LEVEL 3 REPORT

ANALYSIS OF TEMPERATURE CONTROL ALTERNATIVES ADVANCED FROM LEVEL 2 DESIGNED TO MEET WATER QUALITY REQUIREMENTS AND PROTECT COLD FRESHWATER HABITAT ALONG THE NORTH FORK FEATHER RIVER

Prepared For

State Water Resources Control Board

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Prepared By

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TABLE OF CONTENTS PAGE

APPENDICES:

LIST OF TABLES PAGE

LIST OF FIGURES PAGE

LIST OF ABBREVIATIONS/ACRONYMS

af	Acre-foot or acre-feet
afa	Acre-feet per annum
Basin Plan	Water Quality Control Plan for the Central Valley Region
CDFG	California Department of Fish and Game
Central Valley Regional Board	Regional Water Quality Control Board, Central Valley Region
CEQA	California Environmental Quality Act
cfs	Cubic feet per second
CWA	Federal Clean Water Act
cy	Cubic yard
DSOD	Division of Safety of Dams
DWR	California Department of Water Resources
East Branch	East Branch North Fork Feather River
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
FERC	Federal Energy Regulatory Commission
FERC No. 2105	Upper North Fork Feather River Project
FERC No. 1962	Rock Creek – Cresta Project
FERC No. 619	Bucks Creek Project
FERC No. 2107	Poe Project
fps	Feet per second
ft	Feet or Foot
IIHR	Iowa Institute of Hydraulic Research
KWh	Kilowatt-hour
LF	Linear feet
MW	Megawatts
NEPA	National Environmental Policy Act
NFFR	North Fork Feather River
NGVD 1929	National Geodetic Vertical Datum of 1929
No.	Number
NOP	Notice of Preparation
NSR	North State Resources, Inc.
O&M	Operation and Maintenance
Partial Settlement	Upper North Fork Feather River Project Relicensing Settlement Agreement, 2004

LIST OF ABBREVIATIONS/ACRONYMS (CONTINUED)

PG&E	Pacific Gas and Electric Company
PH	Powerhouse
PM&E	Protection, mitigation, and enhancement
sq ft	Square feet
State Water Board	State Water Resources Control Board
Stetson	Stetson Engineers, Inc.
SNTEMP	Stream Network Temperature Model
UNFFR	Upper North Fork Feather River
U.S. EPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
x-section	Cross-section
°C	Degrees Celsius
°F	Degrees Fahrenheit
#	Number

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EXECUTIVE SUMMARY

Pacific Gas and Electric Company (PG&E) has submitted an application to the Federal Energy Regulatory Commission for relicensing of the Upper North Fork Feather River Project (UNFFR Project; FERC Project #2105). Prior to issuance of a new federal license, PG&E must obtain Clean Water Act (CWA) section 401 water quality certification that the project will be in compliance with specified provisions of the CWA (33 U.S.C.§ 1341), including State water quality standards as contained in the applicable water quality control plan. In 2006, the Environmental Protection Agency (EPA) listed the North Fork Feather River (NFFR) upstream of Lake Oroville as a water quality limited segment under Section 303(d) of the CWA. Additionally, portions of the NFFR do not meet the water quality objective for temperature as set forth in the Water Quality Control Plan for the Central Valley Region (Basin Plan). Based in part on information provided during the relicensing studies for the UNFFR Project, the State Water Resources Control Board (State Water Board) has determined that elevated water temperatures are impairing the cold freshwater habitat beneficial use of the NFFR, and has cited hydromodification and flow regulation as potential sources of the impairment (State Water Board Resolution No. 2006-0079). Issuance of a water quality certification for the UNFFR Project is a discretionary action that requires the State Water Board to comply with the California Environmental Quality Act (CEQA). The State Water Board is in the process of preparing an Environmental Impact Report (EIR) that includes water temperature reduction proposals which are designed to achieve compliance with Basin Plan objectives.

Achievement of Basin Plan objectives depends on applying them to controllable water quality factors. *Controllable water quality factors* are those actions, conditions, or circumstances resulting from human activities that may influence the quality of the waters of the State, that are subject to the authority of the State Water Board or Regional Water Board, and that may be reasonably controlled. In preparing this report, the State Water Board recognizes that the controllable factors available to PG&E, which achieve compliance with Basin Plan objectives, should be reasonable, feasible and implementable. The Level 1 and 2 Report (Stetson 2007) documented the first two phases of the three-phased approach on the development and screening of a wide range of potentially feasible alternatives for seasonal cooling of water temperature along the NFFR. Each of the "water temperature reduction alternatives" considered consisted of a combination of measures (including measures within and outside the UNFFR Project boundary), such as modifications to hydropower facilities or operations, which collectively reduce mean daily water temperatures during the summer to 20°C along the approximate 50 river miles of the NFFR, from Lake Almanor's Canyon Dam to the discharge from the Poe Powerhouse afterbay at Big Bend into Lake Oroville.

This Level 3 Report documents detailed analyses of the effectiveness, sustainability, reliability, and feasibility of the water temperature reduction alternatives that passed Level 2. The State Water Board will use this Level 3 Report and the Level 1 and 2 Report to support, in part, its actions regarding issuance of Clean Water Act (CWA) section 401 water quality certification of the UNFFR Project and adoption of an Environmental Impact Report (EIR) for the certification.

ES.1 FORMULATION OF UNFFR PROJECT-ONLY ALTERNATIVES FOR LEVEL 3 ANALYSIS

Table ES-1 provides a summary of the UNFFR Project-only alternatives[1] for this Level 3 analysis that were formulated from the water temperature reduction alternatives advanced from Level 2. These UNFFR Project-only alternatives include a combination of the following measures at Lake Almanor and Butt Valley Reservoir:

Lake Almanor:

- Install Prattville Intake thermal curtain with removal of submerged levees;
- Install Prattville Intake thermal curtain without removal of submerged levees;
- Repair/modify Canyon Dam low-level outlet and increase release (and decrease Prattville Intake discharge commensurately).

Butt Valley Reservoir:

- Install a single thermal curtain near Caribou #1 and #2 Intakes;
- Use Caribou #1 preferentially over Caribou #2.

Of the nine UNFFR Project-only alternatives formulated for the Level 3 analysis in Table ES-1, Alternatives 3, 4a, 4b, and 4c were described in the Level 1 and 2 Report. Subsequently, the Baseline, "Present Day" alternative, and Alternatives 3x, 3a, and 4d were added in the Level 3 analysis for the following purposes or reasons:

- Baseline was added. Baseline represents the CEQA baseline and provides the basis for comparing the alternatives. For purposes of modeling flow regimes for the UNFFR, the CEQA baseline conditions were the conditions that existed when the Notice of Preparation (NOP) was filed. The EIR scoping process was initiated by submittal of the NOP to the State Clearinghouse on September 1, 2005.
- "Present Day" alternative[2], which is essentially the alternative proposed by PG&E in its license application (essentially the same as the FERC Staff recommended

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[1] In this Level 3 Report, an alternative is called UNFFR Project-only alternative if all measures (operational or physical modifications) comprising the alternative are entirely within the UNFFR Project boundary.

[2] "Present Day" more accurately reflects the foreseeable future conditions under the Partial Settlement without consideration of the water temperature reduction measures at the UNFFR Project. It should not be interpreted to mean "current" operating conditions. Current operating conditions of the UNFFR Project are the conditions under the existing FERC license for the Project and current operating conditions of the Rock

alternative in the Final Environmental Impact Statement (EIS)), was added. This alternative enhances the ability of the EIR to illustrate the comparison of alternatives..

- Alternative 3x was added. Alternative 3x is the alternative that would have the greatest water temperature reduction that could be achieved from modifications to the UNFFR Project-only.
- Alternative 3a was added. Alternative 3a is similar to Alternative 4a except that Alternative 3a includes removal of the submerged levees in front of the Prattville Intake. The purpose of adding this alternative was to isolate and analyze the benefit, in terms of water temperature reduction, of removing the submerged levees compared to not removing them.
- Alternative 4d was added. Alternative 4d is similar to Alternative 4c except that preferential use of Caribou #1 in Alternative 4c is replaced with installation of a thermal curtain near the Caribou #1 and #2 Intakes in Butt Valley Reservoir. The purpose of adding this alternative was to reduce foregone power generation loss caused by the preferential use of Caribou #1 PH, which has about a 15% lower turbine efficiency than Caribou #2 PH.

It is important to point out that the Level 3 analysis evolved and did not end up following the original three-phased approach exactly as described in the Level 1 and 2 Report. Based on the original three-phased approach, the Level 3 analysis was to include the following two major work items:

1) Additional detailed modeling and feasibility-level engineering design and cost estimating work to verify the effectiveness, feasibility, sustainability, and reliability of the water temperature reduction alternatives advanced from Level 2; and
2) Final screening of water temperature reduction alternatives suitable for analysis in the EIR. The resulting set of water temperature reduction alternatives passing the Level 3 screening would represent *the set of effective and feasible water temperature reduction alternatives*.

As mentioned earlier, this Level 3 Report and the Level 1 and 2 Report will be used by the State Water Board to support, in part, its actions regarding issuance of Clean Water Act (CWA) section 401 water quality certification of the UNFFR Project and adoption of an Environmental Impact Report (EIR) for the certification. To carry out the two discretionary actions with consideration to the controllable factors under PG&E's control, which may achieve compliance with Basin Plan objectives, this Level 3 report analyzes the effects of the UNFFR Project-only alternatives, with consideration also given to flow-related operational measures for the Rock Creek, Cresta, and Poe Reaches. No detailed screening of water temperature reduction alternatives was conducted in reaches outside (downstream) of the UNFFR boundary in this Level 3 analysis. Water temperature reduction alternatives in reaches outside of the UNFFR boundary were not carried

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Creek-Cresta Project are the conditions under the 2nd-five year flow schedule. Current operating conditions are neither "Baseline" nor "Present Day" conditions and are not analyzed.

forward into Level 3 based on considerations of their ability to reduce temperature, technical feasibility, and cost.

Table ES-1 Summary of the UNFFR Project-Only Alternatives Formulated for Level 3 Analysis

Alternatives	Measures Included in the UNFFR Project-Only Alternatives	Remarks
Baseline	No action.	• Baseline conditions are those facilities and operating conditions that existed as of the NOP dated September 1, 2005.
"Present Day"	• Increase Canyon Dam release to those given in the Partial Settlement (and decrease Prattville Intake release commensurately).	• The "Present Day" alternative is essentially the alternative proposed by PG&E in its license application and also the FERC Staff recommended alternative in the EIS .
Alternative 3	• Install Prattville Intake thermal curtain and remove submerged levees near the Intake; • Modify Canyon Dam low-level outlet and increase release to 250 cfs (in July and August and decrease Prattville Intake release commensurately); • Install a single thermal curtain near Caribou #1 and #2 Intakes.	• Alternative 3 was examined in the Level 1 and 2 Report.
Alternative 3x	• Install Prattville Intake thermal curtain and remove submerged levees near the Intake; • Modify Canyon Dam low-level outlet and increase release to 600 cfs (in July and August) (and decrease Prattville Intake release commensurately); • Operate Caribou #1 preferentially over Caribou #2.	• Alternative 3x was not examined in the Level 1 and 2 Report. • Alternative 3x is the alternative that would have the greatest water temperature reduction that could be achieved from the UNFFR Project-only.
Alternative 3a	• Install Prattville Intake thermal curtain and remove submerged levees near the Intake; • Install a single thermal curtain near Caribou #1 and #2 Intakes.	• Alternative 3a was not examined in the Level 1 and 2 Report. • Alternative 3a was added in the Level 3 analysis for the purpose of isolating and analyzing the incremental benefit of removing the submerged levees near the Prattville Intake by comparing Alternatives 3a and 4a.
Alternative 4a	• Install Prattville Intake thermal curtain (without removal of submerged levees near the Intake); • Install a single thermal curtain near Caribou #1 and #2 Intakes.	• Alternative 4a was examined in the Level 1 and 2 Report.
Alternative 4b	• Install Prattville Intake thermal curtain (without removal of submerged levees near the Intake); • Operate Caribou #1 preferentially over Caribou #2.	• Alternative 4b was examined in the Level 1 and 2 Report.
Alternative 4c	• Modify Canyon Dam low-level outlet and increase release to 600 cfs (in July and August) (and decrease Prattville Intake release commensurately); • Operate Caribou #1 preferentially over Caribou #2.	• Alternative 4c was examined in the Level 1 and 2 Report.
Alternative 4d	• Modify Canyon Dam low-level outlet and increase release to 600 cfs (in July and August) (and decrease Prattville Intake release commensurately); • Install a single thermal curtain near Caribou #1 and #2 Intakes.	• Alternative 4d was not examined in the Level 1 and 2 Report.

ES.2 SUMMARY OF FINDINGS OF LEVEL 3 ANALYSIS

This Level 3 Report includes the following technical and engineering analyses:

a) This report contains an analysis of the effectiveness, sustainability, and reliability of the UNFFR Project-only alternatives in reducing NFFR water temperatures, in terms of mean daily water temperature, maximum weekly average water temperature (MWAT), and diel water temperature. Mean daily water temperature is defined as the average water temperature for each 24-hour day. MWAT is defined as the maximum seven-day running average of daily average water temperatures during a given period of interest. MWAT provides an index for assessing the effects of chronic thermal conditions on cold freshwater habitat within riverine environments. The effects on cold water aquatic organisms include acute lethal exposures to very warm temperatures and chronic sub-lethal exposures to warm temperatures sufficient to cause detrimental effects on long-term survival, growth, and reproduction. Diel water temperature is the diel cycle of water temperatures during each 24-hour day. It provides an index for assessing the effects of acute thermal conditions on cold freshwater habitat. Either one of these indices may influence the quality and availability of cold freshwater habitat in the NFFR. Analysis of mean daily water temperature is consistent with the Rock Creek – Cresta Relicensing Settlement Agreement which states: "In order to reasonably protect cold freshwater habitat, Licensee shall maintain mean daily water temperatures of 20 degrees Celsius or less in the Rock Creek and Cresta Reaches, to the extent that Licensee can reasonably control such temperatures".

b) Analysis of the effects of the UNFFR Project-only alternatives on cold freshwater habitat in Lake Almanor and Butt Valley Reservoir, in terms of cold freshwater habitat volume, top of thermocline elevation, and metalimnion surface area.

c) Preparation of feasibility-level design layouts, operational requirements, cost estimates, and power generation for the UNFFR Project-only alternatives.

The findings from the above analyses are summarized below:

a) Analysis of effectiveness, sustainability, and reliability of the formulated UNFFR Project-only alternatives in reducing NFFR water temperatures

1) All of the UNFFR Project-only alternatives can effectively, sustainably, and reliably reduce NFFR mean daily water temperatures, but to varying degrees. The ranking of alternatives in terms of mean daily water temperature reduction, from the greatest water temperature reduction to the least, is Alternative 3x, Alternative 4c, Alternative 4d, Alternative 3, Alternative 4b, and Alternative 4a. The highest ranked alternative (Alternative 3x) reduces the mean daily water temperature by about 5.9°C in July and 4.3°C in August on average at the upstream end of Belden Reach over the 19-year analysis period (1984 – 2002), and by about 2.0°C in July

and 1.6°C in August at the downstream end of Poe Reach. The lowest ranked alternative (Alternative 4a) reduces the mean daily water temperature by about 2.5°C in July and 1.9°C in August at the upstream end of Belden Reach, and by about 0.8°C in July and 0.7°C in August at the downstream end of Poe Reach.

2) The water temperature reduction benefit of removing the submerged levees near the Prattville Intake is minimal, with a maximum temperature reduction of about 0.3°C in July and 0.6°C in August at the upstream end of Belden Reach. The benefit diminishes gradually downstream along the NFFR.

3) Mean daily water temperature modeling results indicate that preferential use of Caribou #1 over Caribou #2 (Alternatives 4b and 4c) appears to be more effective in reducing the NFFR water temperature than a thermal curtain at Butt Valley Reservoir near the Caribou Intakes (Alternatives 4a and 4d) in July, but these two measures have similar temperature reduction benefits in August.

4) All of the UNFFR Project-only alternatives infuse cold water from Lake Almanor to the NFFR through selective cold water withdrawal by way of either increased Canyon Dam low-level release and/or a Prattville Intake thermal curtain. Increasing Canyon Dam low-level releases would enhance water temperature reduction in Belden Reservoir, which would benefit all downstream reaches. Increasing Canyon Dam low-level releases would also reduce warming in the Seneca Reach, which would reduce inflow water temperature to Belden Reservoir. The amount of temperature reduction resulting from increased Canyon Dam low-level release depends on the magnitude of the release. Analysis of the relationship between increased Canyon Dam low-level release and water temperature reduction benefit at Belden Reservoir indicates that for every 100 cfs increased release above "Present Day" conditions at Canyon Dam in July and August the UNFFR Project-only alternatives could reduce the Belden Reservoir water temperature by about 0.5°C in July and 0.4°C in August. The monthly foregone power generation loss in July or August was estimated to be about 7.54×10^6 kwh for every 100 cfs increased release. These developed relationships together with the simulated mean daily temperature profiles for the UNFFR Project-only alternatives can be used to assist in the refinement of the analyzed alternatives if/when needed.

   Constructing a thermal curtain at the Prattville Intake would also enhance water temperature reduction in Belden Reservoir and benefit all downstream reaches. But it would not have any foregone power generation loss.

5) The Level 3 analysis considered water temperature reduction along the Rock Creek, Cresta, and Poe Reaches by increasing dam releases. It is important to point out that increasing releases from these dams really only reduces warming along these reaches; it does not reduce the temperature of water at the starting point of the reach. Relationships between increased releases at these dams and warming reductions along these reaches were developed. These developed

relationships together with the simulated temperature profiles can be used to assist in further, more refined management of water temperature along the Rock Creek, Cresta, and Poe Reaches if/when needed.

6) MWAT provides an index for assessing the effects of chronic thermal conditions in river reaches on cold freshwater habitat. Modeling the MWAT profile along the NFFR first required identifying the MWAT period (i.e., the 7-day period that had the warmest water temperature profile) that could be applied for different years. Analysis of the observed water temperatures at Belden Reservoir and along the NFFR and air temperatures in water years 2002, 2003, and 2004 was conducted to identify the MWAT period. The analysis found that the periods with the warmest 7-day average water temperature in Belden Reservoir in 2002, 2003, and 2004 could be used to identify the MWAT period for the downstream reaches.

7) MWAT analysis results also indicate that preferential use of Caribou #1 over Caribou #2 (Alternatives 4b and 4c) appears to be more effective in reducing the NFFR water temperature than a thermal curtain at Butt Valley Reservoir near the Caribou Intakes (Alternatives 4a and 4d) in July, but these two measures have similar temperature reduction benefits in August. This corroborates finding #3 above from the mean daily water temperature modeling results.

8) The MWAT analysis results indicate that some alternatives (Alternatives 3x, 4c, and 4d in particular) may shift the annual MWAT period from July/August under the Baseline condition to September under the alternative conditions. It is worth noting that, in the analyses of mean daily water temperature and MWAT profiles, the preferential use of Caribou #1 was assumed to operate in July and August, while the thermal curtain at Butt Valley Reservoir was assumed to operate all year round. Apparently preferential use of Caribou #1 would reduce July and August MWATs but would have little effect on September MWAT. This is one of the reasons that the September MWAT could be the highest MWAT in a year (i.e., annual MWAT) for the alternatives that include the preferential use of Caribou #1. Another factor that could cause the September MWAT to be the highest MWAT in a year is the increased Canyon Dam release measure. This measure was assumed to operate in July and August only. This measure would reduce the July and August MWATs but would have little effect on the September MWAT. The alternatives which could have higher September MWAT include Alternatives 3x, 4c, and 4d. September MWAT for these alternatives could be reduced further if the alternatives were allowed to operate in September based on model outputs. Comparison of the simulated monthly (Jul, Aug, and Sep) MWAT for Alternatives 3x, 4c, and 4d indicate that in general the three alternatives may have higher September MWAT in the Rock Creek Reach but lower September MWAT in the Poe Reach.

9) The MWAT analysis results indicate that the ranking of alternatives in terms of MWAT reduction is similar to the ranking of alternatives in terms of mean daily water temperature reduction (finding #1 above). The highest ranked alternative

(Alternative 3x) reduces the monthly MWAT by about 4.5°C in July and 3.0°C in August on average at the Belden Reach above the East Branch over the 19-year analysis period (1984 – 2002), and by about 2.0°C in July and 2.2°C in August at the downstream end of Poe Reach. The lowest ranked alternative (Alternative 4a) reduces the monthly MWAT by about 2.2°C in July and 2.1°C in August at the Belden Reach above the East Branch, and by about 1.0°C in July and 1.4°C in August at the downstream end of Poe Reach.

10) Diel water temperature provides an index for assessing the effect of acute thermal conditions in river reaches. Analysis of the hourly temperature data produced by PG&E through its annual NFFR monitoring efforts during the summer months of water years 2002, 2003, and 2004 indicates that the maximum diel water temperatures observed over the three years for the Belden Reach above East Branch, the Rock Creek Reach above Bucks Creek, the Cresta Reach above Cresta PH, and the Poe Reach above Poe PH were 24.0°C, 24.0°C, 24.0°C, and 26.6°C, respectively.

11) The diel water temperature ranges (i.e., diel maximum minus diel minimum in any given day) shown in Table 2-11 were derived from the hourly water temperature monitoring results for water years 2002, 2003, and 2004 under <u>Baseline flow</u> conditions. The summertime diel water temperature ranges observed over the three years for the Belden Reach above East Branch, the Rock Creek Reach above Bucks Creek, the Cresta Reach above Cresta PH, and the Poe Reach above Poe PH were, on average, 4.8°C, 3.6°C, 2.9°C, and 3.2°C, respectively, in June, 4.8°C, 3.1°C, 2.8°C, and 3.1°C, respectively, in July, 4.1°C, 2.7°C, 2.5°C, and 2.7°C, respectively, in August, and 4.1°C, 2.5°C, 2.0°C, and 2.4°C, respectively, in September. For a given UNFFR Project-only alternative, the maximum or minimum diel water temperature could be estimated using the predicted mean daily temperature profile plus or minus one half of the diel water temperature range. However, further analysis would need to be conducted to estimate the diel water temperature for a reach if much higher dam releases (than the Baseline flow conditions) are used.

12) The uncertainty of the mean daily water temperature modeling results (in terms of the model-simulated <u>absolute</u> temperature values) for the Baseline condition and the alternative conditions are generally within ±0.5°C along the NFFR. The uncertainty of the MWAT modeling results would be expected to be lower than the uncertainty of the mean daily water temperature modeling results. The uncertainty would have minimal effect on the analysis results of incremental changes in water temperature profiles between alternatives.

b) Analysis of the effects of the formulated UNFFR Project-only alternatives on cold freshwater habitat in Lake Almanor and Butt Valley Reservoir

Following is a summary of findings based on CE-QUAL-W2 modeling analyses of selected UNFFR Project-only alternatives, including Baseline, the "Present Day" alternative, and Alternatives 3x, 4a, and 4c, for the "normal" hydrologic year 2000 and the "critical dry" hydrologic year 2001. Baseline was selected for analysis because it provides the CEQA baseline for comparing the effects of the alternatives. The "Present Day" alternative was selected for analysis because it provides a comparison with the proposed alternative by PG&E in its license application (essentially the same as the FERC Staff recommended alternative in the EIS). Alternative 4a was selected for analysis of the effects of cold water withdrawal using a thermal curtain at the Prattville Intake. Alternative 4c was selected for analysis of the effects of cold water withdrawal using a modified Canyon Dam low-level outlet. Alternative 3x was selected for analysis of the effects of cold water withdrawal using both the Prattville Intake thermal curtain and the modified Canyon Dam low-level outlet. Alternatives 3, 4b, and 4d were not analyzed because: (a) It would be expected that Alternative 3 would have less effect on Lake Almanor than Alternative 3x since Alternative 3 has similar water temperature reduction measures at Lake Almanor as Alternative 3x, but has lower releases at the Canyon Dam low-level outlet (see Table 1-2); (b) Alternative 4b would have the same effect on Lake Almanor as Alternative 4a; and (c) Alternative 4d would have the same effect on Lake Almanor as Alternative 4c.

13) The magnitudes of the effects of the three water temperature reduction alternatives (Alternatives 3x, 4a, and 4c) on the suitable cold freshwater habitat volume of Lake Almanor are sensitive to the criteria used to define the suitable cold freshwater habitat. Three different criteria were analyzed: a) $T \leq 20°C$ and $DO \geq 5$ mg/L; b) $T \leq 21°C$ and $DO \geq 5$ mg/L; and c) $T \leq 22°C$ and $DO \geq 5$ mg/L. Analysis results of the selected alternatives were compared to those for Baseline and are summarized in Tables ES-2a and ES-2b.

    In terms of percentage of the suitable cold freshwater habitat volume to the total lake storage, the changes between each alternative and Baseline in June, July, and August are all within 1%. If the suitable cold freshwater habitat is defined as the water layer that has water temperature $\leq 20°C$ and $DO \geq 5$mg/L, then, compared to Baseline conditions, the three water temperature reduction alternatives selected for analysis (Alternatives 3x, 4a, and 4c) *reduce* the suitable cold freshwater habitat volume of Lake Almanor in August of the normal hydrologic year 2000 and in July, August, and early September of the critical dry year 2001. Alternatives 3x and 4a increase the suitable cold freshwater habitat volume in June through October, except in August, in 2000 and in late September in 2001. Alternative 4c increases the suitable cold freshwater habitat volume in September and October in 2000 and in late September in 2001. The "Present Day" alternative, which is essentially the alternative proposed by PG&E in its license application, also has some effect on the suitable cold freshwater habitat volume relative to Baseline. The effect of the "Present Day" alternative results from the increased Canyon Dam releases to those given in the Partial Settlement. .

    Increased withdrawal of cold water from the hypolimnion of Lake Almanor in summer (e.g., through Prattville thermal curtain and increased Canyon Dam low-level release) has two effects on water temperature and dissolved oxygen (DO) in the lake: 1) it reduces the volume of cold water (compared to Baseline conditions); and 2) it induces the movement of lake bottom water which increases interfacial mixing between hypolimnion water and thermocline water and, in turn, increases DO concentrations in the hypolimnion. So, the net effect on the suitable cold freshwater habitat of a given water temperature reduction alternative depends on the relative reduction in cold water volume and the increase in water volume with DO ≥ 5 mg/L. In June and July, Lake Almanor generally has sufficient cold water volume available for withdrawal and, thus, DO is the limiting factor for determining the incremental change in suitable cold freshwater habitat for a given alternative relative to Baseline conditions. In August, both water temperature and DO are important factors but water temperature appears to be the more limiting factor. In September, depending on the water temperature and the hydrologic condition, either water temperature or DO may be the limiting factor. Generally speaking, by September the ambient air temperature is decreasing and Lake Almanor is subject to mixing as the thermocline begins breaking down. In October, air temperatures have reduced substantially, water temperature in the entire lake is typically cold, so water temperature is not a limiting factor for cold freshwater habitat.

If the temperature criterion of T ≤ 20°C is relaxed to T ≤ 21°C or T ≤ 22°C, the computed absolute volumes of the suitable cold freshwater habitat for the Baseline and the alternatives increase considerably in July and August. The high sensitivity of the suitable cold freshwater habitat volume to the temperature criterion arises from the fact that the top of the Lake Almanor thermocline in summer normally has a water temperature of about 20°C to 22°C. Above the thermocline (i.e., in the epilimnion), where DO ≥ 5 mg/L, a small increase in water temperature can cause a great change in elevation and suitable habitat volume because the water temperature profile in the epilimnion is relatively uniform. On the other hand, given a water temperature criterion, the high incremental change in the suitable habitat volume between an alternative and the Baseline condition may not necessarily mean the alternative has a considerable effect. This is because a small difference in temperature between the alternative and the Baseline condition can cause a considerable change in elevation and suitable habitat volume. So, it is necessary to further examine the water temperature profiles to help identify the cause of the considerable change in the computed suitable habitat volume between the alternative and the Baseline condition.

14) Increasing the release of cold water at the Canyon Dam low-level outlet (Alternative 4c) to 600 cfs or withdrawing cold water at the Prattville Intake through use of a thermal curtain (Alternative 4a) appears to have similar effects on the suitable cold freshwater habitat of Lake Almanor.

15) The CE-QUAL-W2 model, due to its inherent coarseness, is not able to capture the potentially small, isolated "pockets" of cold freshwater habitat that may occur in some local areas.

16) The top of thermocline is defined as the shallowest depth (i.e., highest elevation) where the highest temperature gradient occurs. After careful examination of Lake Almanor temperature profiles at the representative site near Canyon Dam, it was determined that a temperature gradient ΔT/ Δd ≥ 0.5°C/m would be a suitable criterion to identify the top of Lake Almanor thermocline. The analysis results indicate that the three alternatives (Alternatives 3x, 4a, and 4c) could lower the thermocline elevation by up to 3 feet in July and August (in both years 2000 and 2001) when the lake epilimnion water temperature is relatively warm. Although the three alternatives could lower the thermocline elevation by up to 7 feet in September and October in 2000 and by up to 10 feet in September 2001, it may not be a meaningful effect because the lake water temperature at these times is generally cooler than the summer and below 20°C. The effect evaluation should focus on July and August when using the thermocline elevation and metalimnion surface area as additional evaluation criteria.

17) Metalimnion surface area is defined as the lake-wide surface area at the top of the thermocline. Once the top of thermocline elevation is identified, the metalimnion surface area can be estimated using the lake-wide elevation-surface area curve. The analysis results of Lake Almanor metalimnion surface area indicate that in general, but to varying degrees, the three alternatives (Alternatives 3x, 4a, and 4c) reduce the metalimnion surface area from July to October in both years 2000 and 2001, with highest reduction in September or October. The “Present Day” alternative reduces the metalimnion surface area in October of 2000 and in September and October of 2001. In terms of percentage of the metalimnion surface area to total lake surface area, the change between each of the three alternatives (Alternatives 3x, 4a, and 4c) and the Baseline condition is generally within 3% in July and August of year 2000 and 5% in July and August of year 2001.

18) The effect of installing a thermal curtain at the Prattville Intake on the suitable cold freshwater habitat volume in Butt Valley Reservoir is highly correlated to the temperature criterion. If the temperature criterion for the reservoir is set at T ≤ 20°C, installing a thermal curtain at the Prattville Intake generally increases the suitable cold freshwater habitat. The increase is due to the low water temperature produced by the Prattville Intake thermal curtain at the Butt Valley PH discharge, which, overall, cools the reservoir and increases the volume of water less than 20°C. Although the Prattville Intake thermal curtain also produces low DO, this is more than offset by its cooling effect, which suggests that water temperature is the more limiting factor under a temperature criterion of T ≤ 20°C. If the temperature criterion is relaxed to T ≤ 21°C, depending on the reservoir water temperature and the hydrologic condition, either water temperature or DO may be the limiting factor. If the temperature criterion is relaxed to T ≤ 22°C, DO would the limiting factor. Therefore, if the temperature criterion is set at T ≤ 21°C or T ≤ 22°C, measures that increase DO in the Butt Valley PH discharge to offset the effect of the Prattville Intake thermal curtain on the suitable cold freshwater

habitat of Butt Valley Reservoir would be needed if a thermal curtain was to be installed at the Prattville Intake.

c) Feasibility-level design layouts, operational requirements, and estimated costs[3] for the formulated UNFFR Project-only alternatives

19) The estimated capital costs in 2009 dollars for the physical modification measures at Lake Almanor and Butt Valley Reservoir are as follows:
    - Prattville Intake thermal curtain with dredging of the submerged levees near the Intake: $21,338,000;
    - Prattville Intake thermal curtain without removal of the submerged levees near the Intake: $14,847,000;
    - Modification of Canyon Dam low-level outlet structure: $10,702,000;
    - Caribou Intake thermal curtain: $8,720,000.

20) The capital cost for constructing a hydroelectric generation plant below Canyon Dam is estimated to be about $48.9 million dollars. The maximum annual power generation under Alternatives 3x or 4c is estimated to be about 9.6×10^6 KWh. This is equivalent to $624,000 per year based on the unit power purchase price of $0.065/KWh. The amortized annual capital cost (over 50 years) is estimated to be about $6,000,000 per year. The amortized annual capital cost is about 10 times higher than the annual power generation benefit.

21) The estimated total costs of Level 3 Alternatives are summarized in Table ES-3. Figures ES-1 and ES-2 compare the estimated capital costs and the annualized costs among the Level 3 alternatives, respectively. The annualized costs include amortized annual capital cost, annual O&M cost, and annual foregone power generation loss. Amortized annual capital cost was calculated in 50 years based on a Fixed Charge Rate (FCR) of 12.25%.

22) Tables ES-4a and ES-4b summarize the estimated total annualized costs of Level 3 alternatives, the mean daily water temperature reduction benefits in July and August estimated based on the 25% exceedence temperature profiles, and the estimated annualized costs for each degree Celsius water temperature reduction at the points of interest.

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[3] Costs presented in this report are used as an evaluation tool of alternatives and do not reflect profit to PG&E on power and PG&E's ability to recover cost through rate increases.

Table ES-2a Summary of Simulated Lake Almanor Habitat Volume for Different Alternatives and Change in Habitat Volume Relative to Baseline Condition for Different Criteria Defined for Cold Freshwater Habitat

(2000, Normal Hydrologic Year)

Date	Total Reservoir Storage on Date (acre-ft)	Simulated Habitat Volume (acre-ft)					Change in Habitat Volume Relative to Baseline Condition (acre-ft)				% of Habitat Volume to Total Reservoir Storage on Date				
		Baseline	Present Day	Alt 3x	Alt 4a	Alt 4c	Present Day	Alt 3x	Alt 4a	Alt 4c	Base line	Pres. Day	Alt 3x	Alt 4a	Alt 4c
Criteria: Water Temperature ≤ 20°C and DO ≥ 5 mg/L															
May 15	1,011,490	993,600	989,670	989,110	989,110	989,670	-3,930	-4,490	-4,490	-3,930	98%	98%	98%	98%	98%
June 7	1,015,410	876,500	874,470	883,350	881,800	874,470	-2,030	6,850	5,300	-2,030	86%	86%	87%	87%	86%
Jun 22	1,010,250	452,400	449,750	465,600	462,510	449,750	-2,650	13,200	10,110	-2,650	45%	45%	46%	46%	45%
July 7	993,780	216,200	214,940	230,770	227,740	214,950	-1,260	14,570	11,540	-1,250	22%	22%	23%	23%	22%
Jul 20	938,020	145,600	143,790	151,770	148,400	145,040	-1,810	6,170	2,800	-560	16%	15%	16%	16%	15%
Aug 7	913,180	65,000	63,690	63,410	61,150	63,110	-1,310	-1,590	-3,850	-1,890	7%	7%	7%	7%	7%
Aug 17	859,160	44,400	40,910	32,490	35,030	38,240	-3,490	-11,910	-9,370	-6,160	5%	5%	4%	4%	4%
Sep 7	836,720	636,600	639,480	698,340	683,250	661,180	2,880	61,740	46,650	24,580	76%	76%	83%	82%	79%
Sep 28	777,330	607,400	609,130	663,450	649,750	622,960	1,730	56,050	42,350	15,560	78%	78%	85%	84%	80%
Oct 15	761,020	676,200	678,940	712,080	702,680	694,830	2,740	35,880	26,480	18,630	89%	89%	94%	92%	91%
Criteria: Water Temperature ≤ 21°C and DO ≥ 5 mg/L															
May 15	1,011,490	993,550	989,670	989,110	989,110	989,670	-3,880	-4,440	-4,440	-3,880	98%	98%	98%	98%	98%
June 7	1,015,410	876,510	874,470	883,350	881,800	874,470	-2,040	6,840	5,290	-2,040	86%	86%	87%	87%	86%
Jun 22	1,010,250	669,500	659,150	673,510	670,150	659,150	-10,350	4,010	650	-10,350	66%	65%	67%	66%	65%
July 7	993,780	584,410	585,350	598,010	594,810	587,100	940	13,600	10,400	2,690	59%	59%	60%	60%	59%
Jul 20	938,020	228,530	223,930	231,700	227,170	222,930	-4,600	3,170	-1,360	-5,600	24%	24%	25%	24%	24%
Aug 7	913,180	97,120	95,040	98,350	94,350	96,170	-2,080	1,230	-2,770	-950	11%	10%	11%	10%	11%
Aug 17	859,160	69,040	66,590	58,970	58,750	63,710	-2,450	-10,070	-10,290	-5,330	8%	8%	7%	7%	7%
Sep 7	836,720	636,600	639,480	698,340	683,250	661,180	2,880	61,740	46,650	24,580	76%	76%	83%	82%	79%
Sep 28	777,330	607,380	609,130	663,450	649,750	622,960	1,750	56,070	42,370	15,580	78%	78%	85%	84%	80%
Oct 15	761,020	676,160	678,940	712,080	702,680	694,830	2,780	35,920	26,520	18,670	89%	89%	94%	92%	91%
Criteria: Water Temperature ≤ 22°C and DO ≥ 5 mg/L															
May 15	1,011,490	993,550	989,670	989,110	989,110	989,670	-3,880	-4,440	-4,440	-3,880	98%	98%	98%	98%	98%
June 7	1,015,410	876,510	874,470	883,350	881,800	874,470	-2,040	6,840	5,290	-2,040	86%	86%	87%	87%	86%
Jun 22	1,010,250	798,650	798,700	818,190	815,210	798,700	50	19,540	16,560	50	79%	79%	81%	81%	79%
July 7	993,780	743,860	745,570	778,400	775,130	748,270	1,710	34,540	31,270	4,410	75%	75%	78%	78%	75%
Jul 20	938,020	632,400	631,140	661,580	657,470	638,300	-1,260	29,180	25,070	5,900	67%	67%	71%	70%	68%
Aug 7	913,180	144,170	143,320	155,090	149,440	147,300	-850	10,920	5,270	3,130	16%	16%	17%	16%	16%
Aug 17	859,160	458,170	440,650	345,350	342,380	406,800	-17,520	-112,820	-115,790	-51,370	53%	51%	40%	40%	47%
Sep 7	836,720	636,600	639,480	698,340	683,250	661,180	2,880	61,740	46,650	24,580	76%	76%	83%	82%	79%
Sep 28	777,330	607,380	609,130	663,450	649,750	622,960	1,750	56,070	42,370	15,580	78%	78%	85%	84%	80%
Oct 15	761,020	676,160	678,940	712,080	702,680	694,830	2,780	35,920	26,520	18,670	89%	89%	94%	92%	91%

Note: The bold dates have observed profiles.

Table ES-2b Summary of Simulated Lake Almanor Habitat Volume for Different Alternatives and Change in Habitat Volume Relative to Baseline Condition for Different Criteria Defined for Cold Freshwater Habitat

(2001, Critical Dry Hydrologic Year)

Date	Total Reservoir Storage on Date (acre-ft)	Simulated Habitat Volume (acre-ft)					Change in Habitat Volume Relative to Baseline Condition (acre-ft)				% of Habitat Volume to Total Reservoir Storage on Date				
		Baseline	Present Day	Alt 3x	Alt 4a	Alt 4c	Present Day	Alt 3x	Alt 4a	Alt 4c	Base line	Pres. Day	Alt 3x	Alt 4a	Alt 4c
Criteria: Water Temperature ≤ 20°C and DO ≥ 5 mg/L															
May 15	717,310	712,230	709,010	709,010	709,010	709,010	-3,220	-3,220	-3,220	-3,220	99%	99%	99%	99%	99%
June 6	721,260	588,900	585,970	590,050	589,390	585,970	-2,930	1,150	490	-2,930	82%	81%	82%	82%	81%
Jun 22	715,340	210,900	207,400	210,310	207,520	207,400	-3,500	-590	-3,380	-3,500	29%	29%	29%	29%	29%
July 10	702,590	85,420	82,720	84,830	82,900	84,240	-2,700	-590	-2,520	-1,180	12%	12%	12%	12%	12%
Jul 20	695,920	40,870	39,070	35,640	37,090	37,770	-1,800	-5,230	-3,780	-3,100	6%	6%	5%	5%	5%
Aug 9	648,010	360	0	0	0	0	-360	-360	-360	-360	0%	0%	0%	0%	0%
Aug 17	642,460	0	0	0	0	0	0	0	0	0	0%	0%	0%	0%	0%
Sep 12	634,800	490,230	493,040	352,170	463,000	442,000	2,810	-138,060	-27,230	-48,230	77%	78%	55%	73%	70%
Sep 28	625,800	543,700	545,630	575,920	558,700	565,360	1,930	32,220	15,000	21,660	87%	87%	92%	89%	90%
Oct 15	578,400	544,160	541,910	547,750	542,930	547,790	-2,250	3,590	-1,230	3,630	94%	94%	95%	94%	95%
Criteria: Water Temperature ≤ 21°C and DO ≥ 5 mg/L															
May 15	717,310	712,230	709,010	709,010	709,010	709,010	-3,220	-3,220	-3,220	-3,220	99%	99%	99%	99%	99%
June 6	721,260	588,900	585,970	590,050	589,390	585,970	-2,930	1,150	490	-2,930	82%	81%	82%	82%	81%
Jun 22	715,340	326,300	324,330	329,610	326,170	324,330	-1,970	3,310	-130	-1,970	46%	45%	46%	46%	45%
July 10	702,590	137,960	134,360	137,910	134,680	136,420	-3,600	-50	-3,280	-1,540	20%	19%	20%	19%	19%
Jul 20	695,920	74,230	73,060	69,690	68,900	72,360	-1,170	-4,540	-5,330	-1,870	11%	10%	10%	10%	10%
Aug 9	648,010	51,900	49,850	37,100	41,050	43,090	-2,050	-14,800	-10,850	-8,810	8%	8%	6%	6%	7%
Aug 17	642,460	23,260	20,250	8,160	14,730	12,930	-3,010	-15,100	-8,530	-10,330	4%	3%	1%	2%	2%
Sep 12	634,800	505,370	509,840	545,620	524,010	533,150	4,470	40,250	18,640	27,780	80%	80%	86%	83%	84%
Sep 28	625,800	543,700	545,630	575,920	558,700	565,360	1,930	32,220	15,000	21,660	87%	87%	92%	89%	90%
Oct 15	578,400	544,160	541,910	547,750	542,930	547,790	-2,250	3,590	-1,230	3,630	94%	94%	95%	94%	95%
Criteria: Water Temperature ≤ 22°C and DO ≥ 5 mg/L															
May 15	717,310	712,230	709,010	709,010	709,010	709,010	-3,220	-3,220	-3,220	-3,220	99%	99%	99%	99%	99%
June 6	721,260	588,900	585,970	590,050	589,390	585,970	-2,930	1,150	490	-2,930	82%	81%	82%	82%	81%
Jun 22	715,340	544,990	542,240	553,650	550,580	542,240	-2,750	8,660	5,590	-2,750	76%	76%	77%	77%	76%
July 10	702,590	427,730	428,850	426,390	420,380	435,440	1,120	-1,340	-7,350	7,710	61%	61%	61%	60%	62%
Jul 20	695,920	420,180	421,170	410,020	405,990	422,840	990	-10,160	-14,190	2,660	60%	61%	59%	58%	61%
Aug 9	648,010	160,750	153,060	149,100	146,780	152,710	-7,690	-11,650	-13,970	-8,040	25%	24%	23%	23%	24%
Aug 17	642,460	282,590	254,640	103,720	124,360	142,530	-27,950	-178,870	-158,230	-140,060	44%	40%	16%	19%	22%
Sep 12	634,800	505,370	509,840	545,620	524,010	533,150	4,470	40,250	18,640	27,780	80%	80%	86%	83%	84%
Sep 28	625,800	543,700	545,630	575,920	558,700	565,360	1,930	32,220	15,000	21,660	87%	87%	92%	89%	90%
Oct 15	578,400	544,160	541,910	547,750	542,930	547,790	-2,250	3,590	-1,230	3,630	94%	94%	95%	94%	95%

Note: The bold dates have observed profiles.

Table ES-3 Estimated Costs of Level 3 Alternatives

Alternative	Measures	Capital Cost ($)	Annualized Cost ($/year)				
			Amortized Capital (50 years)	Annual O&M	Foregone Power Generation Loss		Total ($/year)
					KWh ×10^6/ year	$/year	
Baseline	None	-	-	-	-	-	**0**
"Present Day"	Modify Canyon Dam Low-Level Outlet to Increase Canyon Dam Release to Those Given in the Partial Settlement	4,894,000	601,000	24,000	47.94[1]	3,116,000	**3,741,000**
Alternative 3	Install Prattville Intake Thermal Curtain and Remove Submerged Levees	21,338,000	2,622,000	213,000	0.00	0	2,835,000
	Install Caribou Intake Thermal Curtain	8,720,000	1,072,000	87,000	0.00	0	1,159,000
	Modify Canyon Dam Low-Level Outlet to Increase Canyon Dam Release to 250 cfs (in July and August)	4,894,000	601,000	24,000	26.39[2]	1,715,000	2,340,000
					47.94[1]	3,116,000	3,116,000
	Total	**34,952,000**	**4,295,000**	**324,000**	**74.33**	**4,831,000**	**9,450,000**
Alternative 3x	Install Prattville Intake Thermal Curtain and Remove Submerged Levees	21,338,000	2,622,000	213,000	0.00	0	2,835,000
	Operate Caribou #1 PH Preferentially	0	0	0	11.32[3]	736,000	736,000
	Modify Canyon Dam Low-Level Outlet to Increase Canyon Dam Release to 600 cfs (in July and August)	10,702,000	1,315,000	54,000	79.17[2]	5,146,000	6,515,000
					47.94[1]	3,116,000	3,116,000
	Total	**32,040,000**	**3,937,000**	**267,000**	**138.43**	**8,998,000**	**13,202,000**
Alternative 4a	Install Prattville Intake Thermal Curtain	14,847,000	1,824,000	148,000	0.00	0	1,972,000
	Install Caribou Intake Thermal Curtain	8,720,000	1,072,000	87,000	0.00	0	1,159,000
					47.94[1]	3,116,000	3,116,000
	Total	**23,567,000**	**2,896,000**	**235,000**	**47.94**	**3,116,000**	**6,247,000**
Alternative 4b	Install Prattville Intake Thermal Curtain	14,847,000	1,824,000	148,000	0.00	0	1,972,000
	Operate Caribou #1 PH Preferentially	0	0	0	13.91[3]	904,000	904,000
					47.94[1]	3,116,000	3,116,000
	Total	**14,847,000**	**1,824,000**	**148,000**	**61.85**	**4,020,000**	**5,992,000**
Alternative 4c	Modify Canyon Dam Low-Level Outlet to Increase Canyon Dam Release to 600 cfs (in July and August)	10,702,000	1,315,000	54,000	79.17[2]	5,146,000	6,515,000
	Operate Caribou #1 PH Preferentially	0	0	0	11.32[3]	736,000	736,000
					47.94[1]	3,116,000	3,116,000
	Total	**10,702,000**	**1,315,000**	**54,000**	**138.43**	**8,998,000**	**10,367,000**
Alternative 4d	Modify Canyon Dam Low-Level Outlet to Increase Canyon Dam Release to 600 cfs (in July and August)	10,702,000	1,315,000	54,000	79.17[2]	5,146,000	6,515,000
	Install Caribou Intake Thermal Curtain	8,720,000	1,072,000	87,000	0.00	0	1,159,000
					47.94[1]	3,116,000	3,116,000
	Total	**19,422,000**	**2,387,000**	**141,000**	**127.11**	**8,262,000**	**10,790,000**

1) Foregone power generation loss is due to increased Canyon Dam releases to those given in the Partial Settlement and commensurate flow reductions through the Butt Valley, Caribou #1, and Caribou #2 PHs.
2) Additional foregone power generation loss is due to the increased Canyon Dam release in July and August under the alternative and commensurate flow reductions through the Butt Valley, Caribou #1, and Caribou #2 PHs.
3) Additional foregone power generation loss is due to the lower turbine efficiency of Caribou #1 PH relative to Caribou #2 PH (by about 15%).

Table ES-4a Summary of Total Annualized Costs, Mean Daily Water Temperature Reduction Benefit in July, and Estimated Annualized Costs per Unit Temperature Reduction of Level 3 Alternatives

Alternatives	**Total Annualized Cost [1] ($/year)**	**Mean Daily Water Temperature Reduction Benefit (°C) – July (25% Exceedence Profile)**				**Annualized Cost per Unit Temperature Reduction ($/year/°C)**			
		Belden Reach above East Branch (NF7)	Rock Creek Reach above Bucks Creek (NF12)	Cresta Reach above Cresta PH (NF16)	Poe Reach above Poe PH (NF18)	Belden Reach above East Branch (NF7)	Rock Creek Reach above Bucks Creek (NF12)	Cresta Reach above Cresta PH (NF16)	Poe Reach above Poe PH (NF18)
Alternative 3	9,450,000	2.58	2.09	1.99	1.17	3,663,000	4,522,000	4,749,000	8,077,000
Alternative 3x	13,202,000	4.61	3.80	3.61	2.22	2,864,000	3,474,000	3,657,000	5,947,000
Alternative 4a	6,247,000	1.97	1.60	1.53	0.88	3,171,000	3,904,000	4,083,000	7,099,000
Alternative 4b	5,992,000	2.43	1.97	1.88	1.10	2,466,000	3,042,000	3,187,000	5,447,000
Alternative 4c	10,367,000	3.91	3.23	3.08	1.88	2,651,000	3,210,000	3,366,000	5,514,000
Alternative 4d	10,790,000	3.27	2.71	2.59	1.57	3,300,000	3,982,000	4,166,000	6,873,000

1). Total annualized cost includes amortized annual capital cost, annual O&M cost, and annual foregone power generation loss. Amortized annual capital cost was calculated in 50 years based on a Fixed Charge Rate (FCR) of 12.25%.

Table ES-4b Summary of Total Annualized Costs, Mean Daily Water Temperature Reduction Benefit in August, and Estimated Annualized Costs per Unit Temperature Reduction of Level 3 Alternatives

Alternatives	**Total Annualized Cost [1] ($/year)**	**Mean Daily Water Temperature Reduction Benefit (°C) – August (25% Exceedence Profile)**				**Annualized Cost per Unit Temperature Reduction ($/year/°C)**			
		Belden Reach above East Branch (NF7)	Rock Creek Reach above Bucks Creek (NF12)	Cresta Reach above Cresta PH (NF16)	Poe Reach above Poe PH (NF18)	Belden Reach above East Branch (NF7)	Rock Creek Reach above Bucks Creek (NF12)	Cresta Reach above Cresta PH (NF16)	Poe Reach above Poe PH (NF18)
Alternative 3	9,450,000	2.24	1.88	1.81	1.13	4,219,000	5,027,000	5,221,000	8,363,000
Alternative 3x	13,202,000	3.17	2.73	2.63	1.65	4,165,000	4,836,000	5,020,000	8,001,000
Alternative 4a	6,247,000	1.44	1.16	1.13	0.69	4,338,000	5,385,000	5,528,000	9,054,000
Alternative 4b	5,992,000	1.52	1.24	1.20	0.74	3,942,000	4,832,000	4,993,000	8,097,000
Alternative 4c	10,367,000	2.65	2.27	2.19	1.38	3,912,000	4,567,000	4,734,000	7,512,000
Alternative 4d	10,790,000	2.56	2.18	2.10	1.32	4,215,000	4,950,000	5,138,000	8,174,000

1). Total annualized cost includes amortized annual capital cost, annual O&M cost, and annual foregone power generation loss. Amortized annual capital cost was calculated in 50 years based on a Fixed Charge Rate (FCR) of 12.25%.

Figure ES-1 Comparison of Capital Cost among Level 3 Alternatives

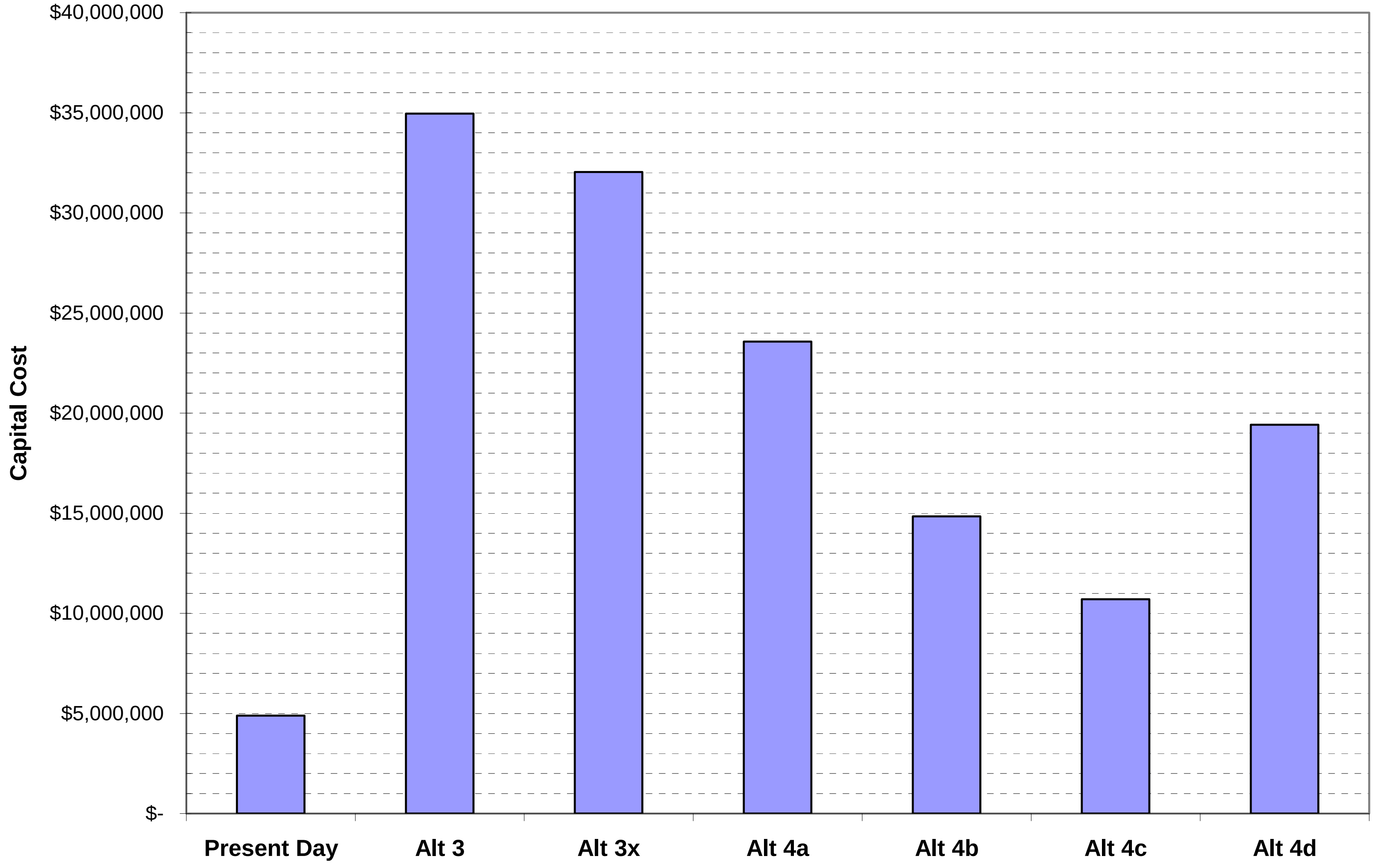
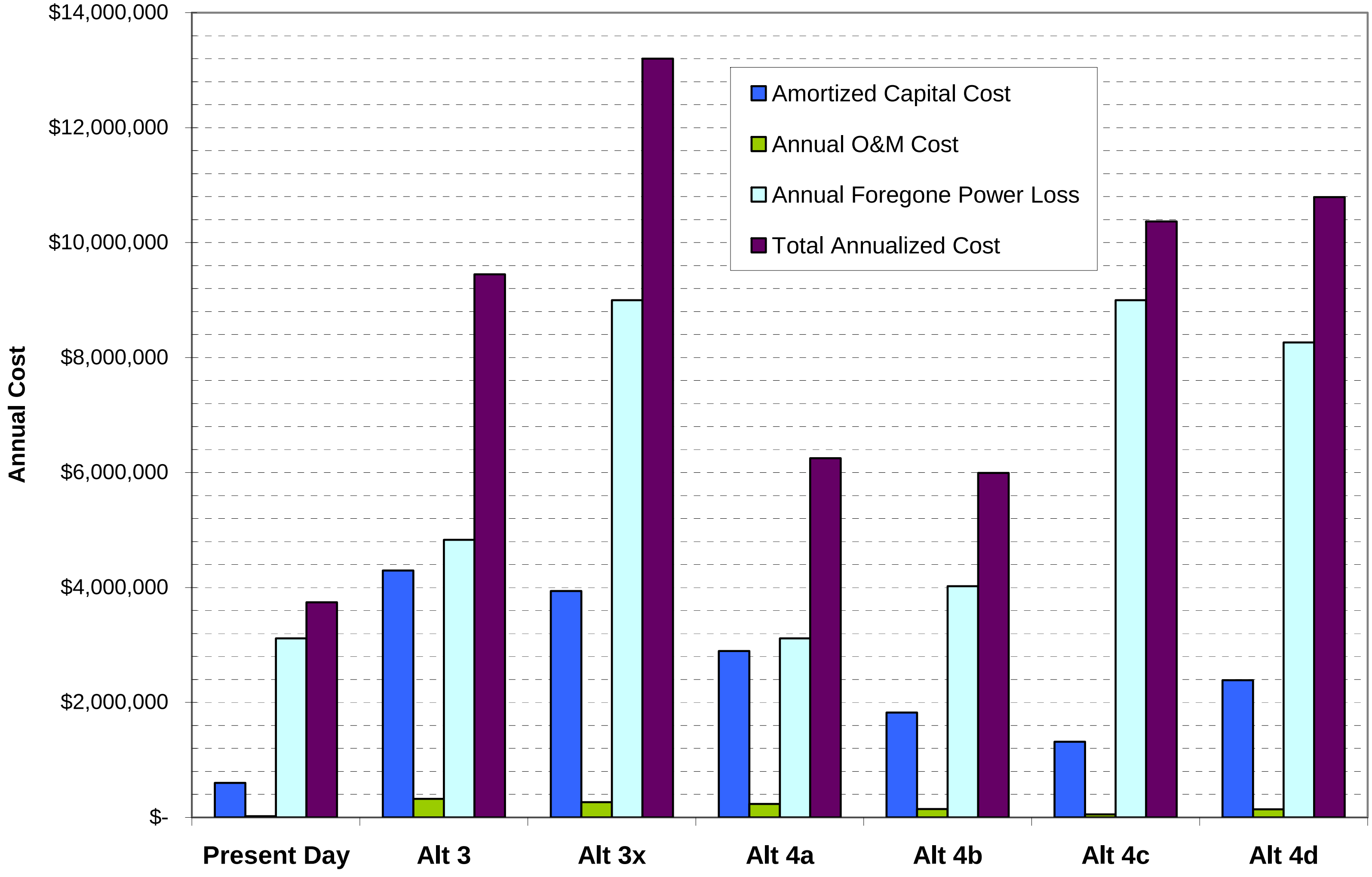


Figure ES-2 Comparison of Annualized Cost among Level 3 Alternatives



1.0 INTRODUCTION

Through the Level 1 and Level 2 water temperature reduction alternatives development and screening process, a set of comprehensive, potentially feasible water temperature reduction alternatives for the NFFR was generated. These water temperature reduction alternatives were formulated using the results of previous modeling studies conducted primarily by PG&E with some enhancements by Stetson. The purpose of this Level 3 Report is to document detailed analyses of the effectiveness, sustainability, reliability, and feasibility of the alternatives that passed Level 2. This Chapter first summarizes the Level 1 and 2 analysis of water temperature reduction alternatives, and then introduces the alternatives formulated for this Level 3 analysis.

1.1 SUMMARY OF LEVEL 1 AND 2 ANALYSIS OF WATER TEMPERATURE REDUCTION ALTERNATIVES

The Level 1 and 2 analysis included the following major work items:

- Characterize the summer thermal regime of the NFFR using historical monitoring data and analyze the response of the infusion of cold water using the July 2003 Caribou PH special test and the summer 2006 special test;
- Identify potential water temperature reduction measures at Lake Almanor, Butt Valley Reservoir, and in each of the five bypass reaches (i.e., Seneca, Belden, Rock Creek, Cresta, and Poe Reaches);
- Develop a framework for formulating water temperature reduction alternatives;
- Develop evaluation criteria for screening Level 1 and 2 alternatives;
- Formulate initial Level 1 water temperature reduction alternatives and conduct Level 1 screening;
- Prepare preliminary engineering designs, cost estimates, and operational requirements for the water temperature reduction alternatives that passed Level 1;
- Conduct Level 2 screening of water temperature reduction alternatives.

