TEMPERATURE ANALYSIS OF PROPOSED TRINITY RIVER FISH AND WILDLIFE RESTRORATION FLOW ALTERNATIVES USING THE BETTER MODEL

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TABLE OF CONTENTS

		page
	EXECUTIVE SUMMARY	1
1.0	INTRODUCTION	2
2.0	APPROACH TO FLOW ALTERNATIVE ANALYSIS	3
	2.1 Selected Temperature Models	3
	2.2 Simulated Period	3
3.0	MODELING METHODS	5
	3.1 Lewiston Lake BETTER Model	5
	3.2 Input Data and Operational Assumptions	5
4.0	BETTER MODELING RESULTS	7
	4.1 Originally Propose Flow Alternatives	7
	4.1.1 Evaluation Period	7
	4.1.2 Evaluation Criteria	8
	4.1.3 Summary of Results	8
	4.2 Temperature Compliance Investigations	9
	4.2.1 Redistribution of CVP Diversions	9
	4.2.2 Slugging of Lewiston Lake	10
	4.2.3 Alternate Lewiston Hatchery Operations	10
	4.2.4 Low Level Auxiliary Bypass Releases from Trinity Dam	10
	4.2.5 Increased Storage and Cool Water Pool of Trinity Lake	11
	4.2.6 Increase Summer Releases to Trinity River	11
	4.2.7 Reevaluation of October Temperature Compliance Objectives	11
	4.3 Refined/Final Flow Alternatives	11
	4.4 Existing Conditions Simulations	13
5.0	CONCLUSIONS AND RECOMMENDATIONS	15
6.0	REFERENCES	16

LIST OF TABLES

Table 1. Temperature Objectives Established on the Trinity River: California SWRCB, 1991

Table 2. Average Weekly Flow (cfs) - Proposed Trinity River Mainstem Fishery Restoration EIS/EIR Flow Alternatives

Table 3. Comparison of Average Monthly Input Data Used in BETTER Model Simulations: Original State Permit Alternative

TABLE OF CONTENTS (continued)

Table 4. Comparison of Average Monthly Input Data Used in BETTER Model Simulations: Original and Refined No Action Alternative

Table 5. Comparison of Average Monthly Input Data Used in BETTER Model Simulations: Original and Refined Flow Study Alternative

Table 6. Comparison of Average Monthly Input Data Used in BETTER Model Simulations: Original and Refined 40% Inflow Alternative

Table 7. Comparison of Average Monthly Input Data Used in BETTER Model Simulations: Original and Refined Maximum Flow Alternative

Table 8. BETTER Model Output Evaluation Criteria: Discharge and Release Temperature Combinations that meet the SWRCB Temperature Objectives

Table 9. Daily Results of BETTER Temperature Model Simulations

Table 10. Number of Days and Percent Time Flow Alternatives Comply with Temperature Objectives: Median Evaluation Criteria

Table 11. Number of Days and Percent Time Flow Alternatives Comply with Temperature Objectives: Cold-Wet Evaluation Criteria

Table 12. Number of Days and Percent Time Flow Alternatives Comply with Temperature Objectives: Hot-Dry Evaluation Criteria

Table 13. Number of Days and Percent Time Flow Alternatives Comply with Temperature Objectives: Very Hot-Critically Dry Evaluation Criteria

Table 14. Comparison of Average Monthly Input Data Used in BETTER Model Simulations: Existing Conditions Simulations vs. No Action Alternative

Table 15. Number of Days and Percent of Time Existing Conditions Simulation and No Action Alternative Results Comply with Temperature Objectives: Median Evaluation Criteria

EXECUTIVE SUMMARY

This report summarizes results of a thermal evaluation of the proposed Trinity River Restoration Act flow alternatives. The thermal evaluation was completed using a series of models that simulate flow and temperature in the upper Trinity River basin, including: the Bureau of Reclamation's reservoir temperature model (RTM) of Trinity Reservoir; Trinity County's two dimensional temperature model of Lewiston Lake (BETTER); and the US Fish and Wildlife Service's model of the mainstem Trinity River below Lewiston Lake (SNTEMP).

Initial results of temperature modeling indicate that flow alternatives that provide the greatest total annual release volumes to the mainstem Trinity River (i.e. those alternatives that are based on reestablishing natural hydrologic processes) result in some of the highest downstream temperatures. The reasons for these results lie in the complex "plumbing" and operations of the Trinity Division.

Subsequent model simulations were initiated to explore and develop operational changes that would assist proposed flow alternatives in complying with downstream temperature objectives. Promising mitigations include: shifting CVP diversion patterns so that the highest diversion rates occur during the summer period; revising proposed flow alternative river release schedules; maintaining higher carry-over storage capacity of Trinity Reservoir into the late summer; decreasing prescribed warm summer releases to the Trinity Fish Hatchery; and drawing upon deeper cool-water reservoir pools during critically dry year-types. Interestingly, many of these temperature mitigation strategies not only result in lower river temperatures, but, provided added benefits to other Trinity River stakeholders (e.g. higher summer-time lake levels for recreation, higher CVP diversions during peak power generation periods, and more timely diversions that will help meet summer-time Sacramento River and Bay-Delta flow and water quality objectives).

