include TMFs would be expected to have lower trout abundance and lower mean angler catch rates. The reviewer commented that if this is the case, the catchability coefficient (*q*) used in the model would be a constant even though it was previously presented in the model description that *q* would go down as numbers went up.

Response: In the simulation model, q *was calculated as identified in the response to the previous comment, resulting in a constant (*q*=4.25e-05). The discussion about how* q *may actually not be a linear relationship to fish density was meant to identify potential reasons that the angler catch rates calculated by the model did not provide a strong fit to observed data for angler catch rates during some periods. As stated in the previous paragraph of the section of Appendix F for which this comment was made, the modeled vulnerability of individual trout to angling varies depending on the age of the trout, but the overall trend (as identified in Figure F-14 of Appendix F) is a strong relationship between modeled mean catch rates and modeled mean trout abundance.*

Comment: Given the linear relationship presented in Figure F-18, consider providing the slope and intercept. All that would be needed to predict adult Humpback Chub numbers would be estimated number of outmigrants, slope and intercept.

Response: The authors decided not to provide that information since this is a relationship between mean modeled outmigrants and mean modeled HBC adult abundance. There is actually a considerable amount of variability in the modeled results for both of those values under the various long-term strategies and using a simple relationship to calculate the values would potentially mask that variability.

Comment: The reviewer noted that some of the triangular relationships used in the temperature suitability modeling seem skewed, with the slope on the left side different from the right side. Functions used to create these distributions should probably be provided.

Response: The triangular relationship for suitable temperatures for the life history aspects of each of the species modeled was formed as linear relationships from minimum temperature to optimum temperature to maximum temperature. Because the reported optimum temperature is not always midway between the minimum and maximum values, it is normal for the triangular relationship to be skewed in one direction or the other. The use of relationships other than the triangular relationship (e.g., uniform or normal distributions) were considered. Based on input from the aquatic ecology subject matter experts for the LTEMP EIS, it was decided that a triangular distribution would be used. Although the mathematical relationships (i.e., intercepts, and slopes) are not presented in the appendix, the relationships can be easily discerned from the *graphs and are available in spreadsheets and data files. Discussion regarding the uncertainties associated with the use of a triangular distribution was added to the model description in Appendix F of the DEIS.*

4.2. Minor comments

A number of text additions or changes were suggested by the reviewer and many of these were incorporated into the narrative. There were several corrections made to address comments regarding unclear meaning for some sentences. Revisions incorporated into the model descriptions provided in Appendix F of the DEIS included corrections of formatting errors and text changes such as rewording to improve clarity. Some text was modified to shorten the appendix and remove redundancy.

5. REFERENCES

Korman, J., S. J.D. Martell, C.J. Walters, A.S. Makinster, L.G. Coggins, M.D. Yard, and W.R. Persons, 2012, "Estimating Recruitment Dynamics and Movement of Rainbow Trout (*Oncorhynchus mykiss*) in the Colorado River in Grand Canyon Using an Integrated Assessment Model," *Canadian Journal of Fisheries and Aquatic Sciences* 69:1827–1849.

Yackulic, C.B., M.D. Yard, J. Korman, and D.R. Van Haverbeke, 2014, "A Quantitative Life History of Endangered Humpback Chub that Spawn in the Little Colorado River: Variation in Movement, Growth, and Survival," *Ecology and Evolution* 4:1006–1018.