The Federal Clean Water Act (CWA) was enacted “to restore and maintain the chemical, physical, and biological integrity of the nation’s waters.” (33 U.S.C.§§ 1251-1387.) Prior to issuance of a new federal license, PG&E must obtain a CWA section 401 water quality certification that the UNFFR Project will be in compliance with specified provisions of the CWA (33 U.S.C.§ 1341), including State water quality standards as contained in the applicable water quality control plan. The State Water Board has included the NFFR on the list, prepared pursuant to section 303(d) of the Clean Water Act (33 U.S.C. § 1313(d)), of surface waters that do not meet water quality standards (Water Board Resolution No. 2006-0079). The State Water Board based the listing on the determination that elevated water temperatures are impairing the cold freshwater habitat beneficial use of the NFFR, and cited hydromodification and flow regulation as potential sources of the impairment. With this in mind, a systematic, three-phased approach was used to develop a range of feasible water temperature reduction alternatives for achieving the water temperature objective and protecting the cold freshwater habitat beneficial use of the NFFR. The Level 1 and 2 Report documented the first two phases of the three-phased approach.

Level 1 cast a “wide net” that captured most, if not all, of the possible water temperature reduction alternatives and then subjected these possible alternatives to the following coarse screening criteria:

- Effectiveness and reliability – Is there a reasonable potential that the alternative can effectively and reliably achieve the preliminary temperature target or, is the effectiveness and reliability of the alternative overly speculative?
- Technological feasibility and constructability – Can the alternative be implemented with currently available technology and construction methods?
- Logistics – Can the alternative be implemented when considering current legal obligations, regulatory permitting requirements, public safety needs, right-of-way and access needs, and other real world logistical constraints?
- Reasonability[1] – Are there clearly more reasonable or superior alternatives available based on the other criteria? Is implementation of the alternative remote or highly speculative?

The set of alternatives that passed Level 1 screening represented a reasonable range of potentially effective and feasible water temperature reduction alternatives. These alternatives were carried forward to Level 2.

Level 2 screened-out (eliminated) those alternatives that, after closer examination, were deemed ineffective, infeasible, or clearly inferior to other alternatives. In Level 2 the alternatives were analyzed using the best resource information available at the time. Water temperature reduction alternatives were modified or refined based on the analysis, and rough engineering designs and cost estimates including foregone power generation loss were developed. The alternatives were subjected to the same screening criteria used in Level 1, plus the following additional criteria:

- Substantial Further Study - Is there sufficient information currently available or can it be readily developed in order to evaluate the potential effectiveness and feasibility of the alternative, or is substantial further investigation or study required?
- Environmental challenges – Are there obvious environmental consequences or problems associated with the alternative that would pose a major challenge to overcome?
- Economic feasibility – Can the alternative be implemented at a reasonable cost, including capital, O&M, and considering energy replacement costs?

The resulting Level 2 alternatives represented *the set of potentially effective and feasible water temperature reduction alternatives* that were advanced to Level 3.

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[1] An EIR need not consider an alternative whose effect cannot be reasonably ascertained and whose implementation is remote and speculative (CEQA Guidelines, § 15126, subd. (d)).

The Level 1 and 2 water temperature reduction alternatives for the entire NFFR were formulated in accordance with a developed framework. This framework approaches the problem of reducing water temperatures along the entire NFFR by developing solutions on a reach-by-reach scale, focusing on reduction at Belden Reservoir water temperature because it is central to achieving temperature reduction in the downstream reaches. The cooler the water discharged from Belden Reservoir is, the less further cooling is needed downstream. Conversely, the warmer the water discharged from Belden Reservoir is, the more the water needs to be cooled downstream to meet the water temperature target. Six categories of alternatives were initially identified in Level 1. These categories were differentiated by the amount of temperature reduction provided at Belden Reservoir. A higher numbered category means that more temperature reduction was required in reaches downstream. Within a particular category, alternatives were differentiated by the method of temperature reduction at Belden Reservoir. An alternative may have multiple variations with respect to the method of temperature reduction in the downstream reaches.

Through the Level 1 and Level 2 water temperature reduction alternatives development and screening process, a set of comprehensive, potentially feasible water temperature reduction alternatives for the NFFR was generated. Table 1-1 summarizes the water temperature reduction alternatives that passed Level 2. It shows categories of alternatives, alternatives, and variations for cooling downstream reaches. The shaded cells represent alternatives/measures that passed Level 2 (green); or eliminated (gray). The following summarizes alternatives and alternative variations that passed Level 2:

- ***Alternative Category 2*** **–** one alternative (Alternative 2c) with one variation for the Poe Reach. No water temperature reduction measures are needed for the Belden, Rock Creek, and Cresta Reaches. This Category has *one alternative variation* (i.e., 1 × 1 = 1).

- ***Alternative Category 3*** **–** one alternative (Alternative 3) with one variation for each of the Belden, Cresta, and Poe Reaches. No water temperature reduction measures are needed for the Rock Creek Reach. This Category has *one alternative variation* (i.e., 1 × 1 × 1 × 1 = 1).

- ***Alternative Category 4*** **–** three alternatives (Alternatives 4a, 4b, and 4c) with one variation for the Belden Reach, one variation for the Rock Creek Reach, two variations for the Cresta Reach, and one variation for the Poe Reach, totaling *6 alternative variations* (i.e., 3 × 1 × 1 × 2 × 1 = 6).

- ***Alternative Category 5*** **–** two alternatives (Alternatives 5a and 5b) with one variation for the Belden Reach, one variation for the Rock Creek Reach, two variations for the Cresta Reach, and two variations for the Poe Reach, totaling *8 alternative variations* (i.e., 2 × 1 × 1 × 2 × 2 = 8).

These 16 resulting water temperature reduction alternatives represent *the set of potentially effective and feasible* alternatives to achieving the temperature target[2]. These water temperature reduction alternatives were formulated using the results of previous modeling studies conducted primarily by PG&E with some enhancements by Stetson. The effectiveness of each alternative in reducing temperatures and achieving the temperature target on the NFFR was analyzed using the information and tools summarized below:

- PG&E's *Temperature Modeling Results for 33-years of the Hydrologic Record* (Bechtel Corporation and Thomas R. Payne and Associates 2006);
- PG&E's *Physical-prototype Hydraulic Modeling Results for the Prattville Intake Thermal Curtain* (IIHR 2004);
- PG&E's *2002-2004 Temperature Monitoring Data Reports* (PG&E 2003; PG&E 2004; PG&E 2005);
- PG&E's *2006 NFFR Special Testing Data Report* (Stetson and PG&E 2007);
- Stream water temperature modeling analysis using the SNTEMP models developed by PG&E for the five bypass reaches; and
- Water temperature mixing analysis.

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[2] A temperature value of 20ºC mean daily was used as the water temperature target in the framework for developing Level 1 and 2 water temperature reduction alternatives.

Table 1-1 Final Level 2 Alternatives to Achieve the 20°C Objective Target for Water Temperature along the NFFR

(Green highlighted measures remain as final Level 2 Alternatives and will advance to Level 3; Bright green highlighted measures represent variations for cooling downstream reaches)

Alternative Category	**Alternative**		**Variations for Cooling Downstream Reaches**			
	Alt.	**Measures in reducing source water temperature to Belden Forebay**	**Additional measures for Belden Reach**	**Additional measures for Rock Creek Reach**	**Additional measures for Cresta Reach**	**Additional measures for Poe Reach**
1. Reduce the temperature in Belden Forebay to 12.5 °C. **(eliminated)**	1	• Install Prattville thermal curtain with levee removed ~~• Collect and convey cold spring water (215 cfs, 8°C) to Prattville Intake~~ • Convey Butt Valley PH discharges to Butt Valley Reservoir near Caribou Intake	No	No	No	No
2. Reduce the temperature in Belden Forebay to 14.5 °C. **(1 variation)**	2a	• Install Prattville thermal curtain with levee removed ~~• Convey Butt Valley PH discharges **to 2,000 cfs** to Butt Valley Reservoir near Caribou Intake~~	No	No	No	• Increase shading along Poe Reach
	2b	• Install Prattville thermal curtain with levee removed • Install a thermal curtain near Caribou Intake in Butt Valley Reservoir ~~• Collect and convey cold spring water (215 cfs, 8°C) to Prattville Intake~~				• Increase Poe Dam release **to 360 cfs**
	2c	• Decrease Prattville Intake release **to 500 cfs** to cause cold water selective withdrawal • Extend the existing deeper channel of Butt Valley Reservoir by dredging • Use Caribou #1 exclusively with reduced release to cause cold water selective withdrawal from Butt Valley Reservoir • Repair/modify Canyon Dam low level outlet and increase release to 600 cfs				• Construct outlet/pipeline from the Poe Adit and release **to 180 cfs** of cooler water to the Poe Reach
3. Reduce the temperature in Belden Forebay to 16.0 °C. **(1 variation)**	3	• Install Prattville thermal curtain with levee removed • Install a thermal curtain near Caribou Intake in Butt Valley Reservoir • Increase Canyon Dam release **to 250 cfs** (and decrease Prattville Intake release commensurately)	• Convey warm water **to 100 cfs** from East Branch NFFR to Rock Creek Reservoir by diversion/pipeline Note: This measure is designed to protect the lower Belden Reach	No	• Increase Cresta Dam release **to 390 cfs**	• Increase Poe Dam release **to 300 cfs** • Construct outlet/pipeline from the Poe Adit and release **to 400 cfs** the cooler water to the Poe Reach
					• Increase Grizzly Creek release **to 50 cfs**	

Note: All alternatives will have no affect on Lake Almanor water levels except Alternative 2c which would result in higher than historical lake levels due to significant flow reduction at the Prattville Intake.

Table 1-1 Final Level 2 Alternatives to Achieve the 20°C Objective Target for Water Temperature along the NFFR

(Continued)

Alternative Category	Alternative		Variations for Cooling Downstream Reaches			
	Alt.	**Measures in reducing source water temperature to Belden Forebay**	**Additional measures for Belden Reach**	**Additional measures for Rock Creek Reach**	**Additional measures for Cresta Reach**	**Additional measures for Poe Reach**
4. Reduce the temperature in Belden Forebay to 18.0 °C. **(6 variations)**	**4a**	• Install Prattville thermal curtain • Install a thermal curtain near Caribou Intake in Butt Valley Reservoir	• Convey warm water **to 100 cfs** from East Branch NFFR to Rock Creek Reservoir by diversion/pipeline Note: This measure is designed to protect the lower Belden Reach.	• ~~Construct Yellow Cr/ Belden PH bifurcation or,~~ Convey Yellow Creek flows **to 60 cfs** by pipeline to Rock Creek Reservoir for plunging • Construct low level outlet at Rock Creek Dam • Dredge a submerged channel in Rock Creek Reservoir	• Convey cold Bucks Creek PH flows **to 140 cfs** to Cresta Reservoir for plunging by pipeline • Construct low level outlet at Cresta Dam	• Increase Poe Dam release **to 400 cfs** • Construct outlet/pipeline from the Poe Adit and release **to 450 cfs** of cooler water to the Poe Reach
				• Bypass Yellow Creek flows **to 60 cfs** around Rock Creek Reservoir by diversion/pipeline	• Bypass cold Bucks Creek PH flows **to 95 cfs** around Cresta Reservoir by diversion/pipeline	
	4b	• Install Prattville thermal curtain • Use Caribou #1 preferentially over Caribou #2		• Increase Rock Creek Dam release **to 400 cfs**	• Increase Cresta Dam release **to 500 cfs**	
					• Increase Grizzly Creek releases **to 80 cfs**	
	4c	• Repair/modify Canyon Dam low level outlet and increase release to 600 cfs (and decrease Prattville Intake release commensurately) • Use Caribou #1 preferentially over Caribou #2		• Construct **150 cfs capacity** water chiller at Rock Creek Dam	• Construct **175 cfs capacity** water chiller at Cresta Dam	• Construct **200 cfs capacity** water chiller at Poe Dam
5. Reduce the temperature in Belden Forebay to 19.5 °C. **(8 variations)**	**5a**	• Use Caribou #1 preferentially over Caribou #2 • Repair/modify Canyon Dam low level outlet and increase release to 250 cfs or higher (and decrease Prattville Intake release commensurately)	• Convey cold Seneca Reach flows **to 250 cfs** to Belden Reservoir for plunging by diversion/pipeline • Install a thermal curtain near Belden PH Intake • Convey warm water **to 100 cfs** from East Branch NFFR to Rock Creek Reservoir by diversion/pipeline	• ~~Construct Yellow Cr/ Belden PH bifurcation or,~~ Convey Yellow Creek flows **to 60 cfs** by pipeline to Rock Creek Reservoir for plunging • Convey lower Belden Reach flows **to 140 cfs** to Rock Creek Reservoir for plunging • Dredge a submerged channel in Rock Creek Reservoir • Construct low level outlet at Rock Creek Dam	• Convey cold Bucks Creek PH flows **to 140 cfs** to Cresta Reservoir for plunging by diversion/pipeline • Dredge a submerged channel in Cresta Reservoir • Construct low level outlet at Cresta Dam	• Increase Poe Dam release • Construct outlet/pipeline from the Poe Adit and release the cooler water to the Poe Reach
	5b	• Install thermal curtain near Caribou Intake in Butt Valley Reservoir • Repair/modify Canyon Dam low level outlet and increase release to 250 cfs or higher (and decrease Prattville Intake release commensurately)			• Bypass cold Bucks Creek PH flows **to 110 cfs** around Cresta Reservoir by pipeline	
			• Operate Caribou PHs in strict peaking mode with several hours shut down • Convey warm water **to 100 cfs** from East Branch NFFR to Rock Creek Reservoir by diversion/pipeline	• Bypass Yellow Creek/Chips Creek flows **to 80 cfs** around Rock Creek Reservoir by diversion/pipeline	• Increase Cresta Dam release to **700 cfs**	• Construct **200 cfs capacity** water chiller at Poe Dam
	5c	• ~~Convey Butt Valley PH discharges to 2,000 cfs by pipeline to Butt Valley Res. near the Caribou Intake~~ • Repair/modify Canyon Dam low level outlet and increase release to 250 cfs or higher (and decrease Prattville Intake release commensurately)		• Increase Rock Creek Dam release **to 600 cfs**	• Increase Grizzly Creek releases **to 100 cfs**	
				• Construct **150 cfs capacity** water chiller at Rock Creek Dam	• Construct **175 cfs capacity** water chiller at Cresta Dam	

Table 1-1 Final Level 2 Alternatives to Achieve the 20°C Objective Target for Water Temperature along the NFFR
(Continued)

Alternative Category	Alternative		Variations for Cooling Downstream Reaches			
	Alt.	**Measures in reducing source water temperature to Belden Forebay**	**Additional measures for Belden Reach**	**Additional measures for Rock Creek Reach**	**Additional measures for Cresta Reach**	**Additional measures for Poe Reach**
6. Reduce temperatures in all downstream reaches. **(eliminated)**	**6a**	No	• Repair/modify Canyon Dam low level outlet and increase release to 250 cfs • Convey cold Seneca Reach flows to Belden Reservoir for plunging by diversion/pipeline • **Increase Belden Dam/Oak Flat PH release to 250 cfs** • Convey warm water **to 100 cfs** in East Branch NFFR to Rock Creek Reservoir by diversion/pipeline	• Bypass lower Belden Reach flows **to 250 cfs** around Rock Creek Reservoir by diversion/pipeline Note: Must be combined with bypassing Seneca flows around Belden Reservoir.	• Bypass lower Rock Creek Reach flows **to 250 cfs** around Cresta Reservoir by diversion/pipeline Note: Must be combined with bypassing Seneca flows around Belden Reservoir.	• Bypass lower Cresta Reach flows **to 250 cfs** around Poe Reservoir by diversion/ pipeline Note: Must be combined with bypassing Seneca flows around Belden Reservoir.
	6b		• Increase Canyon Dam low level outlet release to 90 cfs or higher • Operate Caribou PHs in strict peaking mode with several hours shut down • Convey warm water **to 100 cfs** in East Branch NFFR to Rock Creek Reservoir by diversion/pipeline	• Construct **150 cfs capacity** water chiller at Rock Creek Dam	• Construct **175 cfs capacity** water chiller at Cresta Dam	• Construct **200 cfs capacity** water chiller at Poe Dam
	6c		~~• Convey cold water from Lake Oroville to below Belden Dam~~	~~• Convey cold water from Lake Oroville to below Rock Creek Dam~~	~~• Convey cold water from Lake Oroville to below Cresta Dam~~	~~• Convey cold Lake Oroville to below Poe D.~~

1.2 FORMULATION OF UNFFR PROJECT-ONLY ALTERNATIVES FOR LEVEL 3 ANALYSIS

As shown in Table 1-1, the 16 resulting water temperature reduction alternatives advanced from Level 2 included measures within and outside the UNFFR Project boundary (i.e., the FERC Project No. 2105 boundary). Measures outside the UNFFR Project boundary included flow-related operational measures for the Rock Creek, Cresta, and Poe Reaches and physical modification measures for the Poe Reach. In this Level 3 Report, an alternative is called UNFFR Project-only alternative if all measures (operational or physical modifications) comprising the alternative are entirely within the UNFFR Project boundary and subject to FERC jurisdiction in the 2105 relicensing process.

Based on the original three-phased approach, the Level 3 analysis was to include the following two major work items:

1) Additional detailed modeling (including Rock Creek, Cresta and Poe reaches) and feasibility-level engineering design and cost estimating work to verify the effectiveness, feasibility, sustainability, and reliability of the water temperature reduction alternatives advanced from Level 2; and
2) Final screening of water temperature reduction alternatives suitable for analysis in the EIR. The resulting set of water temperature reduction alternatives passing the Level 3 screening would represent *the set of effective and feasible water temperature reduction alternatives*.

It is important to point out that the Level 3 analysis evolved and did not end up following the original three-phased approach exactly as described above. As mentioned in the Executive Summary, this Level 3 Report and the Level 1 and 2 Report will be used by the State Water Board to support, in part, its actions regarding issuance of Clean Water Act (CWA) section 401 water quality certification of the UNFFR Project and adoption of an Environmental Impact Report (EIR). To carry out the two discretionary actions with consideration to the controllable factors under PG&E's control, which may achieve compliance with Basin Plan objectives, this Level 3 report analyzes the effects of the UNFFR Project-only alternatives, with consideration also given to flow-related operational measures for the Rock Creek, Cresta, and Poe Reaches. No detailed screening of water temperature reduction alternatives was conducted in reaches outside (downstream) of the UNFFR boundary in this Level 3 analysis. Water temperature reduction alternatives in reaches outside of the UNFFR boundary were not carried forward into Level 3 based on considerations of their ability to reduce temperature, technical feasibility, and cost.

Of the UNFFR Project-only alternatives advanced from Level 2 (Table 1-1), the following alternatives/measures were further eliminated or were not considered in this Level 3 analysis:

- Alternative 2c: This alternative was eliminated because it would restrict water delivery to downstream powerhouses (Belden, Rock Creek, Cresta, and Poe), significantly reduce Butt Valley PH flows and thereby increase the potential for spill at Lake Almanor, decrease PG&E's ability to meet DWR/Western Canal Contract water deliveries, and require substantial further study to determine the feasibility and cost of dredging Butt Valley Reservoir.

- The measure of conveying warm water from East Branch NFFR to Rock Creek Reservoir by diversion/pipeline: This measure was eliminated because its temperature benefit is limited to the lower Belden Reach (about 1.7 miles) and substantial further study on the feasibility and cost of construction is needed.

- Alternatives 5a and 5b: These two alternatives were not analyzed further because they provide limited water temperature reduction to Belden Reservoir and require intensive water temperature reduction measures in the Rock Creek, Cresta, and Poe Reaches.

The remaining UNFFR Project-only alternatives advanced from Level 2 included Alternatives 3, 4a, 4b, and 4c. These UNFFR Project-only alternatives included the following measures at Lake Almanor and Butt Valley Reservoir:

Lake Almanor:

- Install Prattville Intake thermal curtain with removal of submerged levees;
- Install Prattville Intake thermal curtain without removal of submerged levees;
- Repair/modify Canyon Dam low-level outlet and increase release (and decrease Prattville Intake/Butt Valley PH discharge commensurately)

Butt Valley Reservoir:

- Install a single thermal curtain near Caribou #1 and #2 Intakes;
- Use Caribou #1 preferentially over Caribou #2.

In addition, the following alternatives were added in the Level 3 analysis for the purposes or reasons described below:

- Baseline was added. Baseline conditions are those that existed at the time the Notice of Preparation was submitted to the State Clearinghouse (September 1, 2005) and the CEQA scoping process was initiated. Baseline represents the CEQA baseline and provides a basis for comparing the alternatives.

- "Present Day" alternative, which is essentially the alternative proposed by PG&E in its license application (essentially the same as the FERC staff recommended alternative in the EIS), was added. This alternative enhances the ability of the EIR to illustrate the comparison of alternatives.

- Alternative 3x was added. Alternative 3x is similar to Alternative 3 except that the measure of installing a thermal curtain near the Caribou #1 and #2 Intakes in Butt Valley Reservoir is replaced with the measure of preferential use of Caribou #1 (from Alternative 4c), and the measure of increasing Canyon Dam release is changed from 250 cfs to 600 cfs. The only difference between Alternatives 3x and 4c is that Alternative 3x has the measure of installing Prattville Intake thermal curtain with removal of submerged levees near the Intake, Alternative 4c does not have this measure. Alternative 3x is the alternative that would have the greatest water temperature reduction that could be achieved from modifications to the UNFFR Project-only.

- Alternative 3a was added. Alternative 3a is similar to Alternative 3 except that Alternative 3a does not have the measure of increased Canyon Dam release. The purpose of adding this alternative was to isolate the benefit, in terms of water temperature reduction, of removing the submerged levees near the Prattville Intake. The only difference between Alternative 4a and this added Alternative 3a is that Alternative 3a includes removal of the submerged levees in front of the Prattville Intake. So the comparison of simulated water temperature profiles along NFFR between Alternative 4a and this added Alternative 3a represents the benefit from removal of the submerged levees.

- Alternative 4d was added. Alternative 4d is similar to Alternative 4c, except that preferential use of Caribou #1 in Alternative 4c is replaced with installation of a thermal curtain near the Caribou #1 and #2 Intakes in Butt Valley Reservoir. The purpose of adding this alternative was to reduce foregone power generation loss caused by the preferential use of Caribou #1 PH, which has about a 15% lower turbine efficiency than Caribou #2 PH.

Table 1-2 is a summary of the UNFFR Project-Only alternatives that were analyzed in Level 3. The outcome of the Level 3 analysis is intended to ensure that the State Water Board has the opportunity to evaluate a range of water temperature reduction alternatives which may achieve compliance with Basin Plan objectives.

Table 1-2 Summary of UNFFR Project-Only Alternatives Formulated for Level 3 Analysis

Alternatives	Measures Included in the UNFFR Project-Only Alternatives	Remarks
Baseline	No action.	• Baseline conditions are those facilities and operating conditions that existed as of the NOP dated September 1, 2005.
"Present Day"	• Increase Canyon Dam release to those given in the Partial Settlement (and decrease Prattville Intake release commensurately).	• The "Present Day" alternative is essentially the alternative proposed by PG&E in its license application and also the FERC Staff recommended alternative in the EIS.
Alternative 3	• Install Prattville Intake thermal curtain and remove submerged levees near the Intake; • Modify Canyon Dam low-level outlet and increase release to 250 cfs (in July and August and decrease Prattville Intake release commensurately); • Install a single thermal curtain near Caribou #1 and #2 Intakes.	• Alternative 3 was examined in the Level 1 and 2 Report.
Alternative 3x	• Install Prattville Intake thermal curtain and remove submerged levees near the Intake; • Modify Canyon Dam low-level outlet and increase release to 600 cfs (in July and August) (and decrease Prattville Intake release commensurately); • Operate Caribou #1 preferentially over Caribou #2.	• Alternative 3x was not examined in the Level 1 and 2 Report. • Alternative 3x is the alternative that would have the greatest water temperature reduction that could be achieved from the UNFFR Project-only.
Alternative 3a	• Install Prattville Intake thermal curtain and remove submerged levees near the Intake; • Install a single thermal curtain near Caribou #1 and #2 Intakes.	• Alternative 3a was not examined in the Level 1 and 2 Report. • Alternative 3a was added in the Level 3 analysis for the purpose of isolating and analyzing the incremental benefit of removing the submerged levees near the Prattville Intake (by comparing Alternatives 3a and 4a).
Alternative 4a	• Install Prattville Intake thermal curtain (without removal of submerged levees near the Intake); • Install a single thermal curtain near Caribou #1 and #2 Intakes.	• Alternative 4a was examined in the Level 1 and 2 Report.
Alternative 4b	• Install Prattville Intake thermal curtain (without removal of submerged levees near the Intake); • Operate Caribou #1 preferentially over Caribou #2.	• Alternative 4b was examined in the Level 1 and 2 Report.
Alternative 4c	• Modify Canyon Dam low-level outlet and increase release to 600 cfs (in July and August) (and decrease Prattville Intake release commensurately); • Operate Caribou #1 preferentially over Caribou #2.	• Alternative 4c was examined in the Level 1 and 2 Report.
Alternative 4d	• Modify Canyon Dam low-level outlet and increase release to 600 cfs (in July and August) (and decrease Prattville Intake release commensurately); • Install a single thermal curtain near Caribou #1 and #2 Intakes.	• Alternative 4d was not examined in the Level 1 and 2 Report.

The Level 3 modeling work considered the following flow releases (see also Table 1-3) for the Baseline conditions, "Present Day" conditions, and alternatives conditions:

Baseline Conditions:

CEQA Baseline conditions, for purposes of modeling flow regimes for the UNFFR, were the conditions that existed when the Notice of Preparation (NOP) was filed. The NOP of the UNFFR Project was submitted to the State Clearinghouse on September 1, 2005. Accordingly, the Baseline conditions, with respect to flows, were as follows:

- Canyon Dam releases to the Seneca Reach were those that actually existed as of the NOP, which were also the required minimum flows (i.e., 35 cfs) under the existing FERC license for the UNFFR Project;
- Belden Dam releases to the Belden Reach were those that actually existed as of the NOP, which were also the required minimum flows (i.e., 140 cfs) under the existing FERC license for the UNFFR Project;
- Rock Creek Dam releases to the Rock Creek Reach were those that actually existed as of the NOP, which were also those given in the 2000 Relicensing Settlement Agreement for the Rock Creek-Cresta Project for the first 5-year, plus about 30 cfs of leakage;
- Cresta Dam releases to the Cresta Reach were those that actually existed as of the NOP, which were also those given in the 2000 Relicensing Settlement Agreement for the Rock Creek-Cresta Project for the first 5-year, plus about 30 cfs of leakage; and,
- Poe Dam releases to the Poe Reach were those that actually existed as of the NOP, which were 100 cfs.

"Present Day" Conditions:

"Present Day" conditions more accurately reflect the foreseeable future conditions without consideration of the water temperature reduction measures at the UNFFR Project. "Present Day" conditions, with respect to flows, were as follows:

- Canyon Dam releases to the Seneca Reach were those agreed to in the Partial Settlement for the UNFFR Project (see Table 1-4a);
- Belden Dam releases to the Belden Reach were those given in the Partial Settlement for the UNFFR Project;
- Rock Creek Dam releases to the Rock Creek Reach were those given in the proposed changes to the 2000 Relicensing Settlement Agreement for the Rock Creek-Cresta Project for the second 5-year (see Table 1-4b);
- Cresta Dam releases to the Cresta Reach were those given in the proposed changes to the 2000 Relicensing Settlement Agreement for the Rock Creek-Cresta Project for the second 5-year; and,
- Poe Dam releases to the Poe Reach were those of current operations (about 100 cfs).

Alternatives Conditions:

- Canyon Dam releases to the Seneca Reach were those agreed to in the Partial Settlement for the UNFFR Project, except that flows used in connection with the measures of "increased Canyon Dam releases";
- Belden Dam releases to the Belden Reach were those given in the Partial Settlement for the UNFFR Project;
- Rock Creek Dam releases to the Rock Creek Reach were those given in the proposed changes to the 2000 Relicensing Settlement Agreement for the Rock Creek-Cresta Project for the second 5-year;
- Cresta Dam releases to the Cresta Reach were those given in the proposed changes to the 2000 Relicensing Settlement Agreement for the Rock Creek-Cresta Project for the second 5-year; and,
- Poe Dam releases to the Poe Reach were those of current operations (about 100 cfs).

Table 1-3 Flow Releases for the Baseline, "Present Day", and Alternatives Conditions

	Seneca Reach	**Belden Reach**	**Rock Creek Reach**	**Cresta Reach**	**Poe Reach**
Baseline Conditions	35 cfs	140 cfs	1st-five year flows plus 30 cfs of leakage	1st-five year flows plus 30 cfs of leakage	100 cfs
"Present Day" Conditions	Required minimum flows in the Partial Settlement	Required minimum flows in the Partial Settlement	Proposed changes to the 2nd-five year flows	Proposed changes to the 2nd-five year flows	100 cfs
Alternatives Conditions	Required minimum flows in the Partial Settlement except flows used for the measures of "increased Canyon Dam releases"	Required minimum flows in the Partial Settlement	Proposed changes to the 2nd-five year flows	Proposed changes to the 2nd-five year flows	100 cfs

Table 1-4a Seneca and Belden Instream Flow Release Schedule (cfs)
(Draft Settlement Agreement in April 2004, FERC #2105)

	Seneca Reach				**Belden Reach**			
Water Year Type	Jun	Jul	Aug	Sep	Jun	Jul	Aug	Sep
Wet	150	95	80	60	225	175	140	140
Normal	125	90	80	60	225	175	140	140
Dry	110	80	70	60	160	130	110	100
Critical Dry	80	75	60	60	90	80	75	75

Tale 1-4b Rock Creek and Cresta Instream Flow Release Schedule (cfs), FERC #1962

	Rock Creek Reach				**Cresta Reach**			
Water Year Type	Jun	Jul	Aug	Sep	Jun	Jul	Aug	Sep
First 5-year								
Normal/Wet	220	180	180	180	240	220	220	220
Dry	175	150	150	150	190	175	175	175
Critical Dry	150	150	150	150	140	140	140	140
Second 5-year								
Normal/Wet	260	260	260	260	325 (500)	325 (400)	325	325
Dry	210	210	210	210	260 (400)	260	260	260
Critical Dry	150	150	150	150	140	140	140	140
Third 5-year								
Normal/Wet	390	390	390	390	440	440	440	440
Dry	310	310	310	310	350	350	350	350
Critical Dry	150	150	150	150	140	140	140	140

Note: The numbers in parenthesis are those given in the proposed changes to the 2000 Relicensing Settlement Agreement for the Rock Creek-Cresta Project.

2.0 ANALYSIS OF EFFECTIVENESS, SUSTAINABILITY, AND RELIABILITY OF LEVEL 3 ALTERNATIVES

This chapter documents the Level 3 analysis of the effectiveness, sustainability, and reliability of the formulated UNFFR Project-only alternatives described in Chapter 1. The analysis was conducted for the following three indicators:

- Mean daily water temperature;
- Maximum weekly average water temperature (MWAT); and
- Diel water temperature.

Mean daily water temperature is defined as the average water temperature for each 24-hour day. Analysis of mean daily water temperature is consistent with the Rock Creek – Cresta Relicensing Settlement Agreement which states: “In order to reasonably protect cold freshwater habitat, Licensee shall maintain mean daily water temperatures of 20 degrees Celsius or less in the Rock Creek and Cresta Reaches, to the extent that Licensee can reasonably control such temperatures”.

MWAT is defined as the maximum seven-day running average of daily average water temperatures during a given period of interest. MWAT provides an index for assessing the effects of chronic thermal conditions on cold freshwater habitat within riverine environments. The effects on cold water aquatic organisms include acute lethal exposures to very warm temperatures and chronic sub-lethal exposures to warm temperatures sufficient to cause detrimental effects on long-term survival, growth, and reproduction.

Diel water temperature is the diel cycle of water temperatures during each 24-hour day. It provides an index for assessing the effects of acute thermal conditions on cold freshwater habitat.

2.1 MEAN DAILY WATER TEMPERATURE ANALYSIS

2.1.1 Modeling Approach for Mean Daily Water Temperature Analysis

Following is a list of models that were used in the analysis for mean daily water temperature profiles along the NFFR for the Level 3 alternatives:

- Lake Almanor: MITEMP as modified by Stetson (Appendix A).
- Butt Valley Reservoir: Newly developed CE-QUAL-W2 by Stetson (Appendix B).
- Belden Reservoir: Complete mixing method[1].
- Rock Creek Reservoir: SNTEMP as modified by Stetson[2].
- Cresta Reservoir and Poe Reservoir: Complete mixing method[3].
- Five bypass reaches: SNTEMP for each reach.

Figure 2-1 shows all the models that were used in Level 3 to analyze mean daily water temperature profiles along the NFFR and how these models were related. For example, outflow and temperature at Canyon Dam derived from output of the Lake Almanor MITEMP model were input to the Seneca Reach SNTEMP model. Outflow and temperature at Butt Valley PH derived from output of the Lake Almanor MITEMP model were input to the Butt Valley Reservoir CE-QUAL-W2 model. The outflows and temperatures at Caribou #1 and #2 PHs derived from output of the Butt Valley Reservoir CE-QUAL-W2 model and outflow and temperature derived from output of the Seneca Reach SNTEMP model were completely mixed in Belden Reservoir. The complete mixing method of analysis was performed outside of the modeling work. The mixed water temperature in Belden Reservoir defined the discharge water temperature at Belden PH and was input to the Rock Creek Reservoir SNTEMP model. The mixed water temperature in Belden Reservoir also defined the Belden Dam release water temperature and was input to the Belden Reach SNTEMP model. Water temperature profiles along the Rock Creek, Cresta, and Poe Reaches were computed using the SNTEMP models for these reaches. Water temperature calculations for Cresta and Poe Reservoirs were conducted using the complete mixing method of analysis which was also performed outside of the modeling work.

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[1] Stetson developed a preliminary CE-QUAL-W2 model for Belden Reservoir. The model was intended for analyses of Alternatives 5a and 5b that passed Level 2. Since these two alternatives were not considered for further analysis in Level 3, the Belden Reservoir CE-QUAL-W2 model was not finalized nor used in the Level 3 analysis.

[2] In PG&E's modeling studies for the historical 33 years (1970 – 2002), Rock Creek Reservoir was assumed to be completely mixed and warming in the reservoir was not accounted for. However, about 0.5°C – 1.0°C warming from the upstream to downstream of Rock Creek Reservoir was observed during the July 2003 Caribou special test and again during the 2006 special test. Not accounting for the warming would underestimate water temperatures in the Rock Creek Reach and downstream reaches. A Rock Creek Reservoir SNTEMP model recently modified by Stetson from a previous model developed by PG&E was used to account for warming through the reservoir. Rock Creek Reservoir is relatively long, shallow, narrow, and similar, in terms of thermal behavior, to a river. The previous Rock Creek Reservoir SNTEMP model has been calibrated by PG&E using the July 2003 Caribou special test data. Stetson has verified the Rock Creek Reservoir SNTEMP model using the 2006 special test data.

[3] Historical observations show that water temperatures in the Cresta and Poe Reservoirs are generally well mixed.

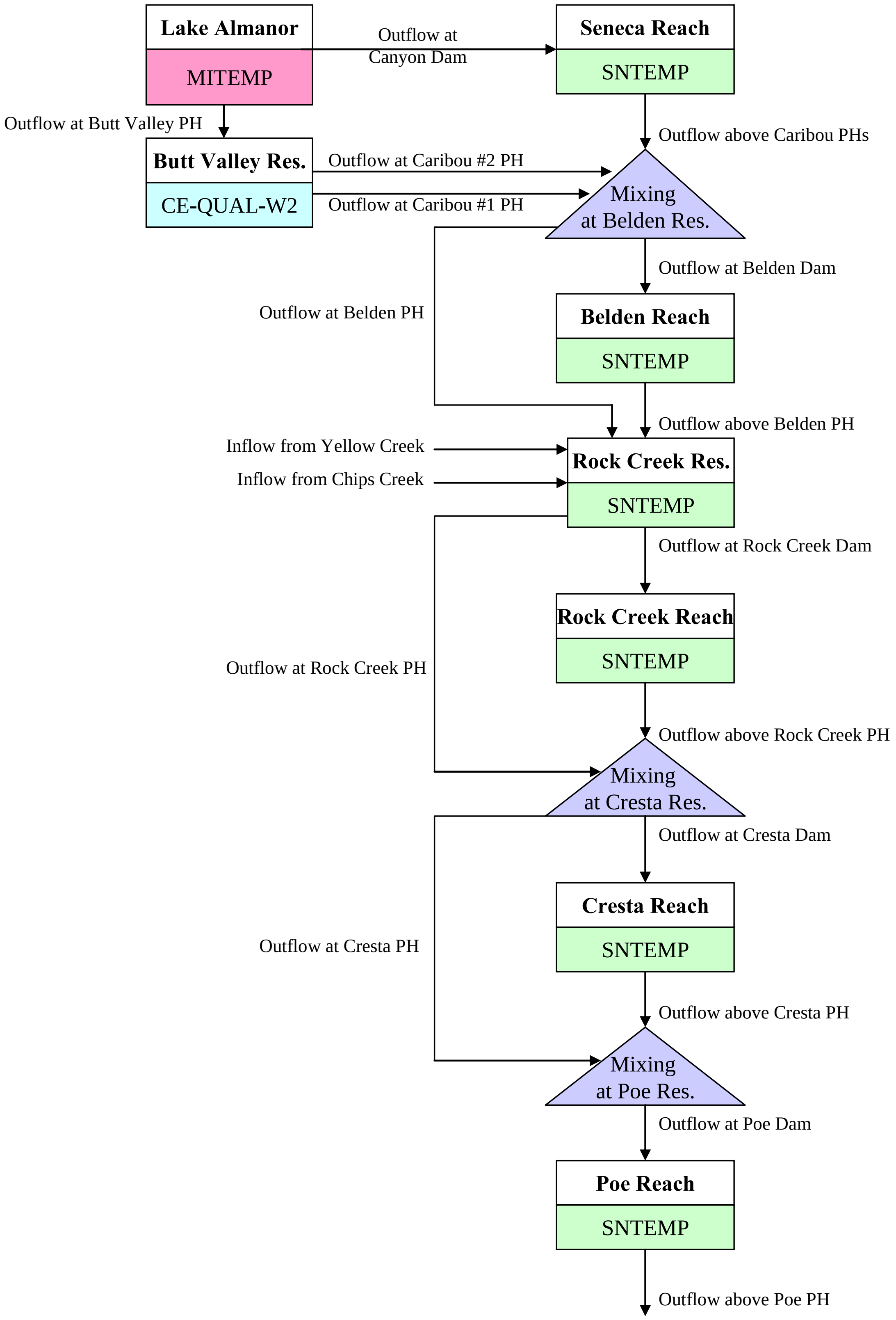

Figure 2-1 NFFR Water Temperature Models and Model Relationships

The water temperature profile of the NFFR is primarily driven by the Belden Reservoir water temperature, which in turn is controlled by the Lake Almanor and Butt Valley Reservoir outflow temperatures. Reservoir outflow temperatures for Lake Almanor and Butt Valley Reservoir are affected by many factors, including meteorology, inflow hydrology, regulated outflows, reservoir water levels, and timing of these factors. There is no straightforward relationship between hydrological year type or meteorology and reservoir outflow temperature. For example, a dry hydrological year and warm meteorological year would not necessarily result in reservoir outflow temperatures that are warmer than a normal hydrological year and a normal meteorological year. Because of this, to cover a range of meteorological and hydrological years, our reservoir modeling approach for Lake Almanor and Butt Valley Reservoir covered a 19-year period (1984-2002) on a daily basis[4, 5, 6]. The computed daily outflow temperatures at Canyon Dam and Caribou PHs over a period of 19 years were grouped by month and then rank-ordered to statistically represent normal (50% exceedence), warm (25% or 10% exceedence), and cool (75% or 90% exceedence) outflow temperatures for each of the summer months (June, July, August, and September)[7].

For a given water temperature at Belden Reservoir, stream water temperatures downstream in the NFFR bypass reaches would have a relatively straightforward relationship with meteorological and hydrological conditions. For example, the stream

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[4] The 19-year period of analysis (1984-2002) included 7 wet years, 3 normal years, 2 dry years, and 7 critical dry years. This analysis period covers a range of hydrologic years that is similar in composition to PG&E’s long-term analysis period of 33 years (1974-2002). PG&E’s 33-year analysis period included 13 wet years, 6 normal years, 4 dry years, and 10 critical dry years.

[5] The Lake Almanor and Butt Valley Reservoir models were used to simulate mean daily water temperatures in the vertical direction and mean daily outflow temperatures beginning March 1 and ending September 30 for each year of the selected long-term analysis period. The long-term hydrologic flow inputs in the Lake Almanor and Butt Valley Reservoir models consisted of estimated long-term daily stream inflows and re-operated outflows through the Prattville Intake and the Canyon Dam outlet and Caribou PHs. These long-term hydrologic data were mainly extracted from PG&E’s 33-year modeling input files and were re-operated to reflect water release measures being analyzed in Level 3. One year of daily water temperature data for stream inflows to Lake Almanor and Butt Valley Reservoir that was synthesized by PG&E was extracted from PG&E’s MITEMP modeling input files and used for all of the Lake Almanor and Butt Valley Reservoir model simulations covering the 19-year long-term analysis period. Submerged spring flows into Lake Almanor were assumed as 430 cfs in normal years and 375 cfs in dry years with a constant water temperature of 8°C (this assumption is the same as the PG&E’s MITEMP modeling assumption for Lake Almanor spring flows).

[6] The long-term daily meteorological data for the period of 1984-2002 for the Prattville Intake station were synthesized based on available data collected at the four meteorology stations; Prattville Intake, Chester, Canyon Dam, and McArthur. PG&E conducted 33-year analysis period simulations using the Lake Almanor and Butt Valley Reservoir MITEMP models. But PG&E only used one year of synthesized “normal year” daily meteorology data for the Prattville Intake station and repeated this data over the 33-year period. It is more reasonable to use long-term daily meteorological data for the lake/reservoir modeling because climate data are a very important driver for the lake/reservoir thermal structures.

[7] The term "exceedence" refers to the percent of the time during a given period (in this case, a given month) that a given temperature is exceeded (i.e., warmer than). For example, the 25% exceedence mean daily temperature for July means that in 25% of the days in July (over the 19 year analysis period) the water would be warmer than the 25% exceedence temperature.

water temperature profile under warm meteorological and dry hydrological conditions would be expected to be warmer than that under normal meteorological/hydrological conditions. Because of this, water temperature profiles along the bypass reaches at each exceedence level for each of the summer months were computed using the combinations of meteorological and hydrological conditions and dam release schedules as summarized in Table 2-1: The SNTEMP models for the bypass reaches were each run for a one-day period for each of the summer months using the combined conditions. The SNTEMP model for the Seneca reach was run for one day for each of the summer months using Lake Almanor MITEMP-computed outflow temperature from Canyon Dam as the starting water temperature for each exceedence level (0% or maximum, 10%, 25%, 50%, 75%, and 90%). The SNTEMP model for the Belden Reach was run for one day for each of the summer months using the mixed temperatures of (a) Seneca Reach SNTEMP ending temperature and (b) Butt Valley CE-QUAL-W2-computed outflow temperatures from Caribou #1 and #2 PHs as the starting water temperature. The SNTEMP models of other bypass reaches were run in a similar fashion.

Table 2-1 Combinations of Meteorological and Hydrological Conditions and Dam Release Schedules Used in SNTEMP Modeling of Bypass Reaches

Water temperature exceedence level at dam release	Meteorological Condition[8]	Hydrological Condition (i.e., stream accretion flows)	Corresponding dam release schedule
0% (Maximum)	Warm	Dry	Critical Dry
10%	Warm	Dry	Critical Dry
25%	Warm	Dry	Dry
50%	Normal	Normal	Normal
75%	Cool	Wet	Wet
90%	Cool	Wet	Wet

The following describes the modeling approach more specifically using the Seneca Reach SNTEMP modeling as an example:

> For the SNTEMP model of the Seneca Reach, Canyon Dam outflow water temperatures, as determined by the output from the Lake Almanor model, were statistically analyzed, and the 10%, 25%, 50%, 75%, and 90% exceedance level

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[8] The typical "normal" meteorology conditions for the summer months were determined from the long-term mean air temperature of the 19-year analysis period (1984 - 2002). Typical "warm" or "cool" air temperature was determined from the long-term mean air temperature plus or minus one point three (± 1.3) standard deviation. Other climate data (i.e., solar radiation, relative humidity, and wind speed) for the typical warm or cool meteorology data are the same as the normal weather. One point three standard deviation around mean statistically represents about 80% confidence interval. So the long-term mean air temperature plus one point three standard deviation can be seen as "warm" air at 10% exceedence level (20% ÷ 2 = 10%) and the long-term mean air temperature minus one point three standard deviation can be seen as "cool" air at 90% exceedence level (80% + 20% ÷ 2 = 90%).

profiles along the reach by month were modeled under the appropriate meteorological conditions and stream accretion flow conditions in the following manner:

1) The 50% exceedence outflow water temperature at Canyon Dam, considered as “normal conditions”, was modeled under normal meteorological conditions with dam releases corresponding to the “normal” year release schedule given in the Partial Settlement. Also, within the Seneca Reach under this modeling, the stream reach was assumed to gain a "normal" amount of accretion at the "normal" temperature. The “normal” accretion flow and temperature were based on observed data for 2000, 2003 and 2004, which were considered “normal” hydrologic years.
2) The 25% and 10% exceedence outflow water temperatures, considered as “reasonable extreme conditions” and “extreme conditions”, respectively, were modeled under “warm” meteorological conditions with dam releases corresponding to the “dry” and “critical dry” year release schedule given in the Partial Settlement. Accretion flows and water temperatures were derived from dry/critical dry year data, for which 2002 was considered representative of a dry year and 2001 was considered representative of a critical dry year.
3) The 75% and 90% exceedence outflow water temperatures, considered as other extremes, were modeled under “cold” meteorological conditions with dam releases corresponding to the “wet” year release schedule given in the Partial Settlement. Accretion flows and water temperatures were derived from wet year data, for which 2006 was considered representative.

The analysis of water temperature profiles along the NFFR involved three types of models: MITEMP, CE-QUAL-W2, and SNTEMP. Each of these models requires a particular input file format and has a particular output format. Because of the complexity of model input format requirements, the length of the analysis period, the large numbers of alternatives, several exceedance levels, and multiple water temperature models, a large amount of work is required to complete the simulation runs of different water temperature reduction alternatives.

To facilitate the scenario modeling analysis, batch files and pre/post-processing files that automatically link all the models were programmed using scripting languages, including MS-DOS Batch Files, MS-DOS QBasic, Matlab, and AutoIt3. Using these batch files and pre/post-processing files in the scenario analyses avoided potential mistakes or errors that could arise from manually dealing with many different input and output files for many different simulation scenarios. Specifically, the automated procedures were as follows:

(1) Create Lake Almanor MITEMP model input files from the 19-year hydrology and meteorology data using Matlab;
(2) Run Lake Almanor MITEMP models using Batch file;
(3) Create Butt Valley Reservoir CE-QUAL-W2 model input files from Lake Almanor MITEMP model outputs using Matlab;
(4) Run Butt Valley Reservoir W2 CE-QUAL-W2 models using Batch files/AutoIt3 scripts;

(5) Compute exceedence statistics of Caribou PH discharge water temperatures from Butt Valley Reservoir CE-QUAL-W2 model outputs using Matlab;
(6) Compute exceedence statistics of Canyon Dam release water temperatures from Lake Almanor MITEMP model outputs using Matlab;
(7) Create stream SNTEMP model input files from the computed exceedence statistics using Matlab;
(8) Run stream SNTEMP models using Batch files/QBasic/AutoIt3 scripts.
(9) Plot longitudinal temperature profiles along the five bypass reaches of NFFR from SNTEMP outputs using Excel.

Prior to using the automatic procedures in scenario simulation runs, careful quality assurance/quality control (QA/QC) processes were performed to ensure that the above procedures were properly conducted and coding of scripts for automatic linkage of models were correctly programmed. These QA/QC processes included development of systematic diagrams of all procedures and associated data input and output file names; careful examination of the various models' inputs and outputs for several selected years by comparing manual treatment and automatic testing; internal independent review of the procedures and the models' inputs and outputs; and careful examination of the reasonability of model results for the baseline scenario by comparing the simulated baseline results to the historical data. More detailed QA/QC processes corresponding to the above-described automated procedures are described in Appendix E.

2.1.2 Analysis Results and Ranking of the UNFFR Project-Only Alternatives

1) Comparison of water temperature reduction benefits among alternatives

Figures 2-2 to 2-5 compare the simulated mean daily water temperature profiles along the NFFR among different UNFFR Project-only alternatives. Table 2-2 shows the ranking of alternatives in terms of water temperature reduction, with the lowest rank number representing the greatest water temperature reduction. The added Alternative 3x has the greatest water temperature reduction that could be achieved from the UNFFR Project-only (see Figures 2-2 to 2-5). Alternative 3x would have the same annual power generation loss as Alternative 4c while reducing the mean daily water temperature by about 5.9°C in July and 4.3°C in August on average at the upstream end of Belden Reach over the 19-year analysis period (1984 – 2002), and by about 2.0°C in July and 1.6°C in August at the downstream end of Poe Reach. The lowest ranked alternative (Alternative 4a) could reduce the mean daily water temperature by about 2.5°C in July and 1.9°C in August at the upstream end of Belden Reach, and by about 0.8°C in July and 0.7°C in August at the downstream end of Poe Reach.

The mean daily water temperature modeling results indicate that preferential use of Caribou #1 over Caribou #2 (Alternatives 4b and 4c) appears to be more effective in reducing the NFFR water temperature than a thermal curtain at Butt Valley Reservoir near the Caribou Intakes (Alternatives 4a and 4d) in July, but the two measures have similar temperature reduction benefits in August.

Figures 2-6 to 2-9 compare the simulated water temperature profiles along the NFFR between Alternative 4a and the added Alternative 3a for the purpose of isolating the benefit of removing the submerged levees in front of the Prattville Intake. It appears the benefit is minimal, with a maximum temperature reduction of about 0.3°C in July and 0.6°C in August at the upstream end of Belden Reach. The benefit diminishes gradually downstream along the NFFR. Note that the simulated temperature difference between the two conditions, with and without the levees, cannot be directly compared to the physical hydraulic model test results by IIHR (IIHR, 2004). The physical model test results were obtained by comparing conditions with and without the levees for the same temperature profile in Lake Almanor. Once the curtain is in place, conditions with and without the levees do not result in the same temperature profile on the same date. With the levees removed, more cold water is removed from Lake Almanor than with the levees in place. Hence, the thermal structure of lake is different, and the temperature profiles are different. What happens is that with the levees removed, the reservoir hypolimnion is warmer than with the levees in place. Hence the difference in the outflow temperatures with different temperature profiles will be smaller than with identical temperature profiles.

Figures 2-10 to 2-13 compare the simulated water temperature profiles along the NFFR between the Baseline and the "Present Day" conditions. The "Present Day" alternative is essentially the alternative proposed by PG&E in its license application and also the FERC

Staff recommended alternative in the EIS, which increases the Canyon Dam releases to those given in the Partial Settlement. The results show that there is only a small difference in water temperature between the Baseline and the "Present Day" conditions.

Table 2-2 Ranking of UNFFR Project-Only Alternatives

Ranking in Terms of Water Temperature Reduction	Alternative	Notes on Foregone Power Generation Loss
1	Alternative 3x	• Alternative 3x would have the same annual power generation loss as Alternative 4c.
2	Alternative 4c	• In addition to the annual power generation loss of 47.94 kwh × 10^6 as the "Present Day" alternative, Alternative 4c would have an additional annual power generation loss of 79.17 kwh × 10^6 in a normal hydrologic year due to increased Canyon Dam release (to 600 cfs in July and August) and the commensurate flow reductions in Butt Valley, Caribou #1, and Caribou #2 PHs. • Alternative 4c would have an additional annual power generation loss of 11.32 kwh × 10^6 due to lower turbine efficiency of Caribou #1 PH relative to Caribou #2 PH (by about 15%) and the preferential use of Caribou #1 PH in July and August. • The power generation loss due to increased Canyon Dam release could be partially recovered by constructing a powerhouse below Canyon Dam.
3	Alternative 4d	• In addition to the annual power generation loss of 47.94 kwh × 10^6 as the "Present Day" alternative, Alternative 4d would have an additional annual power generation loss of 79.17 kwh × 10^6 in a normal hydrologic year due to increased Canyon Dam release (to 600 cfs in July and August) and the commensurate flow reductions in Butt Valley, Caribou #1, and Caribou #2 PHs. • The power generation loss due to increased Canyon Dam release could be partially recovered by constructing a powerhouse below Canyon Dam.
4	Alternative 3	• In addition to the annual power generation loss of 47.94 kwh × 10^6 as the "Present Day" alternative, Alternative 3 would have an additional annual power generation loss of 26.39 kwh × 10^6 in a normal hydrologic year due to increased Canyon Dam release (to 250 cfs in July and August) and the commensurate flow reductions in Butt Valley, Caribou #1, and Caribou #2 PHs. • The power generation loss due to increased Canyon Dam release could be partially recovered by constructing a powerhouse below Canyon Dam.
5	Alternative 4b	• In addition to the annual power generation loss of 47.94 kwh × 10^6 as the "Present Day" alternative, Alternative 4b would have an additional annual power generation loss of 13.91 kwh × 10^6 due to the lower turbine efficiency of Caribou #1 PH relative to Caribou #2 PH (by about 15%) and the preferential use of Caribou #1 PH in July and August.
6	Alternative 4a	• Alternative 4a would have the same annual power generation loss of 47.94 kwh × 10^6 as the "Present Day" alternative.

2) Summary of mean daily water temperature profiles for each alternative

Figures 2-14 to 2-19 present the simulated water temperature profiles along the NFFR at different exceedence levels for different UNFFR Project-only alternatives. The results of July and August are also summarized in Tables 2-3a and 2-3b respectively.

Table 2-3a Summary of Mean Daily Water Temperature Profiles for Different Alternatives - July

Alt.	Exceedence Level	Belden Reach (Reach length = 8.8 miles)		Rock Creek Reach (Reach length = 7.9 miles)		Cresta Reach (Reach length = 4.7 miles)		Poe Reach (Reach length = 7.5 miles)	
		Reach Length That Exceeds 20°C (mile)	Temperature Range along the Reach	Reach Length That Exceeds 20°C (mile)	Temperature Range along the Reach	Reach Length That Exceeds 20°C (mile)	Temperature Range along the Reach	Reach Length That Exceeds 20°C (mile)	Temperature Range along the Reach
Baseline	Maximum	Entire reach	23.2-23.6°C	Entire reach	23.3-23.7°C	Entire reach	23.1-23.8°C	Entire reach	23.3-25.7°C
	10% Exceedence	Entire reach	22.2-23.0°C	Entire reach	22.4-23.0°C	Entire reach	22.3-23.2°C	Entire reach	22.5-25.3°C
	25% Exceedence	Entire reach	21.7-22.7°C	Entire reach	21.9-22.7°C	Entire reach	22.0-22.8°C	Entire reach	22.1-25.1°C
	50% Exceedence	Entire reach	20.4-21.9°C	6.9	18.6-21.1°C	Entire reach	20.1-20.8°C	Entire reach	20.2-23.2°C
Alt. 3	Maximum	Entire reach	21.0-22.7°C	Entire reach	21.4-22.4°C	Entire reach	21.5-22.7°C	Entire reach	21.6-24.8°C
	10% Exceedence	1.6	19.0-22.1°C	7.1	19.7-21.3°C	Entire reach	20.0-21.7°C	Entire reach	20.2-24.1°C
	25% Exceedence	1.6	18.3-21.2°C	4.7	19.2-20.7°C	3.1	19.5-20.8°C	7.0	19.8-23.9°C
	50% Exceedence	0.7	17.0-20.2°C	0	17.5-19.0°C	0	17.9-18.8°C	4.0	18.2-22.1°C
Alt. 4a	Maximum	Entire reach	21.0-22.7°C	Entire reach	21.3-22.3°C	Entire reach	21.5-22.6°C	Entire reach	21.6-24.8°C
	10% Exceedence	Entire reach	20.0-22.4°C	Entire reach	20.6-21.8°C	Entire reach	20.7-22.2°C	Entire reach	20.9-24.5°C
	25% Exceedence	1.6	19.1-21.5°C	7.2	19.9-21.1°C	Entire reach	20.1-21.3°C	Entire reach	20.4-24.2°C
	50% Exceedence	1.6	17.9-20.6°C	0	17.9-19.6°C	0	18.5-19.3°C	4.8	18.7-22.4°C
Alt. 4b	Maximum	Entire reach	20.6-22.6°C	Entire reach	21.0-22.0°C	Entire reach	21.2-22.5°C	Entire reach	21.3-24.7°C
	10% Exceedence	1.6	19.1-22.1°C	7.4	19.9-21.4°C	Entire reach	20.1-21.8°C	Entire reach	20.3-24.2°C
	25% Exceedence	1.6	18.5-21.2°C	5.3	19.4-20.8°C	3.5	19.7-20.9°C	Entire reach	19.9-24.0°C
	50% Exceedence	0.7	17.0-20.2°C	0	17.5-19.0°C	0	18.0-18.8°C	4.0	18.2-22.1°C
Alt. 4c	Maximum	1.6	18.8-22.1°C	6.6	19.6-21.2°C	4.2	19.8-21.6°C	Entire reach	20.0-24.0°C
	10% Exceedence	1.6	17.4-21.6°C	2.9	18.4-20.5°C	2.5	18.7-20.9°C	6.1	19.0-23.5°C
	25% Exceedence	1.1	16.5-20.3°C	0	17.8-19.7°C	0	18.1-19.7°C	4.8	18.4-23.2°C
	50% Exceedence	0	15.3-19.4°C	0	16.7-18.0°C	0	16.8-17.9°C	2.9	17.0-21.5°C
Alt. 4d	Maximum	2.2	19.2-22.2°C	7.6	19.9-21.4°C	Entire reach	20.1-21.8°C	Entire reach	20.3-24.2°C
	10% Exceedence	1.6	17.9-21.8°C	4.1	18.8-20.8°C	3.1	19.1-21.1°C	6.5	19.3-23.7°C
	25% Exceedence	1.6	17.4-20.7°C	0.5	18.4-20.2°C	0.3	18.7-20.2°C	6.1	19.0-23.5°C
	50% Exceedence	0	16.4-19.9°C	0	17.2-18.6°C	0	17.5-18.4°C	3.8	17.7-21.2°C

Notes:
The State Water Board has determined that the Seneca Reach is not impaired for water temperature, therefore it is excluded from this table.
The length of the lower Belden Reach below East Branch = 1.6 miles.
The length of the lower Rock Creek Reach below Bucks Creek = 1.2 miles.