As a result of the temperature compliance work, refined flow alternatives were developed and reanalyzed using the temperature models. Changes incorporated into the revised/final flow alternatives consisted of revised CVP diversions and minor revisions to proposed river release schedules. These operational changes were quite successful in reducing river release temperatures and increasing compliance with downstream temperature objectives.

Temperature models were also used to evaluate the impacts associated with changes in existing versus future operations of the Trinity River Division of the Central Valley Project. Comparison of Existing Conditions simulations (1995 level of development) to the No Action alternative results (2022 level of development) suggest that future Trinity River Division operations will export greater volumes of water to the CVP during dry year-types. Temperature model simulation results indicate that these changes in operations could cause increases in the temperature of water released from Lewiston Lake to the Trinity River.

1.0 INTRODUCTION

This report serves as a technical appendix to the "Trinity River Mainstem Fishery Restoration Environmental Impact Statement and Report" (EIS/EIR) and summarizes the methods and results derived during thermal analysis of the proposed Trinity River Restoration Flow Alternatives. It outlines the temperature modeling approach used to evaluate flow alternatives, results of model simulations, and work conducted to refine and reanalyze many of the proposed flow alternatives. Although the approach and general results of all the temperature analyses are presented here, this report focuses on the temperature modeling results of Lewiston Lake. Companion reports documenting the temperature modeling results of Trinity Lake and the mainstem Trinity River are also included as appendices to the EIS/EIR.

2.0 APPROACH TO FLOW ALTERNATIVE ANALYSIS

2.1 Selected Temperature Models

Although there are six proposed flow alternatives being considered and evaluated as part of the Trinity River Mainstem Fishery Restoration EIS/EIR process, there are only five distinct river release and CVP diversion schedules (i.e. two alternatives are a variation on a single flow schedule). Thus, temperature analyses were only required on five core alternatives. More detailed descriptions of the core flow alternatives analyzed as part of this temperature investigation are provided in the main text of the EIS/EIR.

Thermal evaluation of proposed restoration flow alternatives was initiated using a series of models that simulate flow and water temperatures for sequential portions of the upper Trinity River system. These models include: the Bureau of Reclamation's Temperature Model (RTM) which simulates release volumes and temperatures from Trinity Lake[1]; a reservoir temperature model of Lewiston Lake based on the Box Exchange Transport Temperature and Ecology of Reservoirs model (BETTER); and the U.S. Fish and Wildlife Service's (USFWS) Stream Network Temperature Model (SNTEMP) which simulates water temperatures on the mainstem Trinity below Lewiston Lake[2].

RTM is a modification of the U.S. Army Corps of Engineer's Reservoir Temperature Stratification (RSTEMP) one-dimensional model, and operates on a monthly time-step (Rowell, 1979). BETTER, discussed in more detail below, is a two-dimensional model operating on a daily time-step and was developed for Trinity County in 1991 by Dr. Russ Brown of Jones & Stokes Associates, Inc. (Brown et al., 1992). SNTEMP is a one-dimensional river temperature model package (Theurer et al. 1984), applied to the mainstem Trinity River below Lewiston Dam, operating on a weekly time-step.

The approach to modeling was to simulate the effects each flow alternative would have on water temperatures on the mainstem Trinity River. Simulated river water temperatures could then be compared to the temperature objectives developed by the California State Water Resources Control Board (SWRCB) in 1991 and listed in Table 1. Modeling of each restoration flow alternative was initiated using PROSIM and RTM to estimate release volumes and temperatures from Trinity Lake into Lewiston Lake. These data were then used as input into the BETTER model to estimate release temperatures from Lewiston Lake into the upper Trinity River. In turn, output from the BETTER model acted as input to SNTEMP, which calculates down stream river temperatures.

2.2 Simulated Period

Due to the relatively short time-steps of the BETTER and SNTEMP models (daily and weekly, respectively), the limited period of representative input data for each model (1960 through 1991 and 1975 through 1994, respectively), and the need for consistent simulation periods, it was agreed that BETTER and SNTEMP simulations would be performed on a select number of years which represent a suite of water year-types. Selected water year-types are based on the following percent exceedences applied to the 1912-1991 record of annual inflow to Trinity Lake:

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[1] Input data for RTM comes from the Bureau's project simulation model (PROSIM) which is used to evaluate the CVP and State Water Project (SWP) systems. The close linkage between RTM and PROSIM means that PROSIM also plays an indirect role in the temperature analysis process.