Table 2-3b Summary of Meany Daily Water Temperature Profiles for Different Alternatives - August

Alt.	Exceedence Level	Belden Reach (Reach length = 8.8 miles)		Rock Creek Reach (Reach length = 7.9 miles)		Cresta Reach (Reach length = 4.7 miles)		Poe Reach (Reach length = 7.5 miles)	
		Reach Length That Exceeds 20°C (mile)	Temperature Range along the Reach	Reach Length That Exceeds 20°C (mile)	Temperature Range along the Reach	Reach Length That Exceeds 20°C (mile)	Temperature Range along the Reach	Reach Length That Exceeds 20°C (mile)	Temperature Range along the Reach
Baseline	Maximum	Entire reach	22.8-23.8°C	Entire reach	23.0-23.3°C	Entire reach	22.9-23.2°C	Entire reach	23.1-24.9°C
	10% Exceedence	Entire reach	22.1-22.7°C	Entire reach	22.3-22.6°C	Entire reach	22.2-22.6°C	Entire reach	22.3-24.5°C
	25% Exceedence	Entire reach	21.7-22.0°C	Entire reach	21.8-22.2°C	Entire reach	21.8-22.3°C	Entire reach	21.9-24.2°C
	50% Exceedence	Entire reach	20.7-21.2°C	6.9	18.0-20.9°C	Entire reach	20.0-20.4°C	Entire reach	20.1-22.5°C
Alt. 3	Maximum	Entire reach	20.7-21.6°C	Entire reach	21.1-21.7°C	Entire reach	21.1-21.9°C	Entire reach	21.3-23.9°C
	10% Exceedence	1.6	19.6-21.1°C	Entire reach	20.0-20.9°C	Entire reach	20.1-21.2°C	Entire reach	20.3-23.4°C
	25% Exceedence	1.6	19.0-20.6°C	3.8	19.4-20.4°C	2.5	19.6-20.5°C	6.8	19.8-23.1°C
	50% Exceedence	0	18.2-19.8°C	0	17.2-19.1°C	0	18.2-18.8°C	3.3	18.3-21.5°C
Alt. 4a	Maximum	Entire reach	21.5-22.5°C	Entire reach	22.2-22.5°C	Entire reach	22.0-22.6°C	Entire reach	22.3-24.4°C
	10% Exceedence	Entire reach	20.6-21.5°C	Entire reach	20.0-21.6°C	Entire reach	21.0-21.8°C	Entire reach	21.1-23.8°C
	25% Exceedence	Entire reach	20.0-21.1°C	Entire reach	20.4-21.0°C	Entire reach	20.5-21.2°C	Entire reach	20.6-23.6°C
	50% Exceedence	1.6	19.1-20.2°C	0	17.6-19.7°C	0	18.8-19.3°C	4.3	18.9-21.9°C
Alt. 4b	Maximum	Entire reach	21.6-22.6°C	Entire reach	22.3-22.5°C	Entire reach	22.1-22.6°C	Entire reach	22.3-24.4°C
	10% Exceedence	Entire reach	20.6-21.5°C	Entire reach	21.0-21.6°C	Entire reach	21.1-21.9°C	Entire reach	21.2-23.8°C
	25% Exceedence	4.6	20.0-21.0°C	Entire reach	20.3-21.0°C	Entire reach	20.4-21.1°C	Entire reach	20.5-23.5°C
	50% Exceedence	1.6	19.0-20.2°C	0	17.5-19.6°C	0	18.8-19.3°C	4.2	18.9-21.8°C
Alt. 4c	Maximum	Entire reach	20.2-21.3°C	Entire reach	20.6-21.3°C	Entire reach	20.6-21.6°C	Entire reach	20.8-23.6°C
	10% Exceedence	1.6	19.1-20.9°C	5.3	19.5-20.6°C	3.3	19.6-20.9°C	6.8	19.7-23.1°C
	25% Exceedence	1.1	18.5-20.3°C	0	18.9-20.0°C	0.3	19.1-20.1°C	5.9	19.3-22.9°C
	50% Exceedence	0	17.8-19.6°C	0	17.0-18.8°C	0	17.9-18.6°C	3.3	18.0-21.4°C
Alt. 4d	Maximum	Entire reach	20.7-21.5°C	Entire reach	21.1-21.7°C	Entire reach	21.1-21.9°C	Entire reach	21.3-23.9°C
	10% Exceedence	1.6	19.1-20.9°C	5.3	19.5-20.6°C	3.3	19.6-20.9°C	6.8	19.8-23.1°C
	25% Exceedence	1.6	18.6-20.4°C	0.8	19.1-20.1°C	0.6	19.2-20.2°C	6.1	19.4-22.9°C
	50% Exceedence	0	17.9-19.6°C	0	17.0-18.9°C	0	18.0-18.6°C	3.3	18.1-21.4°C

Notes:
The State Water Board has determined that the Seneca Reach is not impaired for water temperature, therefore it is excluded from this table.
The length of the lower Belden Reach below East Branch = 1.6 miles.
The length of the lower Rock Creek Reach below Bucks Creek = 1.2 miles.

3) Development of the relationship between increased Canyon Dam release and water temperature reduction benefit at Belden Reservoir

All of the identified water temperature reduction alternatives infuse cold water from Lake Almanor to the NFFR through selective cold water withdrawal from either increased Canyon Dam low-level release and/or Prattville Intake thermal curtain. Increasing Canyon Dam low-level releases would enhance water temperature reduction in Belden Reservoir, which would benefit all downstream reaches. Increasing Canyon Dam low-level releases would also reduce warming in the Seneca Reach, which would reduce inflow water temperature to Belden Reservoir. The amount of temperature reduction resulting from increased Canyon Dam release depends on the magnitude of the release. Figures 2-20 to 2-24 present the amount of water temperature reduction at Belden Reservoir with different release rates at Canyon Dam for different alternatives. Table 2-4 summarizes the amount of water temperature reduction at Belden Reservoir for every 100 cfs increased release at Canyon Dam. These developed relationships together with the simulated temperature profiles shown in Figures 2-2 to 2-5 can be used to assist in the refinement of the analyzed alternatives if/when needed.

Table 2-4 Amount of Water Temperature Reduction at Belden Reservoir for Every 100 cfs of Increased Release at Canyon Dam (above "Present Day" Conditions)

Alternative	July	August
Alternative 3	0.4°C	0.3°C
Alternative 4a	0.5°C	0.3°C
Alternative 4b	0.6°C	0.4°C
Alternative 4c	0.8°C if Q<500 cfs 0.4°C if Q>500 cfs	0.6°C
Alternative 4d	0.6°C	0.5°C

4) Development of the relationship between increased Canyon Dam release and foregone power generation loss

Increasing Canyon Dam releases would require decreasing Prattville Intake/ Butt Valley PH and Caribou PHs discharges commensurately to avoid water level fluctuation or changes of Lake Almanor and Butt Valley Reservoir from the operating rules agreed to in the Partial Settlement Agreement. Higher releases from Canyon Dam have higher foregone power generation loss[9]. There would be a tradeoff between the water temperature reduction benefit and foregone power generation loss. It was estimated that the monthly foregone power generation loss in July or August would be about 7.54×10^6 kwh for every 100 cfs of increased release above those described in the "Present Day" alternative.

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[9] The feasibility of hydropower generation to recover the foregone power by constructing a powerhouse below Canyon Dam will be investigated in Chapter 4.

5) Development of the relationship between increased releases at Rock Creek Dam, Cresta Dam, and Poe Dam and warming reductions in the respective reaches

Figures 2-25a and 2-25b present the simulated mean daily water temperatures of the Rock Creek Reach above Bucks Creek confluence for a range of releases at Rock Creek Dam and release temperatures at the dam under July and August warm meteorological conditions. The difference between a temperature reading in a curve and its given release temperature at the dam represents warming along the Rock Creek Reach from the dam to above Bucks Creek confluence under the dam release rate corresponding to the temperature reading. The difference between any two temperature readings in a curve represents the warming reduction benefit resulting from the increased magnitude of water releases at Rock Creek Dam under the given release temperature at the dam. As shown in the figures, increasing dam releases would reduce warming and the warming reduction benefit per unit amount of increased release would be smaller and smaller as the dam release increases. Note that increasing release from Rock Creek Dam can only reduce warming, not reduce the temperature of water at the starting point of the Rock Creek Reach. The water temperature modeling tests indicate that the warming reduction benefit of increasing the magnitude of water releases at Rock Creek Dam is greater if the dam release temperature is lower than 20°C. The modeling tests also indicate that the warming reduction benefit of increasing releases at Rock Creek Dam above 400 cfs is diminished.

Figures 2-26a and 2-26b present the simulated mean daily water temperatures of the Crest Reach above Cresta PH for a range of releases at Cresta Dam and release temperatures at the dam under July and August warm meteorological conditions. The water temperature modeling tests indicate that the warming reduction benefit of increasing the magnitude of water releases at Cresta Dam is greater if the release temperature is lower than 20°C. The modeling tests also indicate that the warming reduction benefit of increasing the magnitude of water releases at Cresta Dam above 400 cfs is diminished.

Figures 2-27a and 2-27b present the simulated mean daily water temperatures of the Poe Reach above Poe PH for a range of releases at Poe Dam and release temperatures at the dam under July and August warm meteorological conditions. The water temperature modeling tests indicate that the warming reduction benefit of increasing the magnitude of water releases from current 100 cfs to 300 cfs at Poe Dam is relatively significant. The warming reduction benefit of increasing the magnitude of water releases from 300 cfs to 600 cfs at Poe Dam is measurable, but less significant.

The mean daily water temperature profiles shown in Figures 2-2 to 2-5 for different alternatives were simulated under the second 5-year flow conditions for the Rock Creek and Cresta Reaches and the current flow condition of about 100 cfs for the Poe Reach. The developed relationships here together with the simulated temperature profiles shown in Figures 2-2 to 2-5 can be used to assist in further, more refined management of water temperature for the Rock Creek, Cresta, and Poe Reaches if/when needed.

Figure 2-2a Comparison of NFFR Water Temperature Longitudinal Profiles between Alternatives — July, 50% Exceedence

(Note: The added Alternative 4D is similar to Alternative 4C, except that the measure of preferential use of Caribou #1 is changed to installation of thermal curtain near Caribou Intake)

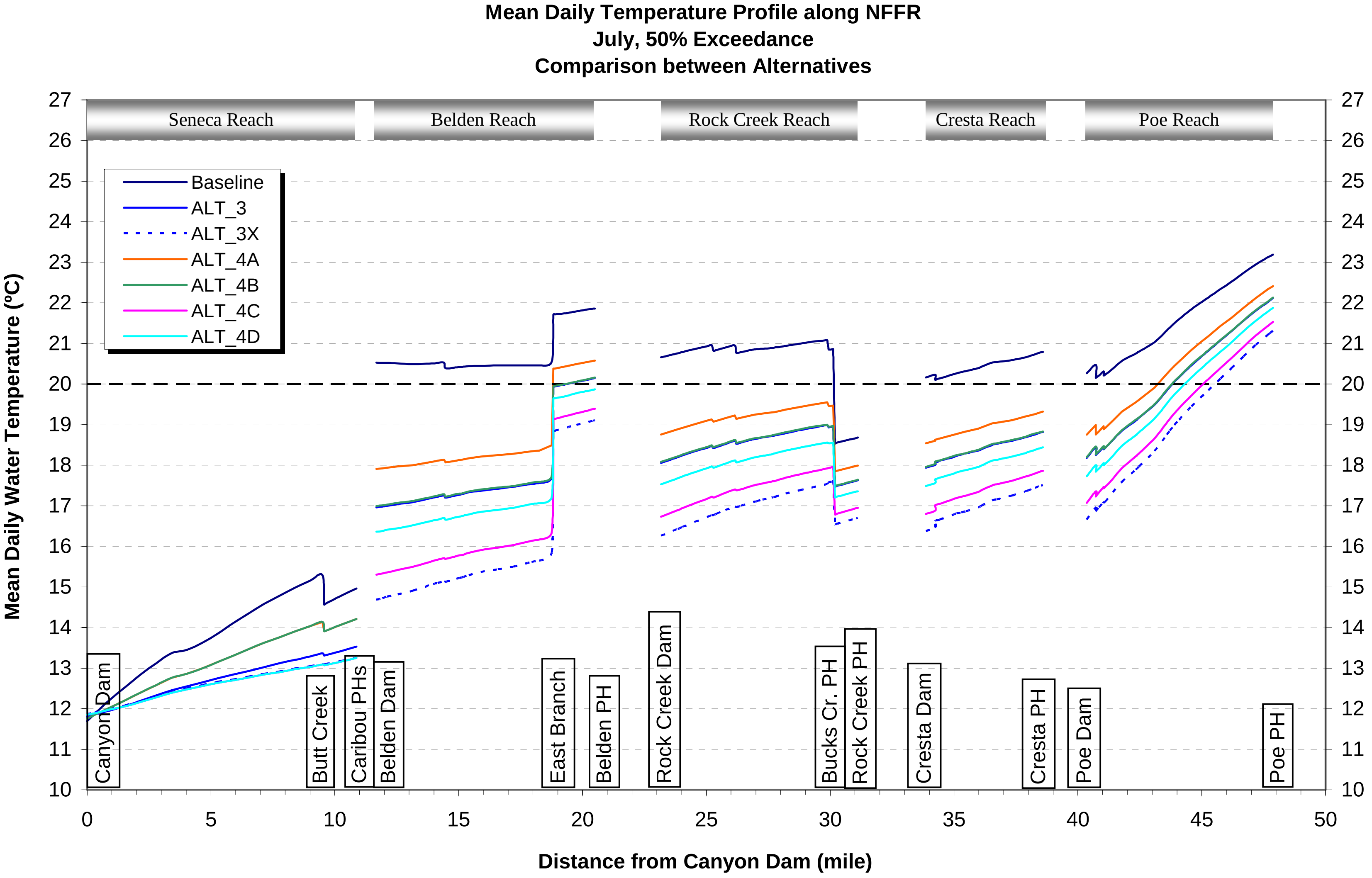


Figure 2-2b Comparison of NFFR Water Temperature Longitudinal Profiles between Alternatives — August, 50% Exceedence

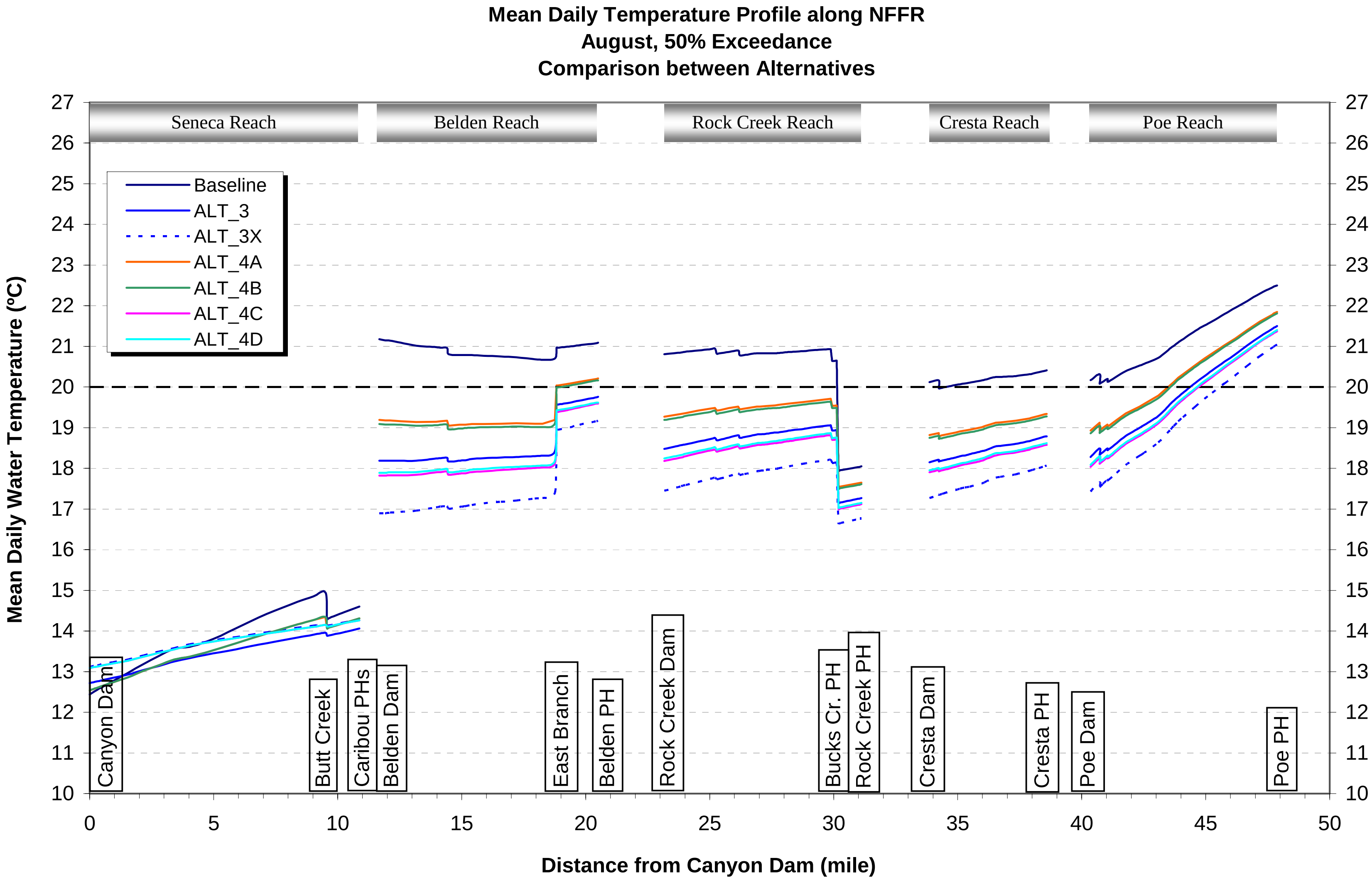


Figure 2-3a Comparison of NFFR Water Temperature Longitudinal Profiles between Alternatives — July, 25% Exceedence

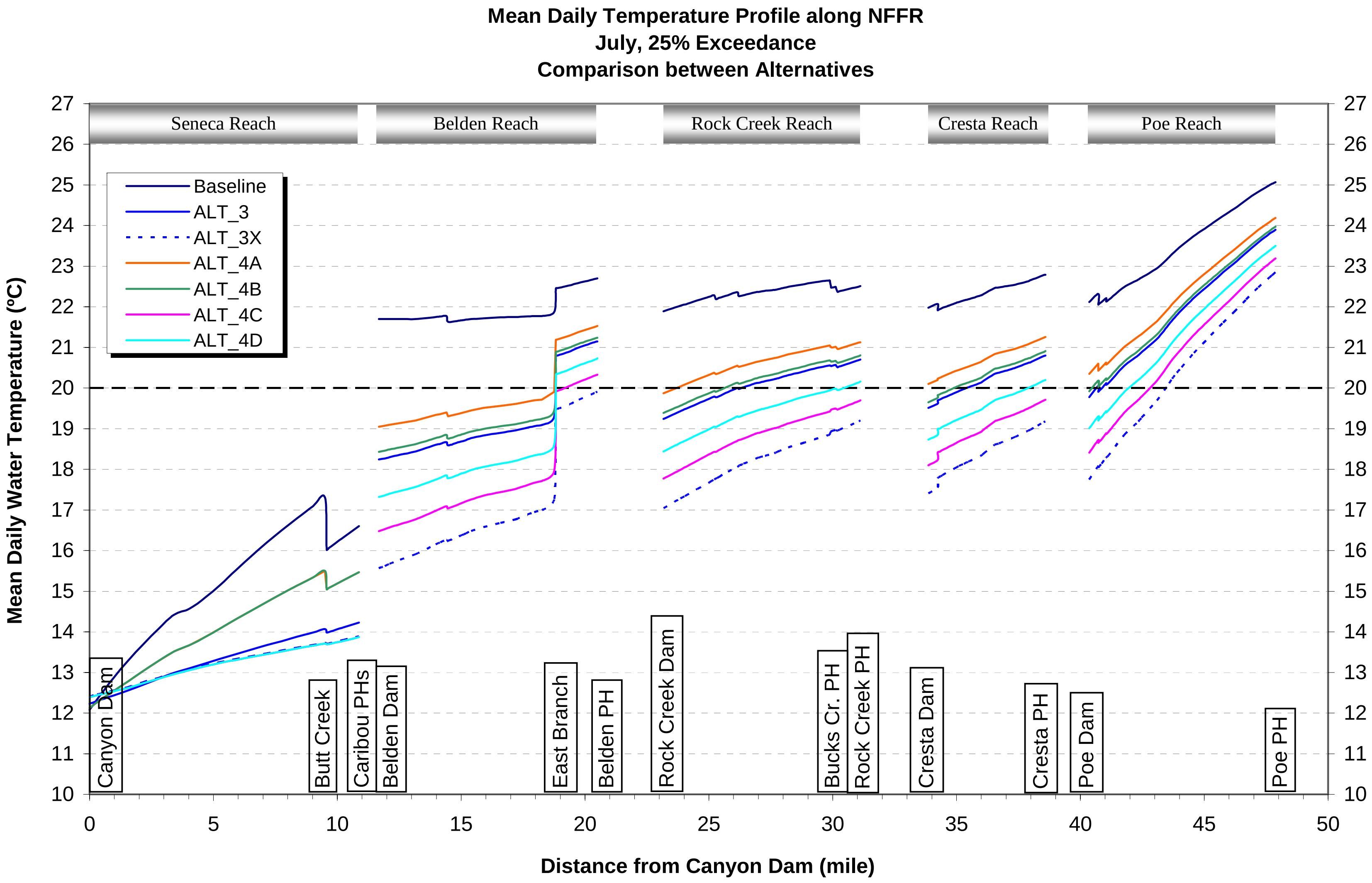


Figure 2-3b Comparison of NFFR Water Temperature Longitudinal Profiles between Alternatives — August, 25% Exceedence

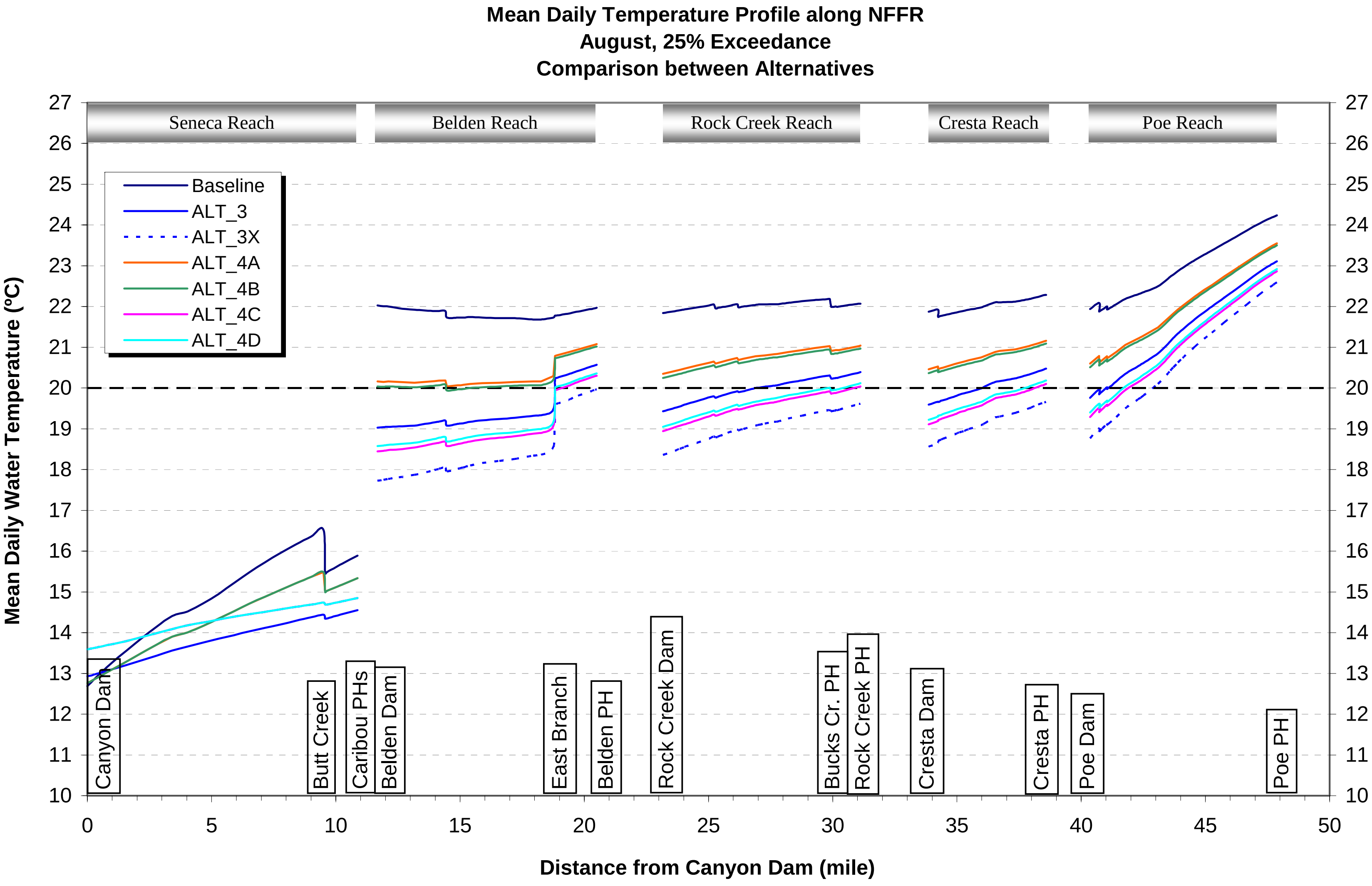


Figure 2-4a Comparison of NFFR Water Temperature Longitudinal Profiles between Alternatives — July, 10% Exceedence

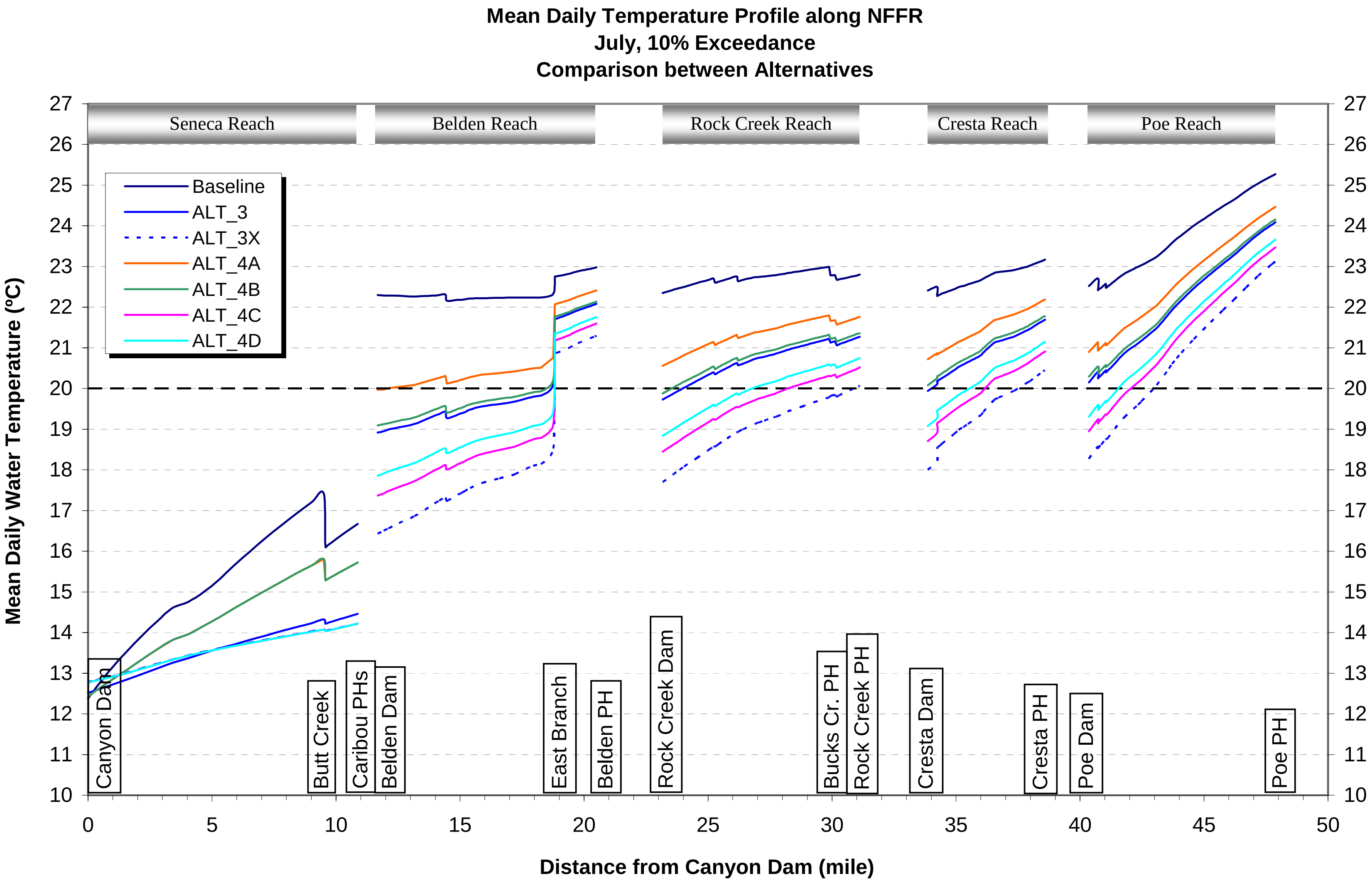


Figure 2-4b Comparison of NFFR Water Temperature Longitudinal Profiles between Alternatives — August, 10% Exceedence

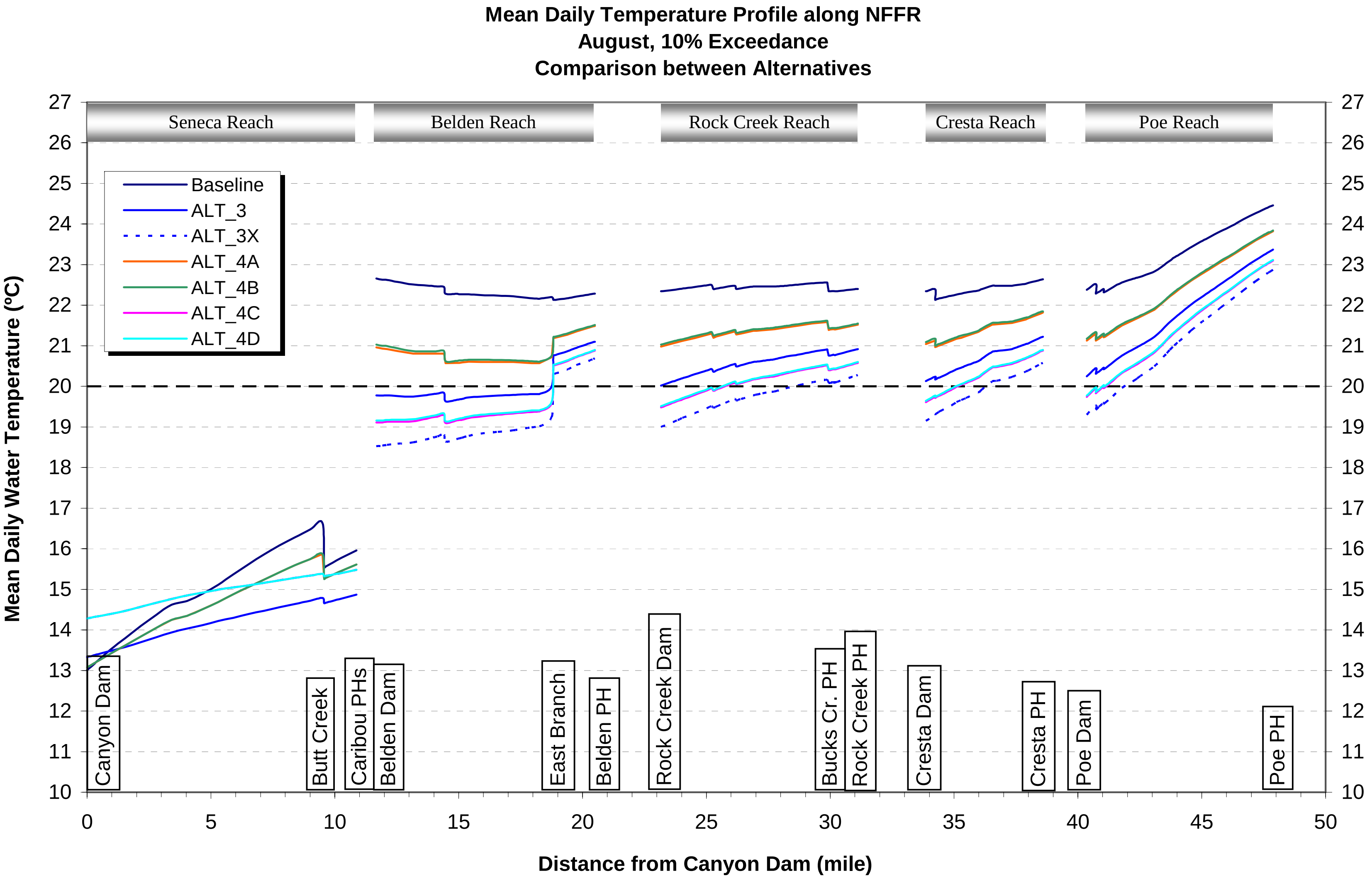


Figure 2-5a Comparison of NFFR Water Temperature Longitudinal Profiles between Alternatives — July, Maximum

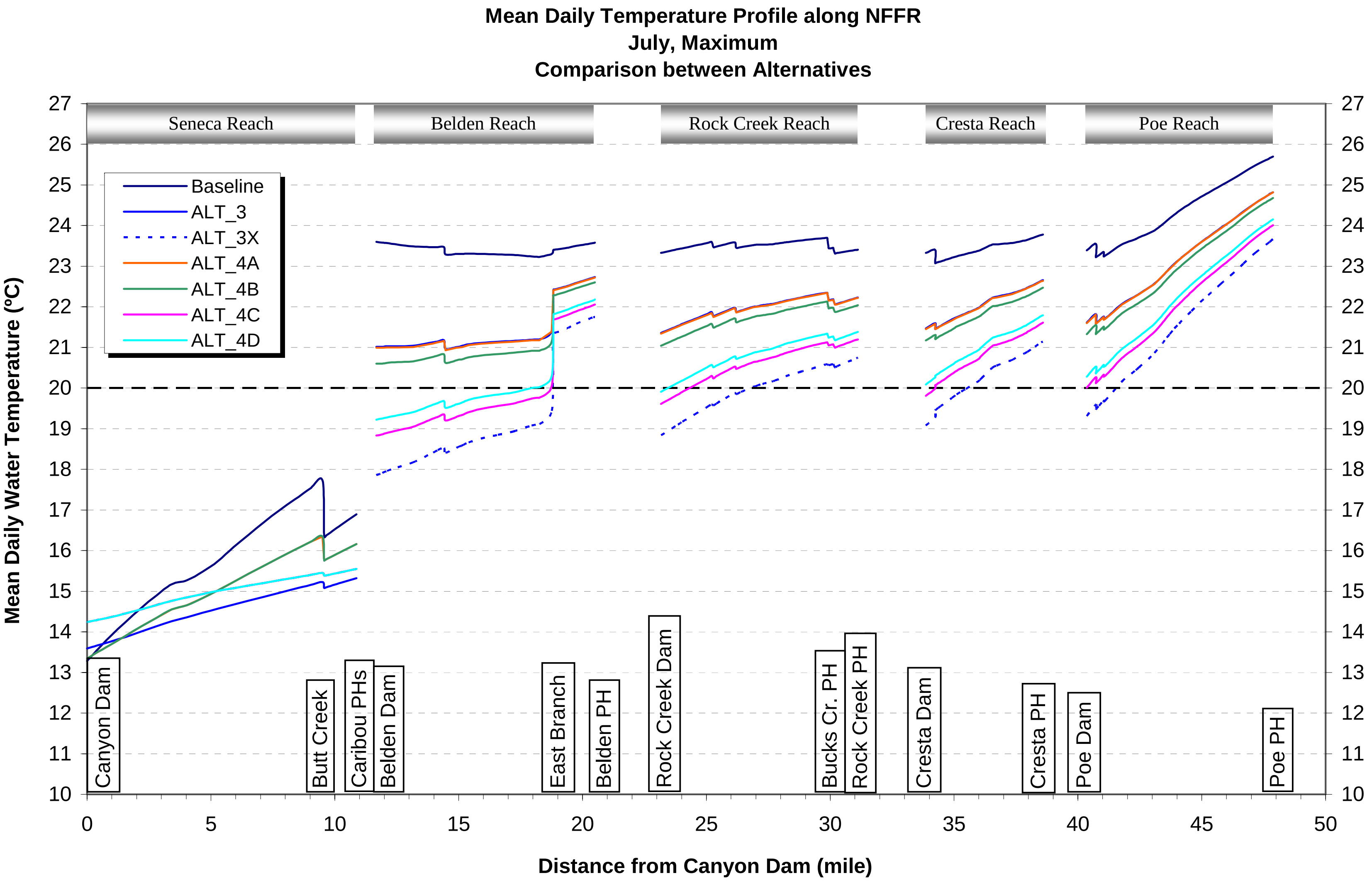


Figure 2-5b Comparison of NFFR Water Temperature Longitudinal Profiles between Alternatives — August, Maximum

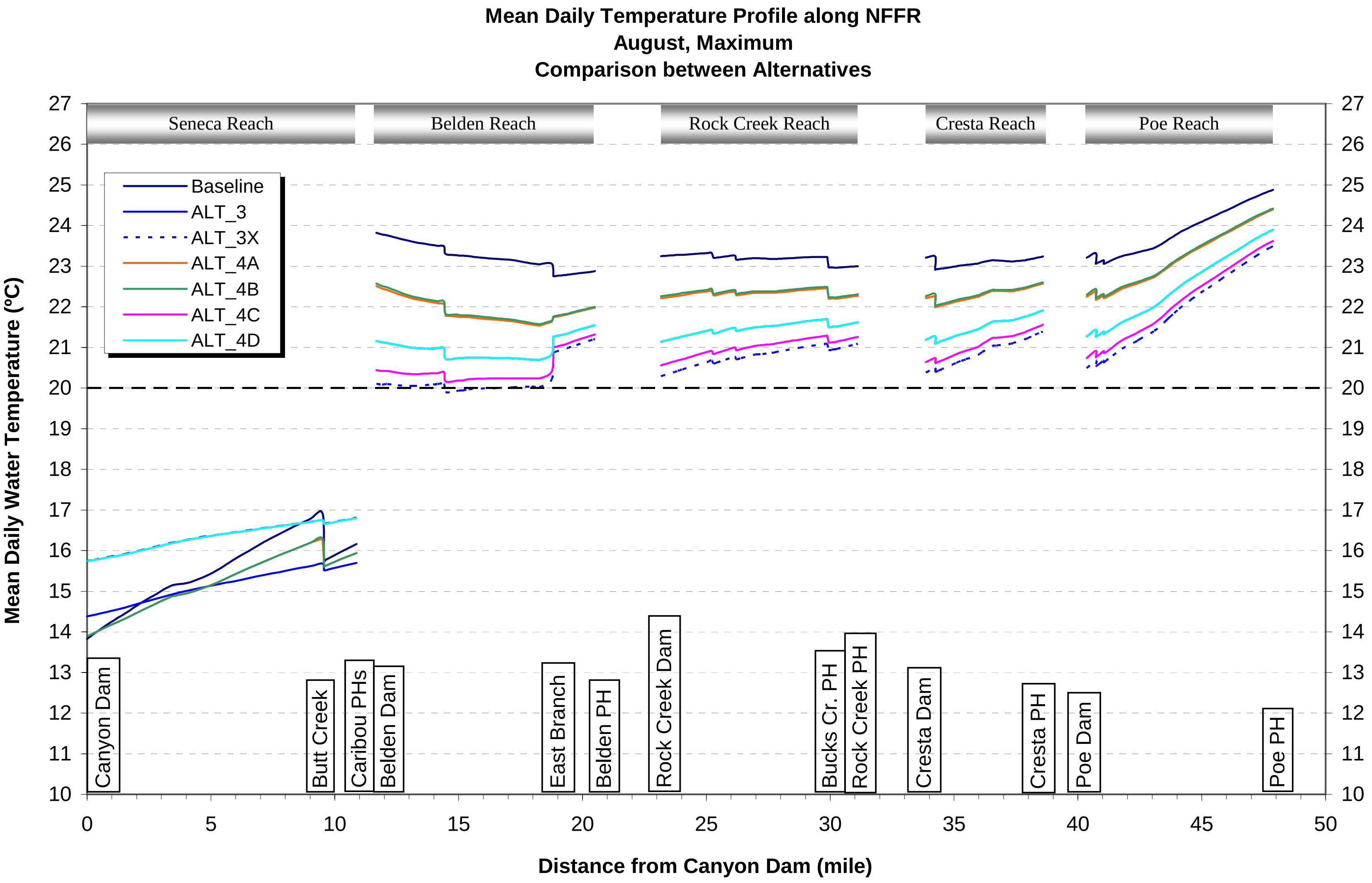


Figure 2-6a Comparison of NFFR Water Temperature Longitudinal Profiles between with and without Removing Submerged Levees — July, 50% Exceedence

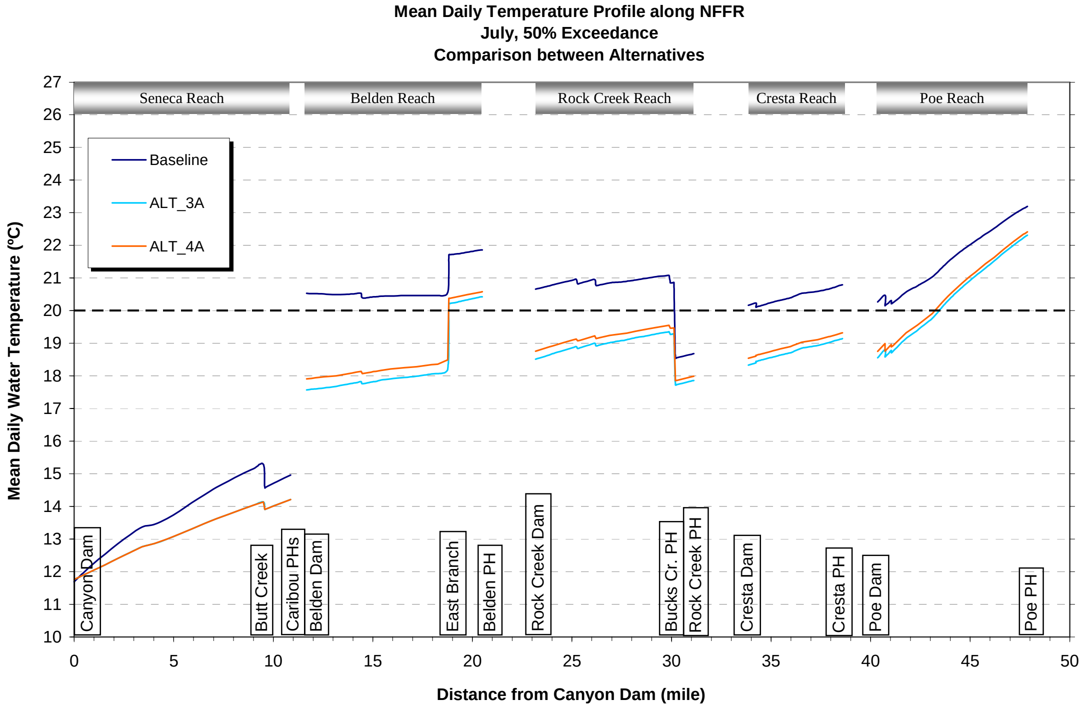
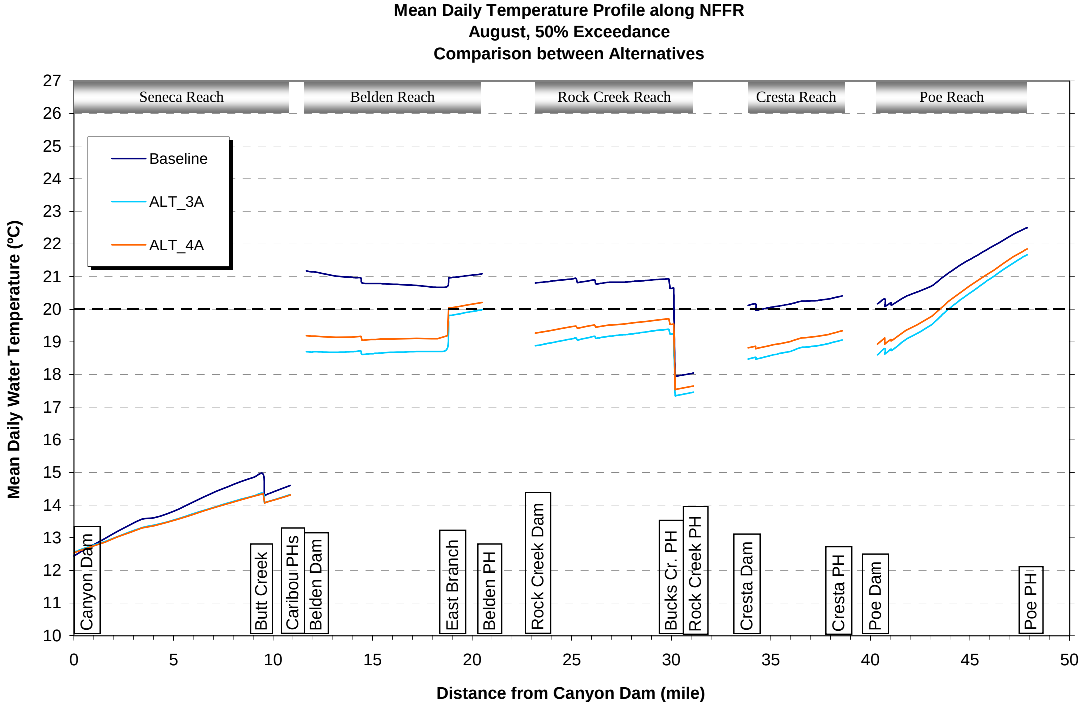


Figure 2-6b Comparison of NFFR Water Temperature Longitudinal Profiles between with and without Removing Submerged Levees — August, 50% Exceedence



Note: The added Alternative 3A is similar to Alternative 4A except that Alternative 3A includes an additional measure of removing the submerged levees near Prattville Intake.

Figure 2-7a Comparison of NFFR Water Temperature Longitudinal Profiles between with and without Removing Submerged Levees — July, 25% Exceedence

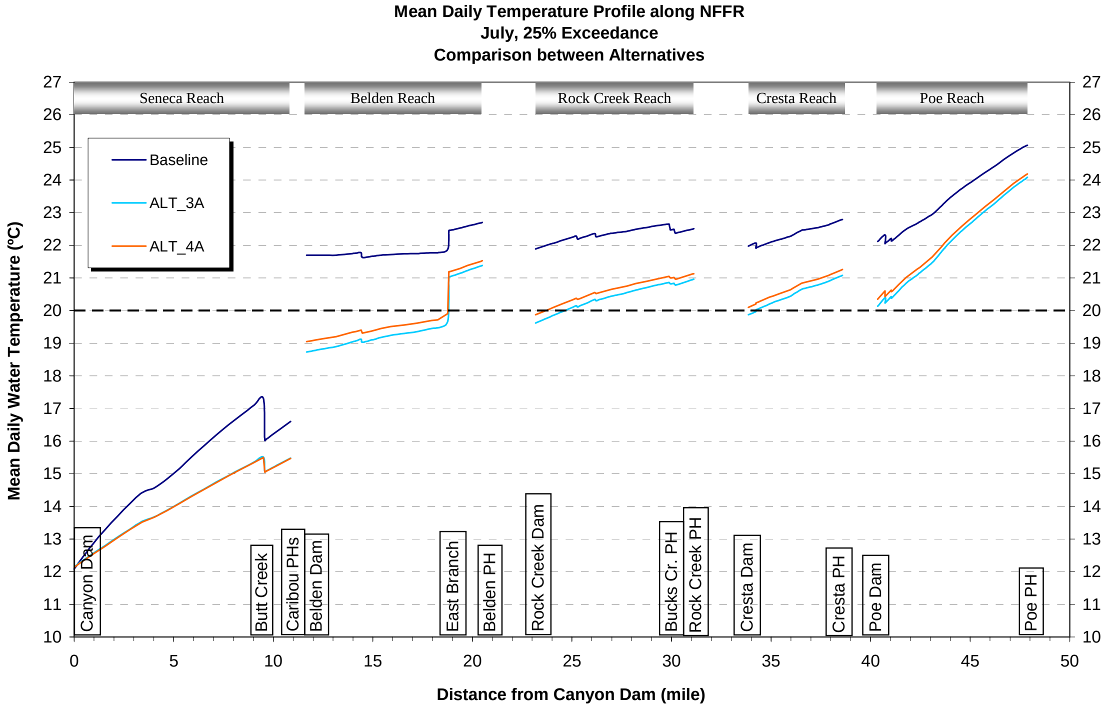


Figure 2-7b Comparison of NFFR Water Temperature Longitudinal Profiles between with and without Removing Submerged Levees — August, 25% Exceedence

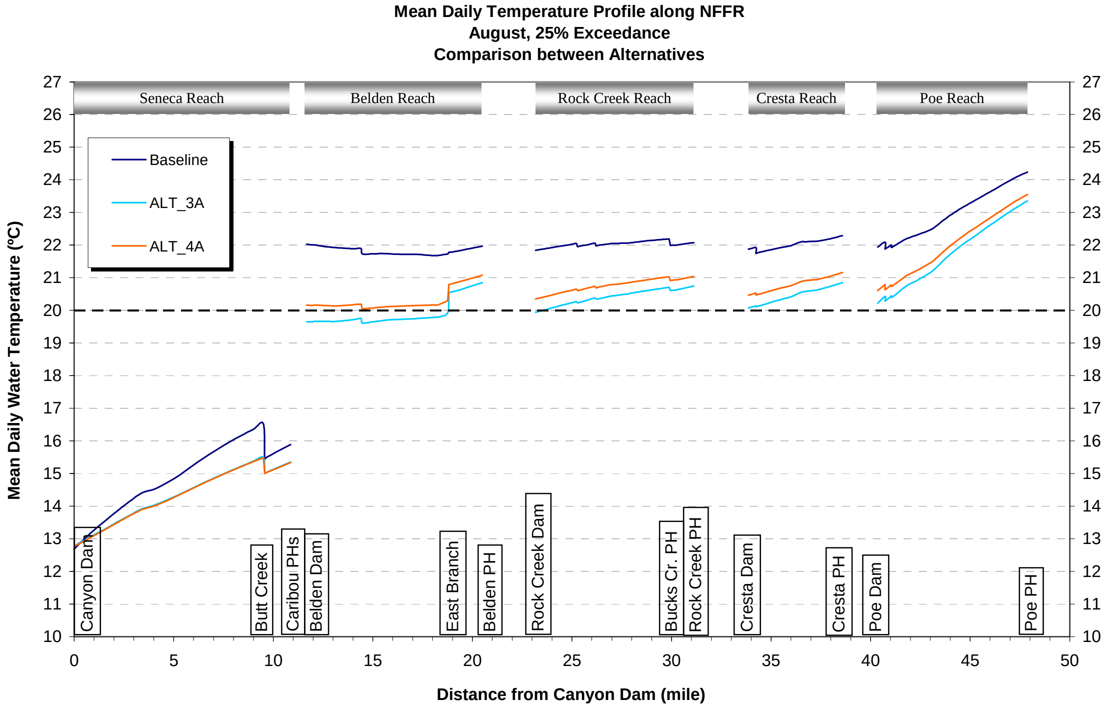


Figure 2-8a Comparison of NFFR Water Temperature Longitudinal Profiles between with and without Removing Submerged Levees — July, 10% Exceedence

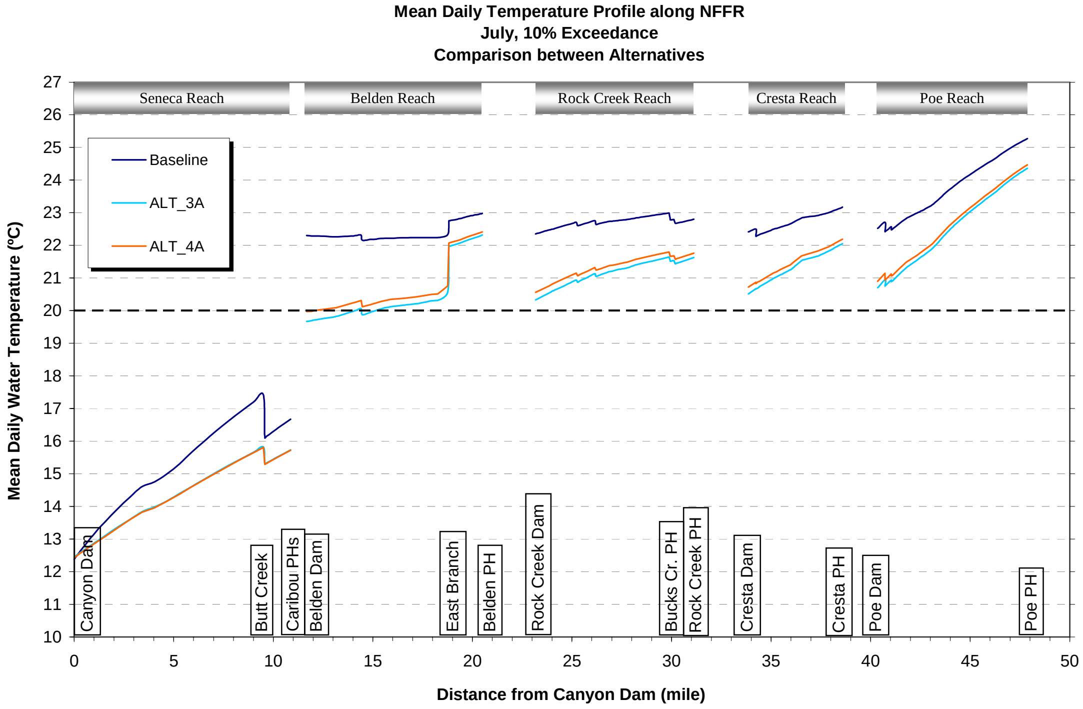


Figure 2-8b Comparison of NFFR Water Temperature Longitudinal Profiles between with and without Removing Submerged Levees — August, 10% Exceedence

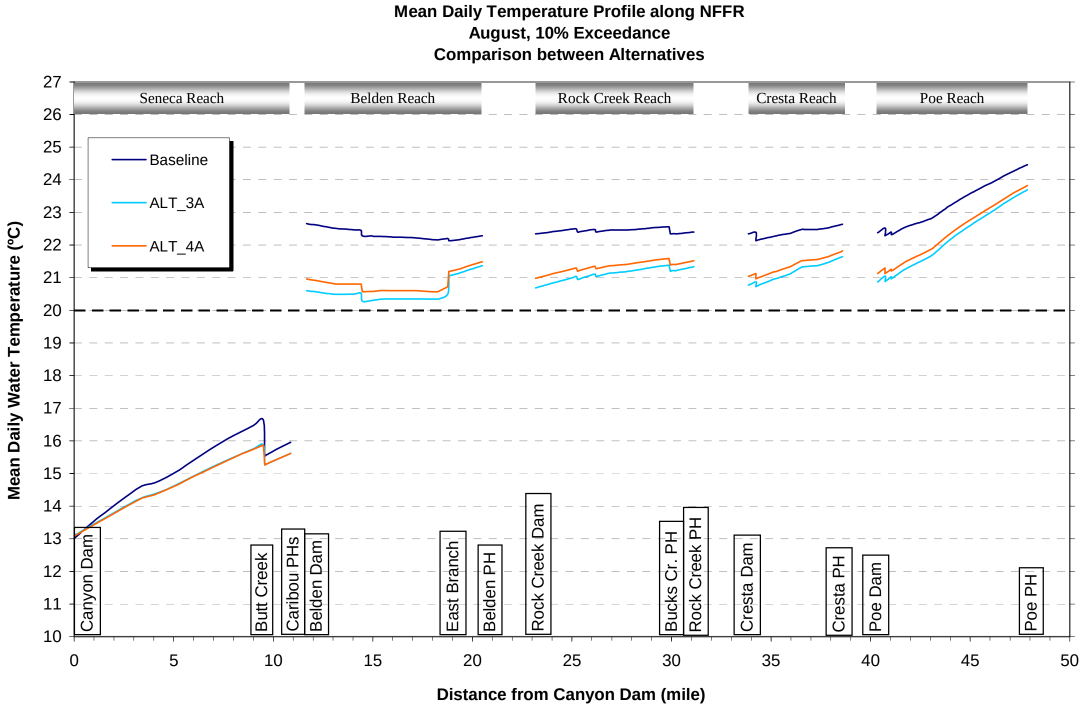


Figure 2-9a Comparison of NFFR Water Temperature Longitudinal Profiles between with and without Removing Submerged Levees — July, Maximum

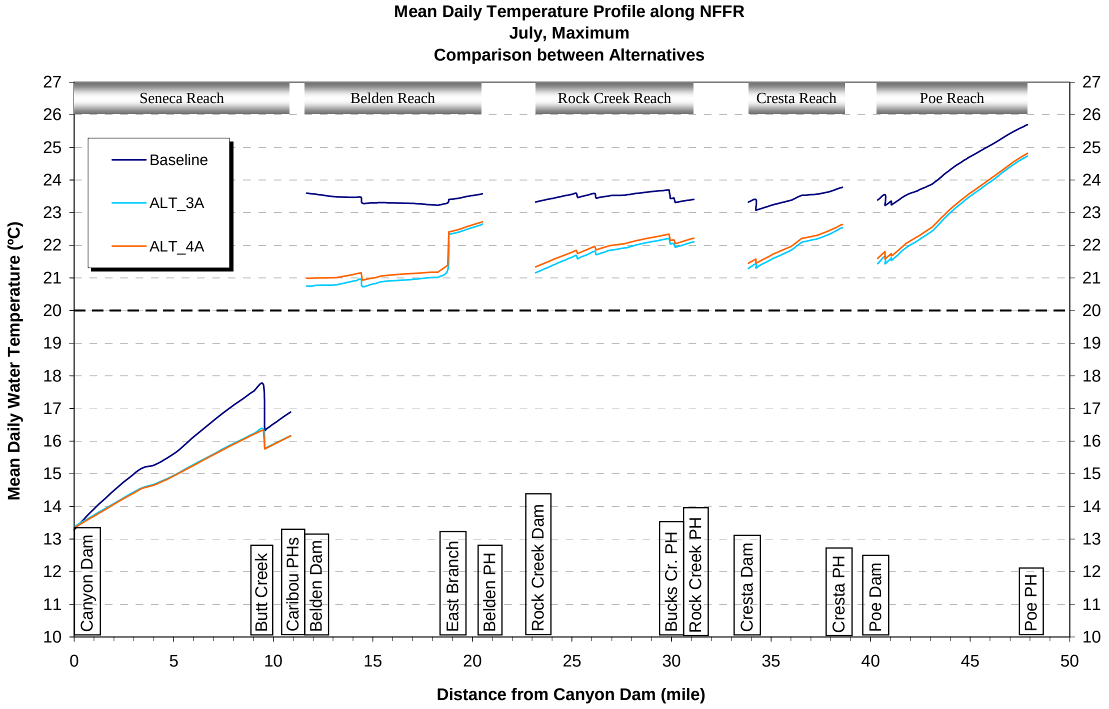


Figure 2-9b Comparison of NFFR Water Temperature Longitudinal Profiles between with and without Removing Submerged Levees — August, Maximum

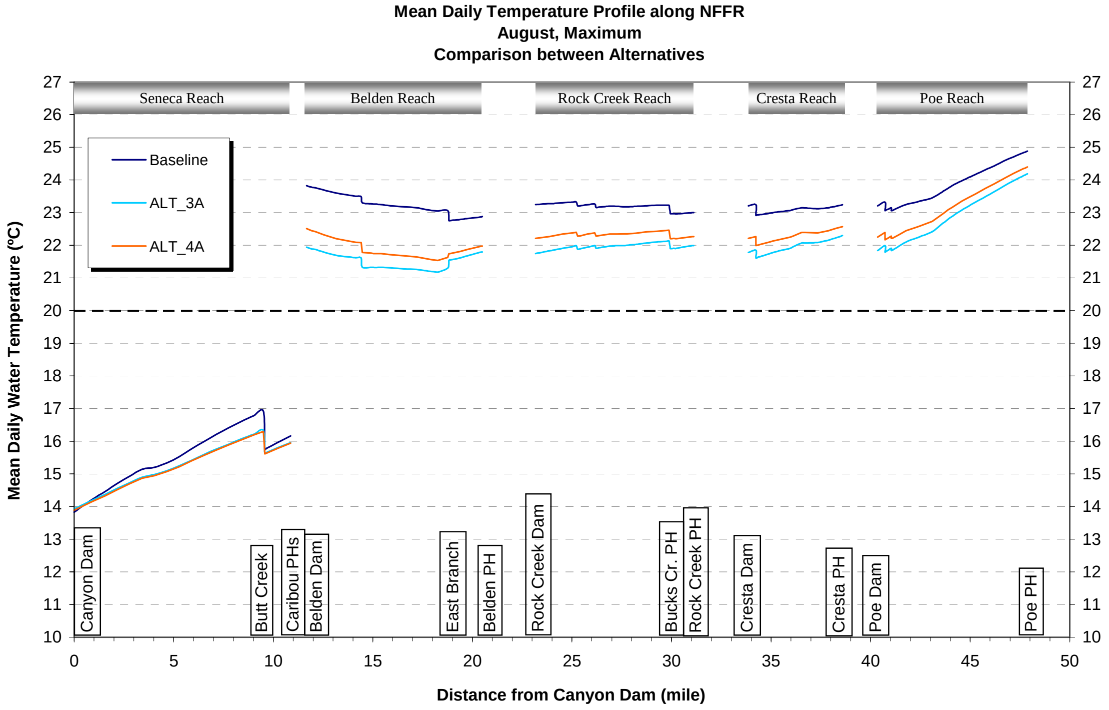


Figure 2-10a Comparison of NFFR Water Temperature Longitudinal Profiles between the Baseline and "Present Day" Conditions — July, 50% Exceedence

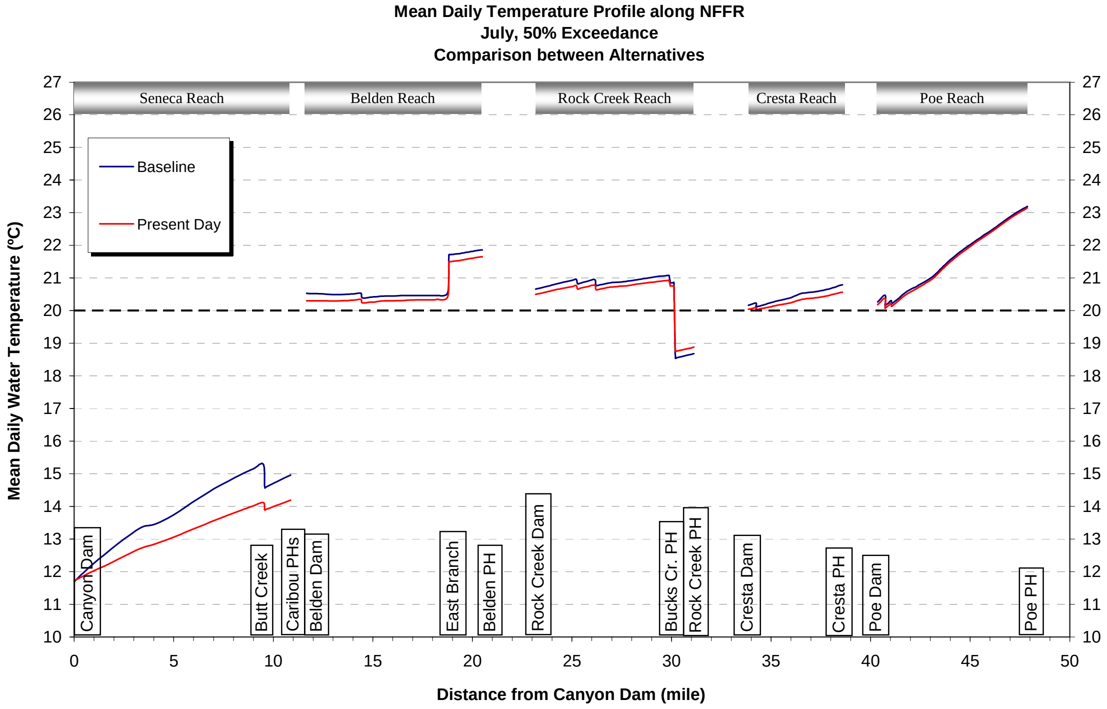


Figure 2-10b Comparison of NFFR Water Temperature Longitudinal Profiles between the Baseline and "Present Day" Conditions — August, 50% Exceedence

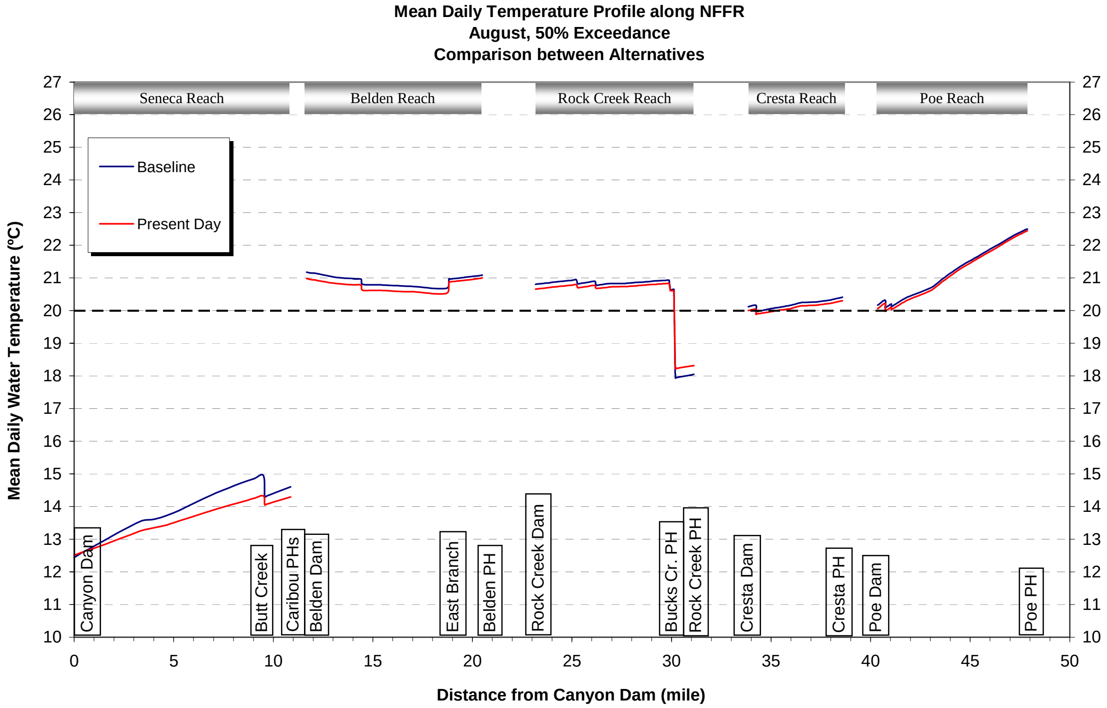


Figure 2-11a Comparison of NFFR Water Temperature Longitudinal Profiles between the Baseline and “Present Day” Conditions — July, 25% Exceedence

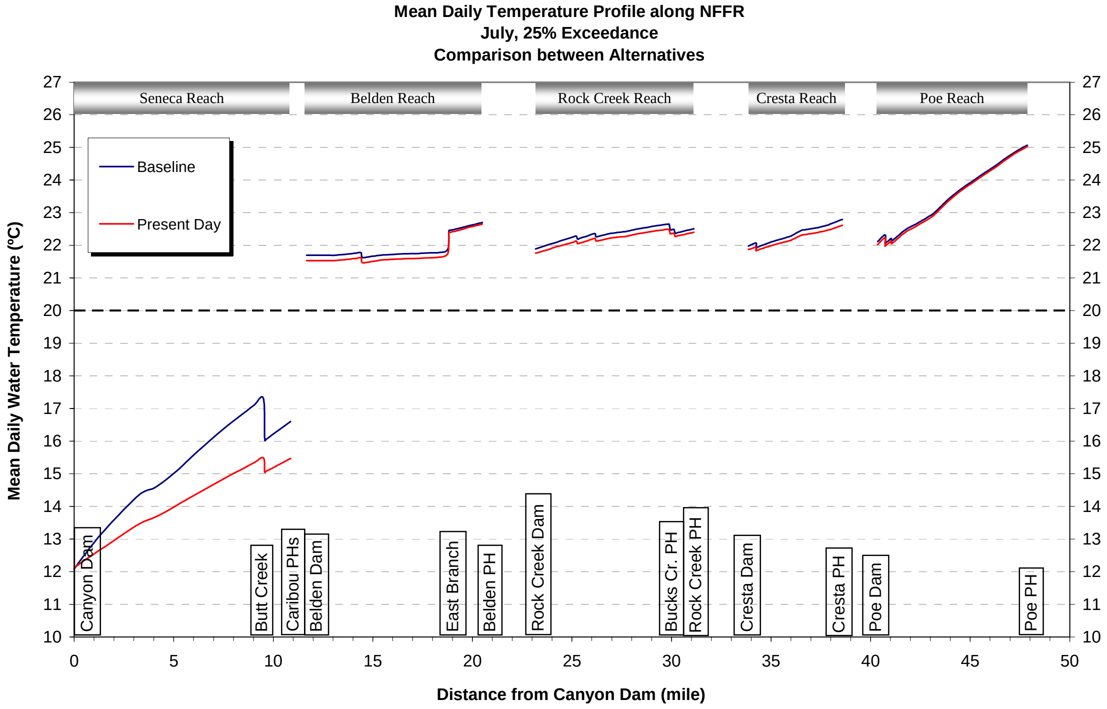


Figure 2-11b Comparison of NFFR Water Temperature Longitudinal Profiles between the Baseline and “Present Day” Conditions — August, 25% Exceedence

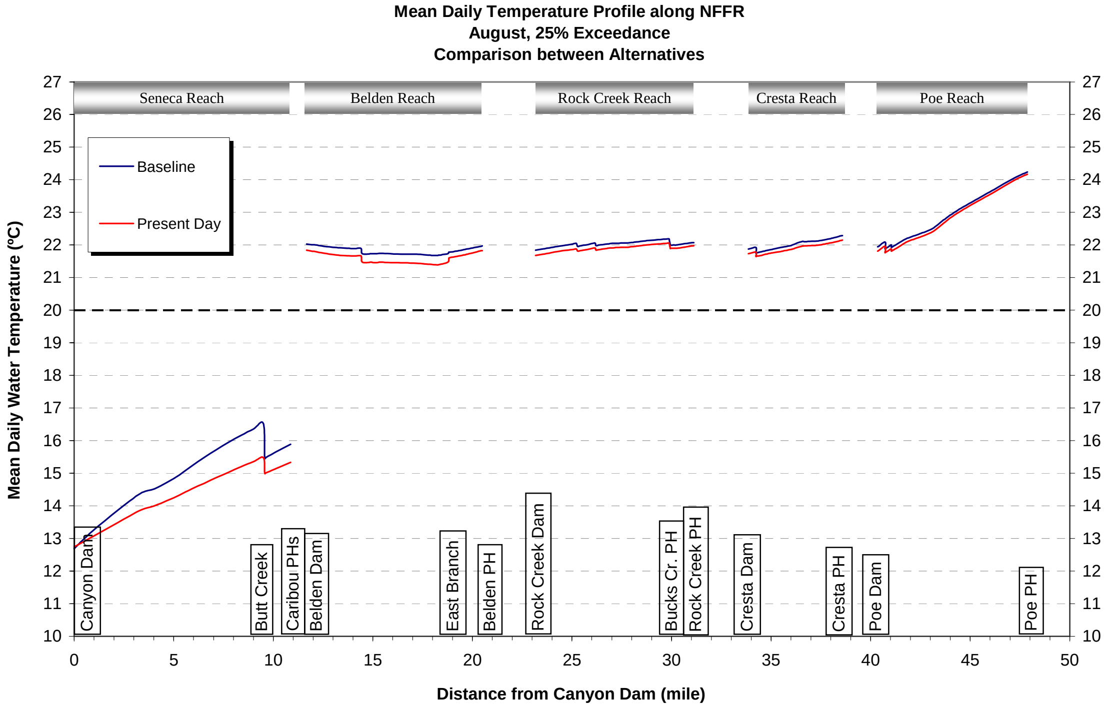


Figure 2-12a Comparison of NFFR Water Temperature Longitudinal Profiles between the Baseline and "Present Day" Conditions — July, 10% Exceedence

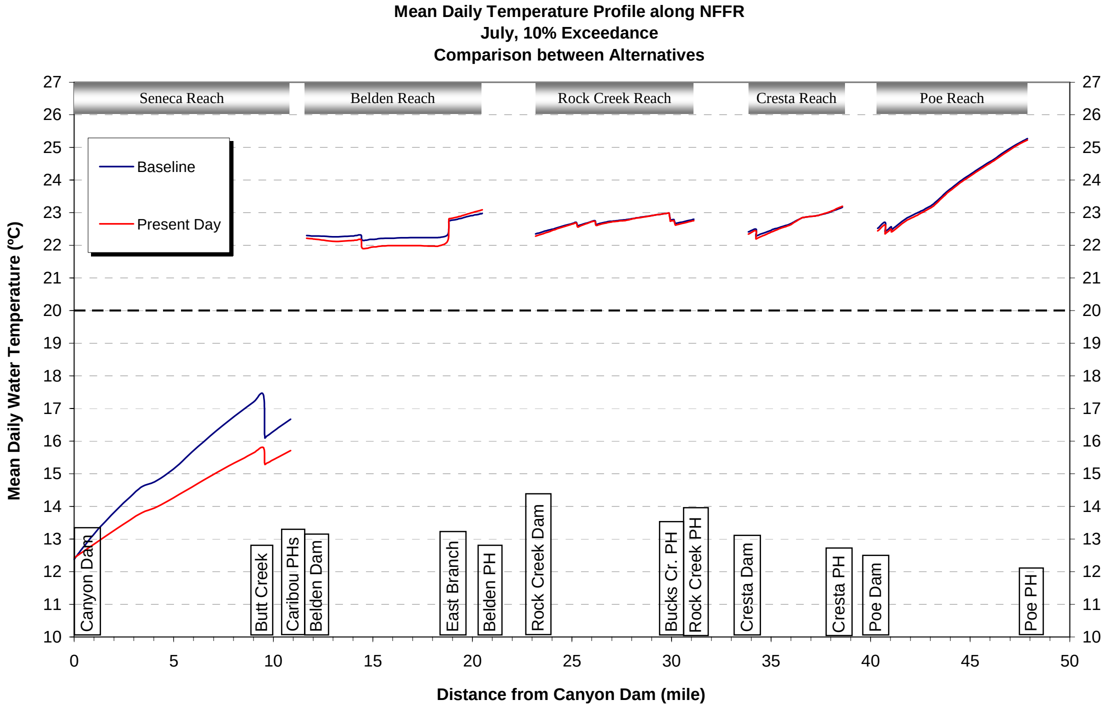


Figure 2-12b Comparison of NFFR Water Temperature Longitudinal Profiles between the Baseline and "Present Day" Conditions — August, 10% Exceedence

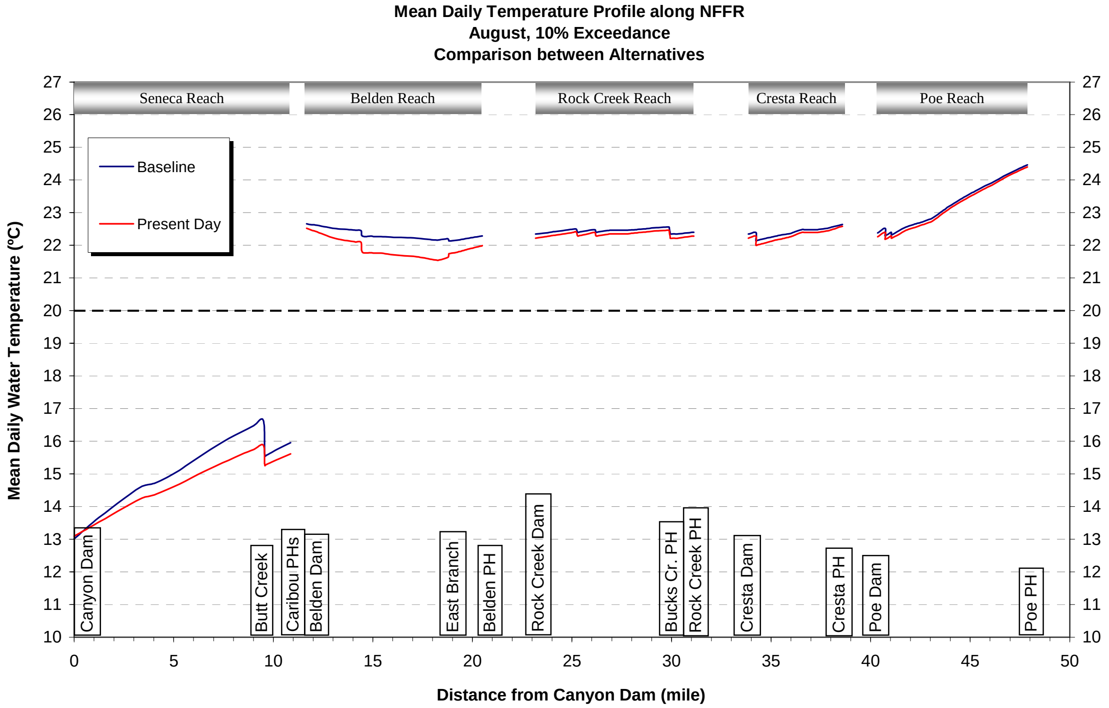


Figure 2-13a Comparison of NFFR Water Temperature Longitudinal Profiles between the Baseline and "Present Day" Conditions — July, Maximum

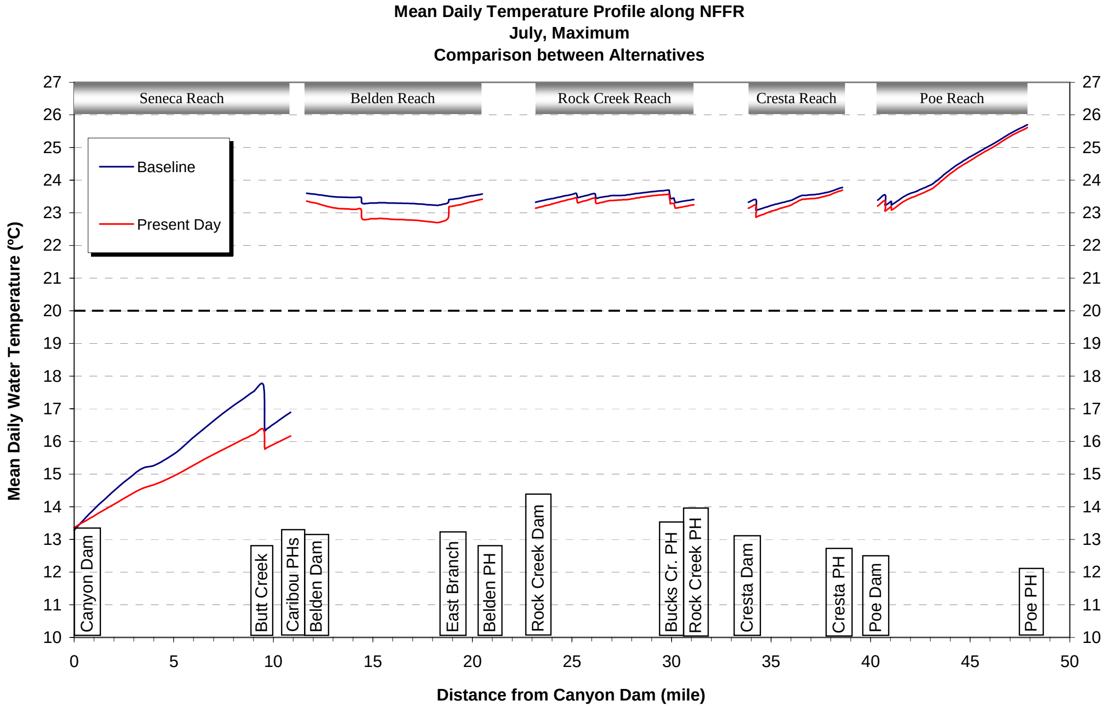


Figure 2-13b Comparison of NFFR Water Temperature Longitudinal Profiles between the Baseline and "Present Day" Conditions — August, Maximum

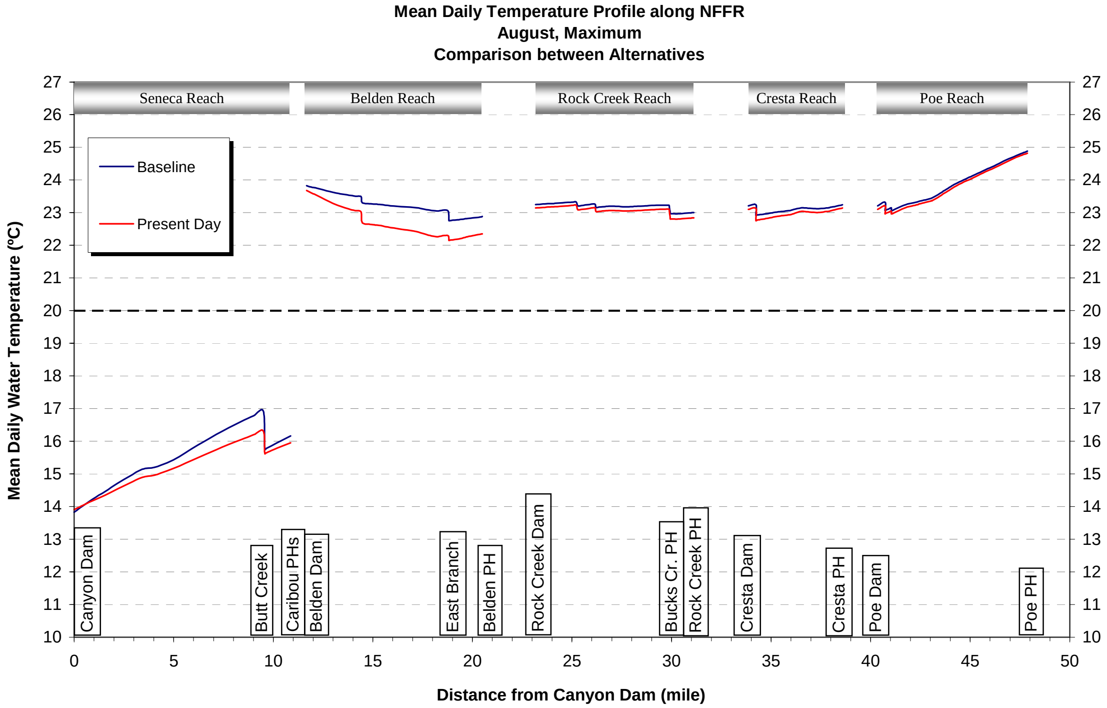


Figure 2-14 NFFR Longitudinal Water Temperature Profiles in Summer Months — Baseline

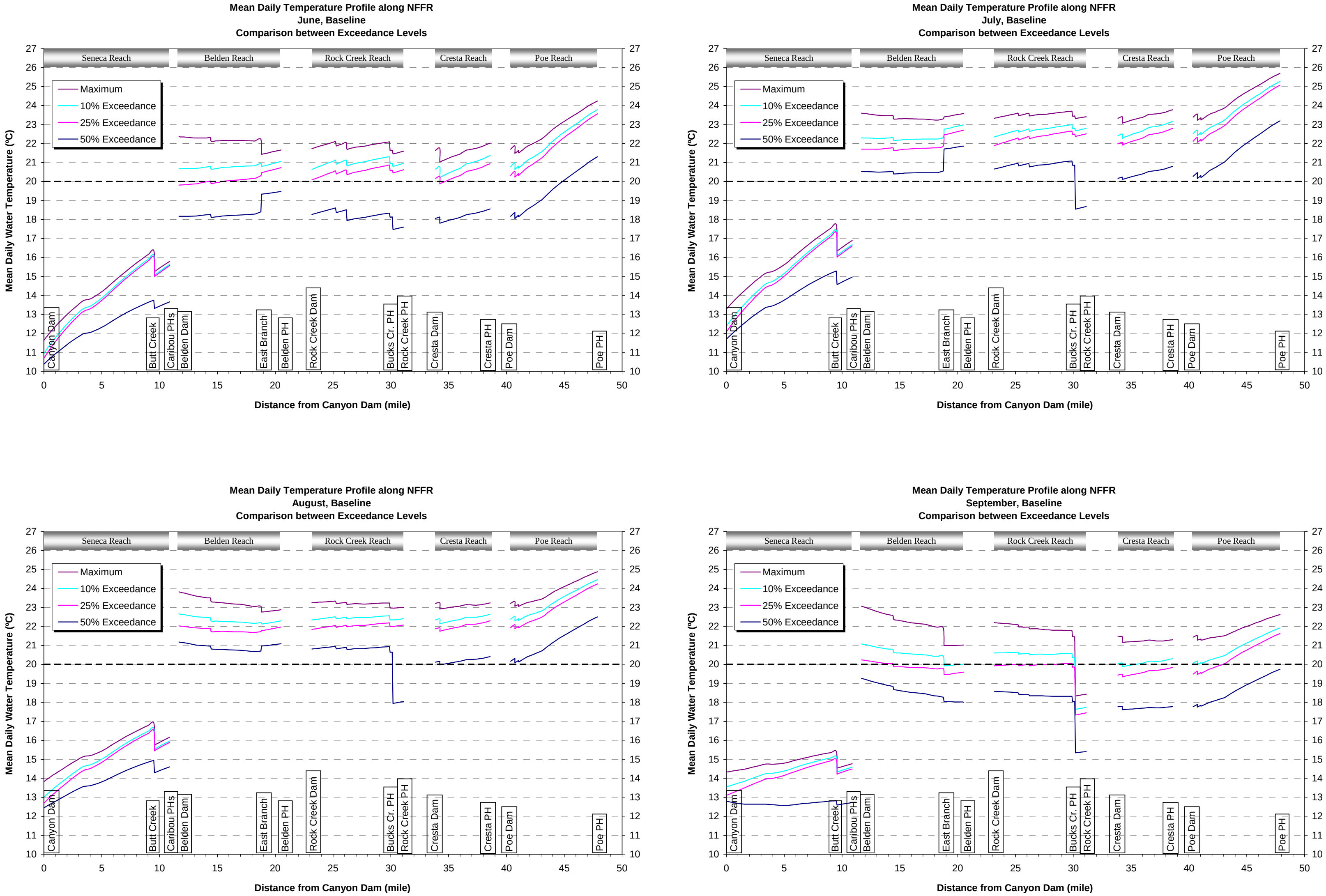
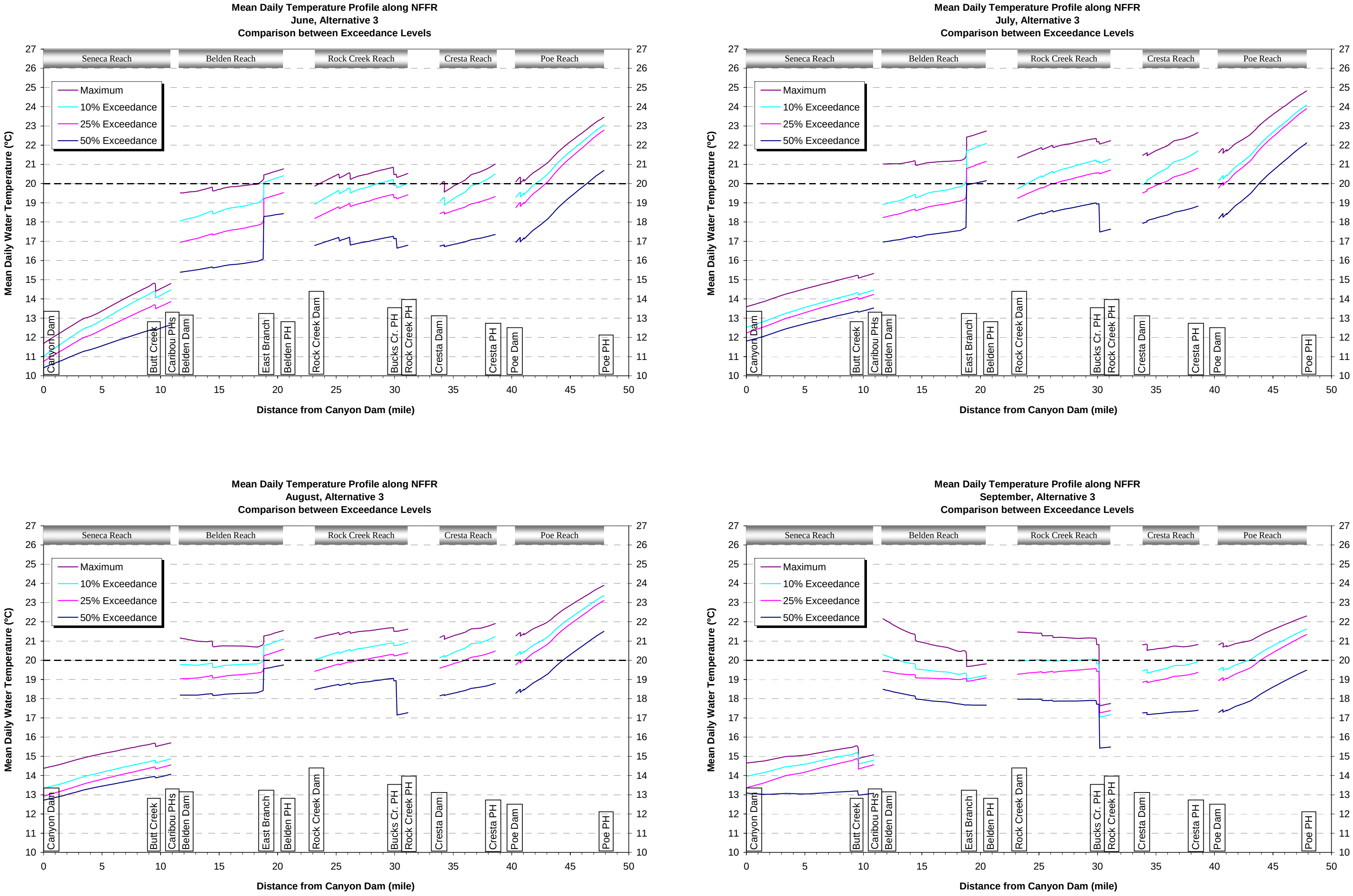


Figure 2-15 NFFR Longitudinal Water Temperature Profiles in Summer Months — Alternative 3



Mean Daily Temperature Profile along NFFR
June, Alternative 3
Comparison between Exceedance Levels

Mean Daily Temperature Profile along NFFR
July, Alternative 3
Comparison between Exceedance Levels

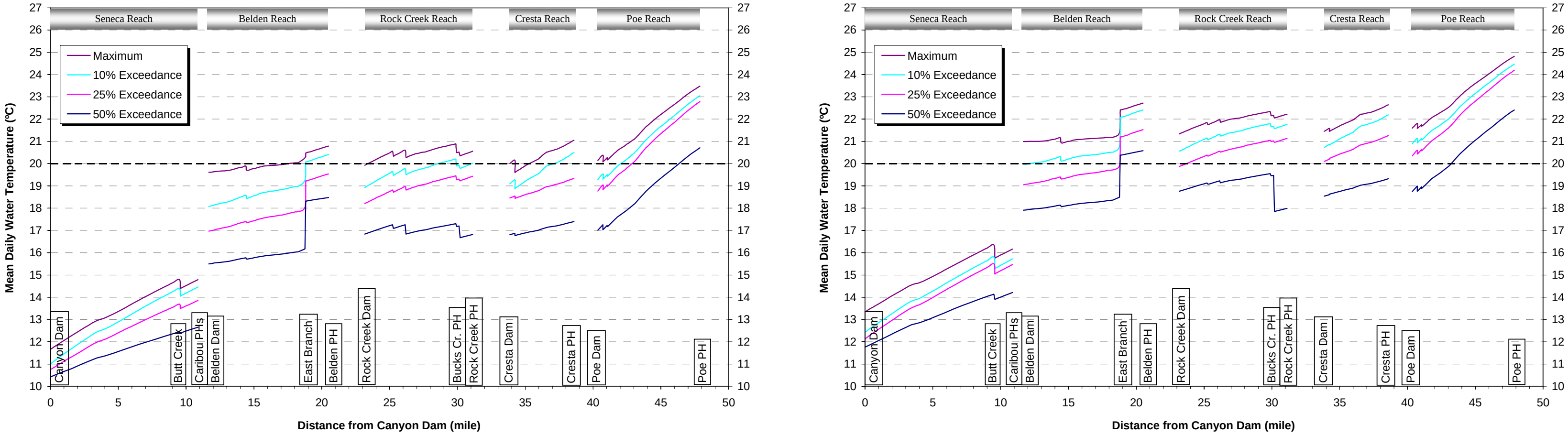
Mean Daily Temperature Profile along NFFR
August, Alternative 3
Comparison between Exceedance Levels

Mean Daily Temperature Profile along NFFR
September, Alternative 3
Comparison between Exceedance Levels

Figure 2-16 NFFR Longitudinal Water Temperature Profiles in Summer Months — Alternative 4A

Mean Daily Temperature Profile along NFFR
June, Alternative 4a
Comparison between Exceedance Levels

Mean Daily Temperature Profile along NFFR
July, Alternative 4a
Comparison between Exceedance Levels



Mean Daily Temperature Profile along NFFR
August, Alternative 4a
Comparison between Exceedance Levels

Mean Daily Temperature Profile along NFFR
September, Alternative 4a
Comparison between Exceedance Levels

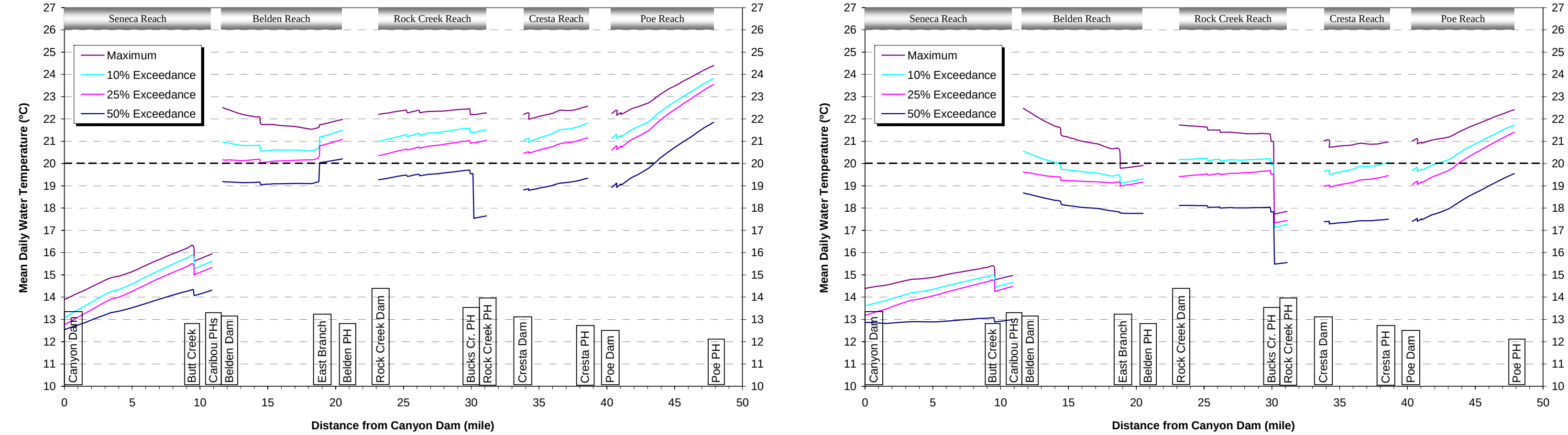


Figure 2-17 NFFR Longitudinal Water Temperature Profiles in Summer Months — Alternative 4B

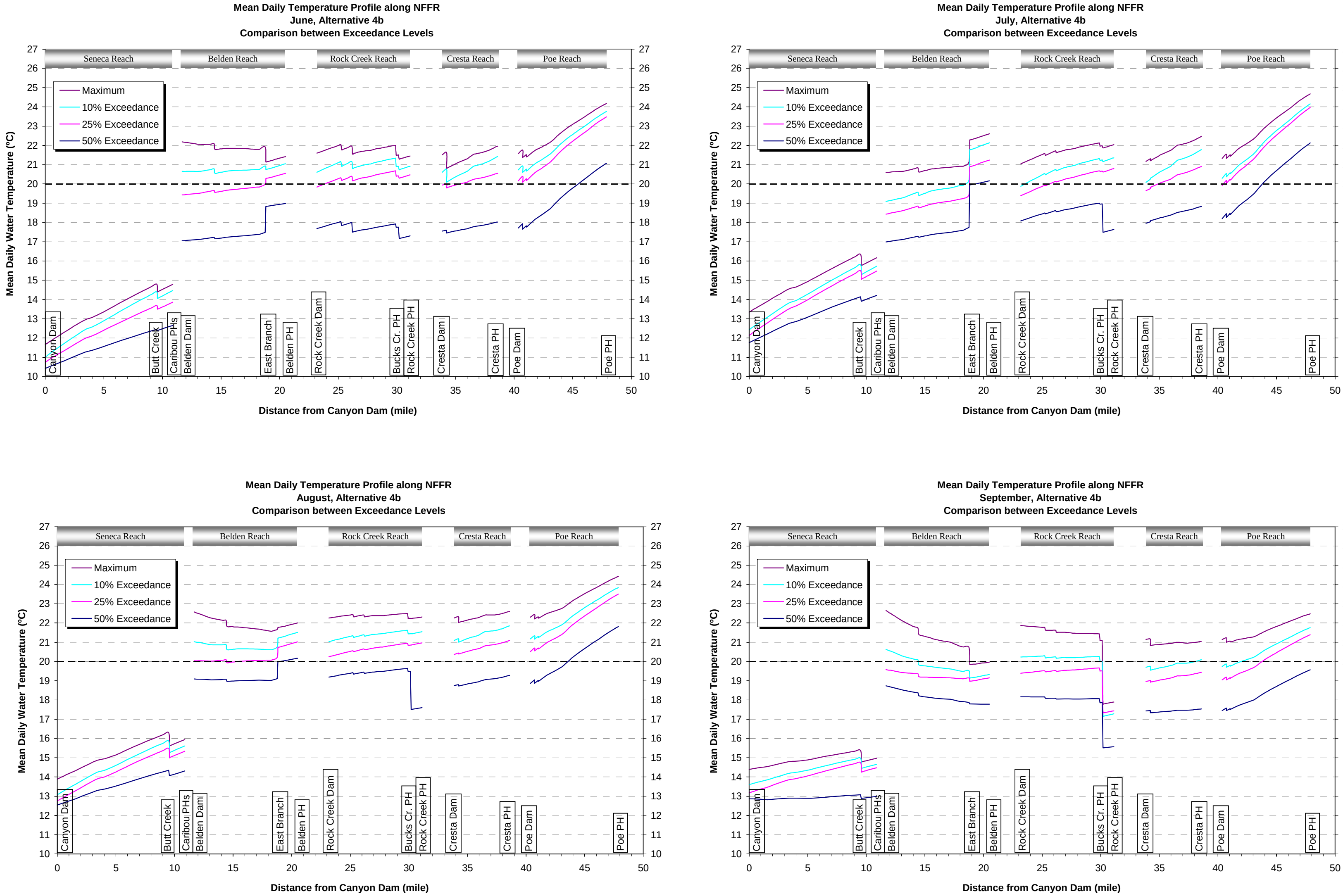
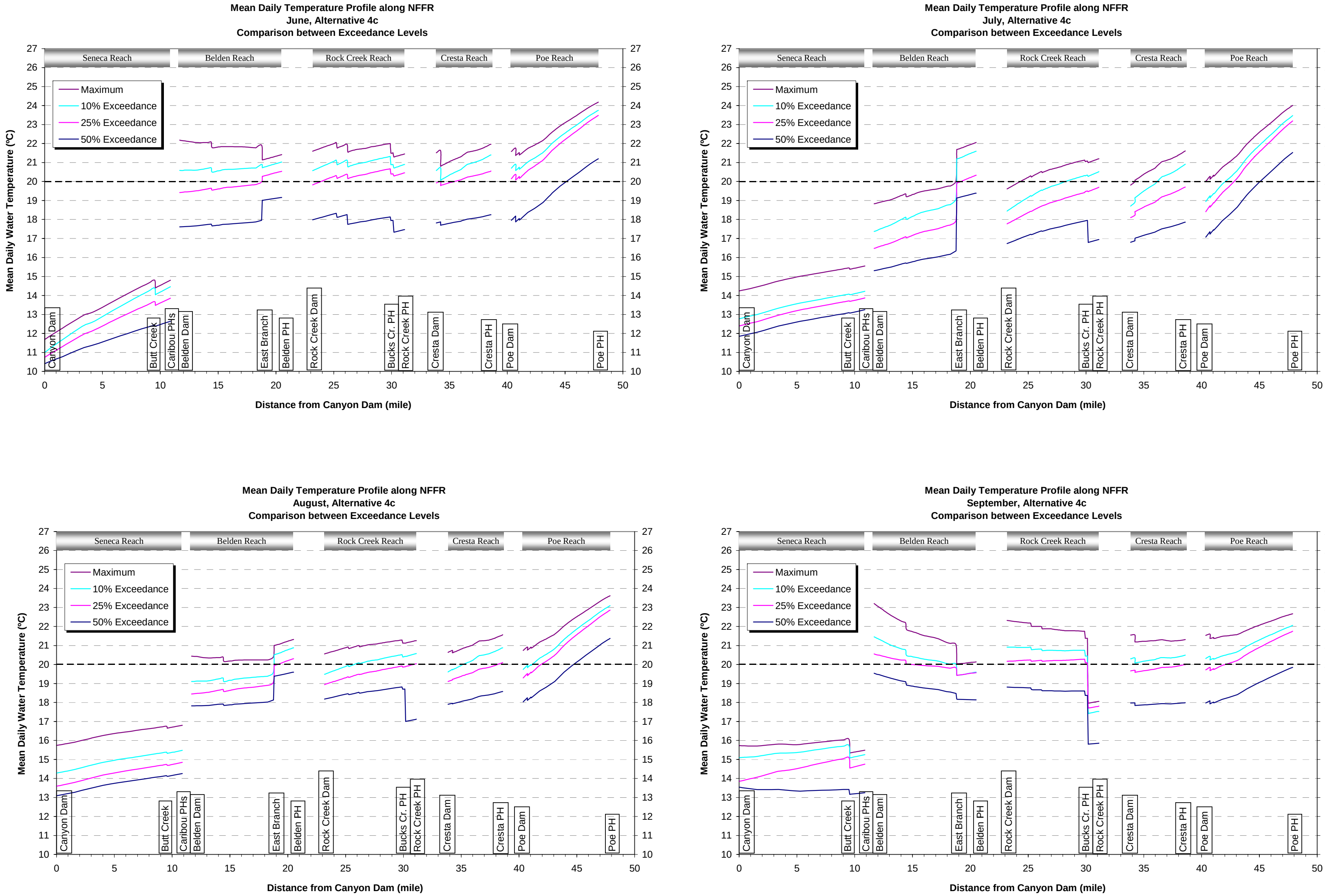


Figure 2-18 NFFR Longitudinal Water Temperature Profiles in Summer Months — Alternative 4C


Mean Daily Temperature Profile along NFFR
June, Alternative 4c
Comparison between Exceedance Levels

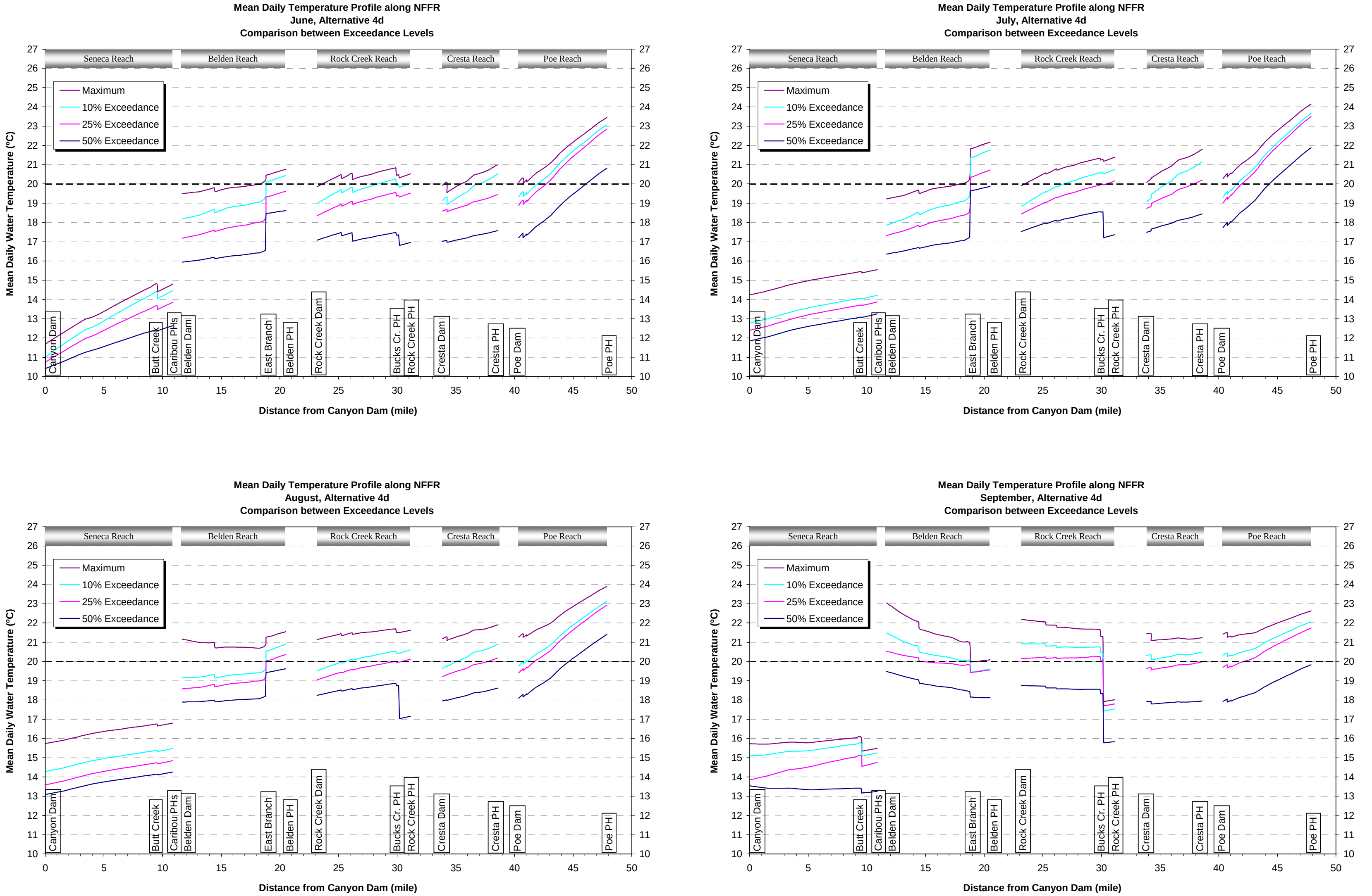
Mean Daily Temperature Profile along NFFR
July, Alternative 4c
Comparison between Exceedance Levels

Mean Daily Temperature Profile along NFFR
August, Alternative 4c
Comparison between Exceedance Levels

Mean Daily Temperature Profile along NFFR
September, Alternative 4c
Comparison between Exceedance Levels

Figure 2-19 NFFR Longitudinal Water Temperature Profiles in Summer Months — Alternative 4D

(Note: The added Alternative 4D is similar to Alternative 4C, except that the measure of preferential use of Caribou #1 is changed to installation of thermal curtain near Caribou Intake)



Mean Daily Temperature Profile along NFFR
June, Alternative 4d
Comparison between Exceedance Levels

Mean Daily Temperature Profile along NFFR
July, Alternative 4d
Comparison between Exceedance Levels

Mean Daily Temperature Profile along NFFR
August, Alternative 4d
Comparison between Exceedance Levels

Mean Daily Temperature Profile along NFFR
September, Alternative 4d
Comparison between Exceedance Levels

Figure 2-20a Belden Reservoir July Water Temperatures for a Range of Release Rates at Canyon Dam Low-Level Outlet – Alternative 3

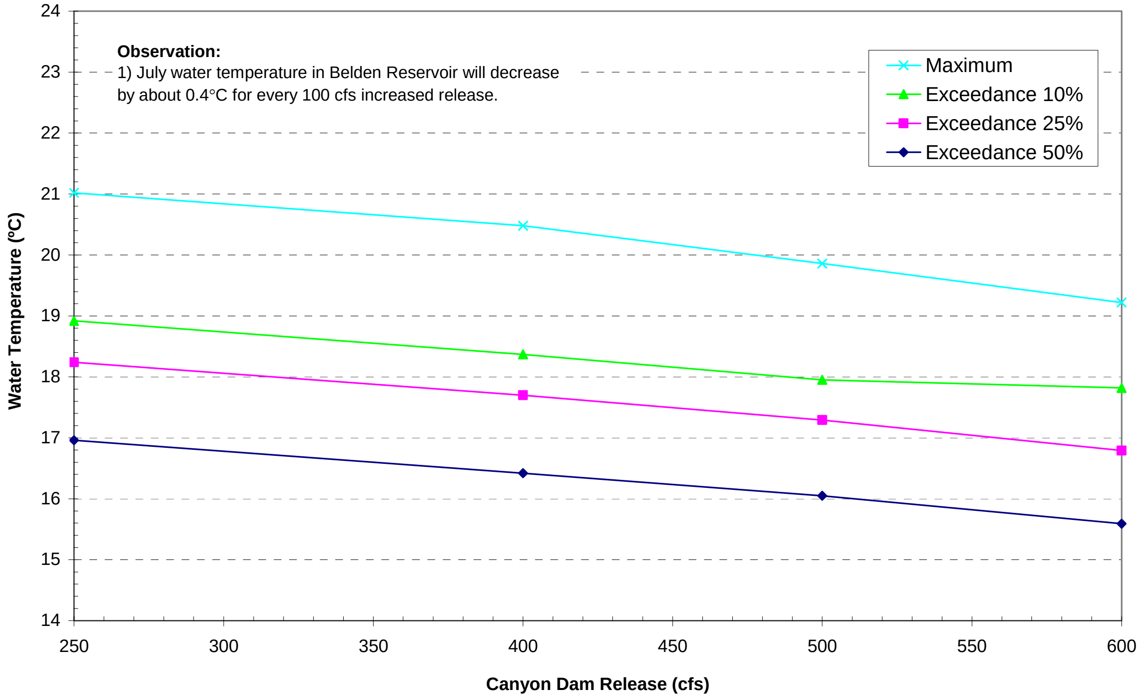


Figure 2-20b Belden Reservoir August Water Temperatures for a Range of Release Rates at Canyon Dam Low-Level Outlet – Alternative 3

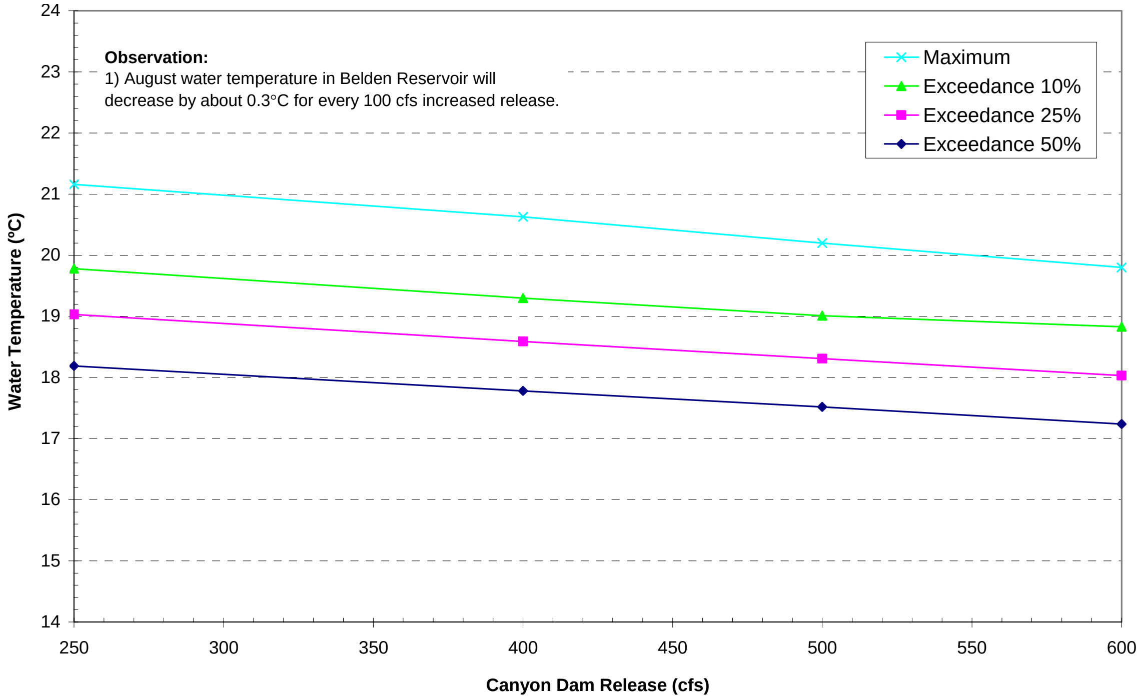


Figure 2-21a Belden Reservoir July Water Temperatures for a Range of Release Rates at Canyon Dam Low-Level Outlet – Alternative 4a

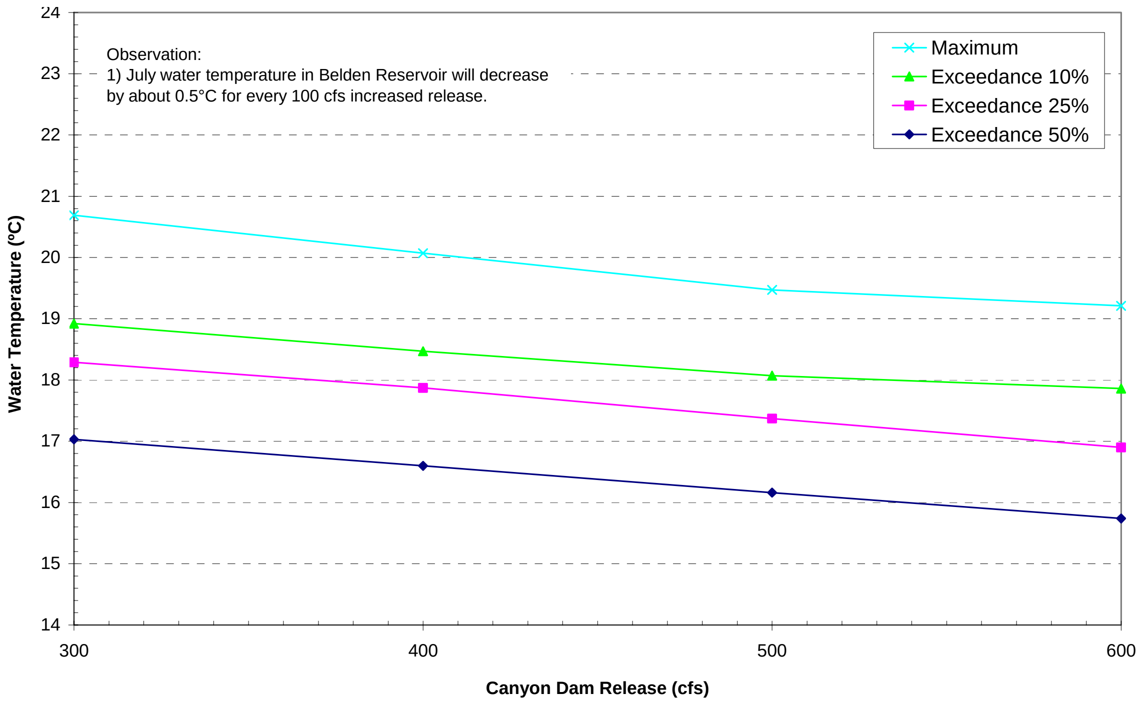


Figure 2-21b Belden Reservoir August Water Temperatures for a Range of Release Rates at Canyon Dam Low-Level Outlet – Alternative 4a

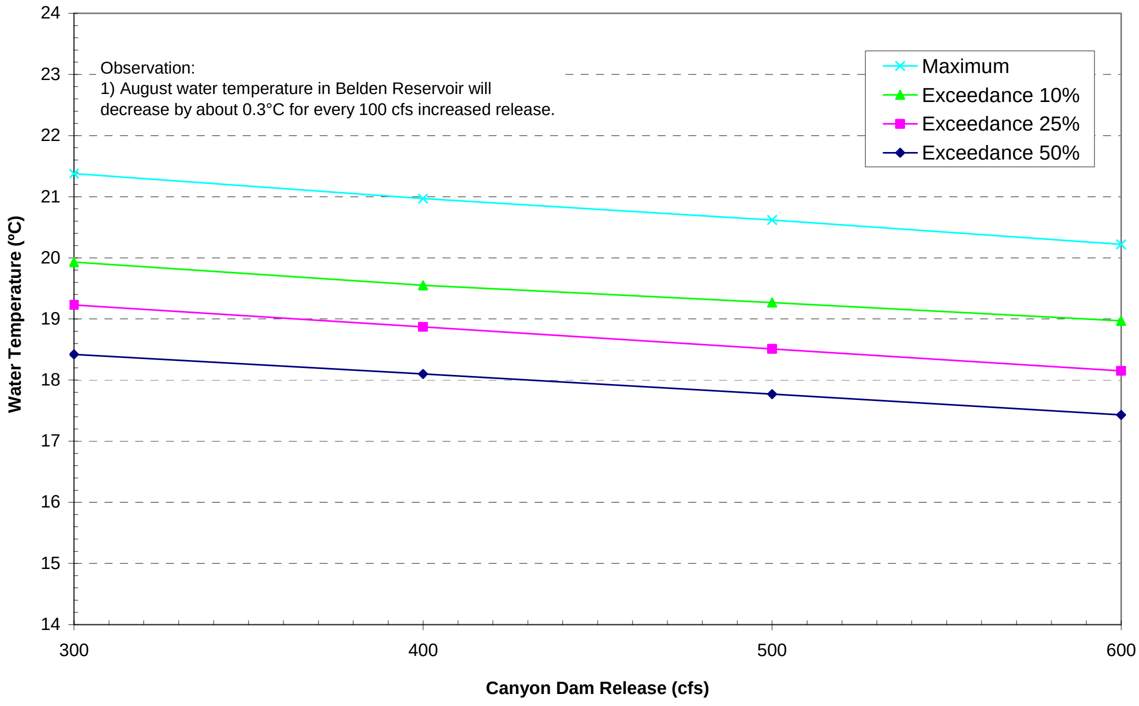


Figure 2-22a Belden Reservoir July Water Temperatures for a Range of Release Rates at Canyon Dam Low-Level Outlet – Alternative 4b

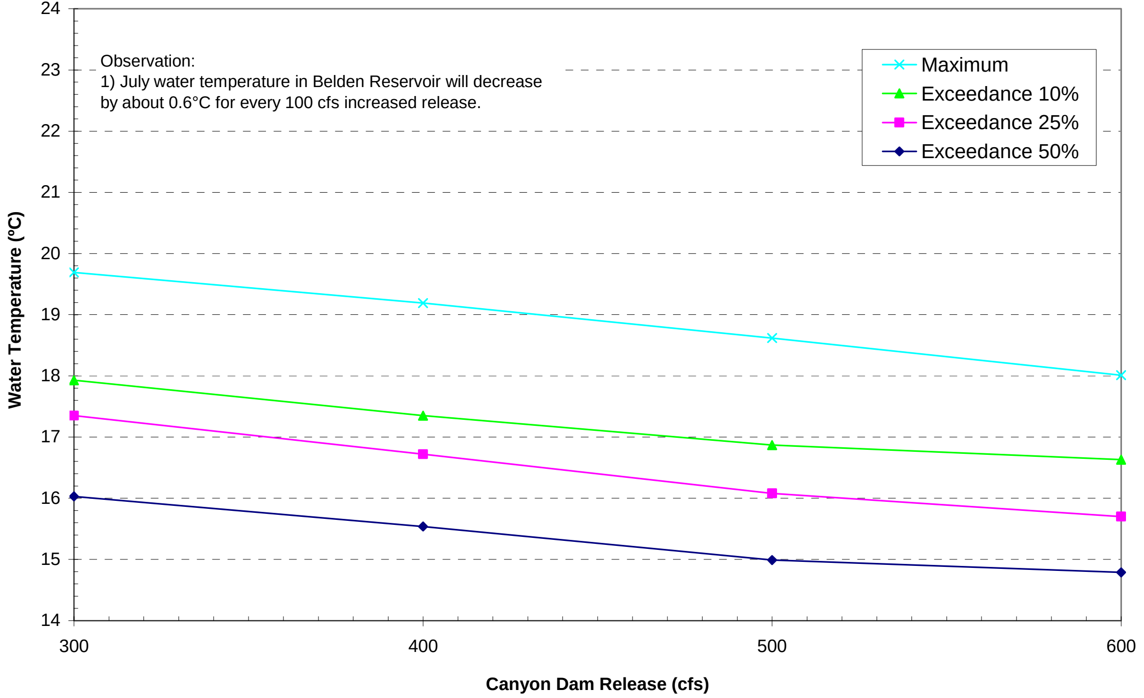

Observation:
1) July water temperature in Belden Reservoir will decrease by about 0.6°C for every 100 cfs increased release.