[2] Originally, TRNMOD, operated by the former National Biological Survey, was also going to be used in coordination with PROSIM and RTM. However, incompatibilities necessitated dropping it from participation.

Water-year Type	% Exceedence
extremely wet	<12%
wet	12%-40%
normal	40%-60%
dry	60%-88%
critically dry	>88%

Representative water year-types that meet the criteria listed above were selected from the 1975 through 1991 period and include: 1977-critically dry; 1990-dry; 1989-normal; 1986-wet; and 1983-extremely wet.

The selection of representative water year-types was based on the hydrologic definition of a water year, the period October 1 through September 30 of the named year. However, the PROSIM model transitions water years on March 1st. In order to establish consistency between all models, it was easiest for the BETTER and SNTEMP models to adopt the PROSIM standard and transition years on March 1. Thus, the specific flow schedules used to simulate operations during the selected simulation years in the BETTER and SNTEMP models are listed below.

Hydrologic Water Year Selected for BETTER and SNTEMP Analyses	Period and Flow Schedule Used in Simulations to Maintain Consistency with PROSIM/RTM simulations
1983 (ex. wet)	October 1982 - February 1983: Wet-Year Type March 1983 - September 1983: Ex. Wet Year-Type
1986 (wet)	October 1985 - February 1986: Dry Year-Type March 1986 - September 1986: Wet Year-Type
1989 (normal)	October 1988 - February 1989: Dry Year-Type March 1989 - September 1989: Normal Year-Type
1990 (dry)	October 1989 - February 1990: Normal Year-Type March 1990 - September 1990: Dry Year-Type
1977 (critically dry)	October 1976 - February 1977: Dry Year-Type March 1977 - September 1977: Crit Dry Year-Type

Proposed flow release schedules representative of extremely wet, wet, normal, dry, and critically dry water year-types for each flow alternative are presented in Table 2.

3.0 MODELING METHODS

3.1 Lewiston Lake BETTER Model

As indicated above, this Appendix focuses on presenting results of the Lewiston Lake Temperature analyses. BETTER is a two-dimensional reservoir temperature and water quality model developed in the early 1980's by Dr. Russ Brown at the Tennessee Valley Authority (TVA). The TVA code was modified and calibrated for Lewiston Lake in 1992 to simulate the longitudinal flow and warming of the releases from Trinity Lake and vertical stratification caused by surface layer warming (Brown et al., 1992).

Model geometry may be visualized by dividing the volume of Lewiston Lake into an array of up to 7 vertical and 6 horizontal cells. Two dimensional flow patterns are determined by this reservoir geometry and the inflows and outflows from the reservoir. Once the flows are estimated, water and heat balance calculations are performed for each model cell. Inflows to Lewiston Lake include releases from Trinity Lake, local stream accretions, and direct precipitation on the surface. Outflows from the lake include evaporation from the surface and four separate withdrawals: diversions through the Clear Creek tunnel to the Carr power plant and Whiskeytown reservoir; releases through the Trinity River Hatchery; releases through Lewiston Dam power plant; and occasional Lewiston spillway releases.

The model calculates average daily flows and temperatures for each modeled cell and temperatures for each reservoir outlet. In addition, the model performs a temperature mass balance calculation of Lewiston dam outflows to derive a river temperature on the Trinity River at Lewiston gage. The model also calculates several other variables including residence time, mixing depths, and vertical flow distributions at the outlets. A more detailed description of the BETTER model and meteorologic data sets used in the model are presented in Brown et al. (1992).

3.2 Input Data and Operational Assumptions

Apart from existing meteorologic and hydrologic data for Lewiston Lake, release volumes and temperatures from Trinity Reservoir and CVP diversions used in the various alternative simulations were derived from PROSIM and RTM output. Summaries of monthly output from the PROSIM and RTM models (used as input to the BETTER model) are presented by alternative in Tables 3 through 7. Because PROSIM and RTM operate on a monthly time-step, data needed to be disaggregated into daily values for input into the BETTER model. Daily temperatures were linearly interpolated from monthly data assuming that the average monthly temperature supplied by RTM occurred on the middle day of each month. The averages of each month's disaggregated temperatures equaled the RTM monthly temperature. On occasion minor adjustments to the middle-of-the-month daily temperature was necessary in order to maintain a monthly average equal to the RTM monthly average (especially for the months in which the annual maximum or minimum average monthly temperatures occurred).

Daily inflow volumes from Trinity Lake were estimated by apportioning the PROSIM monthly total release volumes into daily releases in proportion to the flow alternative release schedules while maintaining monthly averages consistent with PROSIM output. Daily CVP diversions for any given month were simply taken to equal the average monthly values supplied by PROSIM. Daily release rates from Lewiston Lake to the Trinity River were derived from the weekly flow alternative release schedules supplied by the Water Operations/Management Technical Team (WOMTT).

Other operational constraints that were adhered to during modeling as agreed by the WOMTT include:

- when possible, the Bureau's Long-term Central Valley Project Operations Criteria and Plan (OCAP) release criteria from Lewiston Lake to Trinity River were followed;

- operation caps for releases from Trinity to Lewiston were ignored (the WOMTT decided facilities would be modified in the future to accommodate flow alternatives, if needed);

- "slugging" of Lewiston Lake is not considered a routine operation of the system and was not incorporated into model simulations ("slugging", the simultaneous release and refilling of Lewiston Lake to reduce water temperature, is further discussed in Section 4.2.2 of this report);

- it was assumed that diversion capacity of the Carr power plant tunnel was considered and addressed during PROSIM simulations; and

- release operations from the early 1990's were used as a guide for simulating the relative percent/capacity releases through the Lewiston fish hatchery, power plant, and spillway.

4.0 BETTER MODELING RESULTS

Initial temperature modeling results indicated that many of the proposed flow alternatives did not satisfy downstream temperature objectives, especially during the late summer period. In fact, many of the alternatives that were expected to provide adequate flow and temperature conditions resulted in some of the highest river temperatures. In response to these results, a series of temperature compliance investigations were completed to evaluate how Trinity Division operations could be modified to reduce release temperatures and improve compliance with temperature objectives.

This section of the report presents the BETTER model results from temperature analysis of the original and refined flow alternatives. In addition, the temperature compliance methods evaluated in order to refine and finalize the original flow alternative operations are also presented.

4.1 Originally Proposed Flow Alternatives

4.1.1 Evaluation Period

As discussed above, temperature objectives on the Trinity River are in effect for the period July 1 through December 31. Thus, evaluation and comparison of alternatives must focus on the results from this period. However, there are a number of concerns regarding the appropriateness and validity of the temperature objectives stipulated for the October 1 through December 31 period. Some of these concerns include:

1. After October 1^{st}, the temperature compliance point on the mainstem Trinity River shifts from Douglas City to the North Fork Trinity River (from approximately 20 miles to 40 miles below Lewiston dam), requiring relatively higher flows and/or lower release temperatures to meet temperature objectives at the new temperature compliance location (North Fork Trinity River) versus the previous (Douglas City) location.

2. Review of empirical data indicates that temperature objectives after October 15 are met during most years under 300 to 450 cfs release scenarios. Thus, it is probably safe to assume that temperature objectives will likely be met by proposed alternatives with provide similar or greater release rates after October 15.

3. Based on the empirical data, it appears that releases of 300 cfs from Lewiston dam will need to be 47 degrees F or less in order to meet the temperature objectives at the North Fork Trinity River from October 1 through October 15. Given the available release temperatures from Lewiston dam, it is likely that early October releases for most of the proposed flow alternatives would need to be raised to at least 450 cfs to meet downstream temperature objectives during normal year-types. Empirical data suggest flows thereafter will only need to be about 300 cfs. However, biological opinions suggest that significant reductions in flow occurring in mid-October could lead to dewatering of redds.

Based on this information, it is assumed that none of the proposed flow alternatives would impart hostile temperatures to Trinity River fisheries after October 15 during any given year-type. Thus, for purposes of this report, the ability of a proposed flow alternative to meet downstream temperature objectives was evaluated for the period July 1 through October 15.

4.1.2 Evaluation Criteria

As a preliminary evaluation of how simulated Lewiston Lake releases fared in meeting the downstream temperature objectives, a suite of required flow and release temperature relationships were developed using the SNTEMP model. These relationships provide an estimate of the required minimum river release volumes and temperatures necessary to meet the downstream temperature objectives for a given period and year-type. In actuality, 4 sets of flow and release temperature relationships were developed for a variety of hydrometeorological year-type conditions, including: cold-wet; median; hot-dry; and extremely hot-critically dry. These relationships are presented in Table 8. It is important to point out that the SNTEMP flow/temperature release relationships for median hydrometeorological conditions are probably the most appropriate single set of evaluation criteria for all year-type simulations; the median relationships were developed using the broadest and most diverse range of flows and release temperatures. Therefore, this report focuses primarily on reporting the results derived using the median hydrometeorological evaluation criteria.

4.1.3 Summary of Results

In analyzing the original flow alternatives, five BETTER model simulations were completed for each flow alternative; one simulation per representative water year-type for a total of 25 simulations[3]. BETTER modeling results, including daily river release volumes and temperatures for each of the originally proposed alternative simulations are presented in Table 9. In addition, Table 9 indicates the combinations of daily release flow and temperature that satisfied the downstream temperature objectives according to the median year-type evaluation criteria summarized in Table 8. Compliance with the other three sets of evaluation criteria is also presented on Table 9. Tables 10 through 13 summarize the compliance results for each respective evaluation criteria as the number (and percentage) of days in which each flow alternative meets the downstream temperature objectives, again, only for the period July 1 through October 15. However, as indicated above, the following discussion will focus only on the compliance results associated with the median year-type evaluation criteria (Table 10).