Figure 2-22b Belden Reservoir August Water Temperatures for a Range of Release Rates at Canyon Dam Low-Level Outlet – Alternative 4b

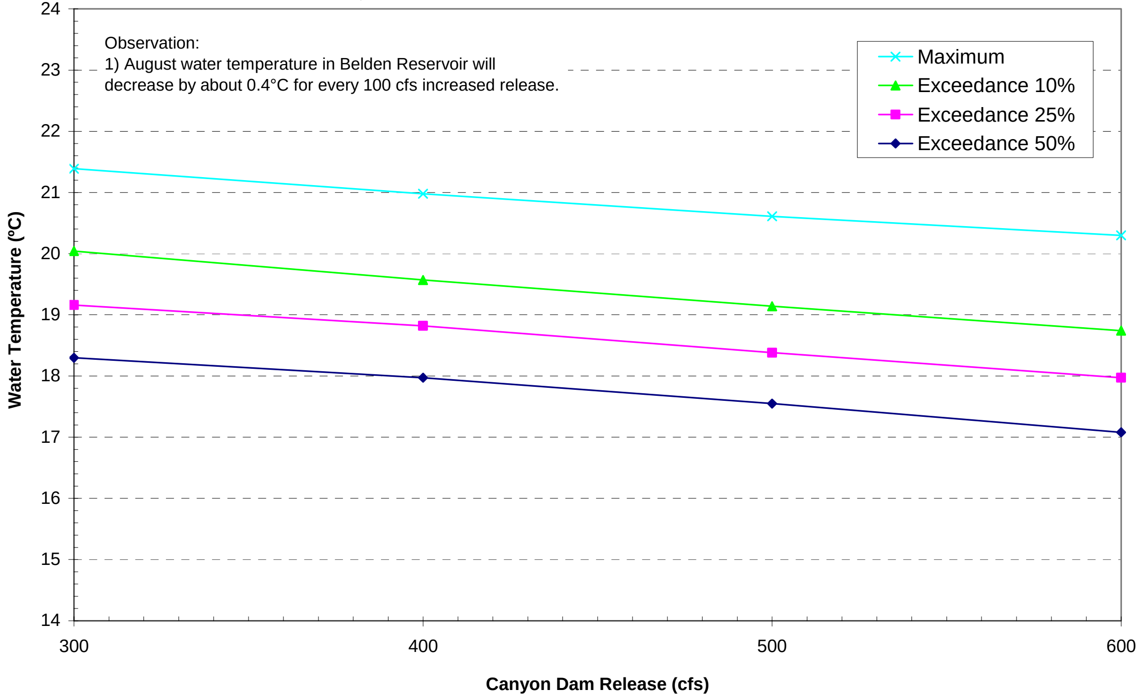
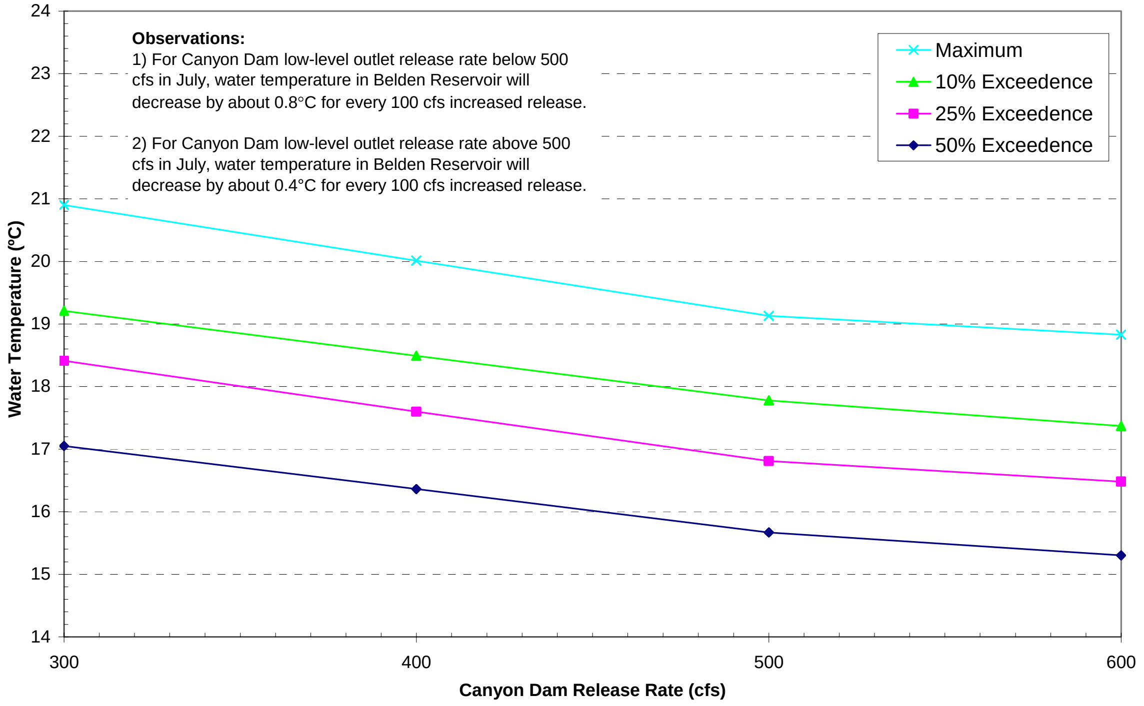

Observation:
1) August water temperature in Belden Reservoir will decrease by about 0.4°C for every 100 cfs increased release.

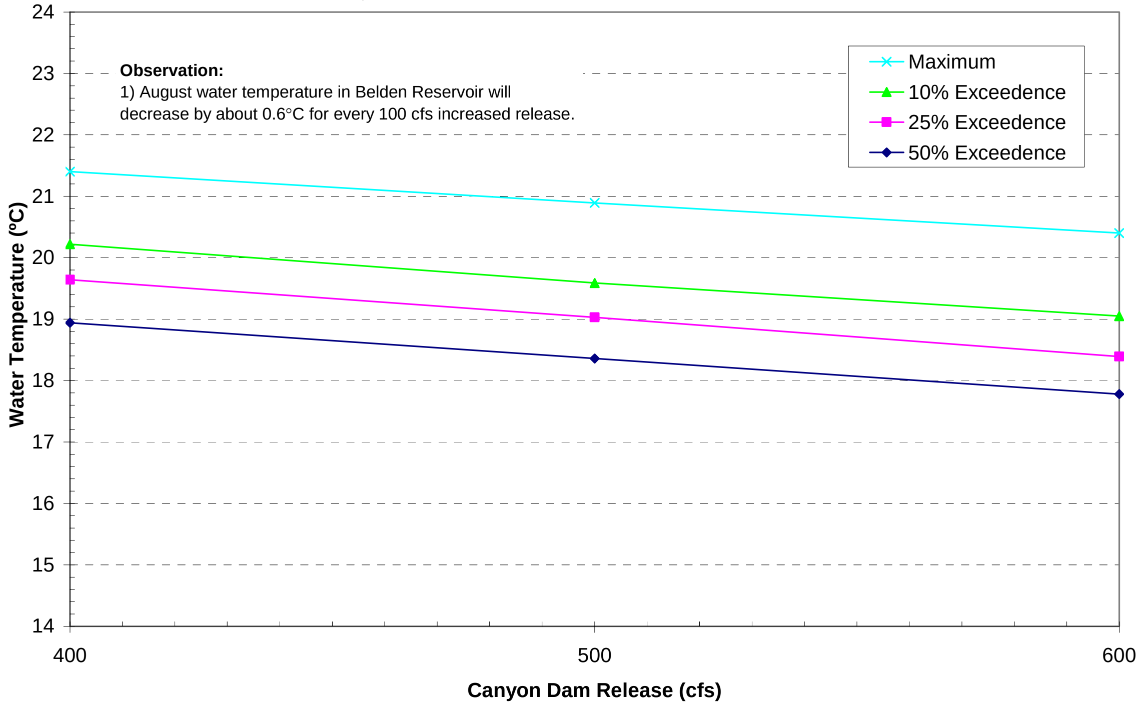
Figure 2-23a Belden Reservoir July Water Temperatures for a Range of Release Rates at Canyon Dam Low-Level Outlet – Alternative 4c


Observations:

1) For Canyon Dam low-level outlet release rate below 500 cfs in July, water temperature in Belden Reservoir will decrease by about 0.8°C for every 100 cfs increased release.

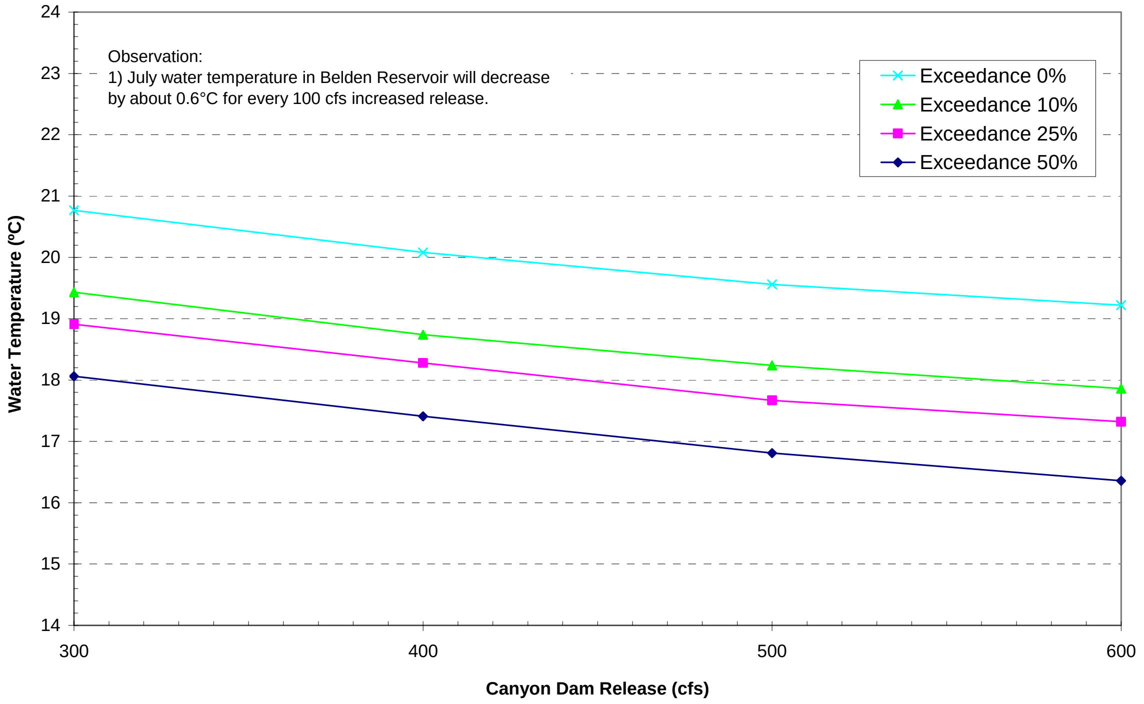
2) For Canyon Dam low-level outlet release rate above 500 cfs in July, water temperature in Belden Reservoir will decrease by about 0.4°C for every 100 cfs increased release.

Figure 2-23b Belden Reservoir August Water Temperatures for a Range of Release Rates at Canyon Dam Low-Level Outlet – Alternative 4c


Observation:

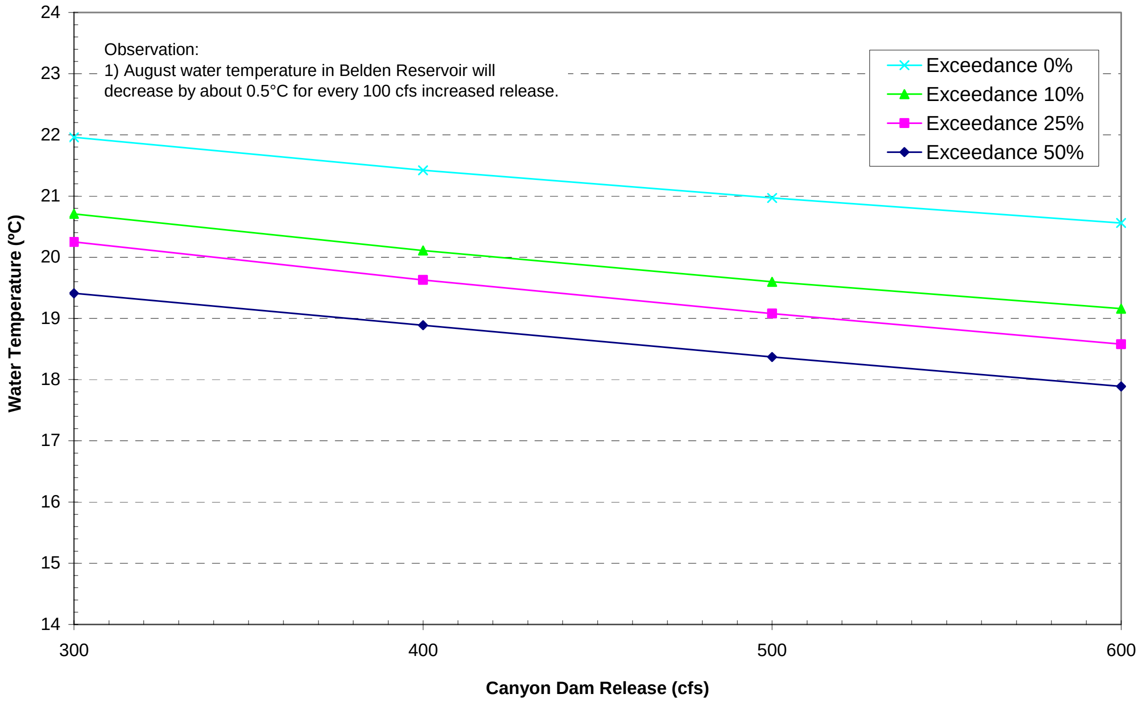
1) August water temperature in Belden Reservoir will decrease by about 0.6°C for every 100 cfs increased release.

Figure 2-24a Belden Reservoir July Water Temperatures for a Range of Release Rates at Canyon Dam Low-Level Outlet – Alternative 4d



Observation:
1) July water temperature in Belden Reservoir will decrease by about 0.6°C for every 100 cfs increased release.

Figure 2-24b Belden Reservoir August Water Temperatures for a Range of Release Rates at Canyon Dam Low-Level Outlet – Alternative 4d



Observation:
1) August water temperature in Belden Reservoir will decrease by about 0.5°C for every 100 cfs increased release.

Figure 2-25a Simulated Mean Daily Water Temperatures of Rock Creek Reach above Bucks Creek for a Range of Dam Releases and Release Temperatures – July, Warm Weather

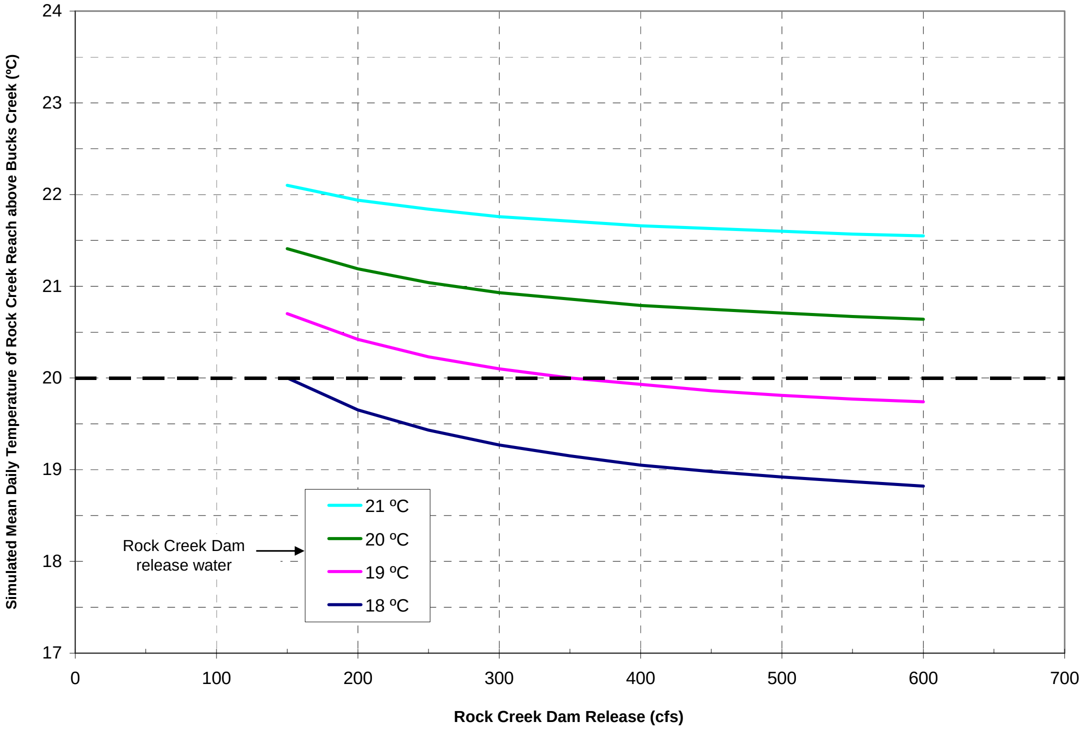


Figure 2-25b Simulated Mean Daily Water Temperatures of Rock Creek Reach above Bucks Creek for a Range of Dam Releases and Release Temperatures – August, Warm Weather

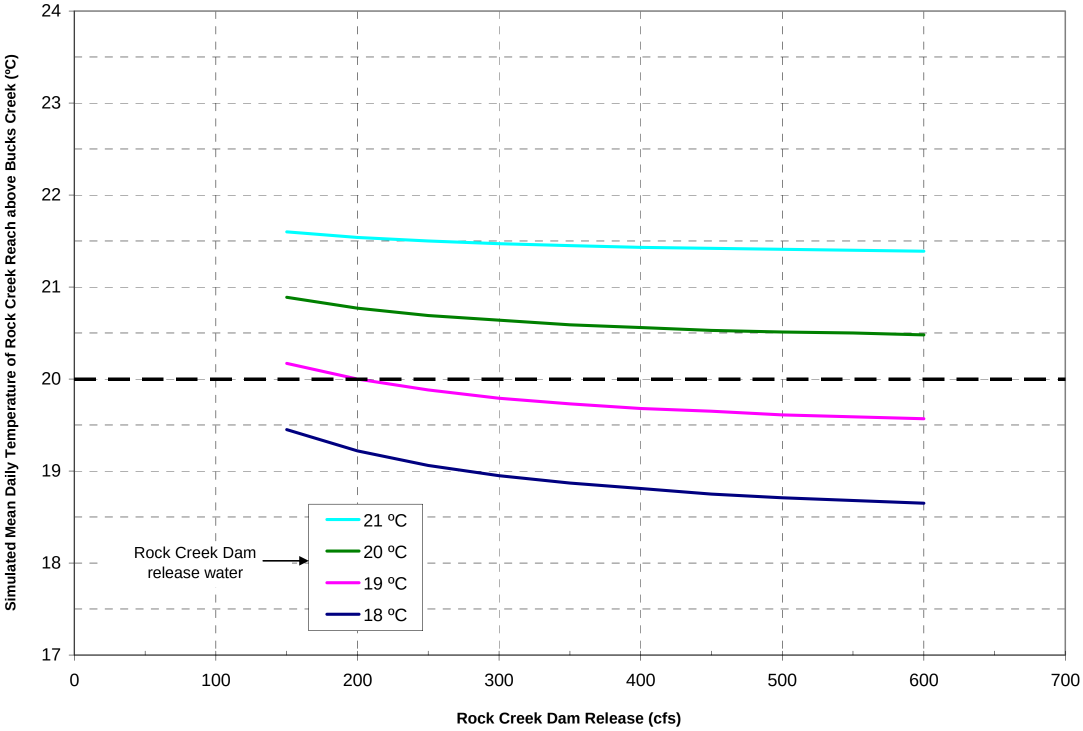


Figure 2-26a Simulated Mean Daily Water Temperatures of Cresta Reach above Cresta PH for a Range of Dam Releases and Release Temperatures – July, Warm Weather

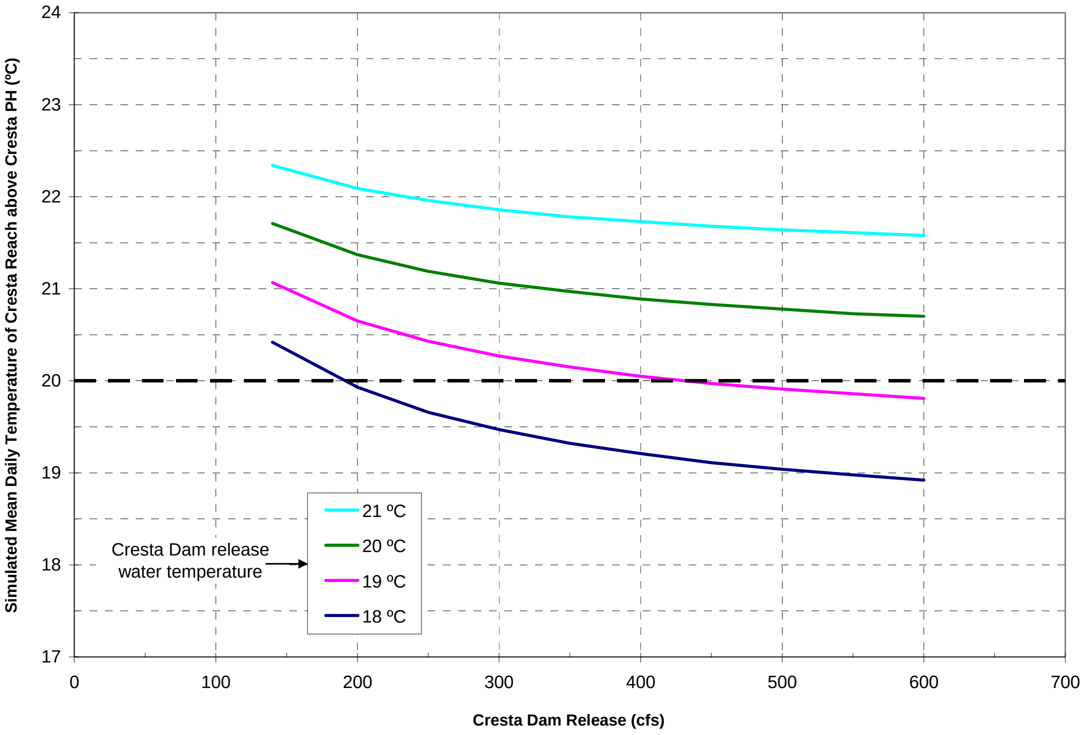


Figure 2-26b Simulated Mean Daily Water Temperatures of Cresta Reach above Cresta PH for a Range of Dam Releases and Release Temperatures – August, Warm Weather

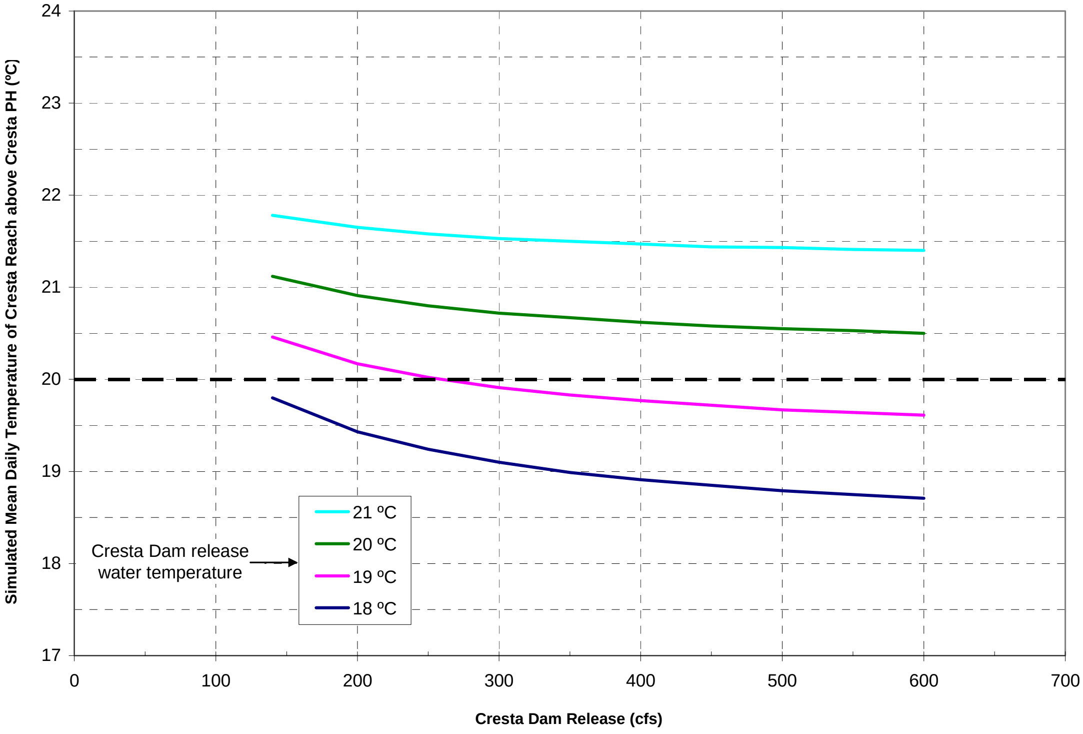


Figure 2-27a Simulated Mean Daily Water Temperatures of Poe Reach above Poe PH for a Range of Dam Releases and Release Temperatures – July, Warm Weather

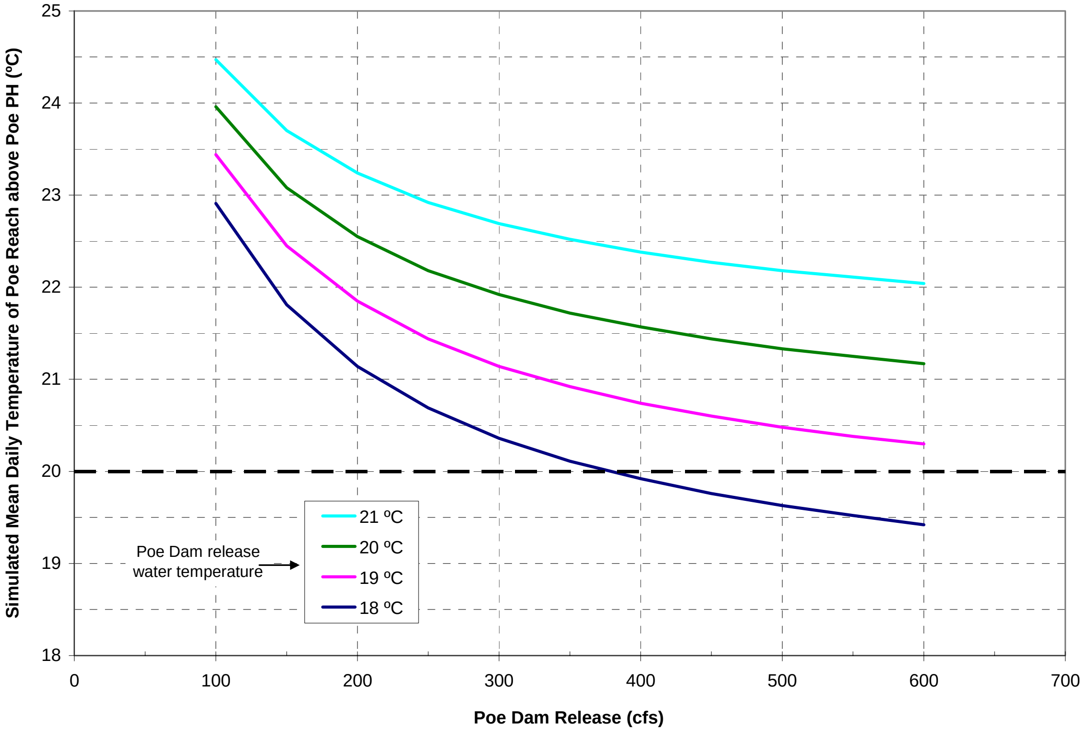
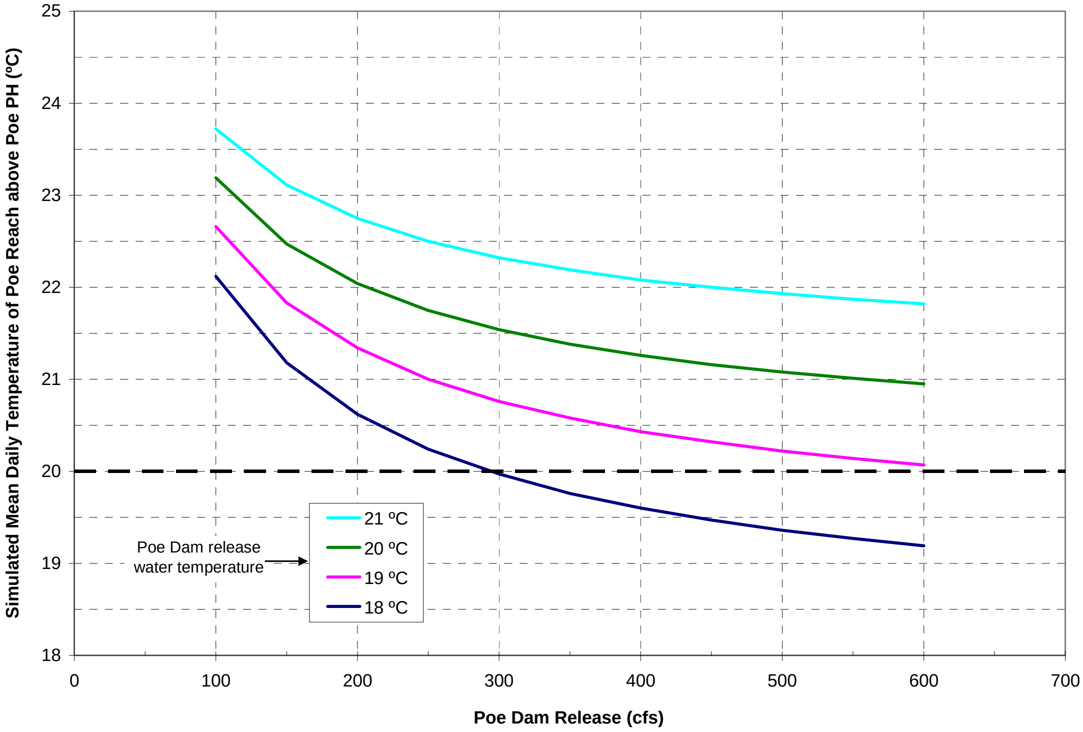


Figure 2-27b Simulated Mean Daily Water Temperatures of Poe Reach above Poe PH for a Range of Dam Releases and Release Temperatures – August, Warm Weather



2.2 MAXIMUM WEEKLY AVERAGE WATER TEMPERATURE ANALYSIS

Maximum Weekly Average Temperature (MWAT) provides an index for assessing the effects of chronic thermal conditions in river reaches on cold freshwater habitat. Modeling the MWAT profile along the NFFR first required identifying the MWAT period (i.e., the 7-day period that had the warmest water temperature profile) that could be applied for different years. This section first describes the modeling approach for the MWAT analysis of different water temperature reduction alternatives for the NFFR and the rationale for the method of MWAT period identification and the modeling approach, and then summarizes the MWAT analysis results for the water temperature reduction alternatives. The following UNFFR Project-only alternatives were analyzed[10].

- Baseline
- “Present Day”
- Alternative 3
- Alternative 3x
- Alternative 4a
- Alternative 4b
- Alternative 4c
- Alternative 4d

2.2.1 MWAT Analysis of Observed 2002 – 2004 Data along the NFFR

Figures 2-29, 2-30, and 2-31 present the observed 7-day rolling average water temperatures at different locations along the NFFR in water years 2002, 2003, and 2004 (Water years 2002, 2003, and 2004 were classified, in hydrologic terms, as “dry”, “normal”, and “normal” hydrologic years, respectively; Refer to Figure 2-28 for monitoring locations of NF5, NF7, NF8, NF9, NF12, NF14, and NF16. The monitoring locations of NF17 and NF18 (not shown on Figure 2-28) are located below Poe Dam and above the Poe PH, respectively). The 7-day rolling average air temperatures observed at the Prattville Intake meteorology station were also plotted to reflect climatic effects on MWAT. The 7-day rolling average water temperatures at the Belden PH discharges were included in the graphs as indicators of the Belden Reservoir water temperature condition. As demonstrated in the figures, water temperatures along the NFFR downstream of Belden Reservoir are primarily driven by the Belden Reservoir water temperature, which in turn is controlled by the Lake Almanor and Butt Valley Reservoir outflow temperatures.

Figure 2-29 shows that 7-day rolling average water temperatures along the NFFR in 2002 (dry year) generally followed the air temperature pattern and were affected by the Belden

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[10] Alternative 3a, which was added for the purpose of isolating and analyzing the incremental benefit of removing the submerged levees near the Prattville Intake by comparing Alternatives 3a and 4a, was not analyzed here because the mean daily water temperature analysis already showed that the temperature reduction benefit is minimal.

PH discharge temperatures. The warmest consecutive 7-day average water temperature (i.e., MWAT) at the Belden PH discharge occurred in early August 2002 and the MWAT at most locations along the NFFR also occurred during this same period. The consecutive 7-day average air temperature in this period was relatively warm, but not the warmest of the summer. The 2002 data indicate that the warmest water temperature in Belden Reservoir coupled with warm weather resulted in the MWAT along the NFFR.

Figure 2-30 clearly shows that the MWAT at different locations along the NFFR in 2003 (normal year) were highly affected by the Belden PH discharge temperatures. The warmest consecutive 7-day average water temperature at the Belden PH discharge occurred in early August 2003 and the MWAT at all locations along the NFFR also occurred during this same period. The consecutive 7-day average air temperature in this period was relatively warm, but not the warmest of the summer. The warmest consecutive 7-day average air temperature occurred in the week of July 24, 2003. However, the Belden Reservoir water temperature in this week was low because this week was also the week of the July 2003 Caribou special test. During this week, PG&E conducted a special short duration test of Caribou PH intake operations. The primary purpose of the special test was to investigate the effectiveness of preferential use of Caribou PH No. 1 over Caribou PH No. 2 as a measure to reduce temperatures in Belden Reservoir and downstream. The Belden PH discharge water temperature (7-day average) was reduced to about 18.1°C during this special test week. The 2003 data also indicate that the warmest water temperature in Belden Reservoir coupled with warm weather resulted in the MWAT along the NFFR.

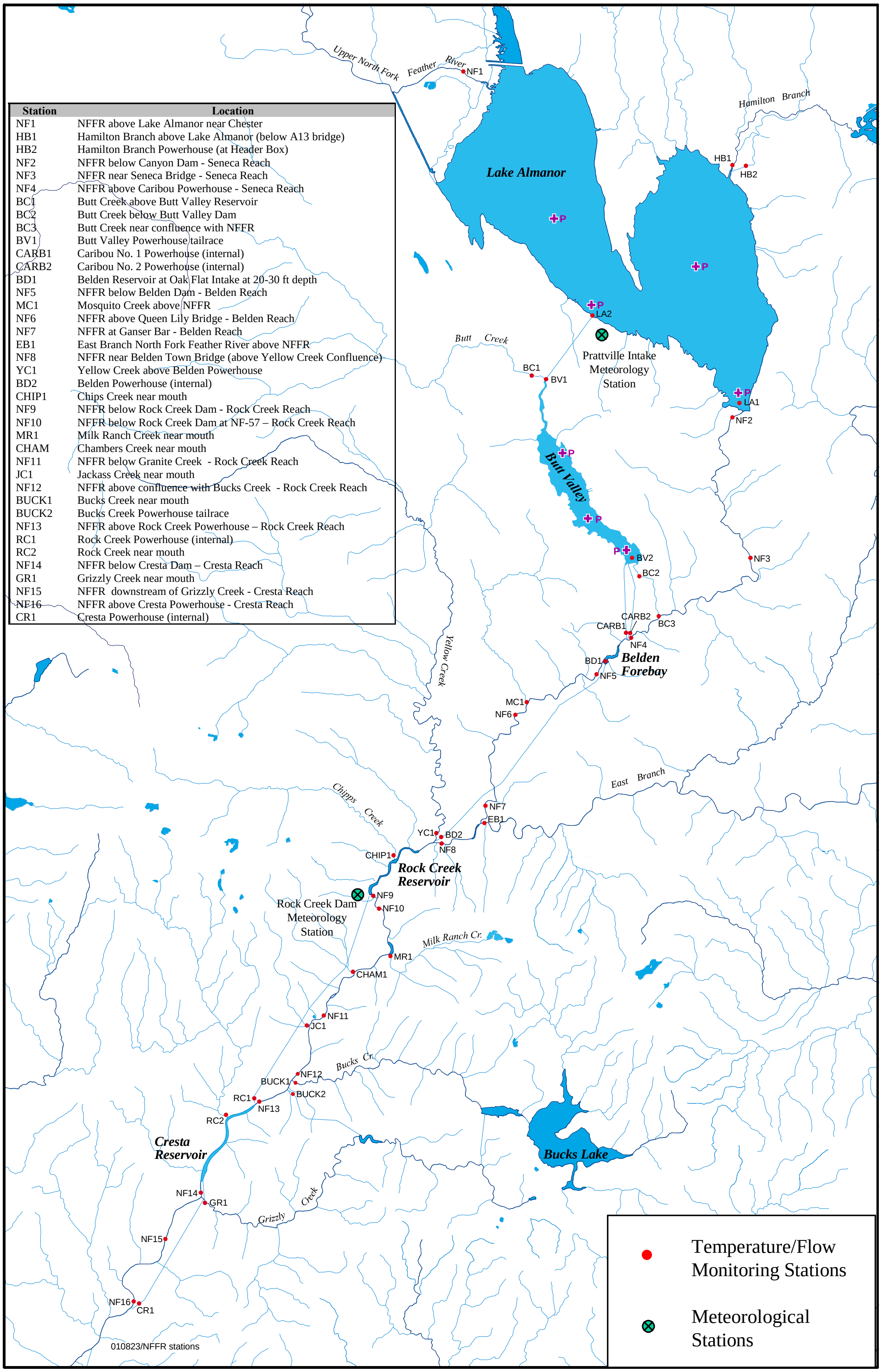
Figure 2-31 shows that the MWAT along the NFFR in 2004 (normal year) occurred in the week of July 26. This week had the warmest 7-day average air temperature. The 7-day average water temperature in Belden Reservoir in this week was relatively warm, but not the warmest of the summer. The 2004 data indicate that warm water temperature in Belden Reservoir coupled with the warmest weather resulted in the MWAT along the NFFR.

The findings are summarized as follows:

- The 2002 and 2003 data indicate that the warmest water temperature in Belden Reservoir coupled with warm weather resulted in the MWAT along the NFFR.
- The 2004 data indicate that warm water temperature in Belden Reservoir coupled with the warmest weather resulted in the MWAT along the NFFR.

The conclusions are summarized as follows:
The period with the warmest 7-day average water temperature in Belden Reservoir would be a good indicator of the MWAT period (i.e., the 7-day period corresponding to the MWAT) for the downstream reaches. In other words, the period with the warmest 7-day average water temperature in Belden Reservoir could be used to identify the MWAT period for the downstream reaches.

Figure 2-28 NFFR Stream Temperature Monitoring Locations



Station	Location
NF1	NFFR above Lake Almanor near Chester
HB1	Hamilton Branch above Lake Almanor (below A13 bridge)
HB2	Hamilton Branch Powerhouse (at Header Box)
NF2	NFFR below Canyon Dam - Seneca Reach
NF3	NFFR near Seneca Bridge - Seneca Reach
NF4	NFFR above Caribou Powerhouse - Seneca Reach
BC1	Butt Creek above Butt Valley Reservoir
BC2	Butt Creek below Butt Valley Dam
BC3	Butt Creek near confluence with NFFR
BV1	Butt Valley Powerhouse tailrace
CARB1	Caribou No. 1 Powerhouse (internal)
CARB2	Caribou No. 2 Powerhouse (internal)
BD1	Belden Reservoir at Oak Flat Intake at 20-30 ft depth
NF5	NFFR below Belden Dam - Belden Reach
MC1	Mosquito Creek above NFFR
NF6	NFFR above Queen Lily Bridge - Belden Reach
NF7	NFFR at Ganser Bar - Belden Reach
EB1	East Branch North Fork Feather River above NFFR
NF8	NFFR near Belden Town Bridge (above Yellow Creek Confluence)
YC1	Yellow Creek above Belden Powerhouse
BD2	Belden Powerhouse (internal)
CHIP1	Chips Creek near mouth
NF9	NFFR below Rock Creek Dam - Rock Creek Reach
NF10	NFFR below Rock Creek Dam at NF-57 – Rock Creek Reach
MR1	Milk Ranch Creek near mouth
CHAM	Chambers Creek near mouth
NF11	NFFR below Granite Creek - Rock Creek Reach
JC1	Jackass Creek near mouth
NF12	NFFR above confluence with Bucks Creek - Rock Creek Reach
BUCK1	Bucks Creek near mouth
BUCK2	Bucks Creek Powerhouse tailrace
NF13	NFFR above Rock Creek Powerhouse – Rock Creek Reach
RC1	Rock Creek Powerhouse (internal)
RC2	Rock Creek near mouth
NF14	NFFR below Cresta Dam – Cresta Reach
GR1	Grizzly Creek near mouth
NF15	NFFR downstream of Grizzly Creek - Cresta Reach
NF16	NFFR above Cresta Powerhouse - Cresta Reach
CR1	Cresta Powerhouse (internal)

Figure 2-29 7-Day Rolling Average Water Temperature along the NFFR, 2002 Summer

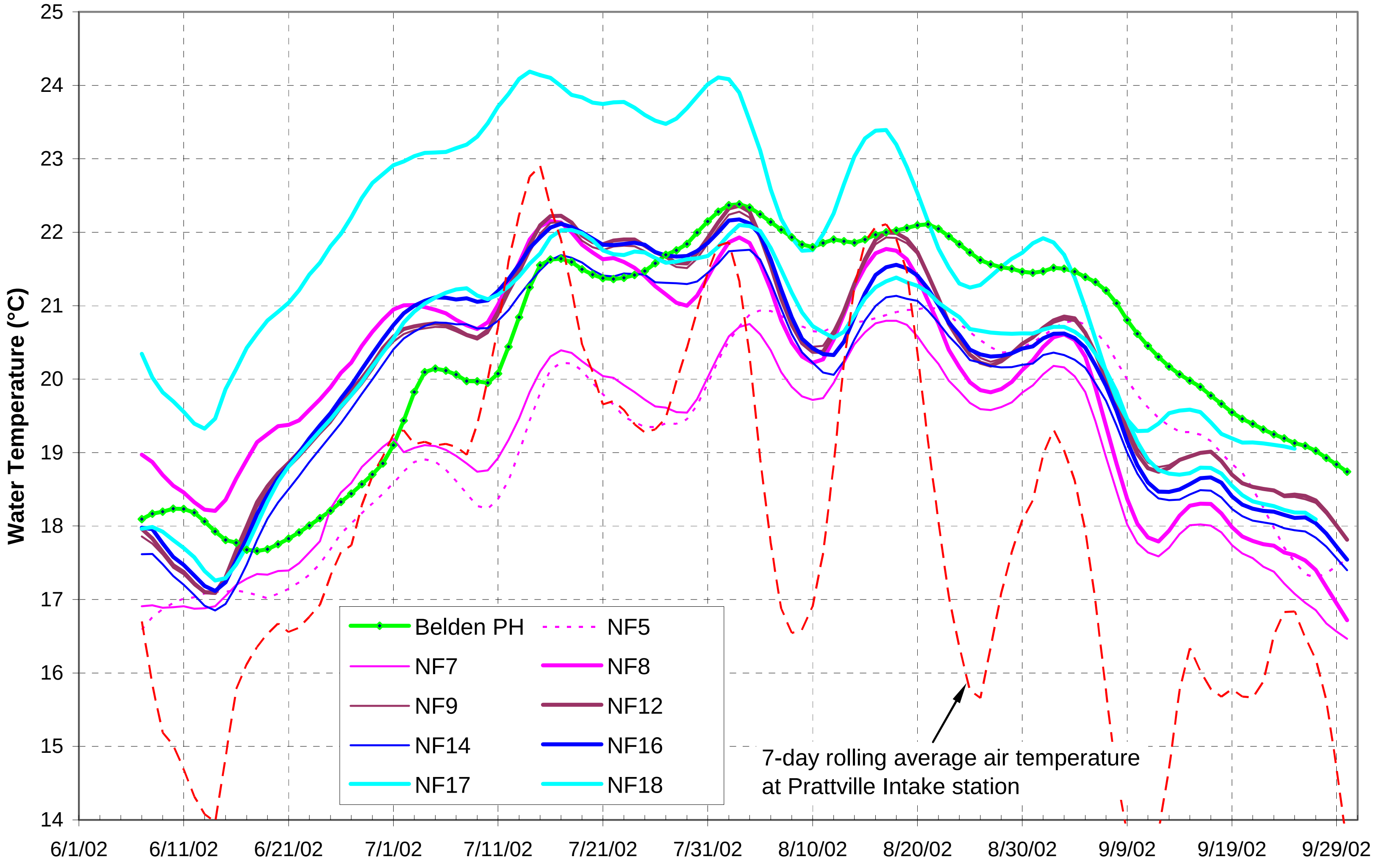


Figure 2-30 7-Day Rolling Average Water Temperature along the NFFR, 2003 Summer

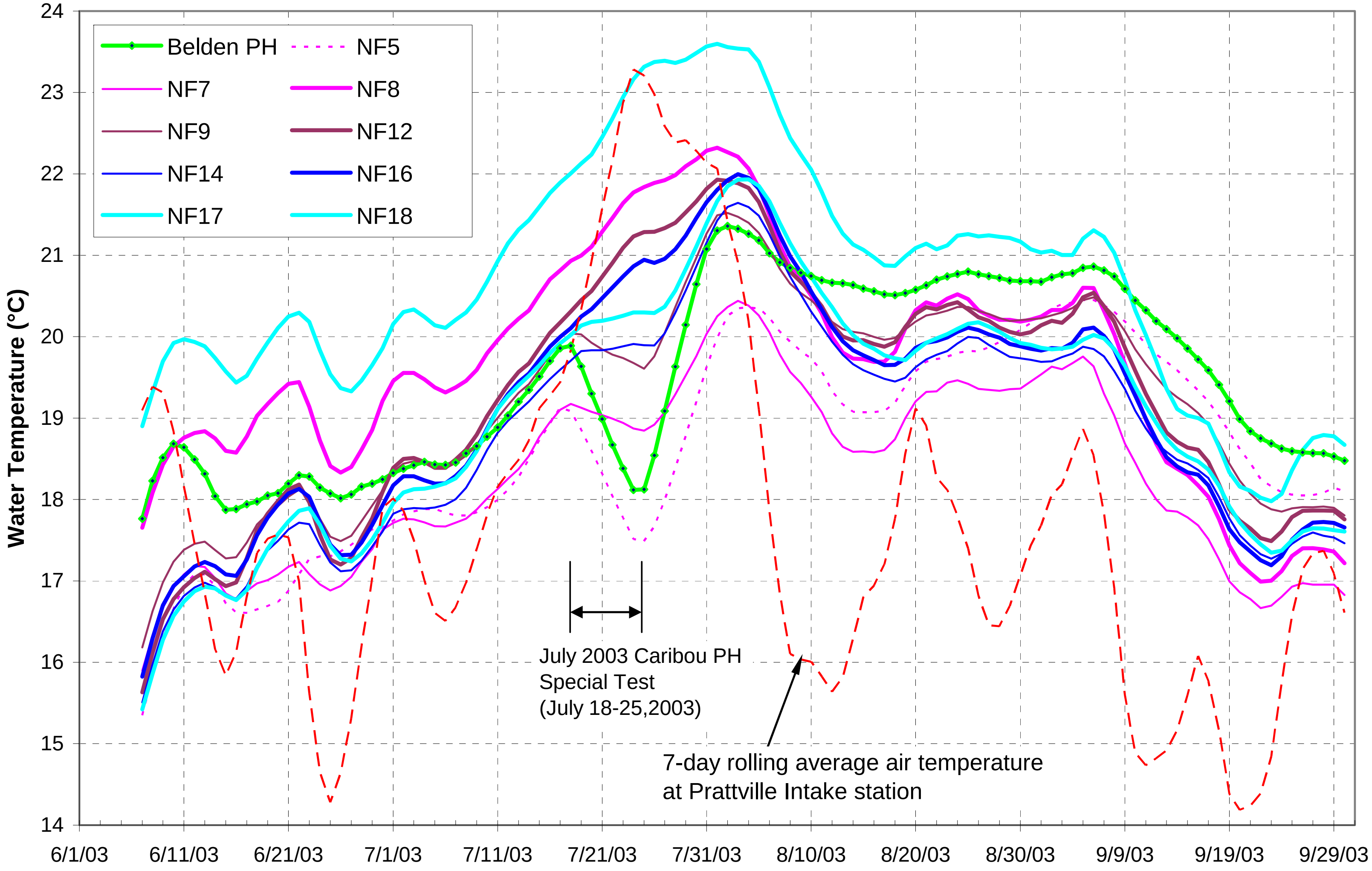
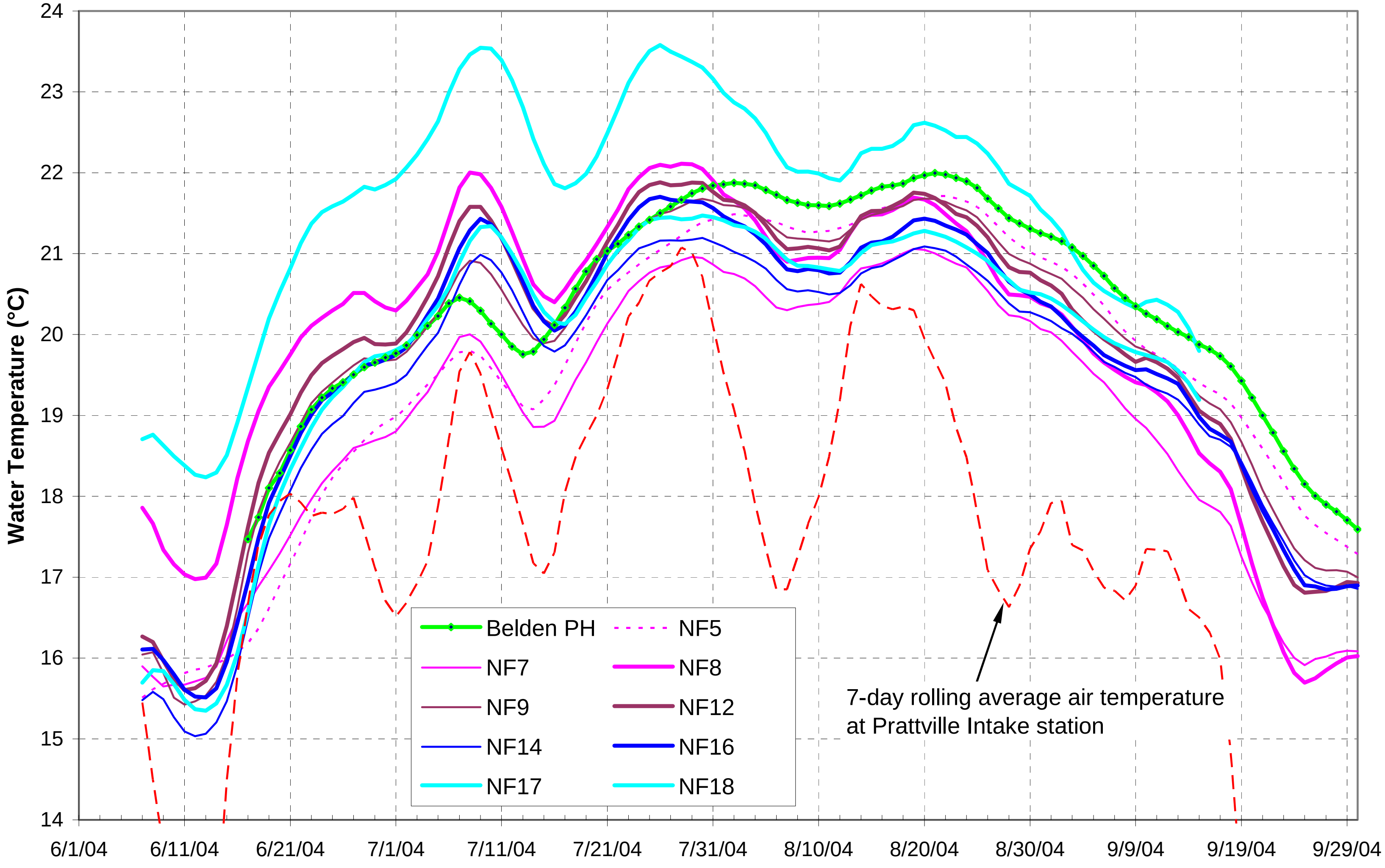


Figure 2-31 7-Day Rolling Average Water Temperature along the NFFR, 2004 Summer



2.2.2 MWAT Analysis of Daily Mixed Caribou PH Discharges and Canyon Dam Releases Simulated for Different Alternatives

Figures 2-32, 2-33, and 2-34 present the 7-day rolling average water temperatures of the daily mixed Caribou PH discharges and Canyon Dam releases simulated for the Baseline and different water temperature reduction alternatives for the water years 1998 (wet year), 2000 (normal year), and 2001 (critical dry year). Since accretion flows along the Seneca Reach are small during the summer (about 30 cfs) relative to the Caribou PH discharges and the proposed magnitude of increased Canyon Dam releases (up to 600 cfs) from the low-level outlet, it would be expected that the MWAT and the MWAT period of the daily mixed Caribou PH discharges and Canyon Dam releases simulated for each of the alternatives would closely approximate the MWAT and the MWAT period of the Belden Reservoir water temperature condition. This expectation or assumption will be verified in the next section.

Figures 2-32, 2-33, and 2-34 show that the "Present Day" alternative shows a very similar pattern to the Baseline condition but the patterns of the other alternatives differ significantly from the Baseline condition. Over the three selected years, the mixed MWAT generally occurs in August for the Baseline and the Present Day conditions, but the mixed MWAT for the other alternatives mainly occurs in September. This is because that these alternatives are designed to reduce July and August water temperatures. With the reduction of the cold water pools in the reservoirs during July and August and without water temperature reduction measures extended to September, there appears to be a shift in the MWAT from July/August to September. September water temperatures for some alternatives could be reduced further if operations of the alternatives were to be extended through September.

The shift of the MWAT period from July/August under the Baseline condition to September under the water temperature reduction alternatives suggested that it was necessary to analyze the monthly MWAT for July, August, and September and the annual MWAT (the annual MWAT would be the maximum of the three monthly MWATs). The *monthly* MWAT analysis was intended to reflect the water temperature reduction benefit in July and August by the proposed alternatives, while the *annual* MWAT analysis was intended to provide an index of chronic thermal conditions.