State Permit Alternative
Temperature objectives were met only 41% of the time (44 out of 107 days) during the extremely wet year-type, 14% (15 days our of 107) during the wet year-type, 39% (42 our of 107 days) during the normal year-type, and 57% (61 days out of 107) during the dry year-type. Lewiston Lake releases and temperatures during the critically dry year-type were not sufficient in meeting any of the downstream temperature objectives for the July 1 through October 15 period.

No Action Alternative
Temperature objectives are met 100% of the time between July 1 and October for the extremely wet and wet year-types, 98% (105 of 107 days) for the normal year-type, 76% (81 days) for the dry year-type, and 22% (24 of 107 days) of the time during the critically dry year-type.

Flow Evaluation Study Alternative
Simulation results indicate that temperature objectives were met 99% of the time (106 days out of 107) during the extremely wet and wet year types, 86% of the time (92 days out of 107) during the selected

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[3] Preliminary BETTER simulations indicated that it takes the first one to two weeks of each run for the model to equilibrate thermal conditions in Lewiston Lake (i.e. proper temperature stratification). Because of this modeling phenomenon, each simulation was run twice in succession to eliminate the inaccuracies of the initial simulation temperature results.

normal year, 71% (76 out of 107 days) during the dry year-type, and only 7% (8 days out of 107) during the critically dry year-type.

40% Inflow Alternative

The original percent inflow alternative had the worst temperature compliance performance of all the originally proposed flow alternatives. Temperature objectives were met 50%, 26%, 13%, and 13% of the time for the extremely wet, wet, normal, and dry water year-types, respectively (53, 28, 14, and 14 days out of 107, respectively). Daily river releases were not able to satisfy any of the temperature objectives during the selected critically dry year-type.

Maximum Flow Alternative

The Maximum Flow Alternative was able to consistently meet temperature objectives for 27% (29 out of 107 days) and 32% (34 days out of 107) of the time during extremely wet and wet year-types, 67% (72 out of 107 days) and 60% (64 out of 107 days) during normal and dry water year-types, but only 4% (4 out of 107 days) during the selected critically dry year-type.

In summary, initial results of temperature modeling indicate that the alternatives that provided the greatest total annual release volumes to the mainstem Trinity River (e.g. "Flow Study", "40% Inflow", and "Maximum Flow" alternatives) did not necessarily result in beneficial down-stream temperatures. This is especially true during summer-time and/or dry year-types when there just isn't enough water flowing through Lewiston Lake to keep temperatures cool and/or release temperatures from Trinity Reservoir are too warm due to low carryover storage.

4.2 Temperature Compliance Investigations

Because several of the originally proposed flow alternatives were expected be more "temperature-friendly" than modeling results indicated, the WOMTT directed the temperature modeling group to investigate ways to modify operations in order to increase compliance with SWRCB temperature objectives. These investigations, hereafter referred to as temperature compliance investigations, evaluated a variety of operational changes to reduce river release temperatures. Summaries of temperature compliance approaches evaluated using the BETTER model are discussed below.

4.2.1 Redistribution of CVP Diversions

Much of the reason for the elevated river release temperatures is associated with the complex "plumbing" and operations of the Trinity Division of the CVP. Due to its geometry and the intermittent operation of the Carr power plant, water temperatures in Lewiston Lake are highly variable. When the Carr power plant diversions are at capacity, the rate of flow through Lewiston Lake is sufficient to displace its entire volume in about 2.5 days and water temperatures remain relatively cool (Brown et al., 1992). On the other hand, when the Carr power plant is not operating, flow through Lewiston Lake stagnates and thermal stratification develops within days, typically leading to the warming of summer surface waters to between 60 and 70 °F (15.6 and 21.1 °C).

Initial modeling results suggest that total flow rates through Lewiston Lake (i.e. the sum of CVP diversions and river releases) should be between approximately 800 cfs during the late summer/early fall months of normal year-types and up to 1900 cfs during the summer/fall months of critically dry year-types in order to comply with downstream temperature objectives. The maximum late summer-time daily releases for many originally proposed flow alternatives range from 300 to 450 cfs. Thus, CVP diversions would need to be maintained between 500 and 1600 cfs to meet summer/early fall temperature needs during normal and critically dry years, respectively.

As proposed under the original flow alternatives, Trinity Division diversions are maximized during the spring while allowing other CVP reservoirs to fill during this high runoff period. These operations are designed to optimize the amount of summer storage in other Sacramento River reservoirs in order to meet water quality objectives for endangered winter run Chinook salmon on the Sacramento River. Unfortunately, this leaves summer storage in Trinity Lake relatively low, prohibiting late season diversions that could keep Lewiston Lake cooler and help meet Trinity River temperature objectives.

BETTER modeling exercises indicate that redistributing maximum CVP diversions from spring to summer (while maintaining the same total annual diversion volume) are effective at reducing summer-time river release temperatures. This solution maintains higher Trinity Lake storage later into the summer, reducing the possibility of thermocline intersection with the Trinity Dam power outlet and warm water releases to Lewiston Lake. Temperature simulations are also on-going to better estimate the minimum carry-over storage necessary to meet river temperature objectives during all water year-types and extended dry periods (Deas, 1998).

4.2.2 Slugging of Lewiston Lake

Slugging is a non-routine operation of the Trinity Division in which a large volume of water is released from Trinity Lake and passed through Lewiston Lake over a relatively short period. The purpose of this operation is to reduce water temperatures in Lewiston Lake and, in turn, the Trinity River. Preliminary BETTER model simulations of slugging were completed on several alternatives. These results, along with empirical data indicate that the benefits of such a mitigation approach are relatively short-lived and of limited long-term use. Thus, no further analyses or routine use of this operation were included in flow alternative refinement.

4.2.3 Alternate Lewiston Hatchery Operations

The Trinity Fish Hatchery, located immediately below Lewiston Dam, historically draws upon warm surface water releases from Lewiston Lake in order to optimize egg incubation and juvenile rearing. During the summer, these hatchery releases make up a large proportion of the total river releases. A temperature curtain can also be raised and lowered as needed at the south end of Lewiston Lake to assist Hatchery personnel to achieve a relatively warm and constant temperature through the Hatchery outlet in order to optimize fish growth. However, results of temperature compliance simulations indicate that reallocating the hatchery releases through the lower power and spillway outlets significantly lower river release temperatures. This mitigation approach would likely have serious adverse effects on hatchery operations and brings to a head the debate related to natural vs. hatchery fishery management philosophies.

Specific results of this analysis indicate the following: 1) in the case of the Percent Inflow alternative, reducing or eliminating hatchery releases were effective at reducing release water temperatures to levels that satisfy downstream temperature objectives during all year-types; 2) results were similar for the Flow Study alternative, except, much lower temperatures resulted versus previous scenarios, but, releases still don't satisfy temperature objectives 100% of the time even when eliminating hatchery releases altogether; and 3) although temperatures were reduced significantly using this mitigation approach on the Maximum Flow alternative, it was not successful in reducing summer-time release temperatures to levels that would consistently meet downstream temperature objectives.

4.2.4 Low Level Auxiliary Bypass Releases from Trinity Dam

Although there was no way to simulate this approach using the BETTER (Lewiston Lake) model, an independent operational analysis, sponsored by Trinity County, indicates that significant temperature reductions to the Trinity River may be realized if more water is released through the deep auxiliary outlet in Trinity Dam (Deas, 1998). This temperature reduction strategy was been implemented successfully in the past as an emergency measure (most notably during September and early October of 1991 and 1992, respectively) and our preliminary analyses suggest it could be part of normal operations. However, likely problems and limitations of this operation include lost power generation at Trinity Dam, a restricted maximum release capacity of 2500 cfs through the low-level bypass (Deas, 1998), and increased turbidity in river releases.

4.2.5 Increased Storage and Cool Water Pool of Trinity Lake

During dry periods, when Trinity reservoir levels get too low, warmer surface waters are drawn into the Trinity dam powerhouse intake, resulting in relatively warm water releases to Lewiston Lake. In turn, these warm temperatures are propagated through Lewiston Lake to the river. To date, it is unclear what the minimum October 1 carryover storage volume is needed for any given alternative to protect against the introduction of warm summer water releases. In addition, the required minimum carry-over storage volume likely changes with seasonal weather patterns and drought cycles. The main factors that affect and/or control the Trinity Lake storage volume and size of the cool water pool are: reservoir inflow temperatures and volumes; CVP diversions and operations; seasonal meteorological patterns; release schedules to the river; and water year-types. Studies to identify the minimum carryover storage and minimum operational lake levels for each of the proposed flow alternatives were initiated by Trinity County at the time this report was written (Deas, 1998 and Kamman, 1998).

4.2.6 Increase Summer Releases to Trinity River

In some cases, operational changes during the summer periods aren't able to reduce release temperatures to levels that would meet downstream temperature objectives. In most of these cases, the limiting factors are low daily river release volumes (i.e. no matter how cold the release temperature, flows are too low to maintain cool water temperatures at nominal distances downstream of Lewiston Dam). This scenario was quite common for the Maximum Flow alternative that had low summer releases and does not include diversions to the CVP, which help keep the water in Lewiston Lake cool during the summer months. Based on a series of iterative temperature model simulations, it was found that raising minimum summer flows to between 450 cfs for alternatives which include CVP diversions and up to 900 cfs for the Maximum Flow alternative, could lead to better compliance with downstream temperature objectives. These results have lead to increases in the late season releases proposed as part of the 1997 and 1998 interim flow schedules and modifications to the proposed Maximum Flow and Flow Study alternatives.