Figure 2-32 7-Day Rolling Average Water Temperatures of Daily Mixed Caribou PH Discharges and Canyon Dam Releases Simulated for Different Alternatives, 1998 (Wet Year)

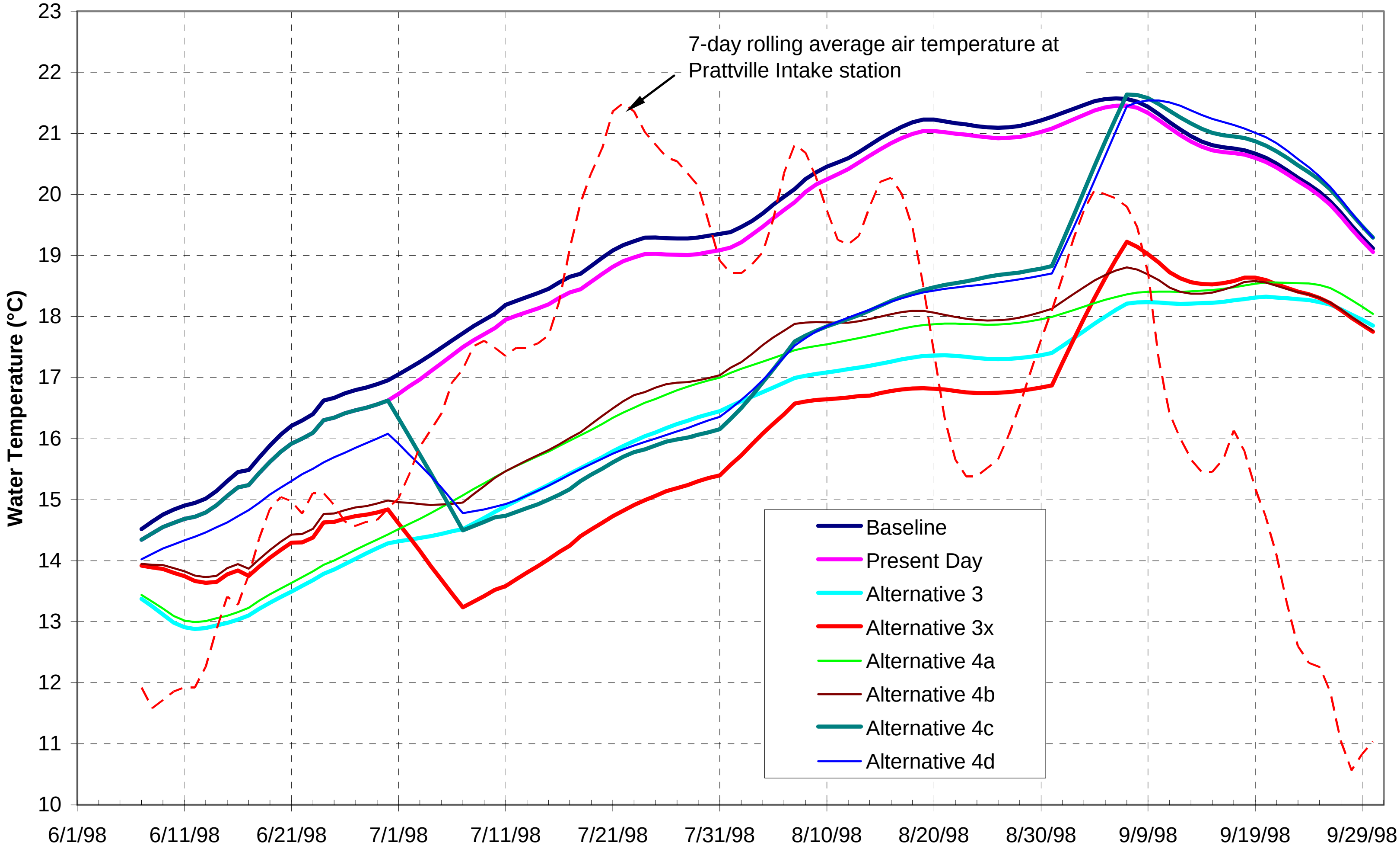


Figure 2-33 7-Day Rolling Average Water Temperatures of Daily Mixed Caribou PH Discharges and Canyon Dam Releases Simulated for Different Alternatives, 2000 (Normal Year)

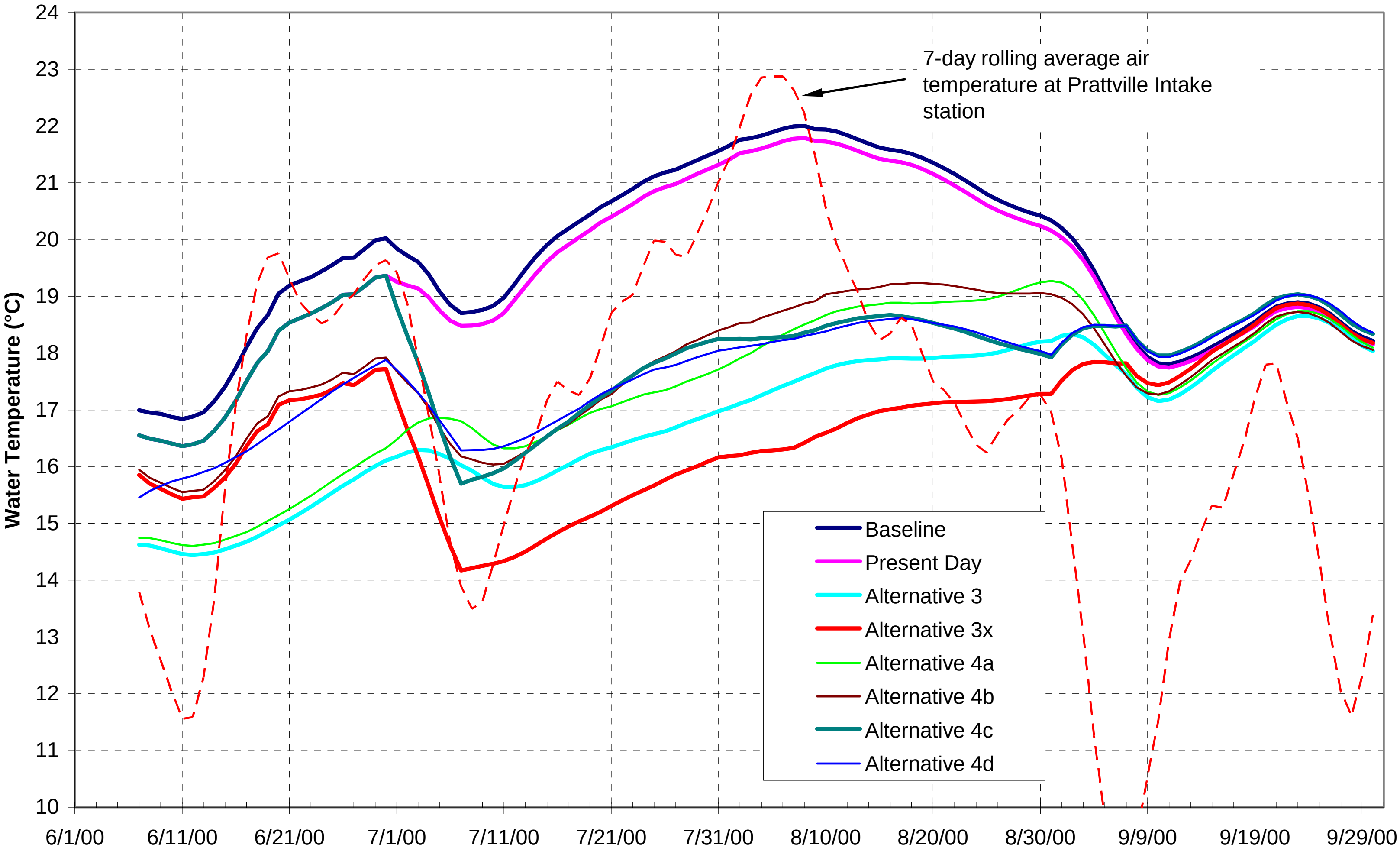
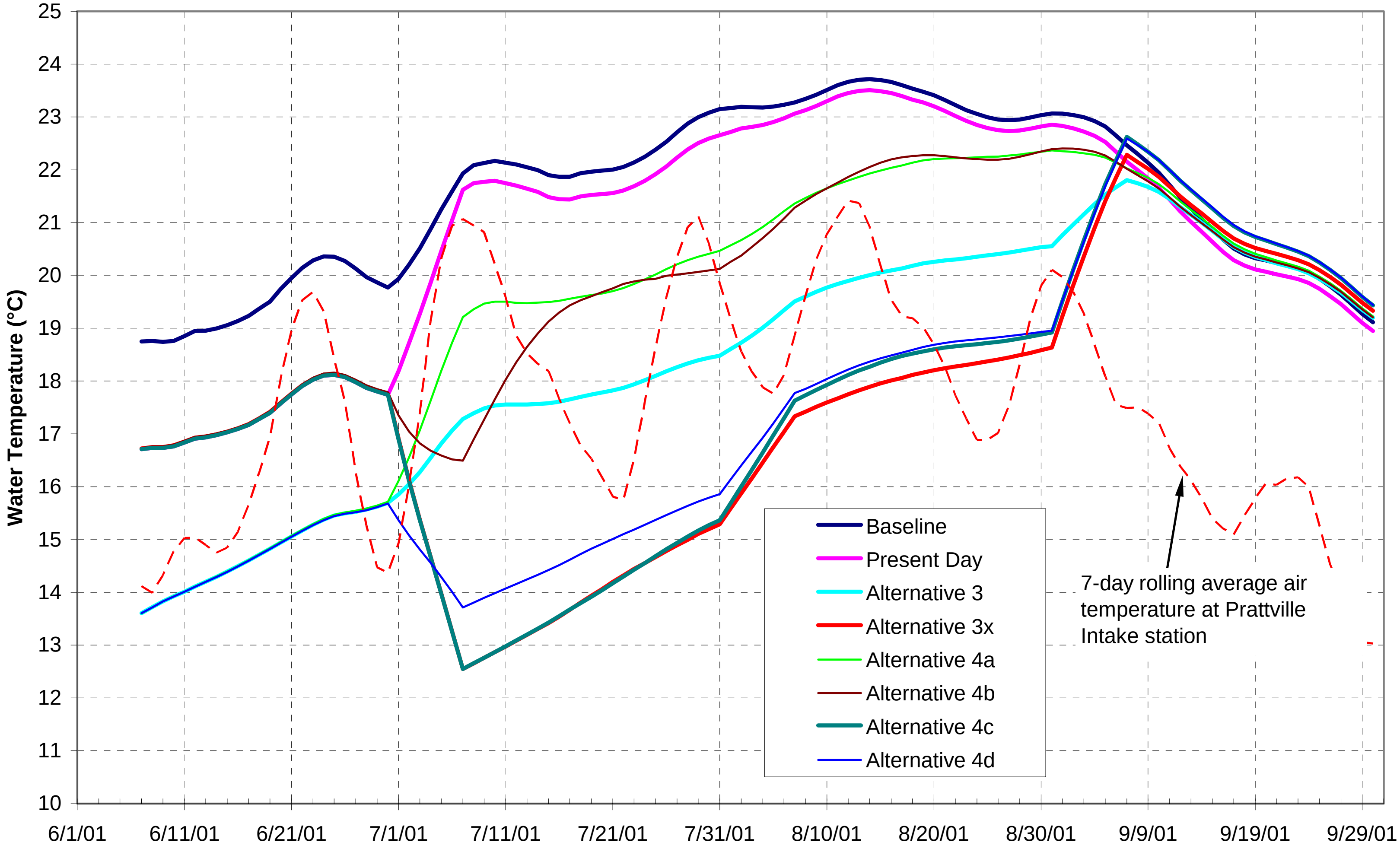


Figure 2-34 7-Day Rolling Average Water Temperatures of Daily Mixed Caribou PH Discharges and Canyon Dam Releases Simulated for Different Alternatives, 2001 (Critical Dry Year)



2.2.3 Determination of the Annual MWAT Period for the Belden Reservoir Water Temperature Condition Simulated for Different Alternatives

As mentioned in the Section 2.2.2, since accretion flows along the Seneca Reach are small during the summer (about 30 cfs) relative to the Caribou PH discharges and the proposed magnitude of increased Canyon Dam releases (up to 600 cfs) from the low-level outlet, it would be expected that the MWAT and the MWAT period of the daily mixed Caribou PH discharges and Canyon Dam releases simulated for each of the alternatives would closely approximate the MWAT and the MWAT period of the Belden Reservoir water temperature condition. In order to verify this expectation or assumption, the following two methods were used to identify the annual MWAT period. Method 2 considered the effects of the Seneca Reach accretion flow and warming on the determination of the annual MWAT period for the Belden Reservoir water temperature condition, while Method 1 did not.

- Method 1: Identify the annual MWAT period by directly mixing the simulated daily Caribou PH discharges and Canyon Dam releases;
- Method 2: Identify the annual MWAT period by first assuming the accretion flow and warming along the Seneca Reach based on the water year type and the current SNTEMP modeling results for the Seneca Reach for each of the summer months, and then mixing the simulated daily Caribou PH discharge/temperature and the estimated daily discharge/temperature at the end of the Seneca Reach.

Tables 2-5a to 2-5h are the results comparing the identified annual MWAT periods between the two methods for different alternatives. The analysis results indicate that the identified annual MWAT periods by the two methods for each of the 19 analysis years (1984-2002) for the Baseline, Alternative 3, Alternative 3x, and Alternative 4c are exactly the same. The most significant difference in the identified annual MWAT period between the two methods was for water year 1984 under the “Present Day” condition, water year 1985 under Alternative 4a, water year 1991 under Alternative 4b, and water year 2000 under Alternative 4d. In all these instances, the difference in the 7-day average water temperature between the two different MWAT periods is small, about 0.1°C.

Since the identified annual MWAT periods by the two methods are generally the same, it was deemed acceptable to use either one of the two methods to identify the annual and/or monthly MWAT period. Since Method 1 was the most simple, it was used to identify the annual and/or monthly MWAT period in the MWAT analysis along the NFFR for different alternatives.

Note that both Method 1 and Method 2 can be used to identify the MWAT period for Belden Reservoir and the downstream reaches, not for the Seneca Reach. The MWAT period for the Seneca Reach is most likely different from the downstream reaches because the Seneca Reach water temperature is primarily driven by the Canyon Dam release water temperature, while the water temperatures along the downstream reaches are primarily driven by the Belden Reservoir water temperature.

Table 2-5a Mixed MWAT and MWAT Period Determined by Method 1 and Method 2 - Baseline

Year	WY Type	Method 1		Method 2	
		Mixed MWAT (°C)	MWAT Period	Mixed MWAT (°C)	MWAT Period
1984	WET	19.81	8/18 - 8/24	19.76	8/18 - 8/24
1985	DRY	21.85	7/23 - 7/29	21.84	7/23 - 7/29
1986	WET	21.15	8/13 - 8/19	21.08	8/13 - 8/19
1987	CD	20.47	8/5 - 8/11	20.25	8/5 - 8/11
1988	CD	23.31	7/29 - 8/4	23.22	7/29 - 8/4
1989	NORMAL	21.10	7/24 - 7/30	21.05	7/24 - 7/30
1990	CD	22.12	8/2 - 8/8	22.04	8/2 - 8/8
1991	CD	22.34	7/28 - 8/3	22.30	7/28 - 8/3
1992	CD	22.76	8/14 - 8/20	22.67	8/14 - 8/20
1993	WET	21.79	8/3 - 8/9	21.73	8/3 - 8/9
1994	CD	22.57	8/3 - 8/9	22.47	8/3 - 8/9
1995	WET	19.75	8/19 - 8/25	19.72	8/19 - 8/25
1996	WET	20.44	8/11 - 8/17	20.44	8/11 - 8/17
1997	WET	22.38	8/9 - 8/15	22.26	8/9 - 8/15
1998	WET	21.57	8/31 - 9/6	21.45	8/31 - 9/6
1999	NORMAL	21.09	8/23 - 8/29	21.05	8/23 - 8/29
2000	NORMAL	22.00	8/2 - 8/8	21.93	8/2 - 8/8
2001	CD	23.71	8/8 - 8/14	23.63	8/8 - 8/14
2002	DRY	22.45	8/13 - 8/19	22.38	8/13 - 8/19

Table 2-5b Mixed MWAT and MWAT Period Determined by Method 1 and Method 2 - "Present Day"

Year	WY Type	Method 1		Method 2	
		Mixed MWAT (°C)	MWAT Period	Mixed MWAT (°C)	MWAT Period
1984	WET	19.69	**9/6 - 9/12**	19.57	**8/17 - 8/23**
1985	DRY	21.59	7/23 - 7/29	21.64	7/24 - 7/30
1986	WET	20.93	8/13 - 8/19	20.90	8/13 - 8/19
1987	CD	19.95	9/1 - 9/7	19.79	9/1 - 9/7
1988	CD	22.93	8/1 - 8/7	22.86	7/31 - 8/6
1989	NORMAL	20.69	7/24 - 7/30	20.73	7/24 - 7/30
1990	CD	21.90	8/2 - 8/8	21.86	8/2 - 8/8
1991	CD	22.04	7/29 - 8/4	22.05	7/28 - 8/3
1992	CD	22.54	8/14 - 8/20	22.48	8/14 - 8/20
1993	WET	21.61	8/3 - 8/9	21.58	8/3 - 8/9
1994	CD	22.29	8/3 - 8/9	22.23	8/3 - 8/9
1995	WET	19.63	8/19 - 8/25	19.62	8/19 - 8/25
1996	WET	20.45	8/11 - 8/17	20.41	8/11 - 8/17
1997	WET	22.09	8/10 - 8/16	22.03	8/10 - 8/16
1998	WET	21.45	9/1 - 9/7	21.35	8/31 - 9/6
1999	NORMAL	20.90	8/23 - 8/29	20.89	8/23 - 8/29
2000	NORMAL	21.79	8/2 - 8/8	21.76	8/2 - 8/8
2001	CD	23.50	8/8 - 8/14	23.45	8/8 - 8/14
2002	DRY	22.14	8/13 - 8/19	22.11	8/13 - 8/19

Note: The significantly different MWAT periods identified by the two methods are bold and colored with red, minor different MWAT periods are colored with pink.

Table 2-5c Mixed MWAT and MWAT Period Determined by Method 1 and Method 2 - Alternative 3

Year	WY Type	Method 1		Method 2	
		Mixed MWAT (°C)	MWAT Period	Mixed MWAT (°C)	MWAT Period
1984	WET	17.67	9/15 - 9/21	17.58	9/15 - 9/21
1985	DRY	19.45	9/1 - 9/7	19.27	9/1 - 9/7
1986	WET	18.67	9/5 - 9/11	18.59	9/5 - 9/11
1987	CD	18.80	9/1 - 9/7	18.65	9/1 - 9/7
1988	CD	21.69	9/5 - 9/11	21.53	9/5 - 9/11
1989	NORMAL	18.76	9/5 - 9/11	18.58	9/6 - 9/12
1990	CD	19.11	9/7 - 9/13	18.99	9/7 - 9/13
1991	CD	20.64	9/3 - 9/9	20.53	9/3 - 9/9
1992	CD	19.71	9/1 - 9/7	19.60	9/1 - 9/7
1993	WET	20.05	9/9 - 9/15	19.93	9/9 - 9/15
1994	CD	20.55	9/1 - 9/7	20.41	9/1 - 9/7
1995	WET	17.54	9/16 - 9/22	17.47	9/16 - 9/22
1996	WET	18.00	9/1 - 9/7	17.87	9/1 - 9/7
1997	WET	20.10	9/6 - 9/12	19.94	9/6 - 9/12
1998	WET	18.32	9/14 - 9/20	18.25	9/14 - 9/20
1999	NORMAL	18.02	9/1 - 9/7	17.88	9/1 - 9/7
2000	NORMAL	18.66	9/18 - 9/24	18.56	9/18 - 9/24
2001	CD	21.80	9/1 - 9/7	21.57	9/1 - 9/7
2002	DRY	19.76	9/1 - 9/7	19.66	9/1 - 9/7

Table 2-5d Mixed MWAT and MWAT Period Determined by Method 1 and Method 2 - Alternative 3x

Year	WY Type	Method 1		Method 2	
		Mixed MWAT (°C)	MWAT Period	Mixed MWAT (°C)	MWAT Period
1984	WET	18.72	9/1 - 9/7	18.59	9/1 - 9/7
1985	DRY	20.15	9/1 - 9/7	19.94	9/1 - 9/7
1986	WET	19.52	9/1 - 9/7	19.42	9/1 - 9/7
1987	CD	19.98	9/1 - 9/7	19.78	9/1 - 9/7
1988	CD	23.07	9/1 - 9/7	22.89	9/1 - 9/7
1989	NORMAL	19.34	9/1 - 9/7	19.14	9/1 - 9/7
1990	CD	19.34	9/6 - 9/12	19.21	9/6 - 9/12
1991	CD	21.02	9/1 - 9/7	20.90	9/1 - 9/7
1992	CD	20.16	9/1 - 9/7	20.04	9/1 - 9/7
1993	WET	20.53	9/6 - 9/12	20.38	9/6 - 9/12
1994	CD	21.30	9/1 - 9/7	21.15	9/1 - 9/7
1995	WET	17.86	9/12 - 9/18	17.77	9/12 - 9/18
1996	WET	18.99	9/1 - 9/7	18.82	9/1 - 9/7
1997	WET	20.78	9/1 - 9/7	20.59	9/1 - 9/7
1998	WET	19.22	9/1 - 9/7	19.12	9/1 - 9/7
1999	NORMAL	18.85	9/1 - 9/7	18.67	9/1 - 9/7
2000	NORMAL	18.87	9/17 - 9/23	18.77	9/17 - 9/23
2001	CD	22.28	9/1 - 9/7	22.04	9/1 - 9/7
2002	DRY	20.66	9/1 - 9/7	20.54	9/1 - 9/7

Note: The significantly different MWAT periods identified by the two methods are bold and colored with red, minor different MWAT periods are colored with pink.

Table 2-5e Mixed MWAT and MWAT Period Determined by Method 1 and Method 2 - Alternative 4a

Year	WY Type	Method 1		Method 2	
		Mixed MWAT (°C)	MWAT Period	Mixed MWAT (°C)	MWAT Period
1984	WET	17.91	9/15 - 9/21	17.82	9/15 - 9/21
1985	DRY	19.69	**8/30 - 9/5**	19.70	**8/24 - 8/31**
1986	WET	18.97	9/5 - 9/11	18.89	9/5 - 9/11
1987	CD	18.84	9/1 - 9/7	18.70	9/1 - 9/7
1988	CD	22.03	9/5 - 9/11	21.87	9/5 - 9/11
1989	NORMAL	19.01	8/15 - 8/21	19.04	8/15 - 8/21
1990	CD	19.76	8/10 - 8/16	19.75	8/10 - 8/16
1991	CD	20.84	9/2 - 9/8	20.74	9/2 - 9/8
1992	CD	20.11	8/17 - 8/23	20.10	8/17 - 8/23
1993	WET	20.36	9/9 - 9/15	20.24	9/9 - 9/15
1994	CD	20.82	9/1 - 9/7	20.68	8/31 - 9/6
1995	WET	17.72	9/17 - 9/23	17.65	9/17 - 9/23
1996	WET	18.45	9/1 - 9/7	18.35	8/29 - 9/4
1997	WET	20.64	9/6 - 9/12	20.48	9/6 - 9/12
1998	WET	18.56	9/14 - 9/20	18.48	9/14 - 9/20
1999	NORMAL	18.43	8/25 - 8/31	18.45	8/25 - 8/31
2000	NORMAL	19.27	8/25 - 8/31	19.28	8/25 - 8/31
2001	CD	22.37	8/25 - 8/31	22.34	8/25 - 8/31
2002	DRY	19.99	9/1 - 9/7	19.89	9/1 - 9/7

Table 2-5f Mixed MWAT and MWAT Period Determined by Method 1 and Method 2 - Alternative 4b

Year	WY Type	Method 1		Method 2	
		Mixed MWAT (°C)	MWAT Period	Mixed MWAT (°C)	MWAT Period
1984	WET	18.23	9/5 - 9/11	18.12	9/5 - 9/11
1985	DRY	19.91	8/26 - 9/1	19.90	8/24 - 8/30
1986	WET	19.20	9/3 - 9/9	19.12	9/3 - 9/9
1987	CD	19.98	9/1 - 9/7	19.82	9/1 - 9/7
1988	CD	22.59	9/1 - 9/7	22.41	9/1 - 9/7
1989	NORMAL	19.17	8/18 - 8/24	19.19	8/18 - 8/24
1990	CD	19.75	8/13 - 8/19	19.75	8/13 - 8/19
1991	CD	20.75	**9/1 - 9/7**	20.67	**8/21 - 8/27**
1992	CD	20.21	8/22 - 8/28	20.20	8/22 - 8/28
1993	WET	20.38	9/7 - 9/13	20.26	9/7 - 9/13
1994	CD	20.89	8/21 - 8/27	20.86	8/21 - 8/27
1995	WET	17.77	9/12 - 9/18	17.70	9/12 - 9/18
1996	WET	19.27	9/1 - 9/7	19.12	9/1 - 9/7
1997	WET	20.80	9/1 - 9/7	20.63	9/1 - 9/7
1998	WET	18.81	9/1 - 9/7	18.73	9/1 - 9/7
1999	NORMAL	18.54	8/27 - 9/2	18.53	8/25 - 8/31
2000	NORMAL	19.24	8/12 - 8/18	19.24	8/12 - 8/18
2001	CD	22.40	8/26 - 9/1	22.36	8/25 - 8/31
2002	DRY	20.29	8/31 - 9/6	20.20	8/31 - 9/6

Note: The significantly different MWAT periods identified by the two methods are bold and colored with red, minor different MWAT periods are colored with pink.

Table 2-5g Mixed MWAT and MWAT Period Determined by Method 1 and Method 2 - Alternative 4c

Year	WY Type	Method 1		Method 2	
		Mixed MWAT (°C)	MWAT Period	Mixed MWAT (°C)	MWAT Period
1984	WET	20.05	9/5 - 9/11	19.89	9/5 - 9/11
1985	DRY	20.32	9/1 - 9/7	20.10	9/1 - 9/7
1986	WET	20.85	9/2 - 9/8	20.73	9/2 - 9/8
1987	CD	20.28	9/1 - 9/7	20.08	9/1 - 9/7
1988	CD	23.21	9/1 - 9/7	23.03	9/1 - 9/7
1989	NORMAL	19.51	9/1 - 9/7	19.30	9/1 - 9/7
1990	CD	19.81	9/1 - 9/7	19.67	9/1 - 9/7
1991	CD	21.53	9/1 - 9/7	21.40	9/1 - 9/7
1992	CD	20.98	9/1 - 9/7	20.85	9/1 - 9/7
1993	WET	21.81	9/6 - 9/12	21.65	9/6 - 9/12
1994	CD	21.58	9/1 - 9/7	21.42	9/1 - 9/7
1995	WET	19.38	9/11 - 9/17	19.26	9/11 - 9/17
1996	WET	20.24	9/1 - 9/7	20.04	9/1 - 9/7
1997	WET	21.47	9/1 - 9/7	21.26	9/1 - 9/7
1998	WET	21.63	9/1 - 9/7	21.50	9/1 - 9/7
1999	NORMAL	20.09	9/1 - 9/7	19.87	9/1 - 9/7
2000	NORMAL	19.37	6/24 - 6/30	19.39	6/24 - 6/30
2001	CD	22.62	9/1 - 9/7	22.37	9/1 - 9/7
2002	DRY	21.49	9/1 - 9/7	21.35	9/1 - 9/7

Table 2-5h Mixed MWAT and MWAT Period Determined by Method 1 and Method 2 - Alternative 4d

Year	WY Type	Method 1		Method 2	
		Mixed MWAT (°C)	MWAT Period	Mixed MWAT (°C)	MWAT Period
1984	WET	20.01	9/8 - 9/14	19.85	9/8 - 9/14
1985	DRY	20.27	9/1 - 9/7	20.06	9/1 - 9/7
1986	WET	20.75	9/4 - 9/10	20.63	9/4 - 9/10
1987	CD	19.59	9/6 - 9/12	19.41	9/6 - 9/12
1988	CD	22.99	9/4 - 9/10	22.81	9/4 - 9/10
1989	NORMAL	19.32	9/5 - 9/11	19.11	9/5 - 9/11
1990	CD	19.83	9/1 - 9/7	19.70	9/1 - 9/7
1991	CD	21.56	9/1 - 9/7	21.44	9/1 - 9/7
1992	CD	21.04	9/1 - 9/7	20.90	9/1 - 9/7
1993	WET	21.96	9/6 - 9/12	21.80	9/6 - 9/12
1994	CD	21.56	9/1 - 9/7	21.40	9/1 - 9/7
1995	WET	19.37	9/12 - 9/18	19.26	9/12 - 9/18
1996	WET	19.93	9/1 - 9/7	19.74	9/1 - 9/7
1997	WET	21.53	9/3 - 9/9	21.32	9/3 - 9/9
1998	WET	21.54	9/3 - 9/9	21.40	9/3 - 9/9
1999	NORMAL	20.17	9/1 - 9/7	19.96	9/1 - 9/7
2000	NORMAL	19.03	**9/17 - 9/23**	18.96	**8/11 - 8/17**
2001	CD	22.59	9/1 - 9/7	22.34	9/1 - 9/7
2002	DRY	21.55	9/1 - 9/7	21.41	9/1 - 9/7

Note: The significantly different MWAT periods identified by the two methods are bold and colored with red, minor different MWAT periods are colored with pink.

2.2.4 Modeling Approach for MWAT Analysis of Alternatives

The mean daily water temperature modeling in Section 2.1 included the following models:

- daily based time-series reservoir models for Lake Almanor and Butt Valley Reservoir that covered a range of meteorological and hydrological years over a 19-year period (1984-2002) and,
- stream SNTEMP models for the bypass reaches that were each run for a one-day period using pre-defined combination of conditions of dam release temperature at an exceedence level (post-processed from Lake Almanor and Butt Valley Reservoir modeling daily output data), meteorology, stream accretion flow, and dam release.

Using a similar approach, these models were used for MWAT analysis along the NFFR. The basic approach of the MWAT analysis was to first run the Lake Almanor and Butt Valley reservoir models and post-process the 7-day rolling average of the daily output data (discharge and water temperature) mixed for the Canyon Dam release and the Caribou #1 and #2 PH discharges to determine the MWAT period for the Belden Reservoir water temperature condition using the Method 1 as discussed previously. Next, the stream SNTEMP models for the bypass reaches were used to compute the MWAT along the NFFR using pre-defined combination of conditions of dam release temperature corresponding to the identified MWAT period, 7-day average meteorology corresponding to the identified MWAT period, stream accretion flow, and dam release. The SNTEMP models for the bypass reaches were each run for a one-week period using the pre-defined combination of conditions. The SNTEMP model for the Seneca reach was run for a one-week period using Lake Almanor MITEMP-computed outflow from Canyon Dam corresponding to the identified MWAT period as the starting water temperature. The SNTEMP model for the Belden Reach was run for a one-week period using the mixed water temperature of (a) Seneca Reach SNTEMP ending temperature corresponding to the identified MWAT period and (b) Butt Valley CE-QUAL-W2-computed outflow from Caribou #1 and #2 PHs corresponding to the identified MWAT period as the starting water temperature. The SNTEMP models of other bypass reaches were run in a similar fashion.

Specifically, the following steps were taken to conduct the MWAT analysis of alternatives for each of the 19-years:

1) Post-processed the 7-day rolling average of the daily output data (discharge and water temperature) mixed for the Canyon Dam release and the Caribou #1 and #2 PH discharges simulated from the Lake Almanor and Butt Valley Reservoir models to identify the 7-day MWAT period for each month of July, August, and September for each of the 19 years.

2) Performed a 7-day rolling average analysis of daily meteorological data that were synthesized for the Prattville Intake meteorology station and determined the 7-

day average meteorological condition corresponding to the identified monthly MWAT period.

3) Determined the corresponding dam release schedule based on the month of the identified 7-day period and the water year type for each of the 19 years. If the identified 7-day period crossed two months, the month with more days over the 7-day period was used to determine dam release schedule. This algorithmic decision did not affect the MWAT analysis if the identified MWAT period crossed August and September. This is because the two months have the same dam release schedule for any water year type (see Table 1-4).

4) Conducted stream SNTEMP modeling for a one-week period to determine MWAT profile using the combined conditions of dam release temperature corresponding to the identified MWAT period (from step 1), 7-day average meteorology corresponding to the MWAT period (from step 2), stream accretion flow (the accretion flow was extracted from the existing SNTEMP models based on water year type and month, and the water temperature of the accretion flow was the “normal” temperature extracted from the existing SNTEMP models), and dam release (from step 3).

5) Presented the MWAT analysis results (from step 4) by month, by year, and by alternatives in graphs and tables.

Note that the above MWAT modeling approach was designed to analyze the MWAT for the bypass reaches below Belden Reservoir. Although the above approach also included SNTEMP modeling for the Seneca Reach, this modeling was conducted for the MWAT period identified for Belden Reservoir or the downstream reaches, not for the Seneca Reach. As mentioned previously, the MWAT period for the Seneca Reach is most likely different from the downstream reaches below Belden Reservoir because the Seneca Reach water temperature is primarily driven by the Canyon Dam release water temperature, while the water temperatures along the downstream reaches are primarily driven by the Belden Reservoir water temperature. However, since the water temperatures of releases from the Canyon Dam low-level outlet are generally cold (without water temperature issue) and relatively stable, no separate MWAT analysis for the Seneca Reach was conducted.

2.2.5 Results of MWAT Analysis of Alternatives

Figures 2-35 through 2-42 present the simulated July and August MWAT profiles along the NFFR for different alternatives using the modeling approach described in the previous section. The monthly (July, August, and September) MWAT periods as determined by mixing the Canyon Dam release and the Caribou #1 and #2 PH discharges simulated for different alternatives are shown in Table 2-6. One of the three monthly MWAT periods should be the same as the annual MWAT period shown in Tables 2-5a to 2-5h as determined under the Method 1.

Figures 2-43 to 2-50 present the monthly (July, August, and September) and annual MWAT profiles along the NFFR for different exceedence levels for each of the alternatives. These exceedence levels were statistically analyzed from the simulated MWAT profiles over the 19 analysis years. For example, the 10% exceedence MWAT profile means there are about two years over the 19 years at any location along the NFFR that have a MWAT greater than the given 10% exceedence MWAT at that location. Note that the annual MWAT profile was generated by using the maximum of the three monthly MWAT at any locations along the NFFR. Careful examination of the simulated monthly MWAT profiles along the NFFR indicates that the simulated monthly MWAT profiles are lower than the simulated maximum mean daily water temperature profiles presented in Figures 2-2 to 2-5, which makes sense.

Figures 2-51 through 2-54 compare the monthly ((July, August, and September) and annual MWAT at the selected locations between the alternatives. The selected locations include Belden Reach above East Branch (NF7), Rock Creek Reach above Bucks Creek (NF12), Cresta Reach above Cresta PH (NF16), and Poe Reach above Poe PH (NF18). The comparisons are also shown in Tables 2-7 to 2-10.

As discussed in Section 2.1.5, the simulated mean daily water temperature results show that the measure of preferential use of Caribou #1 over Caribou #2 (Alternatives 4b and 4c) appears to be more effective in reducing the NFFR water temperature than a thermal curtain at Butt Valley Reservoir near the Caribou Intakes (Alternatives 4a and 4d) in July, and the two measures have similar temperature reduction benefits in August. Looking at Table 2-7, the MWAT analysis results also corroborate this finding. Figures 2-51a and 2-51b are the graphical presentation of Table 2-7 for July and August MWATs.

It is worth noting that, in the analyses of mean daily water temperature and MWAT profiles, the preferential use of Caribou #1 was assumed to operate in July and August, while the thermal curtain at Butt Valley Reservoir was assumed to operate all year round. Apparently, preferential use of Caribou #1 would reduce the July and August MWATs but would have little effect on the September MWAT. This is one of the reasons that the September MWAT could be the highest MWAT in a year (i.e., annual MWAT) for the alternatives that include the preferential use of Caribou #1. So the annual MWAT should not be used for comparing the performance of the preferential use of Caribou #1 and a thermal curtain at Butt Valley Reservoir. Another factor that could cause the September

MWAT to be the highest MWAT in a year would be the increased Canyon Dam release measure. This measure was assumed to operate in July and August only. This measure would reduce the July and August MWATs but would have little effect on the September MWAT. The alternatives which could have higher September MWAT include Alternatives 3x, 4c, and 4d (see Figures 2-46, 2-49, and 2-50). September MWAT for these alternatives could be reduced further if the alternatives were allowed to operate in September. Figures 2-55 to 2-57 compare the monthly (Jul, Aug, and Sep) MWAT for Alternatives 3x, 4c, and 4d. In general the three alternatives have higher September MWAT in the Rock Creek Reach but lower September MWAT in the Poe Reach.

The MWAT analysis results show that the ranking of alternatives in terms of MWAT reduction is similar to the ranking of alternatives in terms of mean daily water temperature reduction. The highest ranked alternative (Alternative 3x) could reduce the monthly MWAT by about 4.5°C in July and 3.0°C in August on average at the Belden Reach above the East Branch (see Table 2-7) over the 19-year analysis period (1984 – 2002), and by about 2.0°C in July and 2.2°C in August at the downstream end of Poe Reach (see Table 2-10). The lowest ranked alternative (Alternative 4a) could reduce the monthly MWAT by about 2.2°C in July and 2.1°C in August at the Belden Reach above the East Branch (see Table 2-7), and by about 1.0°C in July and 1.4°C in August at the downstream end of Poe Reach (see Table 2-10).

Table 2-6 Monthly (Jul, Aug, Sep) MWAT Period as Determined by Mixing the Canyon Dam Release and the Caribou PH Discharges Simulated for Different Alternatives (Note: The date below shows the 4th day of the 7-day period)

		Baseline			Present Day			Alternative 3			Alternative 3x		
WY	Type	Jul	Aug	Sep	Jul	Aug	Sep	Jul	Aug	Sep	Jul	Aug	Sep
1984	W	7/28	8/21	9/9	7/28	8/20	9/9	7/31	8/31	9/18	7/31	8/31	9/4
1985	D	7/26	8/15	9/1	7/26	8/15	9/1	7/28	8/31	9/4	7/28	8/31	9/4
1986	W	7/31	8/16	9/4	7/31	8/16	9/5	7/31	8/31	9/8	7/31	8/31	9/4
1987	CD	7/13	8/8	9/4	7/31	8/8	9/4	7/1	8/31	9/4	7/1	8/31	9/4
1988	CD	7/31	8/1	9/4	7/31	8/4	9/4	7/31	8/31	9/8	7/1	8/31	9/4
1989	N	7/27	8/1	9/1	7/27	8/1	9/1	7/31	8/31	9/8	7/29	8/31	9/4
1990	CD	7/31	8/5	9/9	7/31	8/5	9/9	7/31	8/31	9/10	7/31	8/31	9/9
1991	CD	7/31	8/1	9/1	7/31	8/1	9/1	7/31	8/31	9/6	7/31	8/31	9/4
1992	CD	7/31	8/17	9/1	7/31	8/17	9/1	7/31	8/31	9/4	7/1	8/31	9/4
1993	W	7/31	8/6	9/8	7/31	8/6	9/8	7/31	8/31	9/12	7/31	8/31	9/9
1994	CD	7/31	8/6	9/1	7/31	8/6	9/1	7/31	8/31	9/4	7/1	8/31	9/4
1995	W	7/31	8/22	9/1	7/31	8/22	9/1	7/31	8/31	9/19	7/31	8/31	9/15
1996	W	7/28	8/14	9/1	7/30	8/14	9/1	7/31	8/31	9/4	7/31	8/31	9/4
1997	W	7/25	8/12	9/1	7/25	8/13	9/4	7/31	8/31	9/9	7/31	8/31	9/4
1998	W	7/31	8/31	9/3	7/31	8/31	9/4	7/31	8/31	9/17	7/31	8/31	9/4
1999	N	7/31	8/26	9/1	7/31	8/26	9/1	7/31	8/31	9/4	7/31	8/31	9/4
2000	N	7/31	8/5	9/1	7/31	8/5	9/1	7/31	8/30	9/21	7/31	8/31	9/20
2001	CD	7/30	8/11	9/1	7/31	8/11	9/1	7/31	8/31	9/4	7/31	8/31	9/4
2002	D	7/31	8/16	9/1	7/31	8/16	9/1	7/31	8/31	9/4	7/1	8/31	9/4

		Alternative 4a			Alternative 4b			Alternative 4c			Alternative 4d		
WY	Type	Jul	Aug	Sep	Jul	Aug	Sep	Jul	Aug	Sep	Jul	Aug	Sep
1984	W	7/31	8/31	9/18	7/31	8/31	9/8	7/31	8/31	9/8	7/31	8/31	9/11
1985	D	7/28	8/29	9/2	7/28	8/29	9/1	7/28	8/31	9/4	7/28	8/31	9/4
1986	W	7/31	8/31	9/8	7/31	8/31	9/6	7/31	8/31	9/5	7/31	8/31	9/7
1987	CD	7/31	8/6	9/4	7/31	8/31	9/4	7/1	8/31	9/4	7/1	8/31	9/9
1988	CD	7/31	8/31	9/8	7/31	8/31	9/4	7/1	8/31	9/4	7/31	8/31	9/7
1989	N	7/31	8/18	9/7	7/31	8/21	9/2	7/28	8/31	9/4	7/28	8/31	9/8
1990	CD	7/31	8/13	9/10	7/31	8/16	9/11	7/31	8/31	9/4	7/31	8/31	9/4
1991	CD	7/31	8/31	9/5	7/31	8/24	9/4	7/31	8/31	9/4	7/31	8/31	9/4
1992	CD	7/31	8/20	9/2	7/31	8/25	9/1	7/1	8/31	9/4	7/31	8/31	9/4
1993	W	7/31	8/31	9/12	7/31	8/31	9/10	7/31	8/31	9/9	7/31	8/31	9/9
1994	CD	7/31	8/31	9/4	7/31	8/24	9/3	7/1	8/31	9/4	7/31	8/31	9/4
1995	W	7/31	8/31	9/20	7/31	8/31	9/15	7/31	8/31	9/14	7/31	8/31	9/15
1996	W	7/31	8/31	9/4	7/31	8/31	9/4	7/31	8/31	9/4	7/31	8/31	9/4
1997	W	7/31	8/31	9/9	7/31	8/31	9/4	7/31	8/31	9/4	7/31	8/31	9/6
1998	W	7/31	8/31	9/17	7/31	8/31	9/4	7/31	8/31	9/4	7/31	8/31	9/6
1999	N	7/31	8/28	9/1	7/31	8/30	9/1	7/31	8/31	9/4	7/31	8/31	9/4
2000	N	7/31	8/28	9/20	7/31	8/15	9/20	7/30	8/13	9/20	7/31	8/14	9/20
2001	CD	7/31	8/28	9/1	7/31	8/29	9/1	7/31	8/31	9/4	7/31	8/31	9/4
2002	D	7/4	8/31	9/4	7/31	8/31	9/3	7/1	8/31	9/4	7/31	8/31	9/4

Table 2-7 Comparison of Monthly (Jul, Aug, Sep) and Annual MWAT in Belden Reach above East Branch (NF7) between Alternatives - Belden Reach (°C)

		Baseline				Present Day				Alternative 3				Alternative 3x			
WY	Type	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual
1984	W	19.6	19.7	19.4	19.7	19.4	19.6	19.4	19.6	17.3	17.6	17.8	17.8	16.3	17.7	18.6	18.6
1985	D	21.7	21.2	19.7	21.7	21.5	20.8	19.3	21.5	18.5	18.5	18.7	18.7	17.7	17.9	19.2	19.2
1986	W	20.6	20.8	20.2	20.8	20.5	20.7	20.3	20.7	17.6	18.5	18.5	18.5	17.0	18.4	19.4	19.4
1987	CD	20.5	20.4	19.3	20.5	18.9	19.7	18.7	19.7	17.2	18.2	18.0	18.2	16.0	17.6	18.7	18.7
1988	CD	23.1	22.9	22.3	23.1	22.6	21.9	21.6	22.6	19.8	20.6	20.2	20.6	15.6	20.1	21.7	21.7
1989	N	20.7	20.3	18.8	20.7	20.5	20.1	18.6	20.5	17.7	17.9	18.2	18.2	16.2	17.5	18.6	18.6
1990	CD	21.7	21.8	19.1	21.8	21.3	21.3	18.5	21.3	18.9	17.8	18.1	18.9	17.2	17.6	18.4	18.4
1991	CD	22.1	21.8	20.4	22.1	21.7	21.2	19.7	21.7	19.2	19.2	19.5	19.5	18.1	19.0	19.8	19.8
1992	CD	21.8	22.3	19.9	22.3	21.3	21.7	19.1	21.7	19.0	18.6	18.3	19.0	13.9	18.4	18.6	18.6
1993	W	21.3	21.6	21.2	21.6	21.2	21.5	21.1	21.5	18.2	19.1	19.4	19.4	17.7	19.1	20.2	20.2
1994	CD	22.2	22.1	20.4	22.2	21.7	21.5	19.7	21.7	19.3	19.1	19.3	19.3	16.4	18.8	19.7	19.7
1995	W	19.3	19.6	18.8	19.6	19.1	19.5	18.7	19.5	17.0	17.0	17.2	17.2	16.7	17.0	17.8	17.8
1996	W	20.2	20.6	19.6	20.6	20.0	20.6	19.6	20.6	17.5	18.1	17.6	18.1	16.7	17.9	18.4	18.4
1997	W	22.0	22.0	20.5	22.0	21.7	21.8	20.4	21.8	18.7	19.2	19.5	19.5	17.5	19.0	20.2	20.2
1998	W	20.2	21.3	21.2	21.3	20.0	21.2	21.1	21.2	18.0	18.5	18.0	18.5	17.6	18.7	19.5	19.5
1999	N	20.7	20.7	19.2	20.7	20.6	20.6	19.1	20.6	18.1	17.6	17.6	18.1	17.4	17.5	18.2	18.2
2000	N	21.6	21.6	18.0	21.6	21.5	21.5	18.0	21.5	18.3	17.9	18.2	18.3	17.7	17.4	18.6	18.6
2001	CD	22.6	23.0	21.9	23.0	21.8	22.3	21.1	22.3	19.6	20.6	19.7	20.6	18.2	20.1	20.0	20.1
2002	D	22.0	22.2	20.3	22.2	21.7	21.9	20.1	21.9	19.0	19.3	18.9	19.3	15.9	19.2	19.5	19.5
Mean		**21.3**	**21.4**	**20.0**	**21.4**	**20.9**	**21.0**	**19.7**	**21.2**	**18.4**	**18.6**	**18.6**	**18.8**	**16.8**	**18.4**	**19.2**	**19.2**

		Alternative 4a				Alternative 4b				Alternative 4c				Alternative 4d			
WY	Type	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual
1984	W	17.8	17.9	17.9	17.9	17.7	18.2	18.4	18.4	16.7	18.5	19.7	19.7	16.9	18.4	19.5	19.5
1985	D	19.3	19.4	19.0	19.4	19.3	19.5	19.0	19.5	18.9	18.0	19.3	19.3	18.9	18.0	19.3	19.3
1986	W	18.1	18.9	18.7	18.9	18.2	19.0	19.1	19.1	18.2	19.4	20.5	20.5	18.3	19.4	20.1	20.1
1987	CD	18.6	19.3	18.0	19.3	17.6	18.9	18.7	18.9	16.0	17.6	18.9	18.9	16.4	17.5	18.2	18.2
1988	CD	21.2	21.3	20.4	21.3	20.9	21.5	21.4	21.5	15.6	20.1	21.8	21.8	17.5	20.3	21.2	21.2
1989	N	18.7	19.0	18.4	19.0	18.4	18.8	18.5	18.8	17.2	17.7	18.7	18.7	17.3	17.6	18.6	18.6
1990	CD	19.8	19.6	18.2	19.8	19.7	19.0	18.1	19.7	17.2	17.8	18.6	18.6	17.7	17.8	18.7	18.7
1991	CD	20.0	19.7	19.7	20.0	20.0	19.9	19.7	20.0	18.4	19.3	20.1	20.1	18.5	19.3	20.2	20.2
1992	CD	19.9	19.5	18.7	19.9	19.6	19.1	18.8	19.6	13.9	18.8	19.1	19.1	15.7	18.9	19.1	19.1
1993	W	18.7	19.5	19.6	19.6	18.8	19.8	19.9	19.9	19.2	20.1	21.1	21.1	19.2	19.9	21.2	21.2
1994	CD	20.4	19.7	19.4	20.4	20.2	19.8	19.5	20.2	16.4	18.9	19.9	19.9	17.7	18.9	19.8	19.8
1995	W	17.2	17.2	17.3	17.3	17.4	17.3	17.7	17.7	17.5	18.2	19.0	19.0	17.5	18.3	18.9	18.9
1996	W	18.1	18.6	18.0	18.6	17.9	18.9	18.6	18.9	17.7	19.0	19.3	19.3	17.9	18.8	19.1	19.1
1997	W	19.3	19.9	19.9	19.9	19.1	20.1	20.2	20.2	17.9	19.8	20.7	20.7	18.1	19.7	20.8	20.8
1998	W	18.3	18.8	18.2	18.8	18.5	19.1	19.1	19.1	18.2	20.3	21.3	21.3	18.3	20.2	21.0	21.0
1999	N	18.5	18.4	17.7	18.5	18.5	18.3	17.8	18.5	18.4	18.6	19.1	19.1	18.5	18.6	19.2	19.2
2000	N	18.8	18.8	18.5	18.8	19.2	18.9	18.5	19.2	19.2	18.8	18.7	19.2	19.2	18.8	18.7	19.2
2001	CD	20.6	21.5	20.9	21.5	20.5	21.5	20.9	21.5	18.3	20.2	20.1	20.2	18.6	20.2	20.1	20.2
2002	D	20.0	19.7	19.1	20.0	19.7	20.0	19.5	20.0	15.9	19.7	20.1	20.1	17.8	19.7	20.1	20.1
Mean		**19.1**	**19.3**	**18.8**	**19.4**	**19.0**	**19.3**	**19.1**	**19.5**	**17.4**	**19.0**	**19.8**	**19.8**	**17.9**	**19.0**	**19.7**	**19.7**

Table 2-8 Comparison of Monthly (Jul, Aug, Sep) and Annual MWAT in Rock Creek Reach above Bucks Creek (NF12) between Alternatives – Rock Creek Reach (°C)

		Baseline				Present Day				Alternative 3				Alternative 3x			
WY	Type	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual
1984	W	20.3	20.1	19.7	20.3	20.2	20.0	19.6	20.2	18.7	18.4	18.2	18.7	18.1	18.6	19.0	19.0
1985	D	22.0	21.4	19.6	22.0	21.8	21.3	19.5	21.8	19.3	19.1	19.1	19.3	18.6	18.6	19.5	19.5
1986	W	20.9	21.0	20.4	21.0	20.8	20.9	20.5	20.9	18.8	19.0	18.8	19.0	18.3	19.0	19.7	19.7
1987	CD	21.4	20.3	19.3	21.4	20.1	20.1	19.2	20.1	19.9	19.0	18.6	19.9	18.5	18.4	19.3	19.3
1988	CD	23.2	22.9	22.2	23.2	23.0	22.3	22.1	23.0	21.0	21.3	20.7	21.3	18.2	20.9	22.2	22.2
1989	N	20.9	20.5	18.9	20.9	20.8	20.3	18.8	20.8	18.7	18.6	18.3	18.7	17.6	18.2	18.6	18.6
1990	CD	22.0	22.0	19.3	22.0	21.8	21.9	19.2	21.9	19.9	18.7	18.8	19.9	18.6	18.5	19.1	19.1
1991	CD	22.3	22.0	20.5	22.3	22.2	21.8	20.4	22.2	20.0	20.0	20.2	20.2	19.1	19.7	20.5	20.5
1992	CD	22.0	22.4	19.9	22.4	21.8	22.3	19.8	22.3	20.0	19.3	19.0	20.0	16.6	19.2	19.3	19.3
1993	W	21.4	21.7	21.3	21.7	21.4	21.6	21.3	21.6	19.2	19.6	19.6	19.6	18.8	19.6	20.4	20.4
1994	CD	22.3	22.1	20.4	22.3	22.1	22.0	20.3	22.1	20.2	19.8	19.9	20.2	18.4	19.5	20.3	20.3
1995	W	19.9	20.0	19.0	20.0	19.7	19.9	19.0	19.9	18.2	17.7	17.6	18.2	18.0	17.7	18.2	18.2
1996	W	20.9	21.0	19.6	21.0	20.7	21.0	19.6	21.0	18.9	18.8	17.9	18.9	18.2	18.6	18.5	18.6
1997	W	22.0	21.9	20.4	22.0	21.9	21.8	20.4	21.9	19.7	19.7	19.6	19.7	18.9	19.5	20.3	20.3
1998	W	20.8	21.4	21.4	21.4	20.6	21.3	21.3	21.3	19.2	19.1	18.4	19.2	18.9	19.3	19.8	19.8
1999	N	21.2	21.0	19.1	21.2	21.0	20.9	19.1	21.0	19.0	18.1	17.8	19.0	18.5	18.0	18.3	18.5
2000	N	21.6	21.6	18.1	21.6	21.6	21.6	18.1	21.6	19.1	18.3	18.6	19.1	18.6	17.8	18.9	18.9
2001	CD	22.4	22.9	21.6	22.9	22.2	22.7	21.5	22.7	20.4	21.1	19.9	21.1	19.2	20.7	20.1	20.7
2002	D	22.4	22.4	20.5	22.4	22.2	22.2	20.4	22.2	20.2	19.8	19.3	20.2	18.5	19.8	19.9	19.9
Mean		**21.6**	**21.5**	**20.1**	**21.7**	**21.4**	**21.4**	**20.0**	**21.5**	**19.5**	**19.2**	**19.0**	**19.6**	**18.4**	**19.0**	**19.6**	**19.6**

		Alternative 4a				Alternative 4b				Alternative 4c				Alternative 4d			
WY	Type	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual
1984	W	19.0	18.7	18.4	19.0	19.0	18.9	18.8	19.0	18.3	19.2	19.9	19.9	18.4	19.0	19.7	19.7
1985	D	20.0	19.8	19.2	20.0	20.0	19.9	19.3	20.0	19.6	18.7	19.5	19.6	19.6	18.7	19.5	19.6
1986	W	19.1	19.3	19.0	19.3	19.1	19.4	19.4	19.4	19.2	19.8	20.7	20.7	19.2	19.8	20.3	20.3
1987	CD	20.1	20.1	18.6	20.1	19.7	19.5	19.3	19.7	18.5	18.4	19.4	19.4	18.7	18.3	18.8	18.8
1988	CD	21.9	21.9	20.9	21.9	21.7	22.1	22.0	22.1	18.2	20.9	22.3	22.3	19.2	21.0	21.7	21.7
1989	N	19.3	19.4	18.5	19.4	19.1	19.2	18.7	19.2	18.3	18.4	18.7	18.7	18.4	18.3	18.6	18.6
1990	CD	20.7	20.4	18.9	20.7	20.6	19.8	18.8	20.6	18.6	18.7	19.3	19.3	19.0	18.7	19.4	19.4
1991	CD	20.8	20.5	20.4	20.8	20.7	20.5	20.4	20.7	19.4	20.0	20.8	20.8	19.5	20.0	20.8	20.8
1992	CD	20.6	20.1	19.4	20.6	20.5	19.8	19.5	20.5	16.6	19.6	19.7	19.7	17.4	19.6	19.8	19.8
1993	W	19.5	20.0	19.8	20.0	19.6	20.2	20.1	20.2	19.9	20.5	21.2	21.2	19.9	20.3	21.3	21.3
1994	CD	21.1	20.3	20.1	21.1	20.9	20.4	20.1	20.9	18.4	19.6	20.5	20.5	19.0	19.7	20.5	20.5
1995	W	18.3	17.9	17.7	18.3	18.5	17.9	18.1	18.5	18.6	18.7	19.3	19.3	18.6	18.7	19.2	19.2
1996	W	19.4	19.2	18.2	19.4	19.2	19.4	18.7	19.4	18.9	19.5	19.3	19.5	19.0	19.3	19.1	19.3
1997	W	20.1	20.2	20.0	20.2	20.0	20.4	20.3	20.4	19.2	20.1	20.7	20.7	19.3	20.1	20.7	20.7
1998	W	19.4	19.3	18.6	19.4	19.5	19.5	19.6	19.6	19.3	20.6	21.4	21.4	19.4	20.5	21.2	21.2
1999	N	19.4	18.9	17.9	19.4	19.4	18.7	18.0	19.4	19.3	19.0	19.0	19.3	19.4	19.0	19.1	19.4
2000	N	19.5	19.0	18.9	19.5	19.8	19.1	18.9	19.8	19.8	19.1	19.1	19.8	19.8	19.0	19.1	19.8
2001	CD	21.2	22.0	21.3	22.0	21.1	22.0	21.3	22.0	19.3	20.9	20.2	20.9	19.5	20.8	20.2	20.8
2002	D	20.9	20.2	19.5	20.9	20.7	20.4	19.8	20.7	18.5	20.2	20.4	20.4	19.3	20.2	20.4	20.4
Mean		**20.0**	**19.9**	**19.2**	**20.1**	**20.0**	**19.8**	**19.5**	**20.1**	**18.8**	**19.6**	**20.1**	**20.2**	**19.1**	**19.5**	**20.0**	**20.1**

Table 2-9 Comparison of Monthly (Jul, Aug, Sep) and Annual MWAT in Cresta Reach above Cresta PH (NF16) between Alternatives – Cresta Reach (°C)

WY	Type	Baseline				Present Day				Alternative 3				Alternative 3x			
		Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual
1984	W	20.3	19.7	19.1	20.3	19.9	19.6	19.0	19.9	18.6	18.3	17.8	18.6	18.0	18.4	18.4	18.4
1985	D	22.0	21.5	19.0	22.0	21.9	21.3	18.9	21.9	19.4	19.2	18.6	19.4	18.8	18.8	18.9	18.9
1986	W	20.8	20.5	19.9	20.8	20.6	20.4	19.9	20.6	18.7	18.8	18.4	18.8	18.3	18.8	19.2	19.2
1987	CD	21.6	20.4	18.8	21.6	20.4	20.3	18.8	20.4	20.4	19.3	18.3	20.4	19.2	18.7	18.8	19.2
1988	CD	23.2	22.9	21.6	23.2	23.0	22.3	21.5	23.0	21.4	21.5	20.2	21.5	18.9	21.1	21.6	21.6
1989	N	20.5	19.8	18.0	20.5	20.3	19.7	17.9	20.3	18.5	18.2	17.5	18.5	17.5	17.9	17.7	17.9
1990	CD	22.0	22.0	18.8	22.0	21.8	21.9	18.7	21.9	20.2	18.8	18.4	20.2	19.1	18.6	18.6	19.1
1991	CD	22.3	21.9	19.9	22.3	22.2	21.8	19.9	22.2	20.4	20.0	19.8	20.4	19.6	19.8	20.1	20.1
1992	CD	21.9	22.4	19.4	22.4	21.8	22.3	19.3	22.3	20.3	19.5	18.6	20.3	17.4	19.3	18.8	19.3
1993	W	21.3	21.2	20.5	21.3	21.1	21.1	20.5	21.1	19.1	19.4	18.9	19.4	18.7	19.3	19.7	19.7
1994	CD	22.3	22.0	19.7	22.3	22.2	21.9	19.6	22.2	20.6	19.8	19.3	20.6	19.1	19.6	19.6	19.6
1995	W	19.9	19.8	18.5	19.9	19.6	19.7	18.5	19.7	18.2	17.6	17.3	18.2	18.0	17.6	17.8	18.0
1996	W	20.9	20.6	18.9	20.9	20.5	20.5	18.9	20.5	18.9	18.5	17.4	18.9	18.2	18.4	17.9	18.4
1997	W	21.7	21.2	19.5	21.7	21.5	21.1	19.5	21.5	19.5	19.3	18.8	19.5	18.8	19.2	19.4	19.4
1998	W	20.8	21.0	20.8	21.0	20.4	20.9	20.7	20.9	19.1	18.9	18.0	19.1	18.8	19.1	19.4	19.4
1999	N	21.0	20.7	18.4	21.0	20.7	20.6	18.4	20.7	18.9	17.9	17.2	18.9	18.4	17.8	17.5	18.4
2000	N	21.6	21.4	17.7	21.6	21.4	21.3	17.7	21.4	19.0	18.2	18.1	19.0	18.6	17.7	18.4	18.6
2001	CD	22.3	22.7	20.8	22.7	22.1	22.6	20.7	22.6	20.6	21.2	19.2	21.2	19.6	20.8	19.3	20.8
2002	D	22.5	22.4	20.0	22.5	22.3	22.2	19.9	22.3	20.4	19.9	18.9	20.4	18.9	19.8	19.4	19.8
Mean		**21.5**	**21.3**	**19.4**	**21.6**	**21.2**	**21.1**	**19.4**	**21.3**	**19.6**	**19.2**	**18.5**	**19.6**	**18.6**	**19.0**	**19.0**	**19.3**

WY	Type	Alternative 4a				Alternative 4b				Alternative 4c				Alternative 4d			
		Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual
1984	W	18.9	18.6	18.0	18.9	18.9	18.7	18.3	18.9	18.2	19.0	19.3	19.3	18.4	18.9	19.1	19.1
1985	D	20.1	19.9	18.6	20.1	20.1	20.0	18.6	20.1	19.8	18.9	19.0	19.8	19.7	18.8	18.9	19.7
1986	W	19.0	19.1	18.6	19.1	19.0	19.2	18.9	19.2	19.0	19.5	20.1	20.1	19.1	19.5	19.7	19.7
1987	CD	20.3	20.3	18.3	20.3	20.1	19.7	18.8	20.1	19.2	18.8	19.0	19.2	19.4	18.7	18.4	19.4
1988	CD	22.2	22.1	20.4	22.2	22.0	22.2	21.4	22.2	18.9	21.1	21.6	21.6	19.9	21.3	21.1	21.3
1989	N	19.0	18.9	17.6	19.0	18.9	18.8	17.8	18.9	18.1	18.0	17.8	18.1	18.2	18.0	17.7	18.2
1990	CD	20.9	20.5	18.4	20.9	20.8	19.9	18.4	20.8	19.1	18.8	18.8	19.1	19.4	18.8	18.8	19.4
1991	CD	21.0	20.5	20.0	21.0	20.9	20.5	20.0	20.9	19.9	20.1	20.4	20.4	19.9	20.1	20.4	20.4
1992	CD	20.9	20.1	19.0	20.9	20.7	19.7	19.0	20.7	17.4	19.7	19.2	19.7	18.1	19.7	19.2	19.7
1993	W	19.4	19.7	19.1	19.7	19.5	19.8	19.5	19.8	19.7	20.1	20.4	20.4	19.7	20.0	20.5	20.5
1994	CD	21.3	20.3	19.4	21.3	21.1	20.3	19.5	21.1	19.1	19.7	19.8	19.8	19.5	19.7	19.8	19.8
1995	W	18.3	17.8	17.4	18.3	18.5	17.8	17.8	18.5	18.5	18.5	18.8	18.8	18.5	18.6	18.7	18.7
1996	W	19.3	18.9	17.6	19.3	19.2	19.1	18.0	19.2	18.9	19.2	18.5	19.2	19.0	19.1	18.3	19.1
1997	W	19.9	19.7	19.1	19.9	19.7	19.8	19.4	19.8	19.0	19.7	19.7	19.7	19.2	19.6	19.8	19.8
1998	W	19.3	19.1	18.1	19.3	19.4	19.3	19.1	19.4	19.2	20.3	20.8	20.8	19.3	20.2	20.6	20.6
1999	N	19.2	18.7	17.4	19.2	19.2	18.5	17.5	19.2	19.1	18.6	18.1	19.1	19.2	18.7	18.1	19.2
2000	N	19.4	18.8	18.4	19.4	19.7	18.9	18.4	19.7	19.7	18.9	18.5	19.7	19.7	18.8	18.5	19.7
2001	CD	21.3	22.0	20.5	22.0	21.1	22.0	20.6	22.0	19.7	21.0	19.4	21.0	19.8	21.0	19.4	21.0
2002	D	21.1	20.3	19.0	21.1	20.9	20.5	19.4	20.9	18.9	20.3	19.9	20.3	19.6	20.3	19.9	20.3
Mean		**20.0**	**19.8**	**18.7**	**20.1**	**20.0**	**19.7**	**19.0**	**20.1**	**19.0**	**19.5**	**19.4**	**19.8**	**19.2**	**19.5**	**19.3**	**19.8**

Table 2-10 Comparison of Monthly (Jul, Aug, Sep) and Annual MWAT in Poe Reach above Poe PH (NF18) between Alternatives – Poe Reach (°C)