4.2.7 Reevaluation of October Temperature Compliance Objectives

Based on discussions presented in Section 4.1 of this report, it may be helpful to reevaluate the existing SWRCB temperature objectives, especially in light of the difficulty in meeting temperature objectives between October 1 through October 15. At present, it appears that the flow and release temperatures needed to satisfy temperature objectives during this period are significantly harder to meet than during the earlier summer periods. This is likely a function of shifting the temperature compliance point from 20 to 40 miles downstream of Lewiston Dam while maintaining the same temperature objective of 56 degrees F. However, a relaxation of the existing October temperature objective may result in negative biological impacts to spawning and incubating salmonids and should be carefully analyzed, including a comparison to the benefits of reduced redd dewatering.

4.3 Refined/Final Flow Alternatives

Based on the temperature compliance work discussed above, numerous operational changes were made to the originally proposed Flow Study, 40% Inflow, and Maximum Flow alternatives. Most of these changes took the form of refined CVP diversion schedules and revised flow (river release) schedules. No changes were made to the original State Permit or No Action alternatives. Tables 4 through 7 compare monthly diversion rates between original and refined/final proposed flow alternatives. These changes reflect modifications to diversion patterns while maintaining the same total annual diversion volumes. Modifications made to the proposed flow alternative river release schedules are also presented on Tables 4 through 7. Refinements to the Trinity Lake release volumes were also necessary in order to accommodate for changes to the diversion and river release schedules. Because diversions and river releases were shifted from spring periods to summer periods, operations required maintaining greater Trinity Lake storage into the summer months. This effectively altered the Trinity Lake release water temperatures between the original and refined alternatives also presented in Tables 4 through 7.

Daily BETTER model results, including river release volumes and temperatures for each of the refined alternative simulations are presented in Table 9. Compliance with downstream temperature objectives was assessed using the four sets of evaluation criteria summarized in Tables 8. Table 10 summarizes the daily compliance results as the number of days (and percentage) in which refined/final flow alternatives meet the downstream temperature objectives between July 1 and October 15 for median hydrometeorological conditions. Results for cold-wet, hot-dry, and extremely hot-critically dry hydrometeorological conditions are presented on Tables 11 through 13. Changes made to each of the refined flow alternatives, temperature simulation results, and compliance with the median year-type evaluation criteria are summarized here.

General Results

All of the revisions made to proposed flow alternatives were effective in reducing summertime release temperatures and/or increasing summertime release volumes. However, even with the temperature compliance refinements, temperature objectives were not necessarily satisfied during all periods.

State Permit Alternative

As indicated above, no modifications were made to the State Permit Alternative. Results of temperature model simulations along with available empirical data suggest that downstream temperature objectives can not be met during the summer with such low river release volumes.

No Action Alternative

No modifications were made to the No Action Alternative.

Flow Evaluation Study Alternative

There were considerable refinements made to the flow schedule (river releases) as part of the temperature compliance investigation (see Table 2). Most of these modifications were initiated by the USFWS as part of their internal review process of the Flow Evaluation Study development. The majority of the flow schedule modifications included redistributing peak springtime releases (late April through June) and increasing late September releases from 300 to 450 cfs. Similar to the refined No Action alternative, CVP diversions were modified by shifting peak diversions from the spring to summer months (see Table 5). Again, these changes also required modifying release rates from Trinity Lake (and, in turn release temperatures) in order to accommodate the refined diversion and river release schedules (see Table 5).

The refined/final Flow Study alternative was significantly better at meeting downstream temperature criteria during most year-types versus the original proposed flow alternative. Although there was little change in the number of days meeting the temperature criteria during the selected extremely wet and wet year-types, notable improvements were realized in the remaining year-types; compliance with downstream temperature objectives between the original and refined Flow Study alternatives improved from 86% to 99% during normal years, from 71% to 99% during dry year-types, and from 7% to 99% during critically dry years (see Table 10).

40% Inflow Alternative
There were very few changes in river release patterns incorporated into the refined/final 40% Inflow alternative. Changes made to this alternative consisted predominantly of shifting peak CVP diversions from spring to summer periods and modifying Trinity Lake release volumes (and temperatures) accordingly (see Tables 2 and 6). Although these modifications were effective in reducing daily summer-time releases from Lewiston Lake to the River, there was little to no improvement in compliance with downstream temperature objectives (see Table 10).

Maximum Flow Alternative
The only refinements possible to the Maximum Flow alternative consisted of modifying the proposed flow schedules (i.e. there are no CVP diversions under this alternative). These changes, presented on Table 2, consisted of increasing summer through late-fall release volumes in wet through critically dry years (no changes were made to the extremely wet year-type release schedule).

Results of temperature model simulations of the refined/final Maximum Flow alternative indicate significant improvements in compliance with temperature objectives during wet and critically dry year-types, moderate improvements during normal and dry year-types, but no change during the extremely wet year-type (see Table 10). The lack of significant improvement in the dry year simulation is likely attributable to depleted carryover storage and dramatic increases in release temperatures from Trinity Lake (especially during the months of July through September; see Table 7). For comparison, the normal and critically dry year simulations of the refined Maximum Flow alternative resulted in net improvements to the river temperature conditions due to increases in release volumes to the River which outweighed the slight release temperature increases (up to 1.0 degree F) from Trinity Lake. However, under the dry year simulation, increases in the average monthly Trinity Lake release temperatures between the original and refined Maximum Flow alternatives were 2.3, 3.7, and 4.2 degrees F during the months of July, August, and September, respectively (see Table 9). Inspection of daily simulation results indicate that these elevated Trinity Lake release temperatures are propagated through Lewiston Lake and result in significantly elevated release temperatures to the River, overwhelming the beneficial effects of the increased releases.

4.4 Existing Conditions Simulations
A final suite of temperature model simulations was performed to assess existing conditions as simulated by PROSIM. The PROSIM Existing Conditions simulations reflect a 1995-level of development while all the proposed flow alternative simulations (No Action, Flow Study, Percent Inflow, etc.) reflect a year 2022-level of development. A summary of Existing Conditions output from the PROSIM and RTM models is presented on Table 14. For comparison, similar output for the No Action alternative is also presented on Table 14. The results of BETTER model simulations of the Existing Conditions scenario are presented on Table 9 (starting on page 23 of 44) and summarized on Table 15. Similar to previous summaries, Table 15 expresses the daily model results as the percentage of time a given alternative meets downstream temperature objectives under median year hydrometeorological conditions criteria developed by the USFWS using the SNTEMP model for the period July 1 through October 15 (Table 8). Table 15 also compares the compliance results for the No Action alternative to those for the Existing Conditions simulations.

The only significant difference observed between the No Action and Existing Conditions simulations occurs during the dry year-type (1990); compliance with temperature objectives is much better (100%) under the Existing Conditions simulation than the No Action alternative (76%). The reason for this difference likely arises out of operational changes in the Trinity River Division operations during this year. The most notable change is an increase in CVP diversions under the No Action (2022 conditions) during June and August as compared to the Existing Conditions operations (Table 14). The net effect is that summer storage in Trinity Lake is lower under the year 2022 conditions during 1990 (representative dry year-type) than under existing conditions. This reduction in summer storage allows for significantly warmer (5.5 degrees F; see Table 14) releases from Trinity Lake to Lewiston Lake which are also realized as warmer water releases to Trinity River.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations summarize the findings of this temperature evaluation of proposed Trinity River restoration flow alternatives.

- A suite of models, simulating flow and water temperature of the Trinity River system have been successful in evaluating if proposed flow alternatives meet SWRCB temperature objectives on the Trinity River.

- Analyses of the originally proposed flow alternatives indicate that alternatives that provided the greatest total annual release volumes to the mainstem Trinity River (e.g. "Flow Study", "40% Inflow", and "Maximum Flow" alternatives) do not necessarily result in beneficial down-stream temperatures.

- A series of temperature compliance investigations were conducted to identify viable modifications to proposed operations and flow alternatives to better satisfy downstream temperature objectives. The most promising modifications that were evaluated included shifting peak CVP diversions from spring to summer periods and increasing late summer release rates from Lewiston Lake to the Trinity River.

- Based on results of the temperature compliance studies, numerous refinements were made to proposed flow alternatives. Analysis of these refined flow alternatives indicated that conditions (flows and water temperature) of releases from Lewiston Dam were significantly improved, typically resulting in greater compliance with downstream temperature objectives.

- Many of the temperature mitigation strategies also provide potential benefits to other Trinity River stakeholders, including: higher summer-time lake levels and river flows for recreation; increased CVP diversions during peak power generation periods (summer); and increased summer diversions that could help meet Sacramento River and Bay-Delta flow and water quality objectives.

- Other promising temperature compliance approaches that likely warrant additional investigation include: 1) evaluating minimum carryover storage needs associated with each alternative; 2) the more routine use of the deep, auxiliary outlet from Trinity Lake (recently initiated by Trinity County); 3) decreasing the proportion of relatively warm water releases through the Lewiston Hatchery outlet; and 4) reevaluating the October through December temperature compliance objectives and monitoring locations. Analysis and incorporation of these approaches raise numerous management-related issues that are beyond temperature modeling evaluations.

- Comparison of Existing Conditions simulations (1995 level of development) to the No Action alternative results (2022 level of development) suggest that future Trinity River Division operations may export greater volumes of water to the CVP during dry year-types. Temperature model simulations indicate that these future changes in dry year operations could cause increases in the temperatures of waters released from Lewiston Lake to the Trinity River.

6.0 REFERENCES

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