		Baseline				Present Day				Alternative 3				Alternative 3x			
WY	Type	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual
1984	W	22.5	21.8	21.1	22.5	22.4	21.9	21.1	22.4	21.5	20.8	20.1	21.5	21.2	20.8	20.8	21.2
1985	D	23.8	23.2	20.7	23.8	23.8	23.1	20.6	23.8	21.7	21.1	20.2	21.7	21.3	20.8	20.4	21.3
1986	W	22.9	22.6	21.9	22.9	22.8	22.5	22.0	22.8	21.6	21.2	20.5	21.6	21.4	21.2	21.5	21.5
1987	CD	23.8	22.8	20.4	23.8	22.6	22.6	20.4	22.6	22.8	21.1	20.0	22.8	21.8	20.7	20.4	21.8
1988	CD	25.0	24.8	23.3	25.0	24.9	24.1	23.3	24.9	23.7	23.5	22.0	23.7	21.7	23.2	23.3	23.3
1989	N	22.4	21.8	20.0	22.4	22.3	21.7	20.0	22.3	21.0	20.3	19.6	21.0	20.5	20.1	19.8	20.5
1990	CD	23.9	23.8	20.6	23.9	23.8	23.7	20.6	23.8	22.5	20.5	20.3	22.5	21.7	20.3	20.5	21.7
1991	CD	24.1	23.7	21.7	24.1	24.0	23.6	21.7	24.0	22.6	21.8	21.5	22.6	22.0	21.6	21.8	22.0
1992	CD	23.8	24.2	20.9	24.2	23.7	24.1	20.9	24.1	22.6	21.1	20.3	22.6	19.6	21.0	20.4	21.0
1993	W	23.5	23.5	22.5	23.5	23.5	23.5	22.5	23.5	22.2	21.9	20.9	22.2	22.0	21.9	21.8	22.0
1994	CD	24.1	23.9	21.5	24.1	24.0	23.8	21.4	24.0	22.8	21.6	21.2	22.8	21.8	21.4	21.4	21.8
1995	W	22.3	21.8	20.3	22.3	22.2	21.8	20.3	22.2	21.3	19.9	19.2	21.3	21.2	19.9	20.0	21.2
1996	W	23.1	22.8	21.0	23.1	22.8	22.8	21.0	22.8	21.6	21.0	19.5	21.6	21.2	21.0	19.8	21.2
1997	W	24.1	23.5	21.5	24.1	24.0	23.5	21.5	24.0	22.2	21.5	20.8	22.2	21.7	21.5	21.4	21.7
1998	W	23.3	23.2	22.8	23.3	23.3	23.2	22.7	23.3	22.5	21.9	20.1	22.5	22.3	22.0	21.9	22.3
1999	N	23.3	22.5	19.9	23.3	23.2	22.4	19.9	23.2	22.1	20.0	19.4	22.1	21.8	19.9	19.7	21.8
2000	N	23.9	23.7	18.7	23.9	23.8	23.7	18.7	23.8	22.5	19.9	19.9	22.5	22.2	19.2	20.4	22.2
2001	CD	24.2	24.6	22.6	24.6	23.9	24.5	22.5	24.5	22.7	23.1	21.0	23.1	22.0	22.8	21.1	22.8
2002	D	24.4	24.2	21.9	24.4	24.3	24.1	21.8	24.3	23.2	22.1	20.6	23.2	22.4	22.0	21.0	22.4
Mean		**23.6**	**23.3**	**21.2**	**23.6**	**23.4**	**23.2**	**21.2**	**23.5**	**22.3**	**21.3**	**20.4**	**22.3**	**21.6**	**21.1**	**20.9**	**21.8**

		Alternative 4a				Alternative 4b				Alternative 4c				Alternative 4d			
WY	Type	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual	Jul	Aug	Sep	Annual
1984	W	21.7	20.9	20.2	21.7	21.7	21.0	20.7	21.7	21.3	21.2	21.3	21.3	21.4	21.1	21.0	21.4
1985	D	22.1	21.8	20.5	22.1	22.2	21.9	20.5	22.2	22.0	20.9	20.5	22.0	21.9	20.8	20.5	21.9
1986	W	21.8	21.4	20.6	21.8	21.9	21.4	21.2	21.9	21.9	21.6	22.1	22.1	21.9	21.6	21.5	21.9
1987	CD	22.5	22.8	20.0	22.8	22.3	21.5	20.4	22.3	21.8	20.7	20.5	21.8	21.9	20.7	20.0	21.9
1988	CD	24.3	23.9	22.2	24.3	24.2	24.0	23.2	24.2	21.7	23.2	23.4	23.4	22.6	23.3	22.8	23.3
1989	N	21.3	21.2	19.7	21.3	21.2	20.7	19.9	21.2	21.0	20.2	19.8	21.0	21.0	20.1	19.7	21.0
1990	CD	23.0	22.4	20.3	23.0	23.0	21.5	20.2	23.0	21.7	20.5	20.6	21.7	21.9	20.5	20.7	21.9
1991	CD	23.1	22.1	21.8	23.1	23.0	22.4	21.7	23.0	22.2	21.8	22.0	22.2	22.2	21.8	22.0	22.2
1992	CD	23.0	22.1	20.6	23.0	22.9	21.5	20.7	22.9	19.6	21.3	20.7	21.3	20.9	21.3	20.8	21.3
1993	W	22.4	22.1	21.0	22.4	22.5	22.2	21.6	22.5	22.6	22.4	22.3	22.6	22.6	22.3	22.3	22.6
1994	CD	23.4	22.0	21.3	23.4	23.2	22.1	21.3	23.2	21.8	21.5	21.5	21.8	22.0	21.5	21.5	22.0
1995	W	21.4	20.0	19.3	21.4	21.5	20.0	19.9	21.5	21.5	20.5	20.7	21.5	21.5	20.5	20.5	21.5
1996	W	21.9	21.3	19.6	21.9	21.8	21.4	19.9	21.8	21.6	21.4	20.2	21.6	21.6	21.4	20.1	21.6
1997	W	22.4	21.8	21.0	22.4	22.3	21.9	21.4	22.3	21.9	21.8	21.7	21.9	22.0	21.8	21.7	22.0
1998	W	22.6	22.1	20.2	22.6	22.7	22.2	21.7	22.7	22.6	22.8	22.7	22.8	22.6	22.7	22.3	22.7
1999	N	22.3	20.8	19.3	22.3	22.3	20.4	19.3	22.3	22.3	20.4	20.0	22.3	22.3	20.4	20.0	22.3
2000	N	22.7	20.8	20.3	22.7	22.9	21.5	20.3	22.9	22.7	21.5	20.4	22.7	22.8	21.6	20.4	22.8
2001	CD	23.3	23.8	22.4	23.8	23.2	23.8	22.5	23.8	22.0	22.9	21.2	22.9	22.2	22.9	21.2	22.9
2002	D	23.7	22.3	20.7	23.7	23.4	22.4	21.2	23.4	22.4	22.3	21.3	22.4	22.6	22.3	21.3	22.6
Mean		**22.6**	**21.9**	**20.6**	**22.6**	**22.5**	**21.8**	**20.9**	**22.6**	**21.8**	**21.5**	**21.2**	**22.1**	**22.0**	**21.5**	**21.1**	**22.1**

Figure 2-35a Simulated July MWAT Profile along NFFR - Baseline

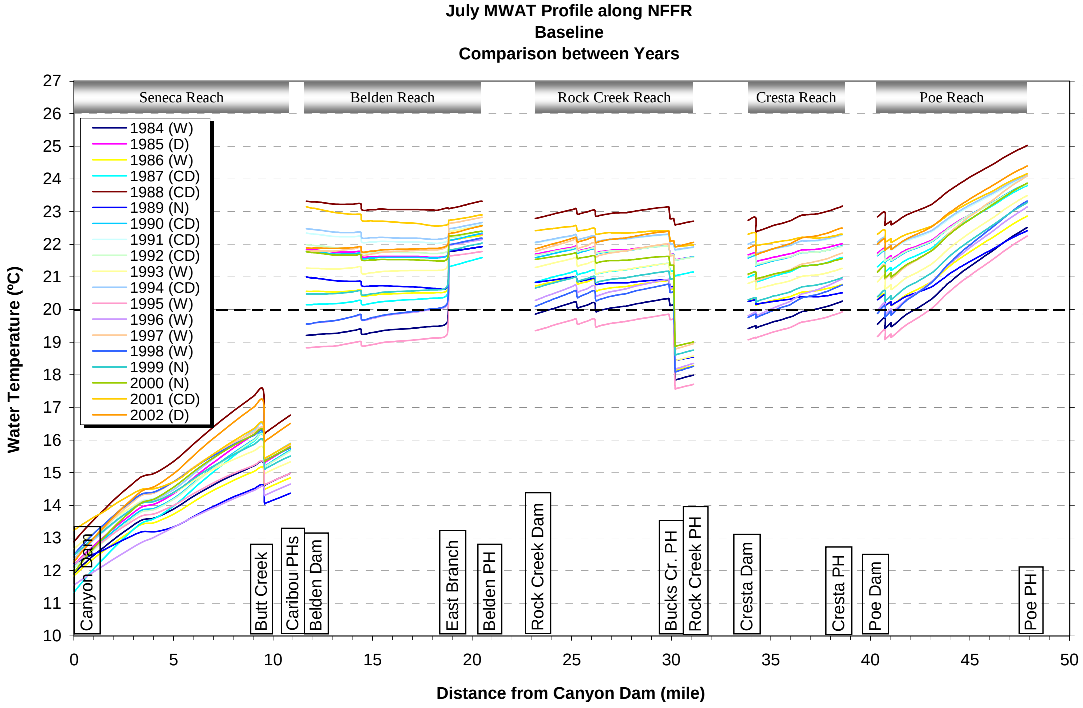


Figure 2-35b Simulated August MWAT Profile along NFFR – Baseline

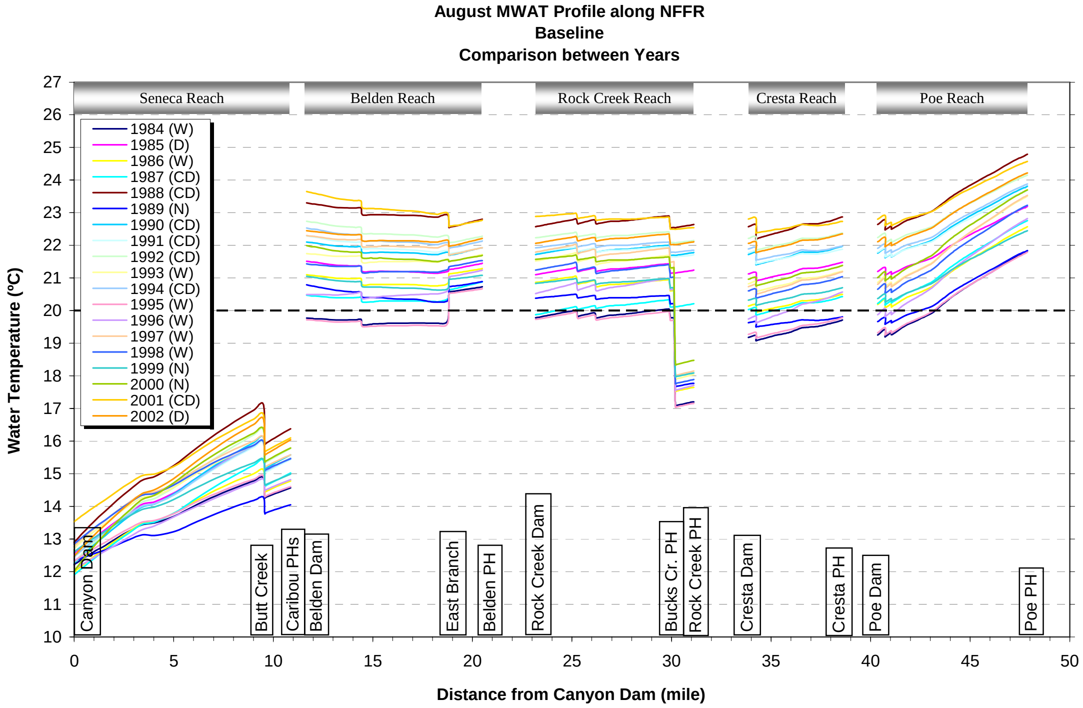


Figure 2-36a Simulated July MWAT Profile along NFFR – Present Day

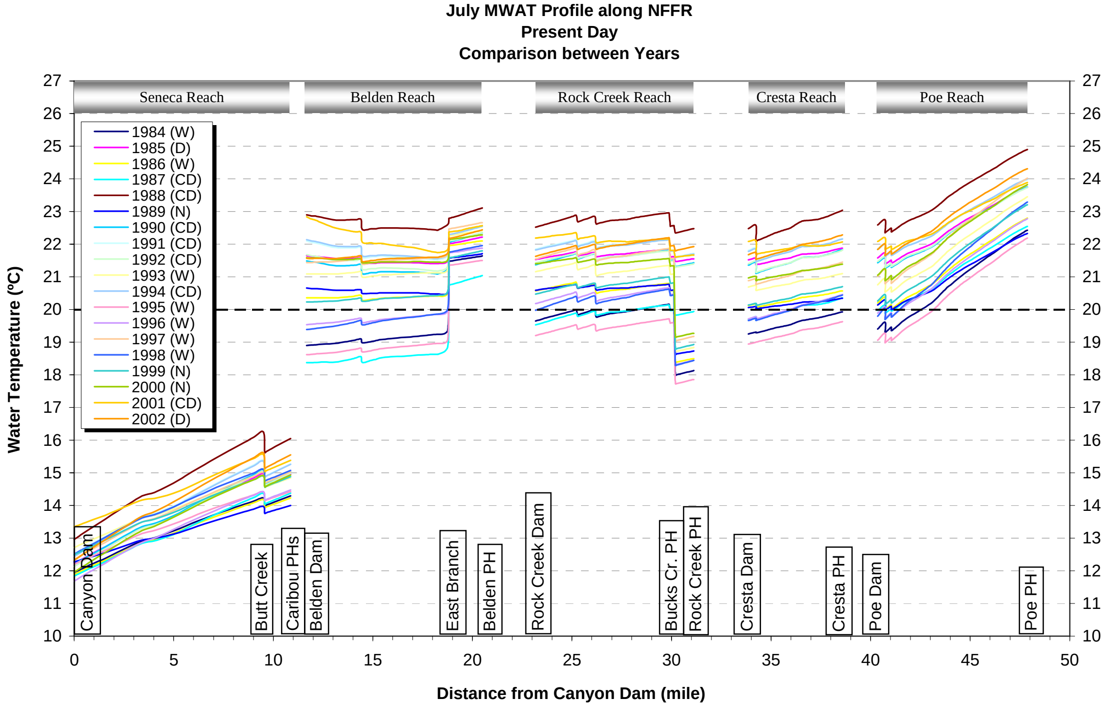


Figure 2-36b Simulated August MWAT Profile along NFFR – Present Day

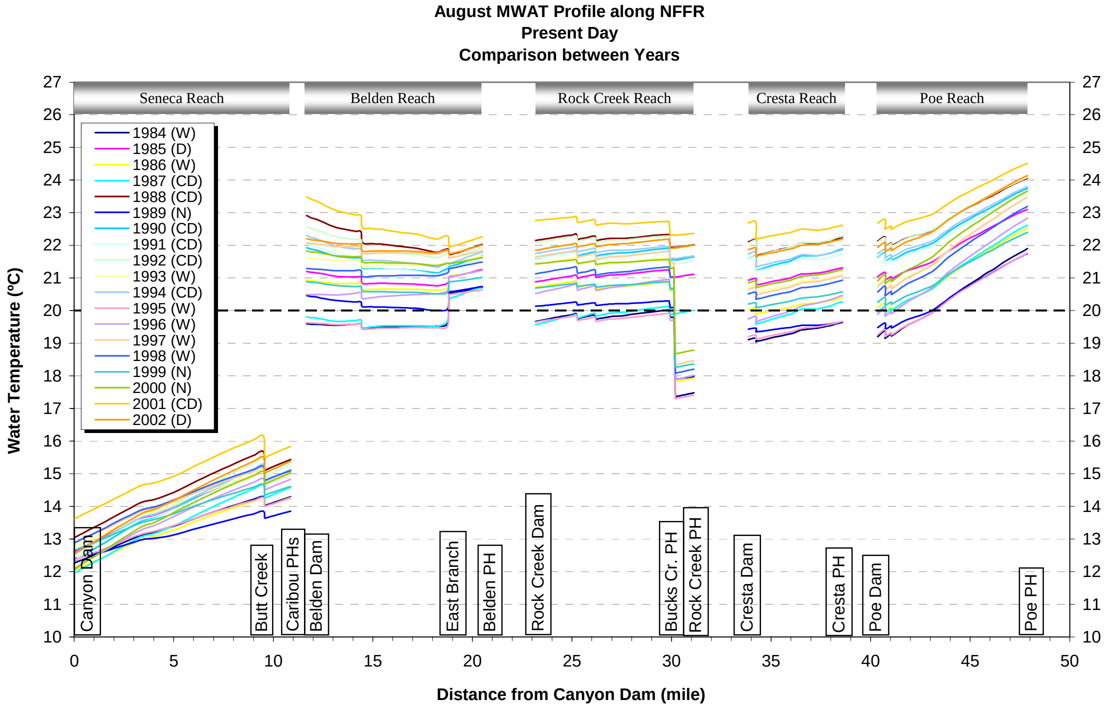


Figure 2-37a Simulated July MWAT Profile along NFFR – Alternative 3

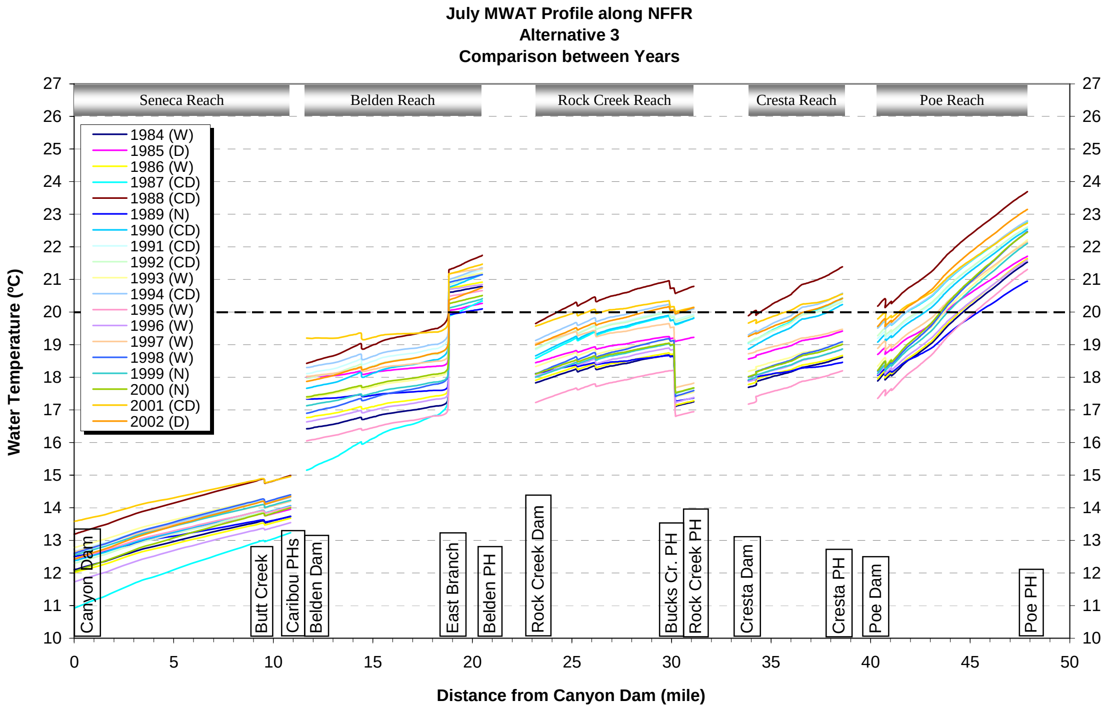


Figure 2-37b Simulated August MWAT Profile along NFFR – Alternative 3

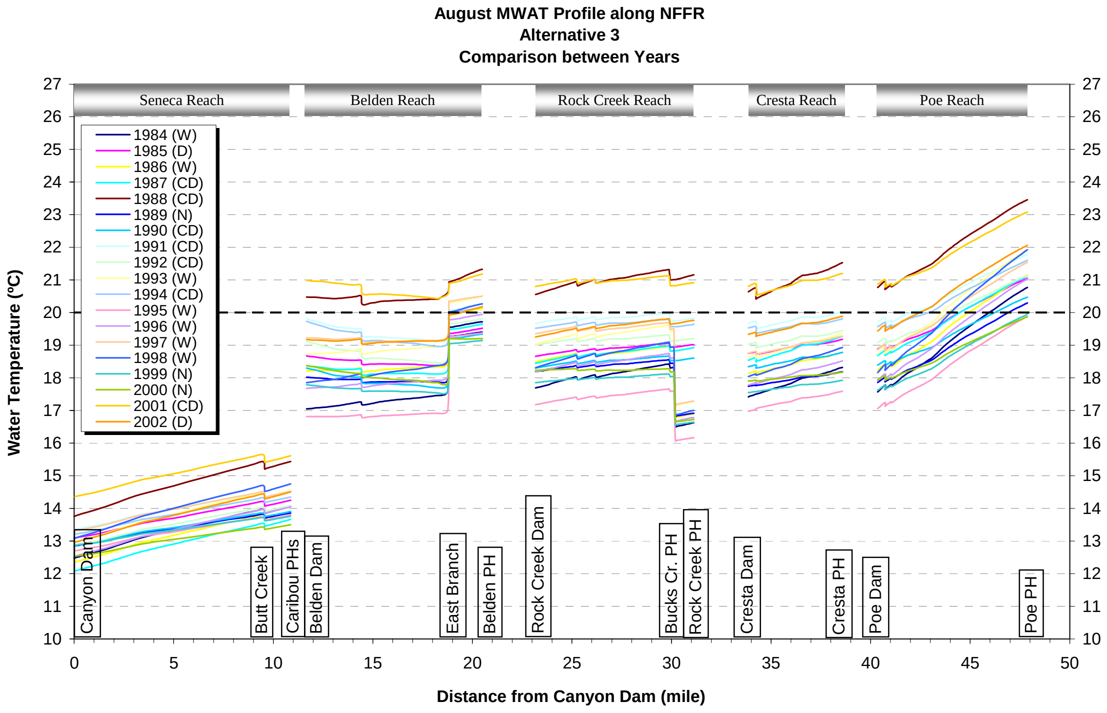


Figure 2-38a Simulated July MWAT Profile along NFFR – Alternative 3x

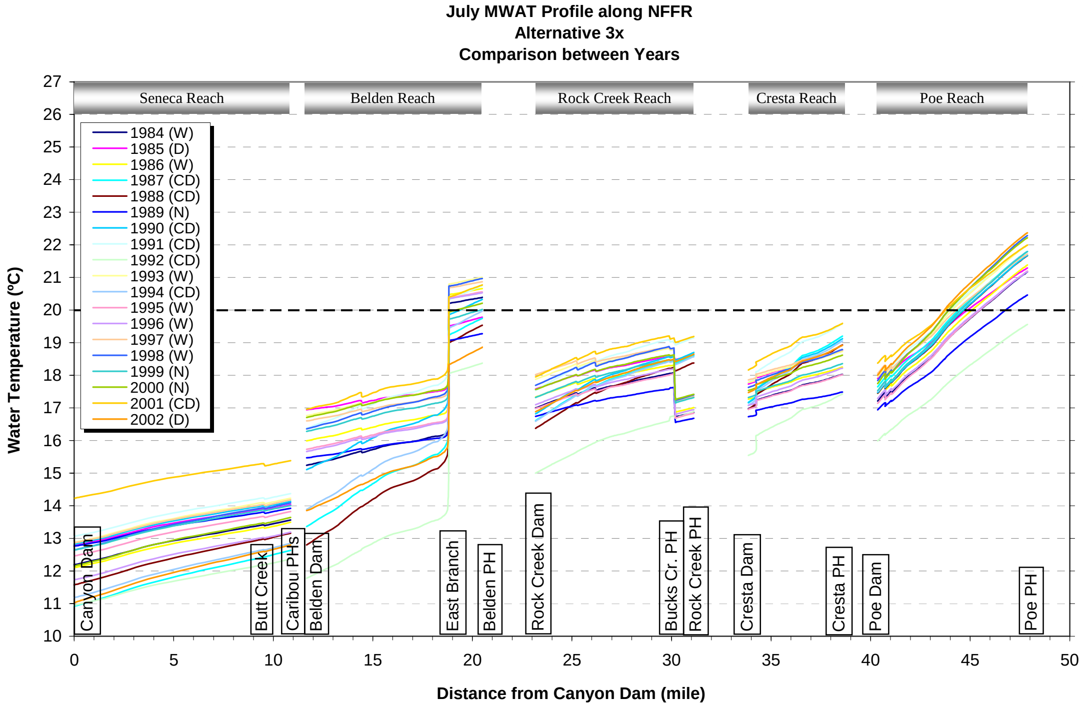


Figure 2-38b Simulated August MWAT Profile along NFFR – Alternative 3x

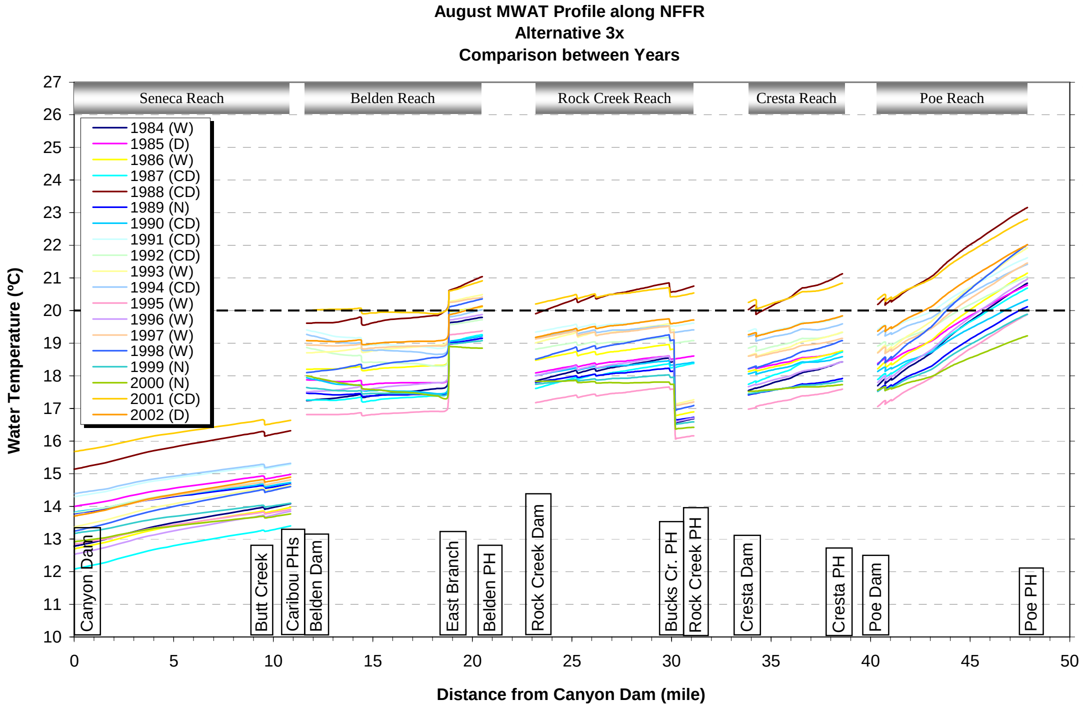


Figure 2-39a Simulated July MWAT Profile along NFFR – Alternative 4a

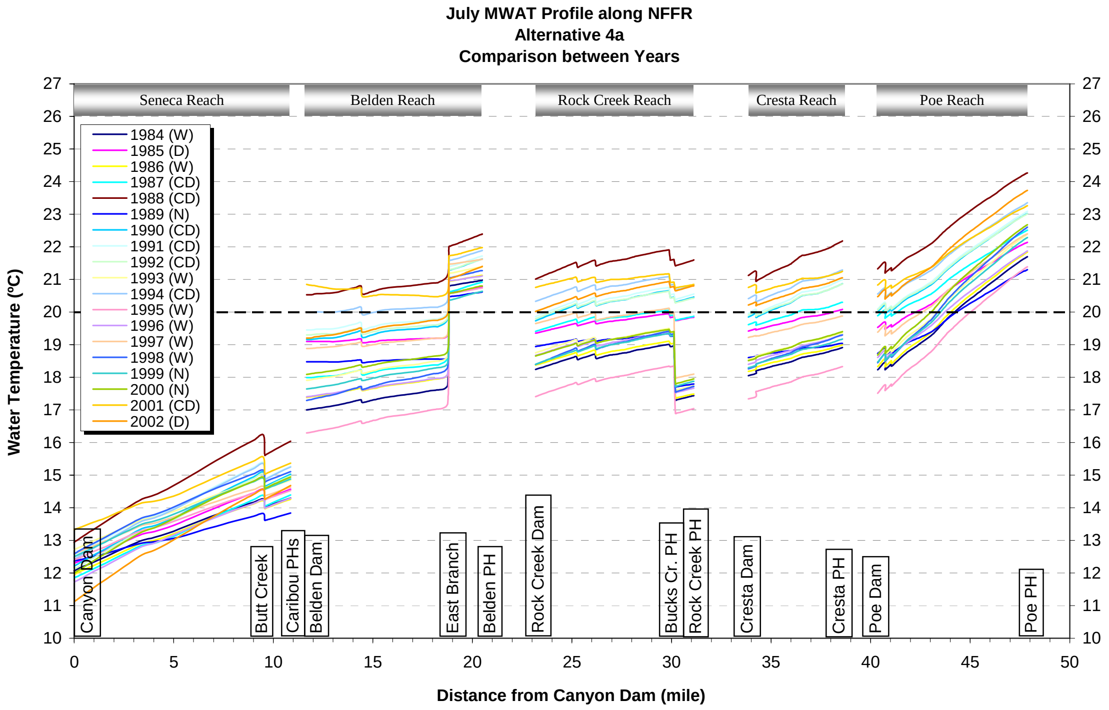


Figure 2-39b Simulated August MWAT Profile along NFFR – Alternative 4a

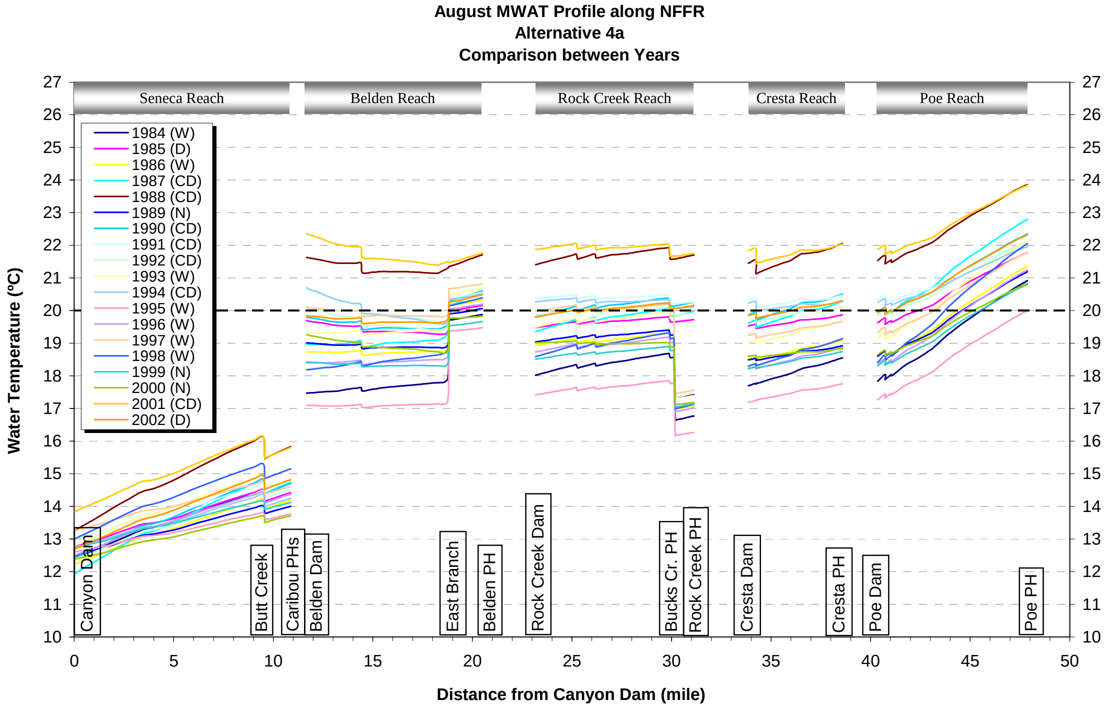


Figure 2-40a Simulated July MWAT Profile along NFFR – Alternative 4b

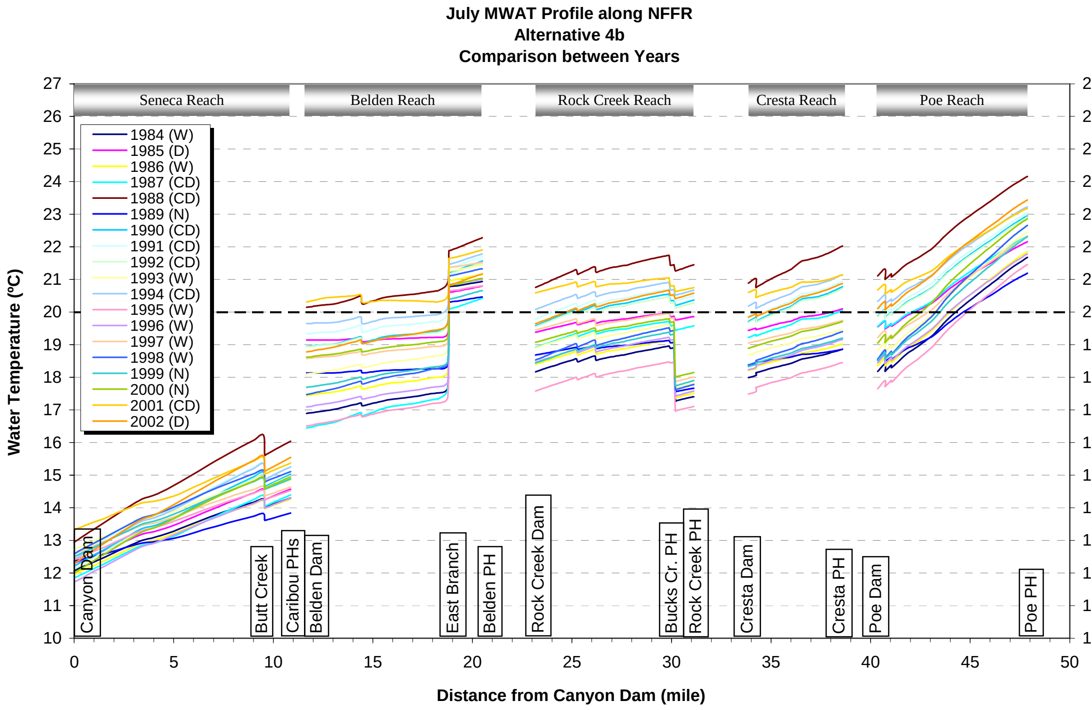


Figure 2-40b Simulated August MWAT Profile along NFFR – Alternative 4b

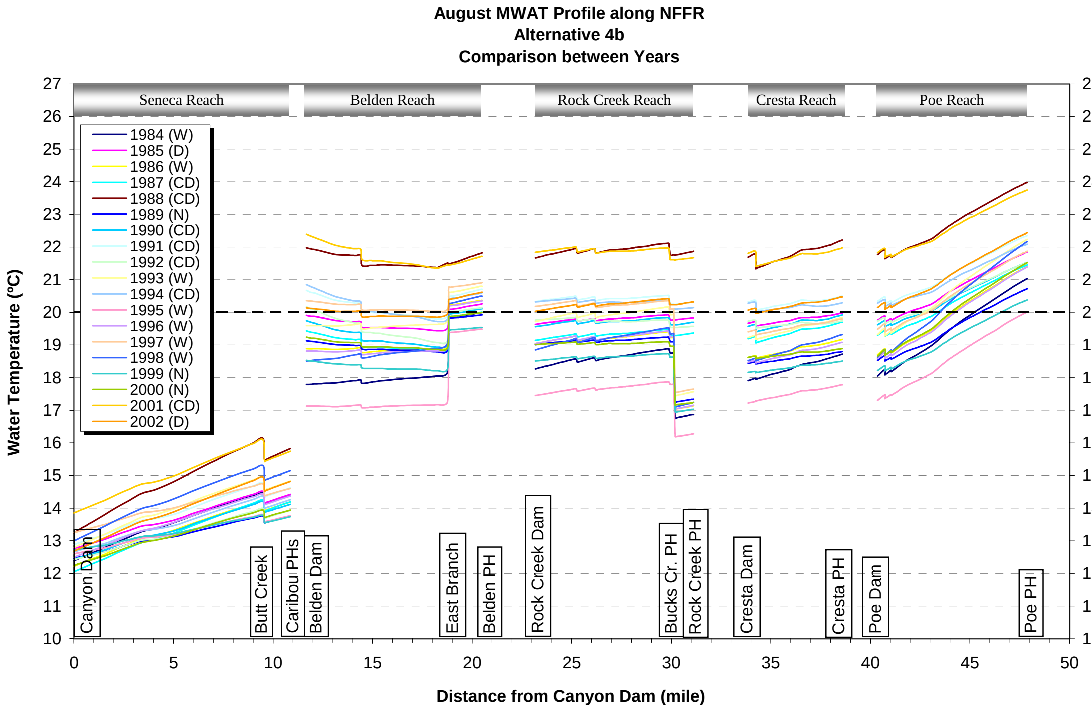


Figure 2-41a Simulated July MWAT Profile along NFFR – Alternative 4c

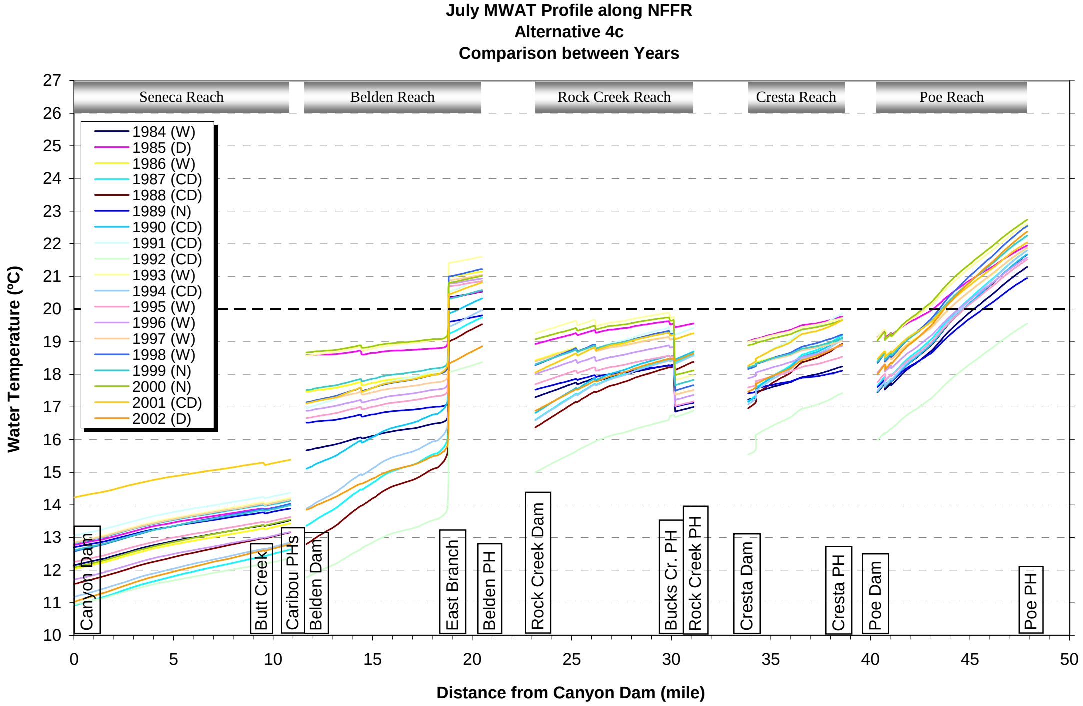


Figure 2-41b Simulated August MWAT Profile along NFFR – Alternative 4c

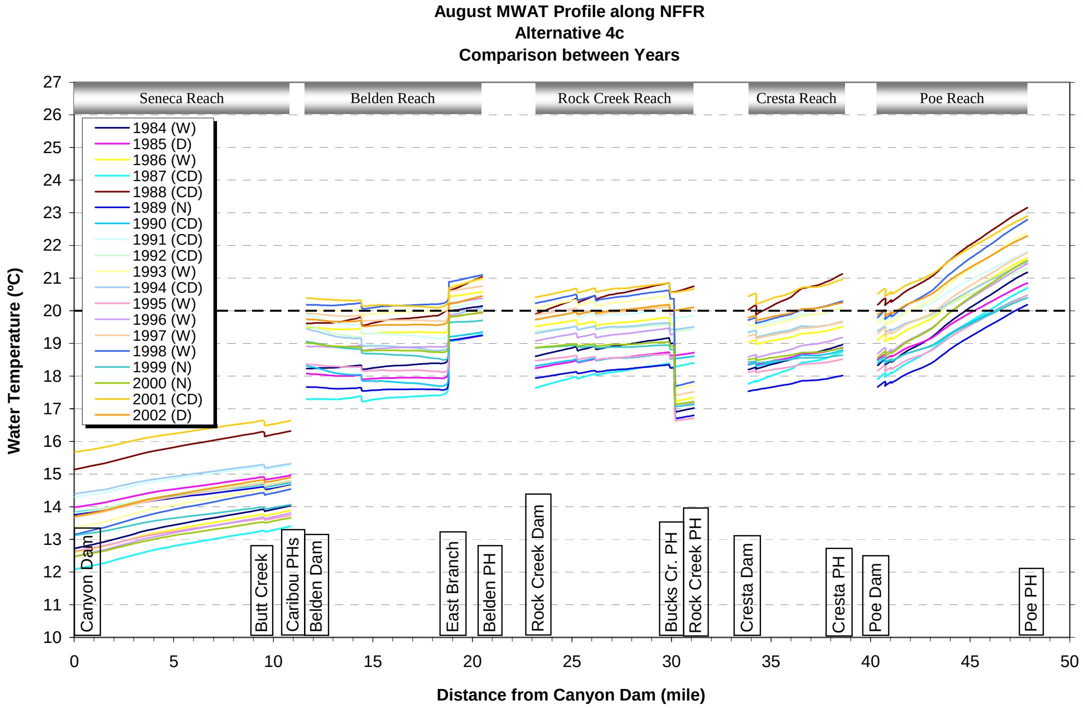


Figure 2-42a Simulated July MWAT Profile along NFFR – Alternative 4d

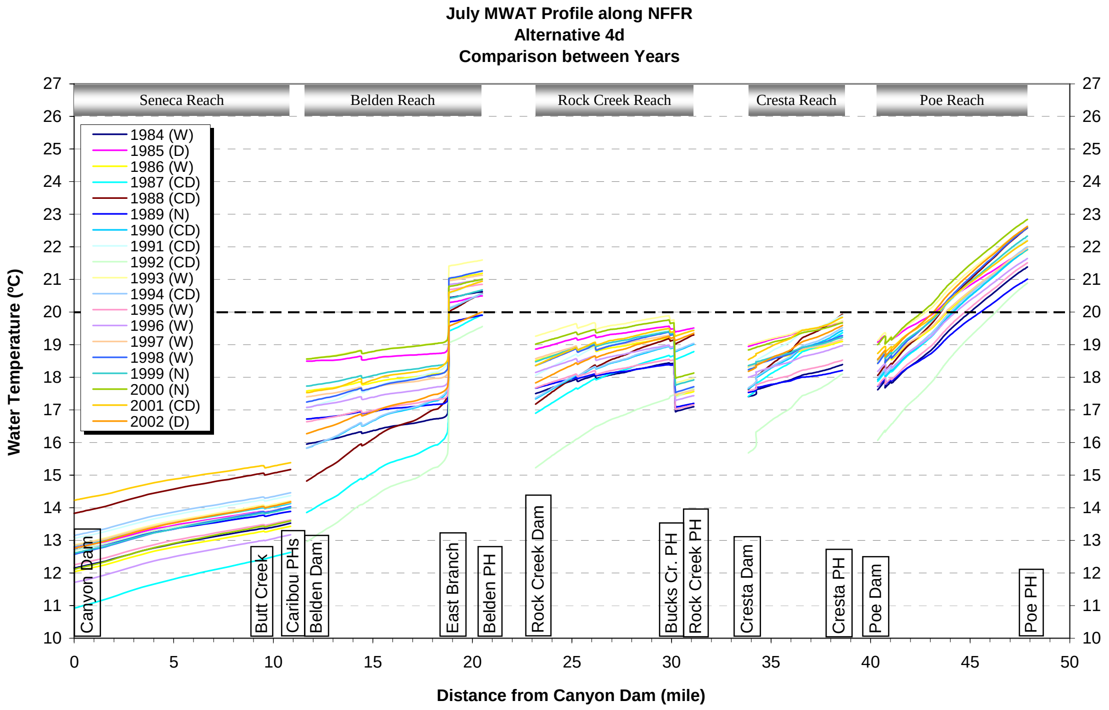


Figure 2-42b Simulated August MWAT Profile along NFFR – Alternative 4d

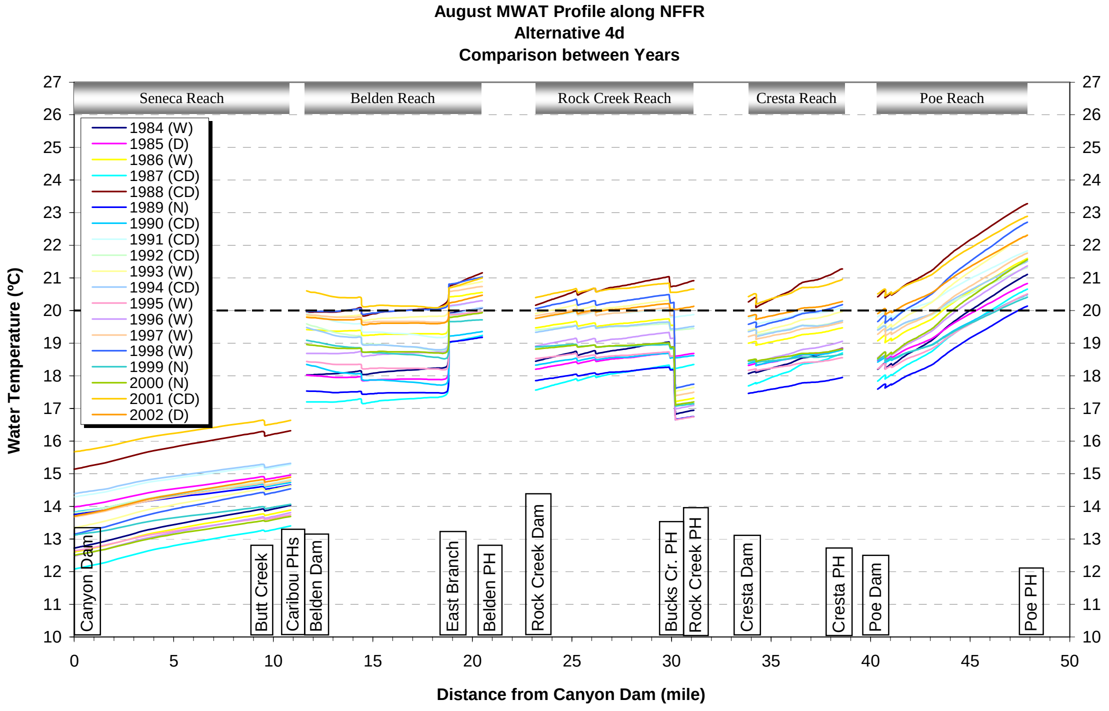
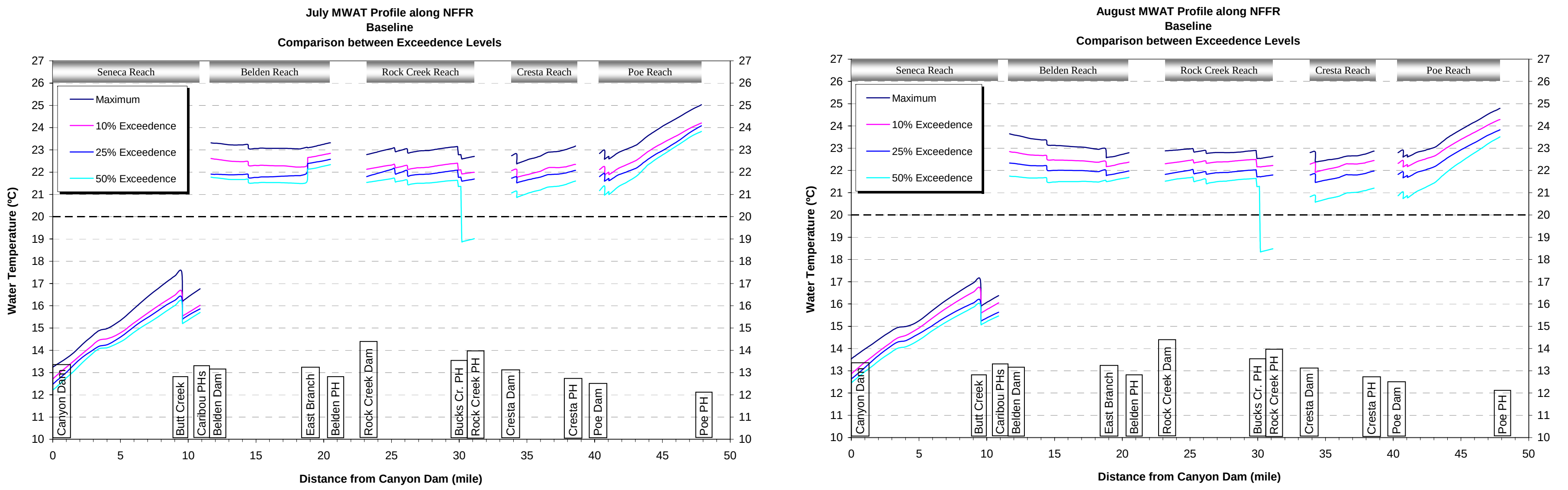
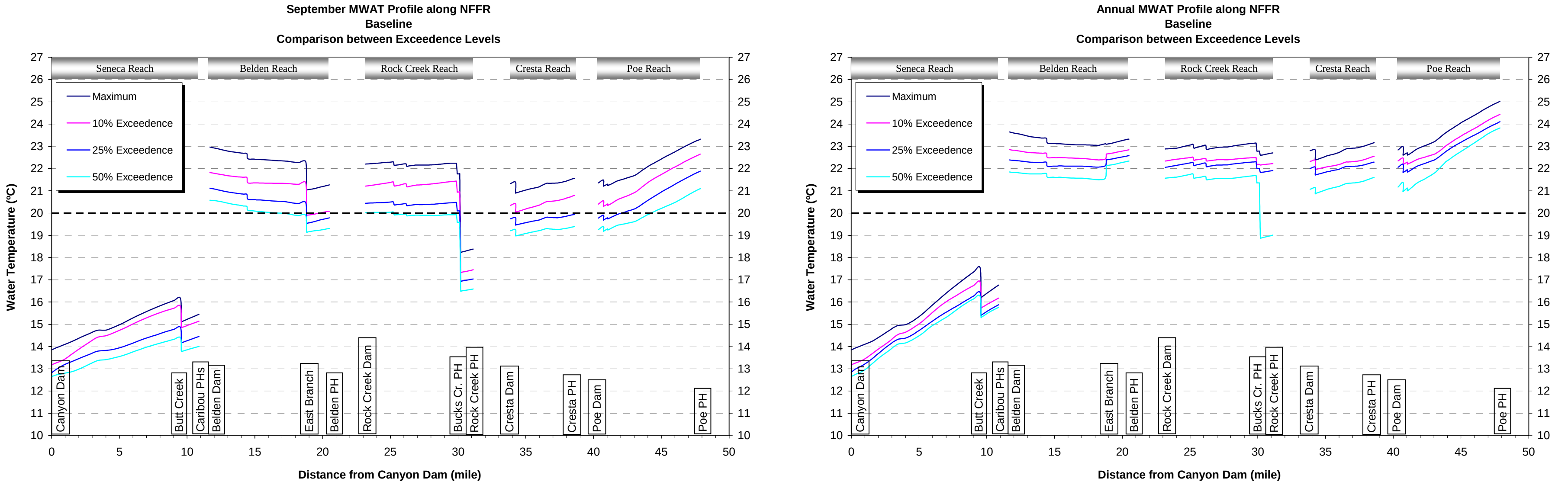


Figure 2-43 Monthly (July, Aug, Sep) and Annual MWAT Profiles along NFFR – Baseline

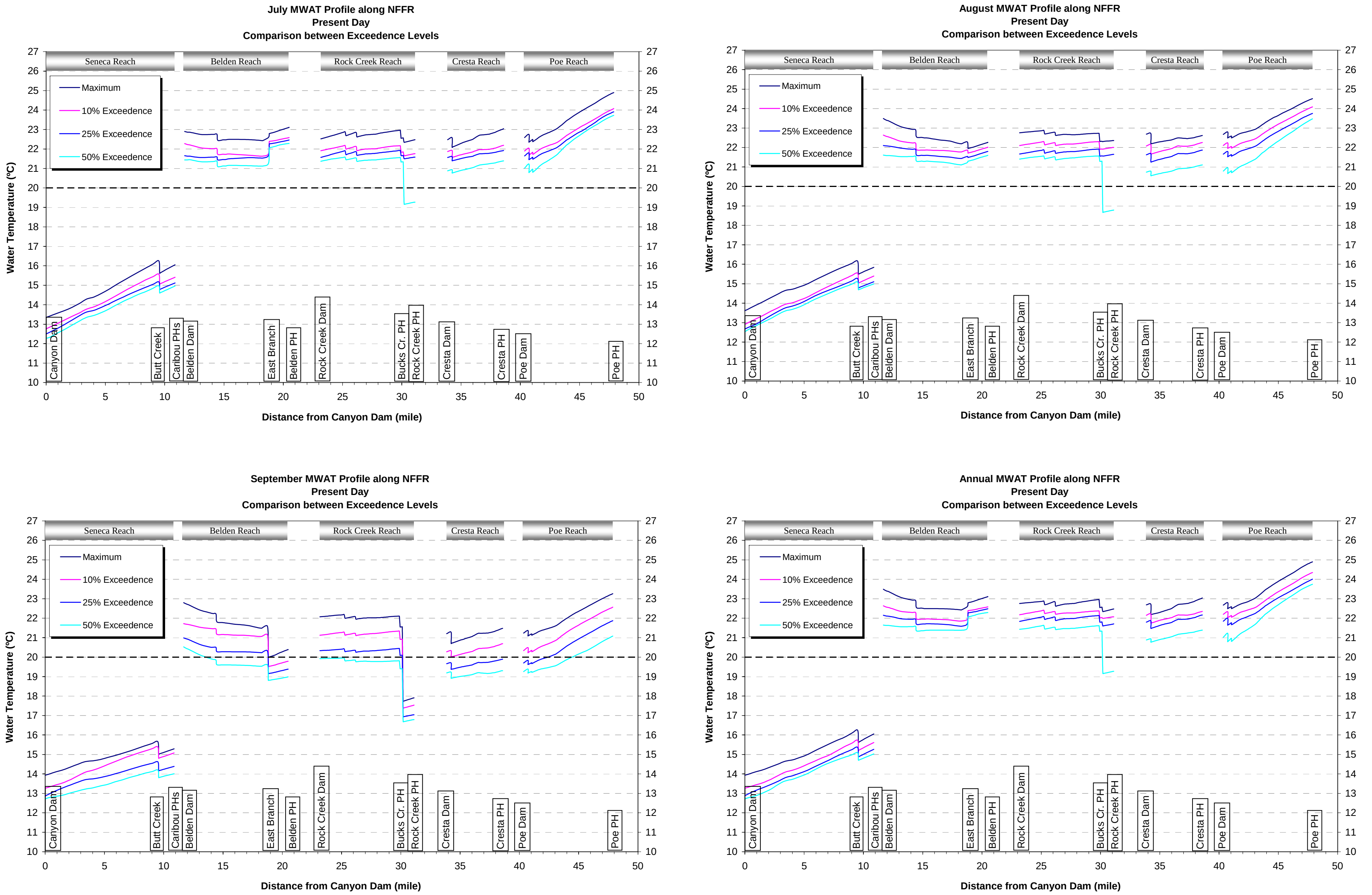

July MWAT Profile along NFFR
Baseline
Comparison between Exceedence Levels

August MWAT Profile along NFFR
Baseline
Comparison between Exceedence Levels


September MWAT Profile along NFFR
Baseline
Comparison between Exceedence Levels

Annual MWAT Profile along NFFR
Baseline
Comparison between Exceedence Levels

Figure 2-44 Monthly (July, Aug, Sep) and Annual MWAT Profiles along NFFR – Present Day



July MWAT Profile along NFFR
Present Day
Comparison between Exceedence Levels

August MWAT Profile along NFFR
Present Day
Comparison between Exceedence Levels

September MWAT Profile along NFFR
Present Day
Comparison between Exceedence Levels

Annual MWAT Profile along NFFR
Present Day
Comparison between Exceedence Levels

Figure 2-45 Monthly (July, Aug, Sep) and Annual MWAT Profiles along NFFR – Alternative 3

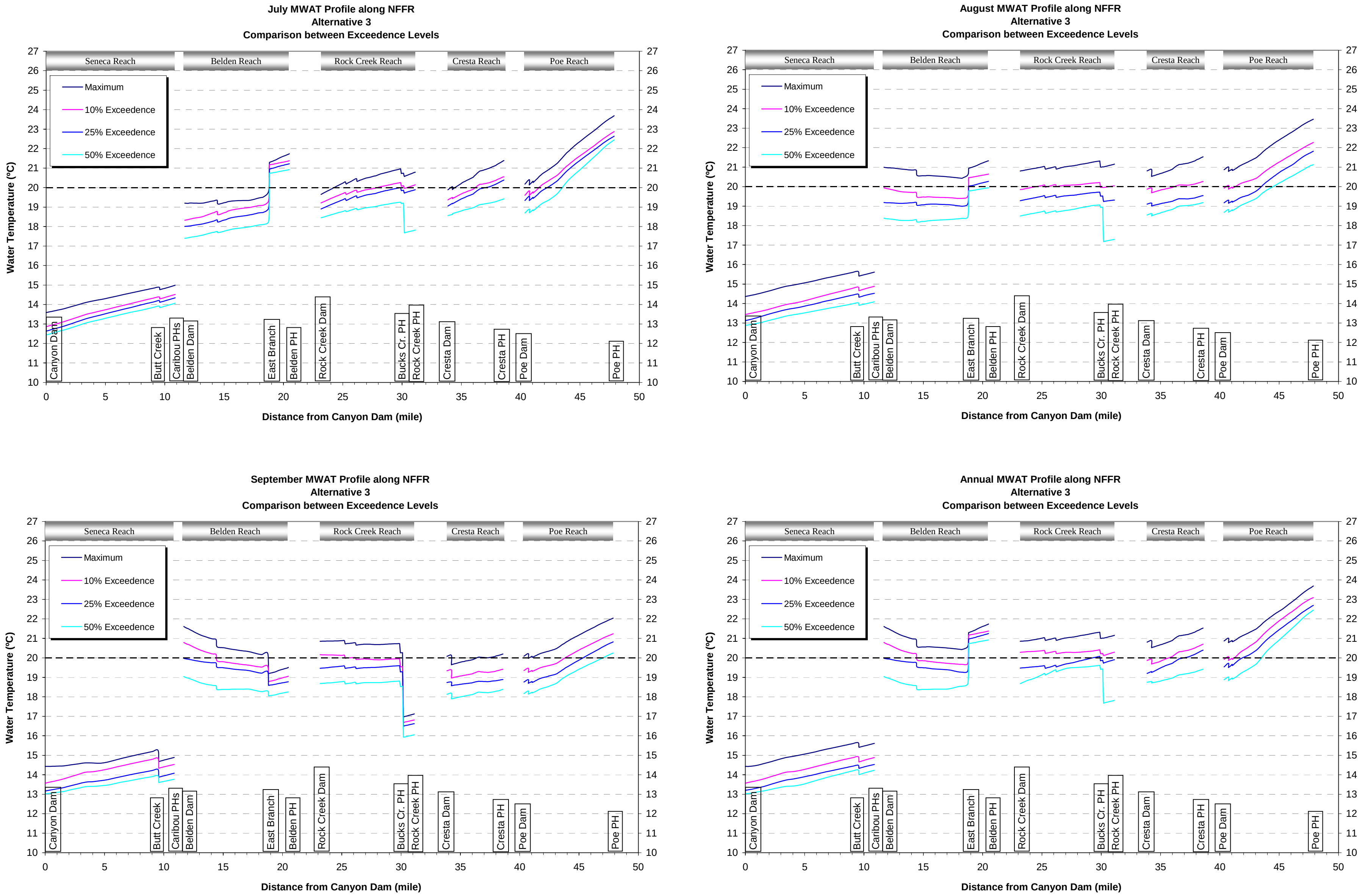


Figure 2-46 Monthly (July, Aug, Sep) and Annual MWAT Profiles along NFFR – Alternative 3x

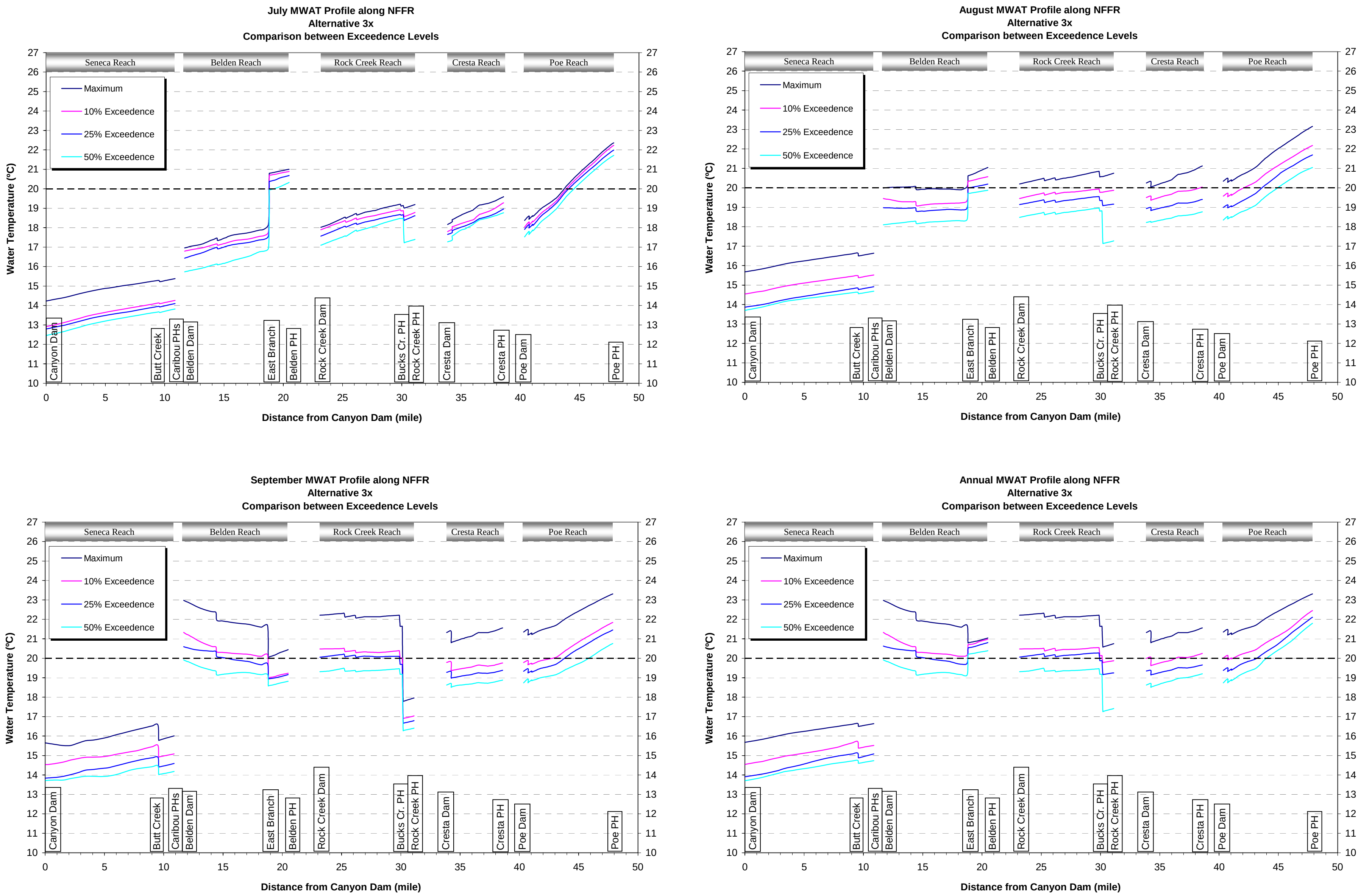


Figure 2-47 Monthly (July, Aug, Sep) and Annual MWAT Profiles along NFFR – Alternative 4a

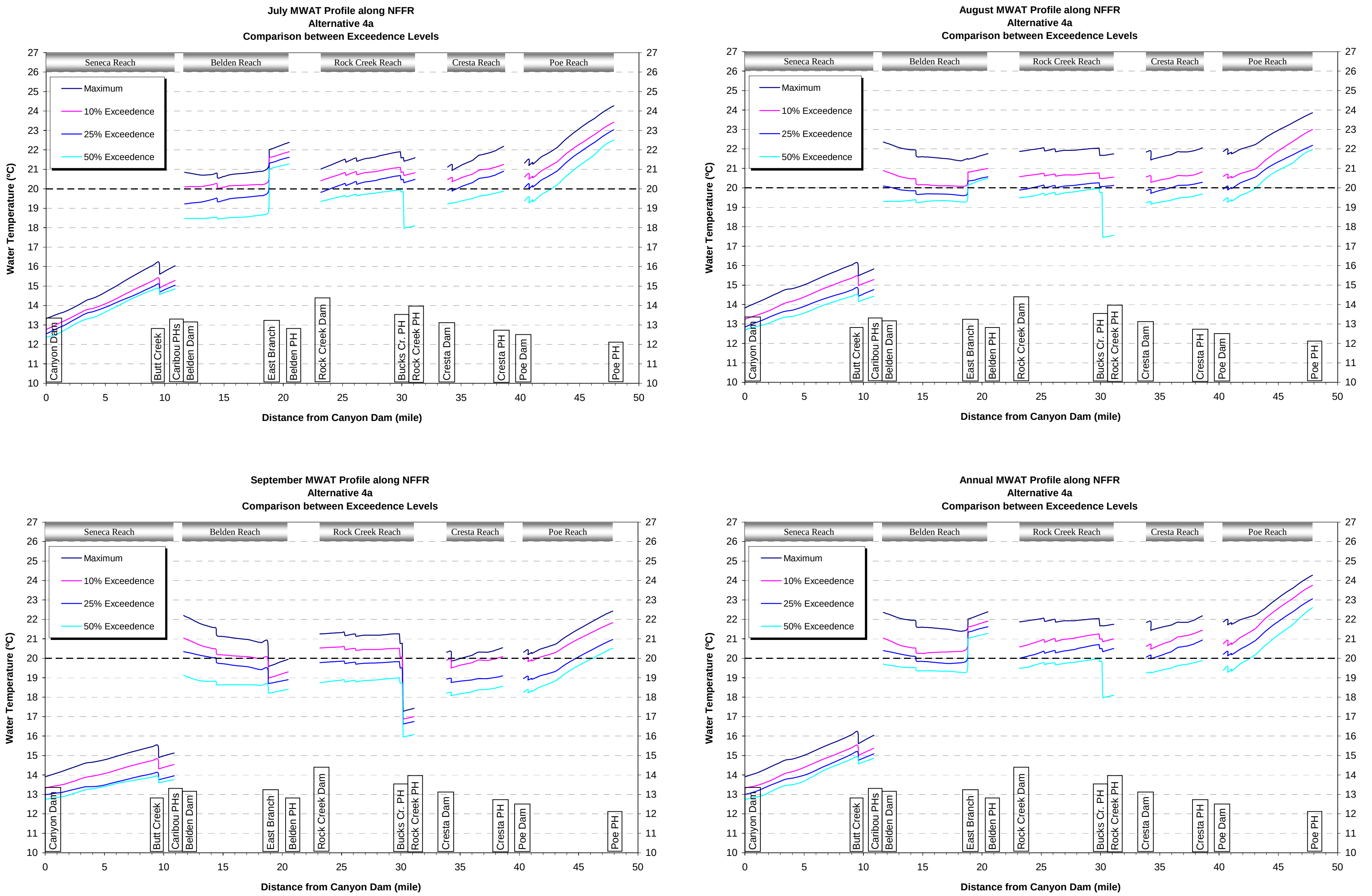


Figure 2-48 Monthly (July, Aug, Sep) and Annual MWAT Profiles along NFFR – Alternative 4b

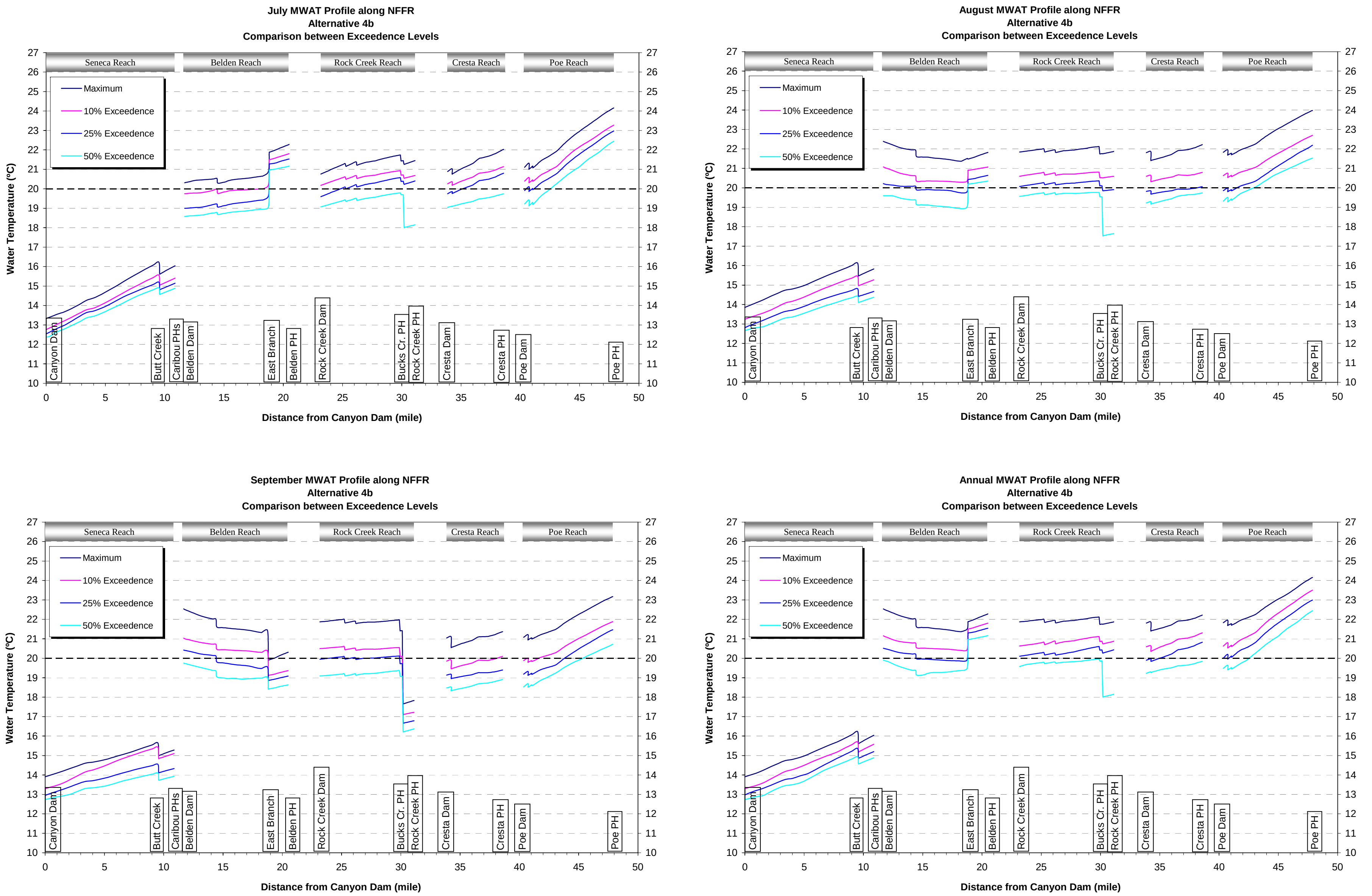
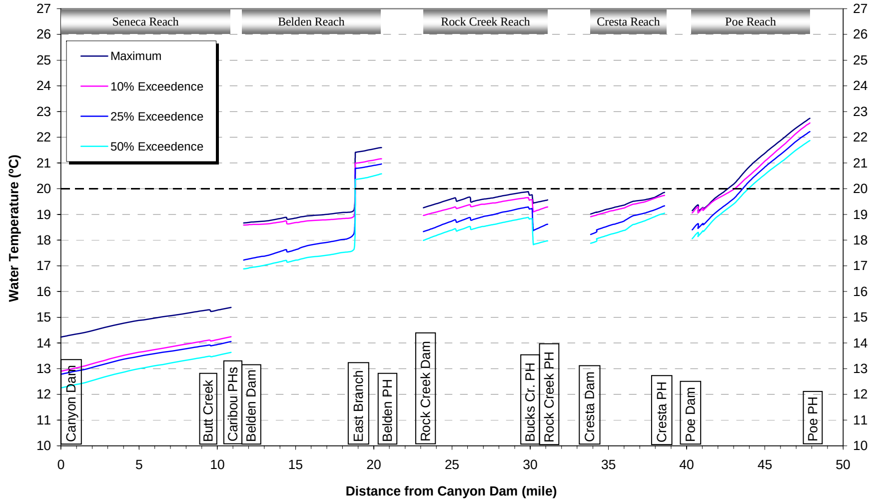
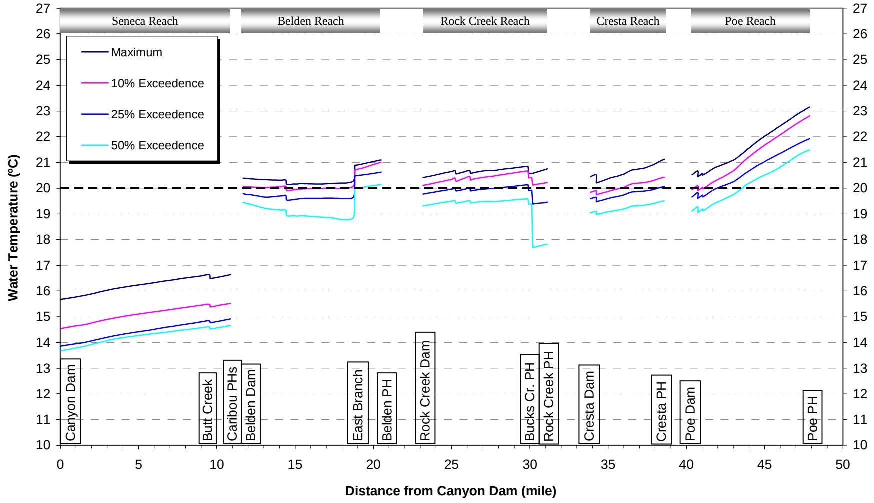


Figure 2-49 Monthly (July, Aug, Sep) and Annual MWAT Profiles along NFFR – Alternative 4c

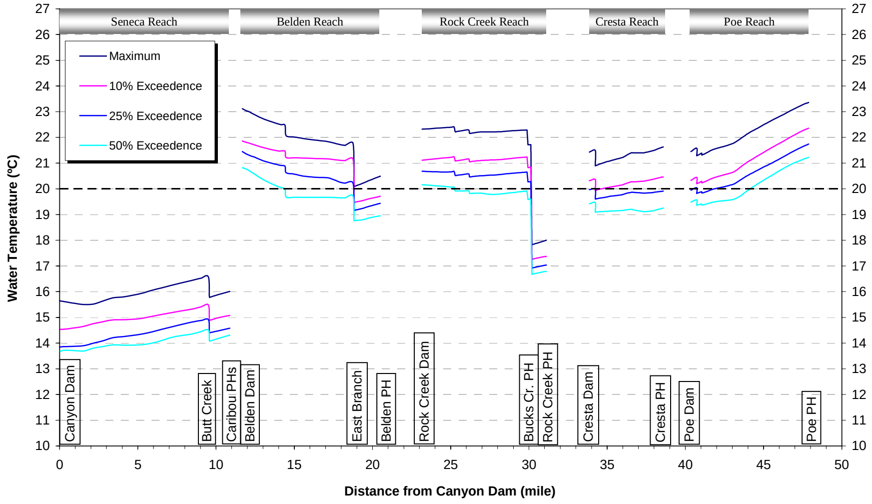
July MWAT Profile along NFFR
Alternative 4c
Comparison between Exceedence Levels



August MWAT Profile along NFFR
Alternative 4c
Comparison between Exceedence Levels



September MWAT Profile along NFFR
Alternative 4c
Comparison between Exceedence Levels



Annual MWAT Profile along NFFR
Alternative 4c
Comparison between Exceedence Levels

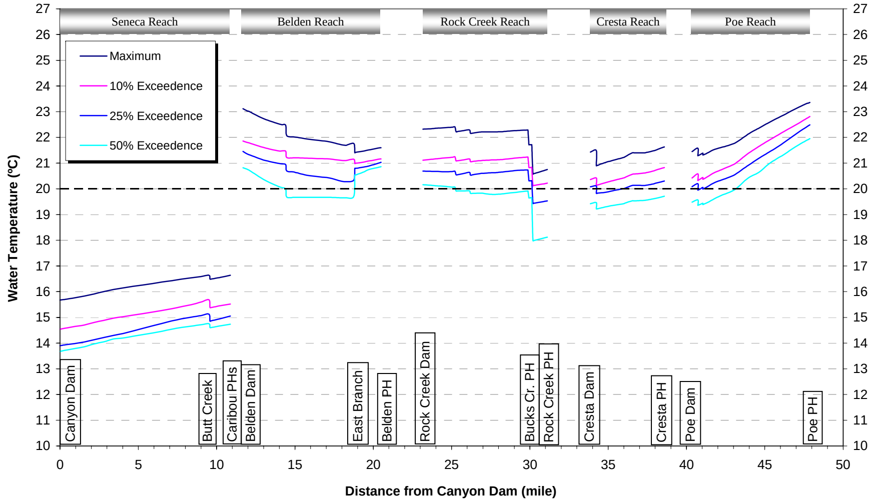


Figure 2-50 Monthly (July, Aug, Sep) and Annual MWAT Profiles along NFFR – Alternative 4d

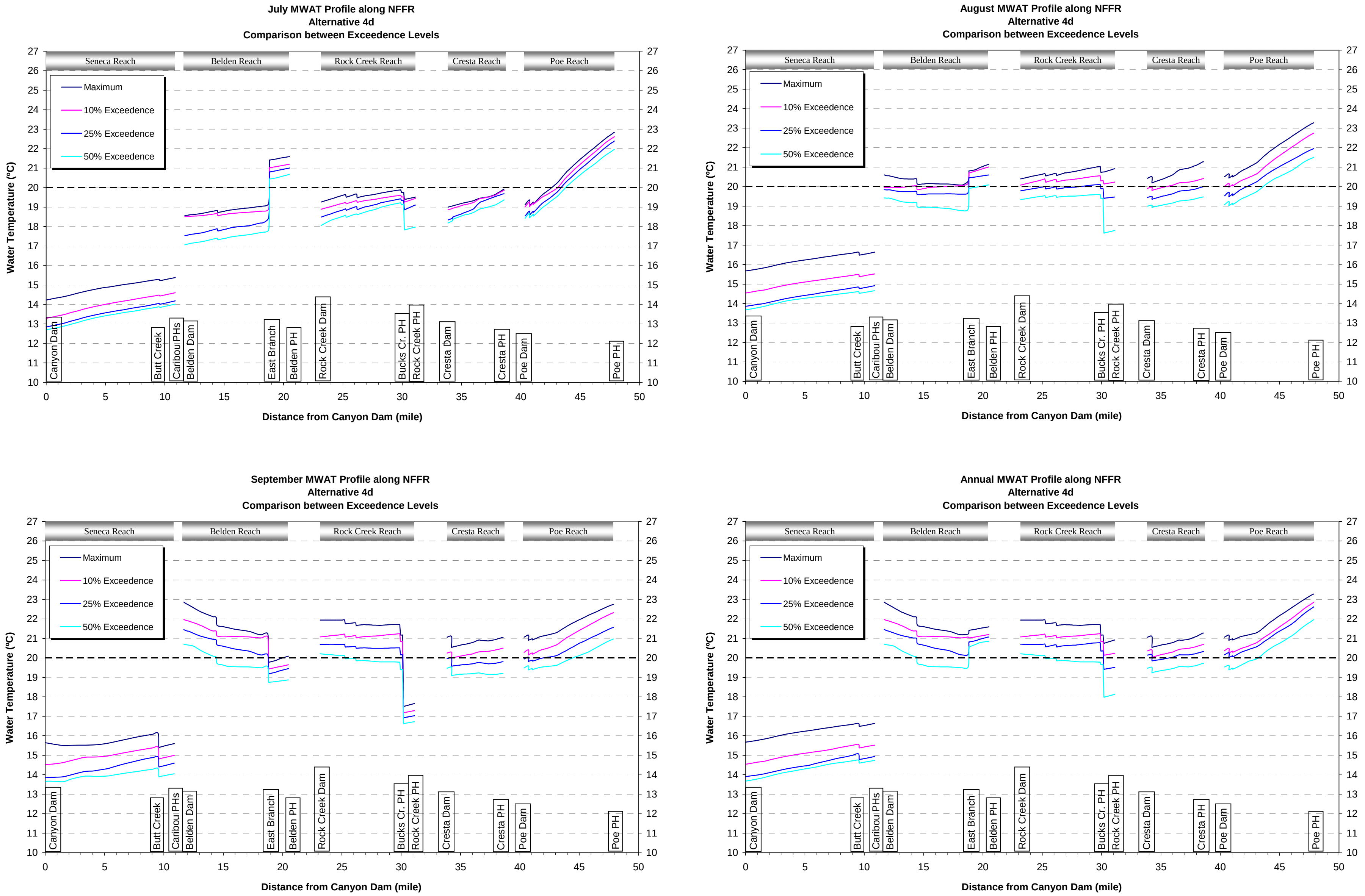


Figure 2-51a Comparison of July MWAT in Belden Reach above East Branch (NF7) between Alternatives – Belden Reach

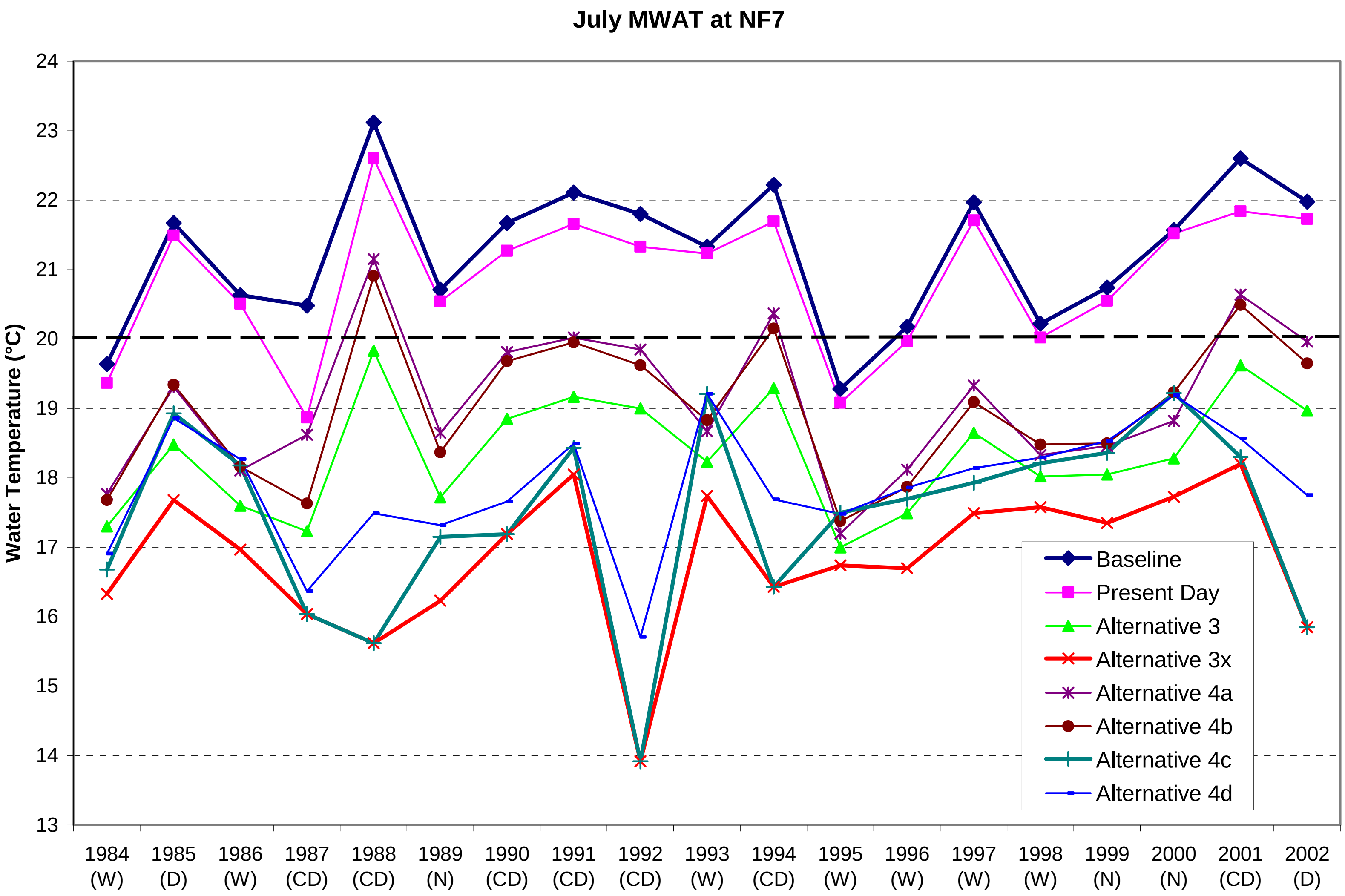


Figure 2-51b Comparison of August MWAT in Belden Reach above East Branch (NF7) between Alternatives – Belden Reach

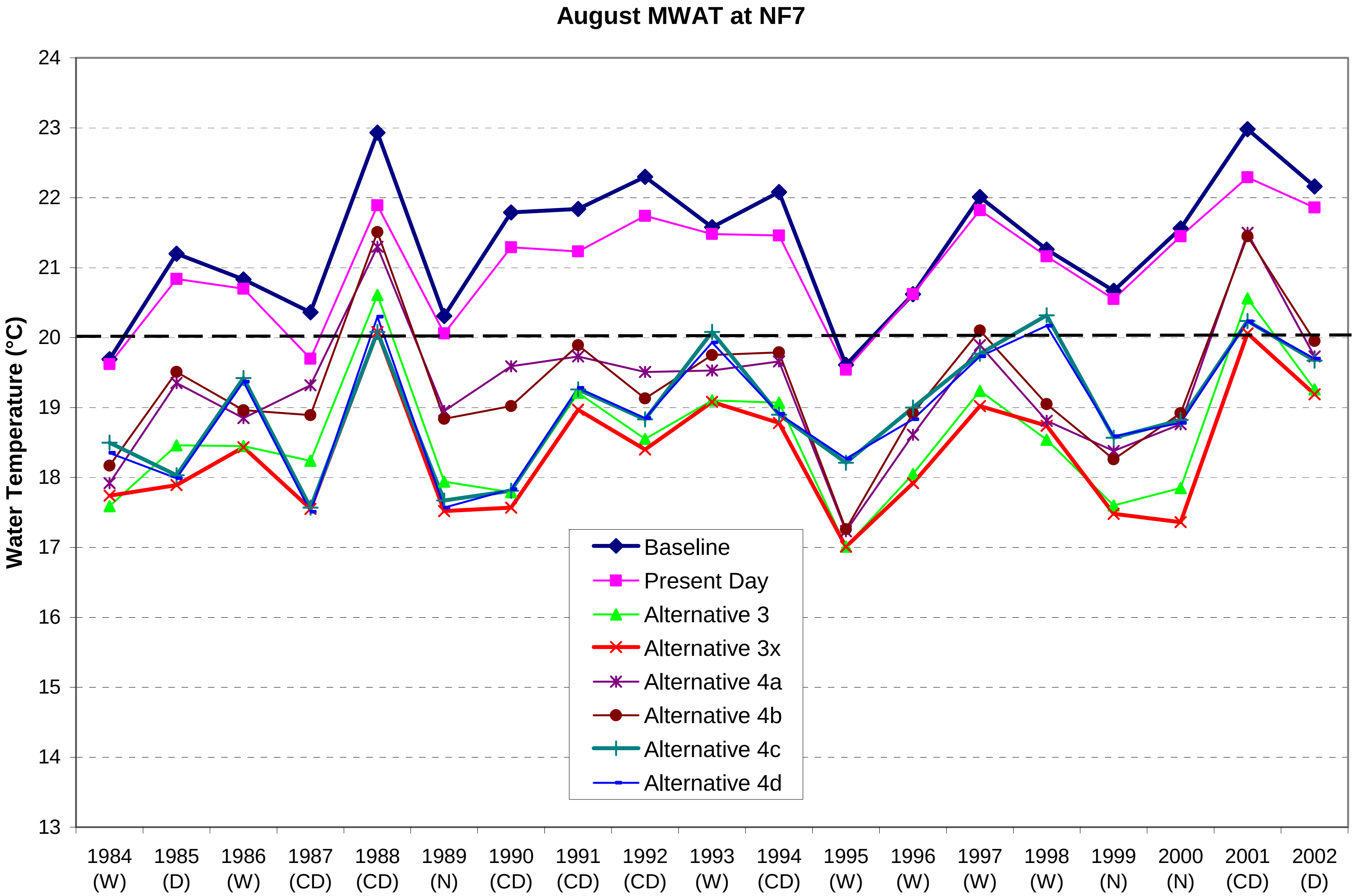


Figure 2-51c Comparison of September MWAT in Belden Reach above East Branch (NF7) between Alternatives – Belden Reach

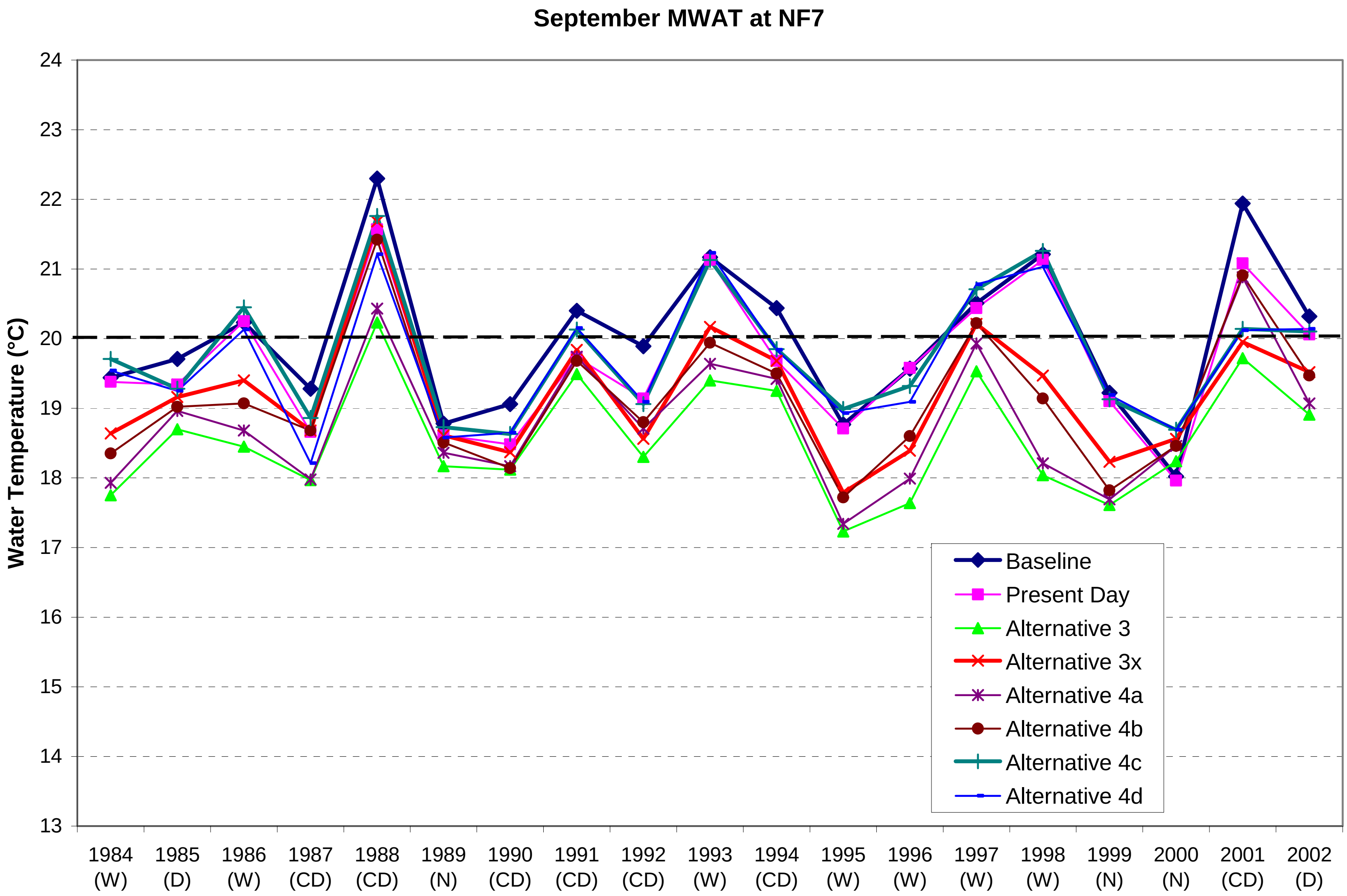


Figure 2-51d Comparison of Annual MWAT in Belden Reach above East Branch (NF7) between Alternatives – Belden Reach

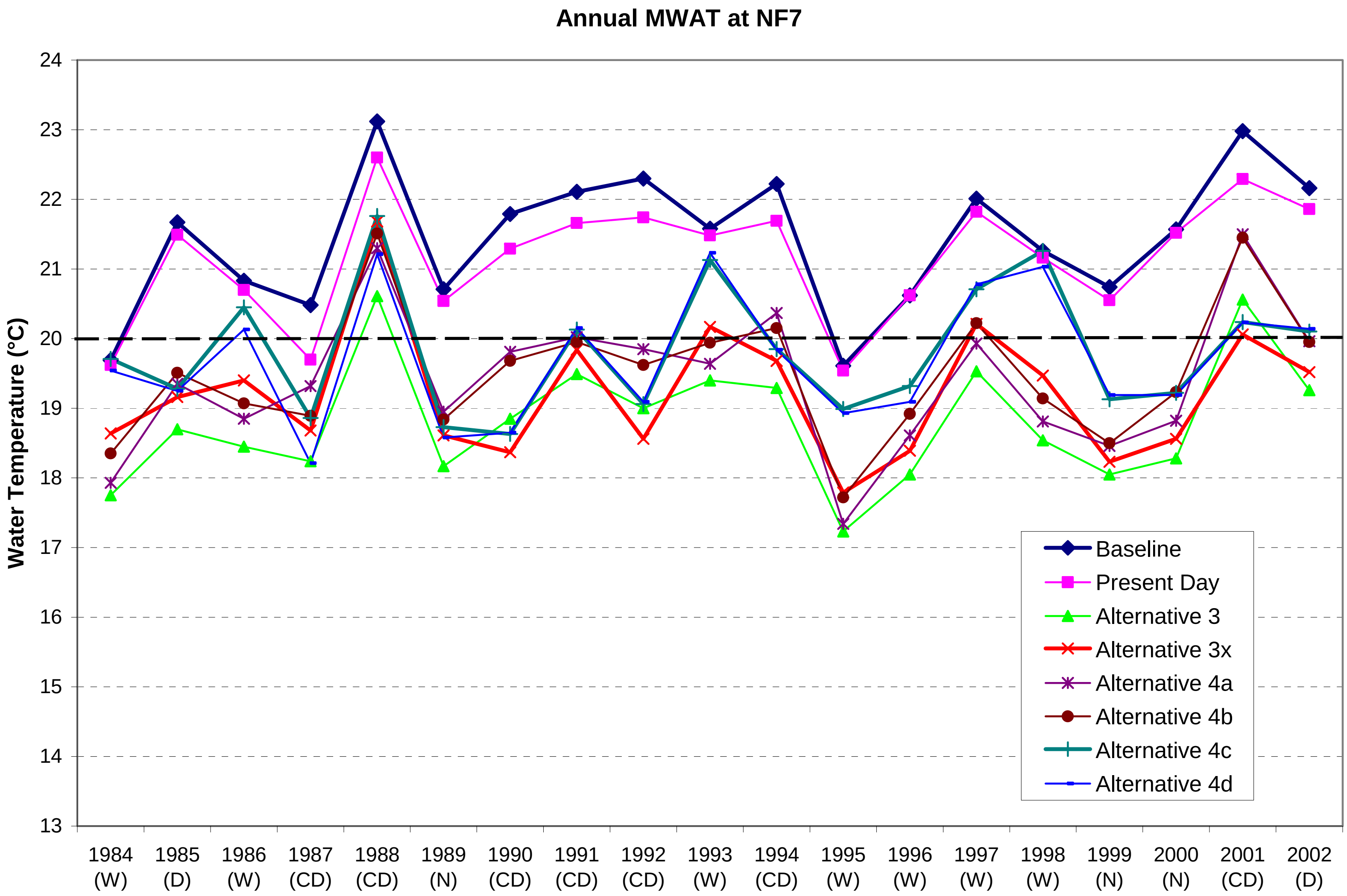


Figure 2-52a Comparison of July MWAT in Rock Creek Reach above Bucks Creek (NF12) between Alternatives – Rock Creek Reach

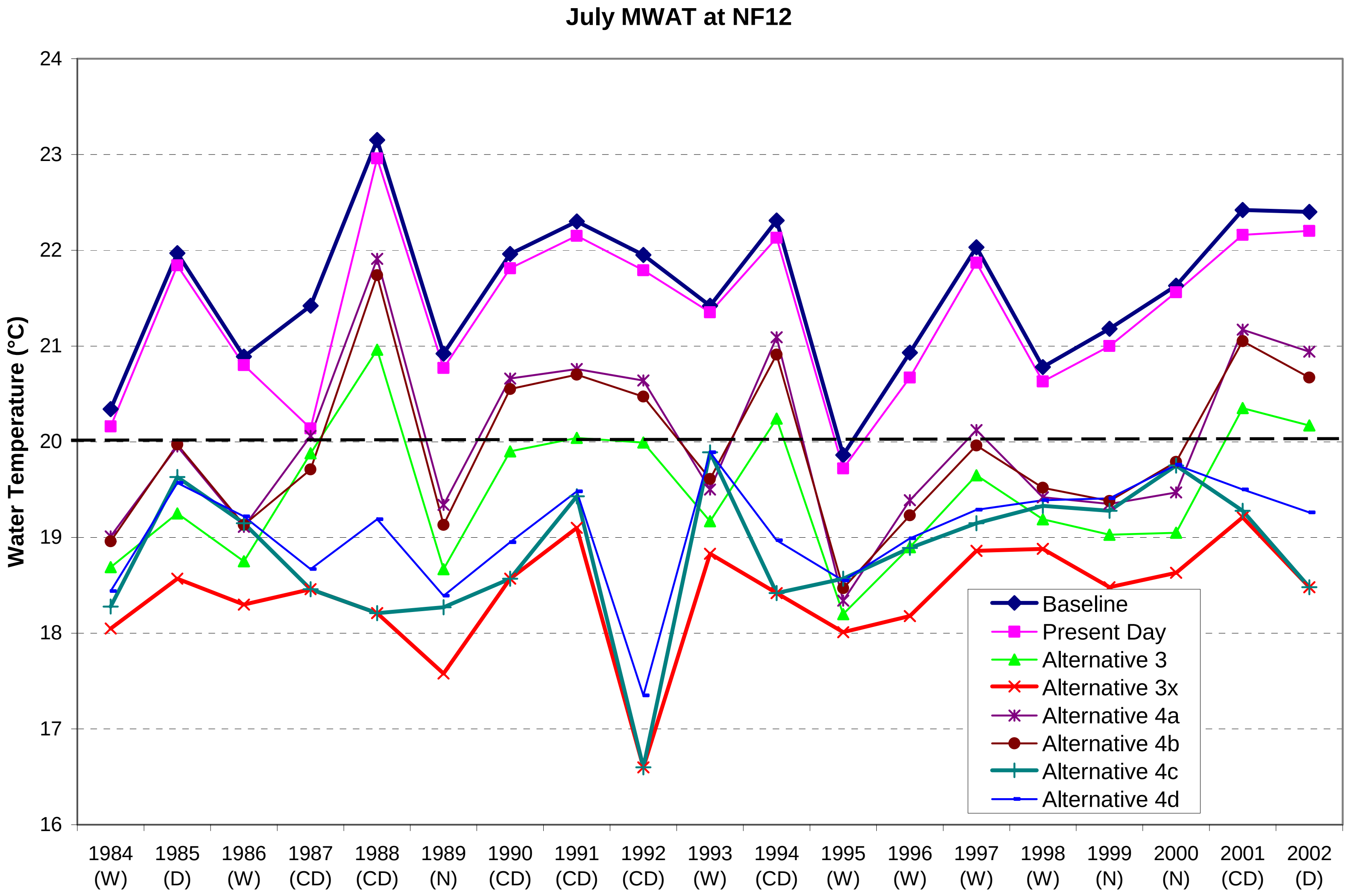


Figure 2-52b Comparison of August MWAT in Rock Creek Reach above Bucks Creek (NF12) between Alternatives – Rock Creek Reach

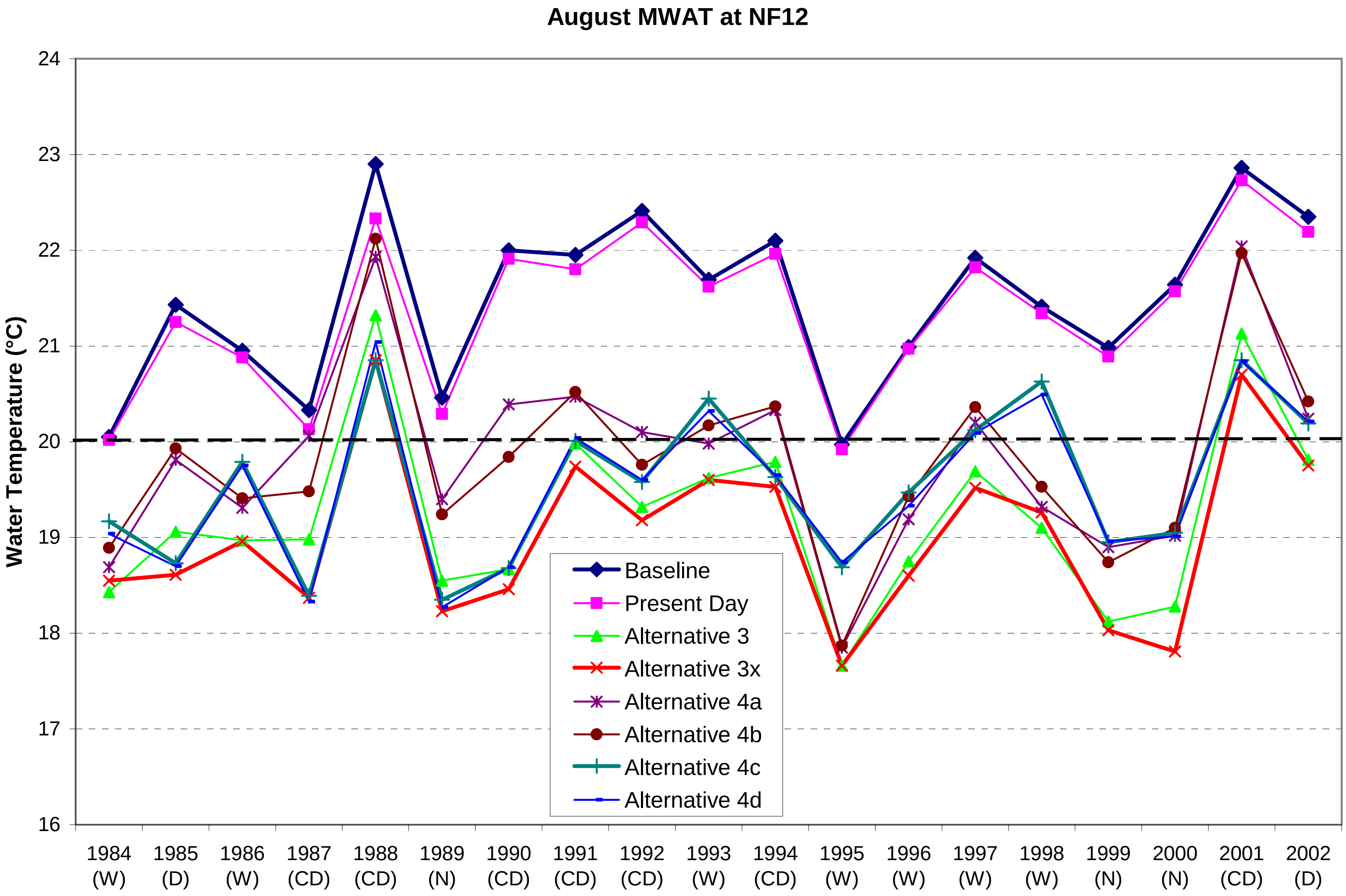


Figure 2-52c Comparison of September MWAT in Rock Ck. Reach above Bucks Creek (NF12) between Alternatives – Rock Creek Reach

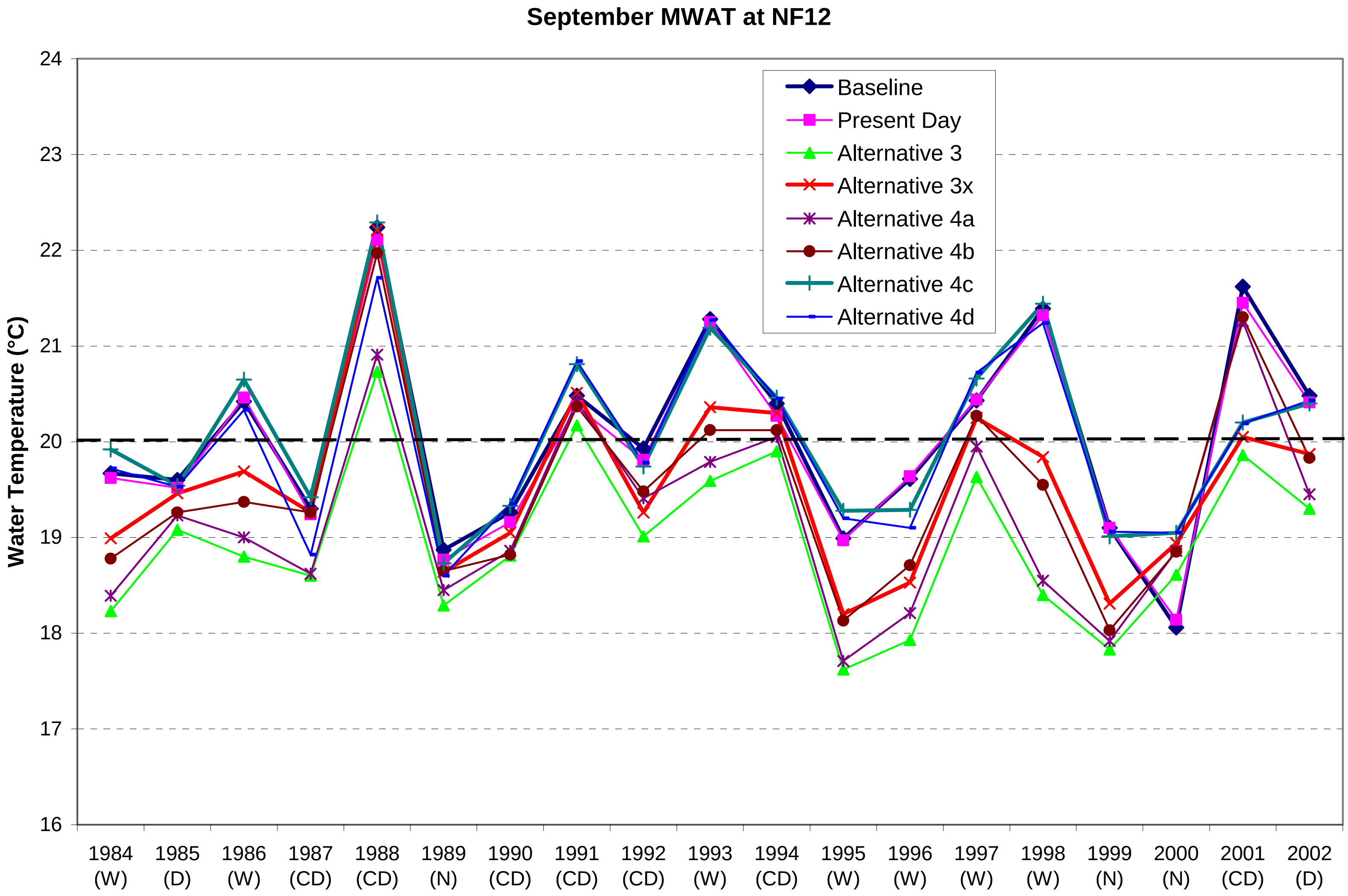


Figure 2-52d Comparison of Annual MWAT in Rock Creek Reach above Bucks Creek (NF12) between Alternatives – Rock Creek Reach

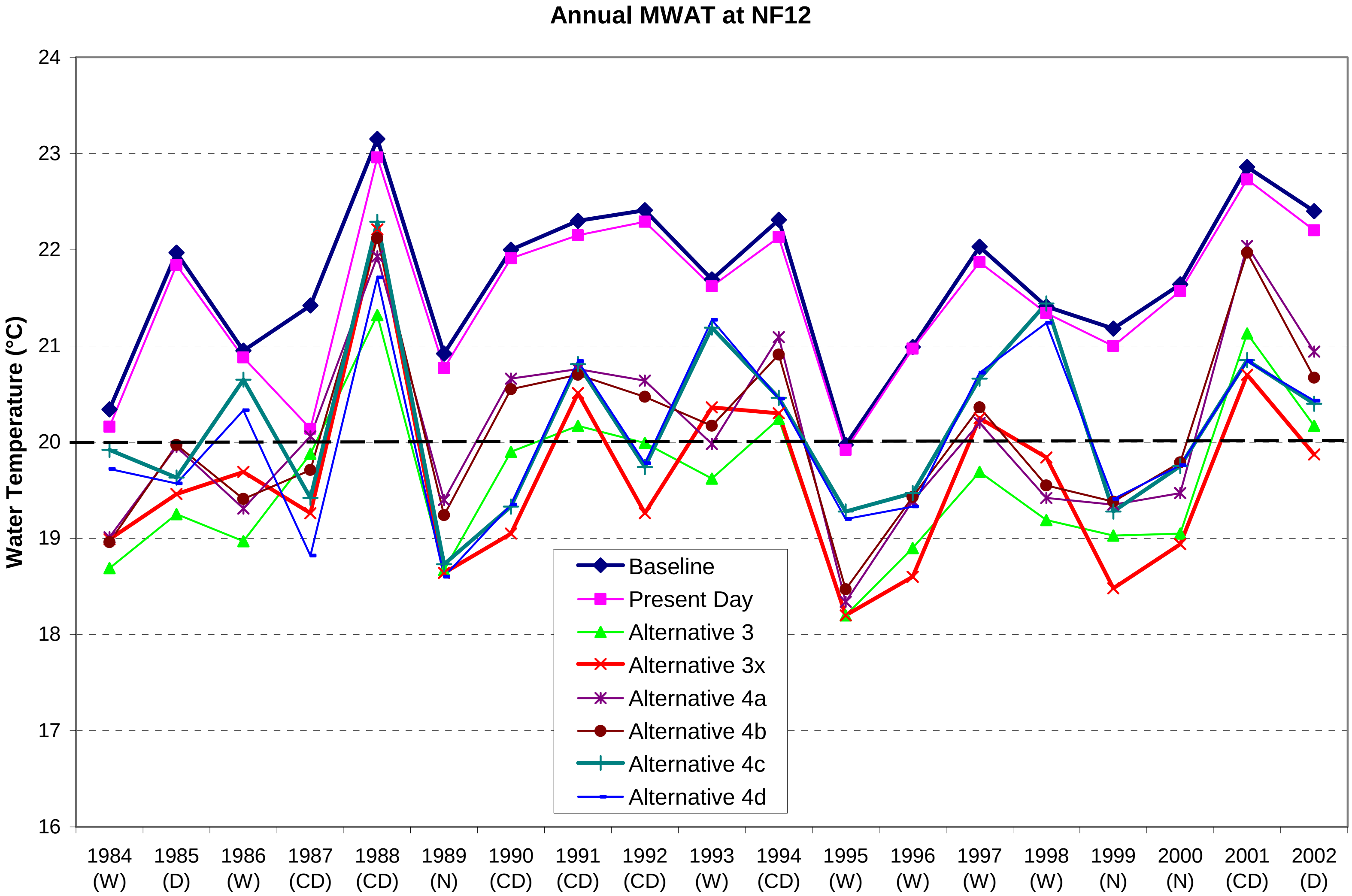


Figure 2-53a Comparison of July MWAT in Cresta Reach above Cresta PH (NF16) between Alternatives – Cresta Reach

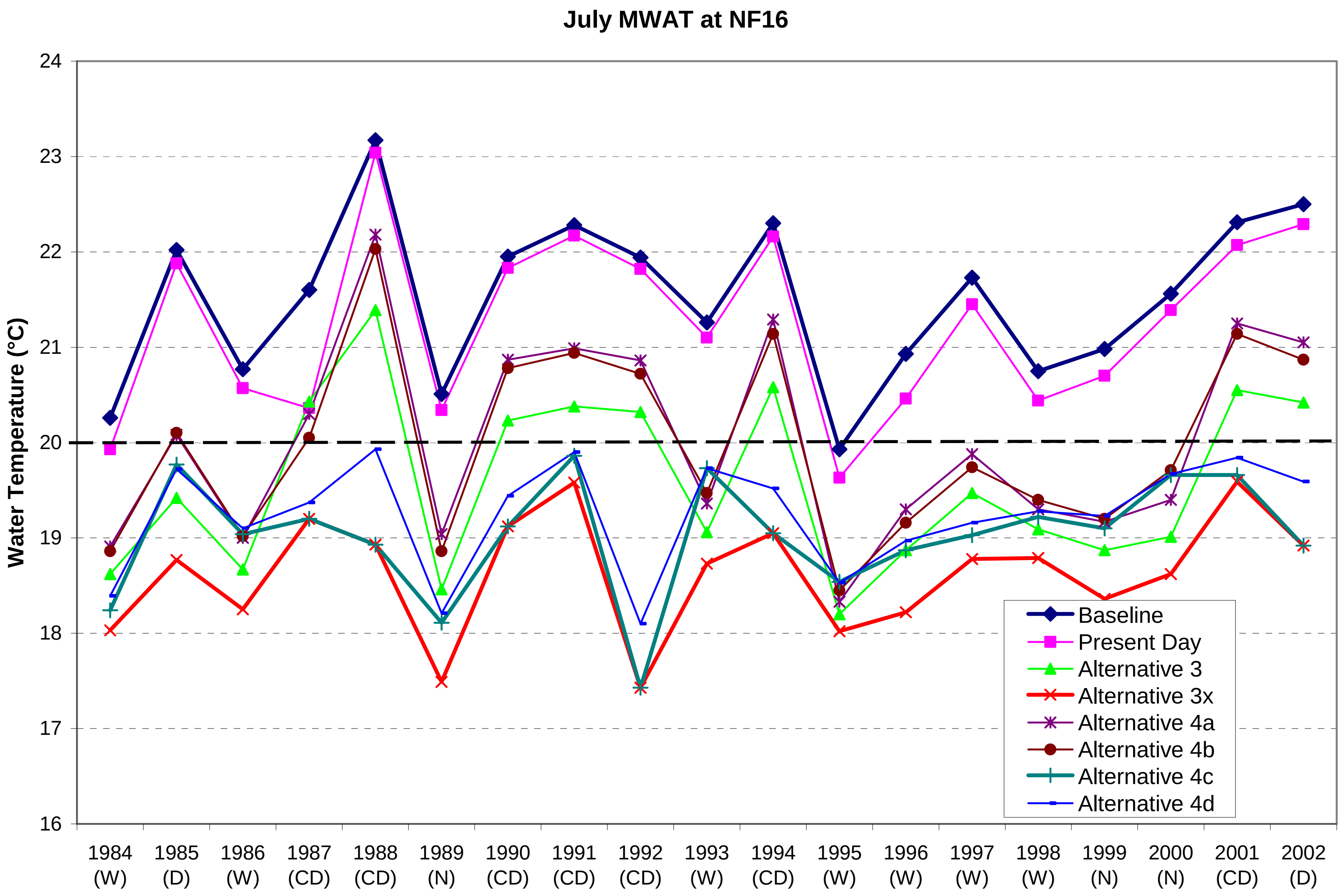


Figure 2-53b Comparison of August MWAT in Cresta Reach above Cresta PH (NF16) between Alternatives – Cresta Reach

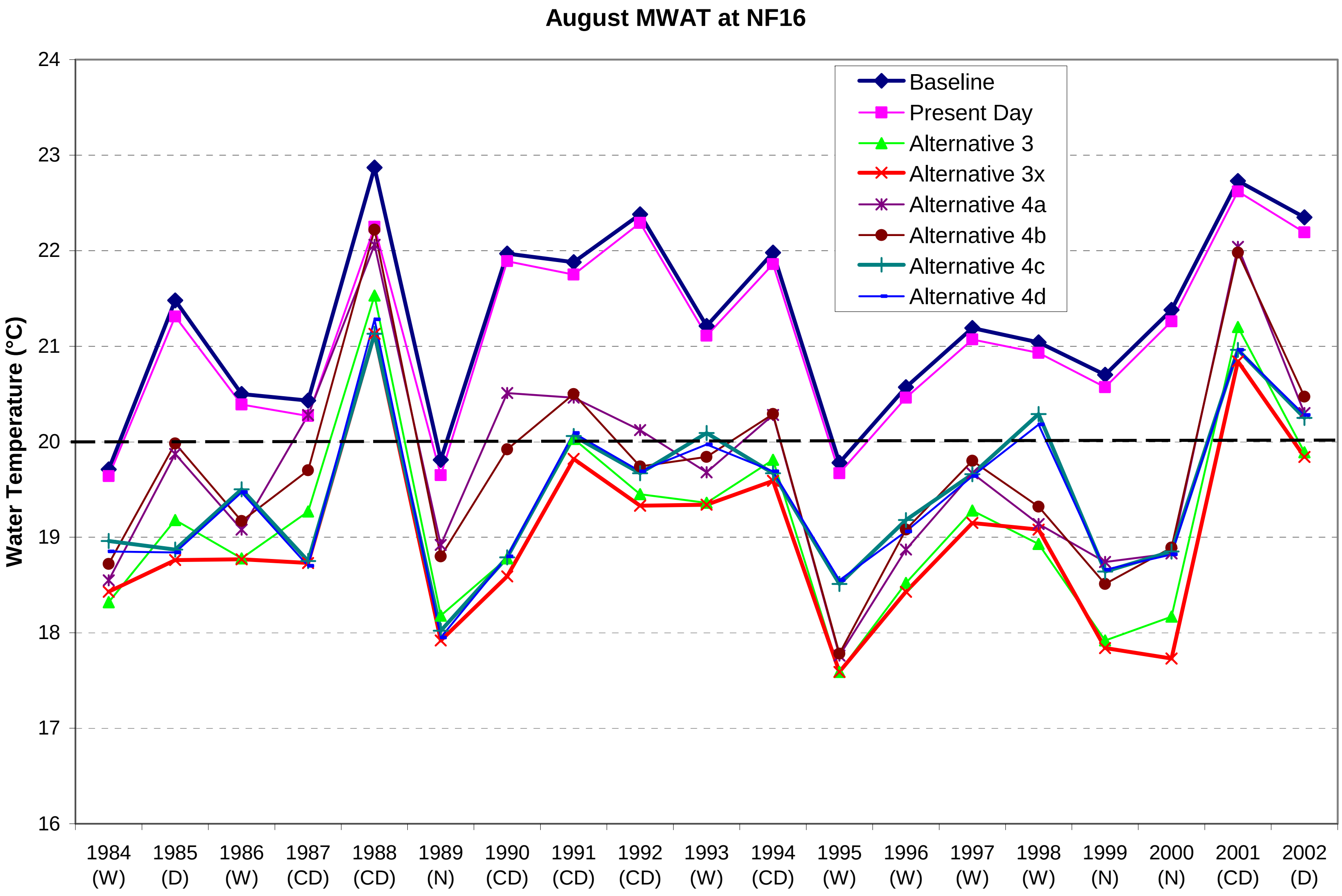


Figure 2-53c Comparison of September MWAT in Cresta Reach above Cresta PH (NF16) between Alternatives – Cresta Reach

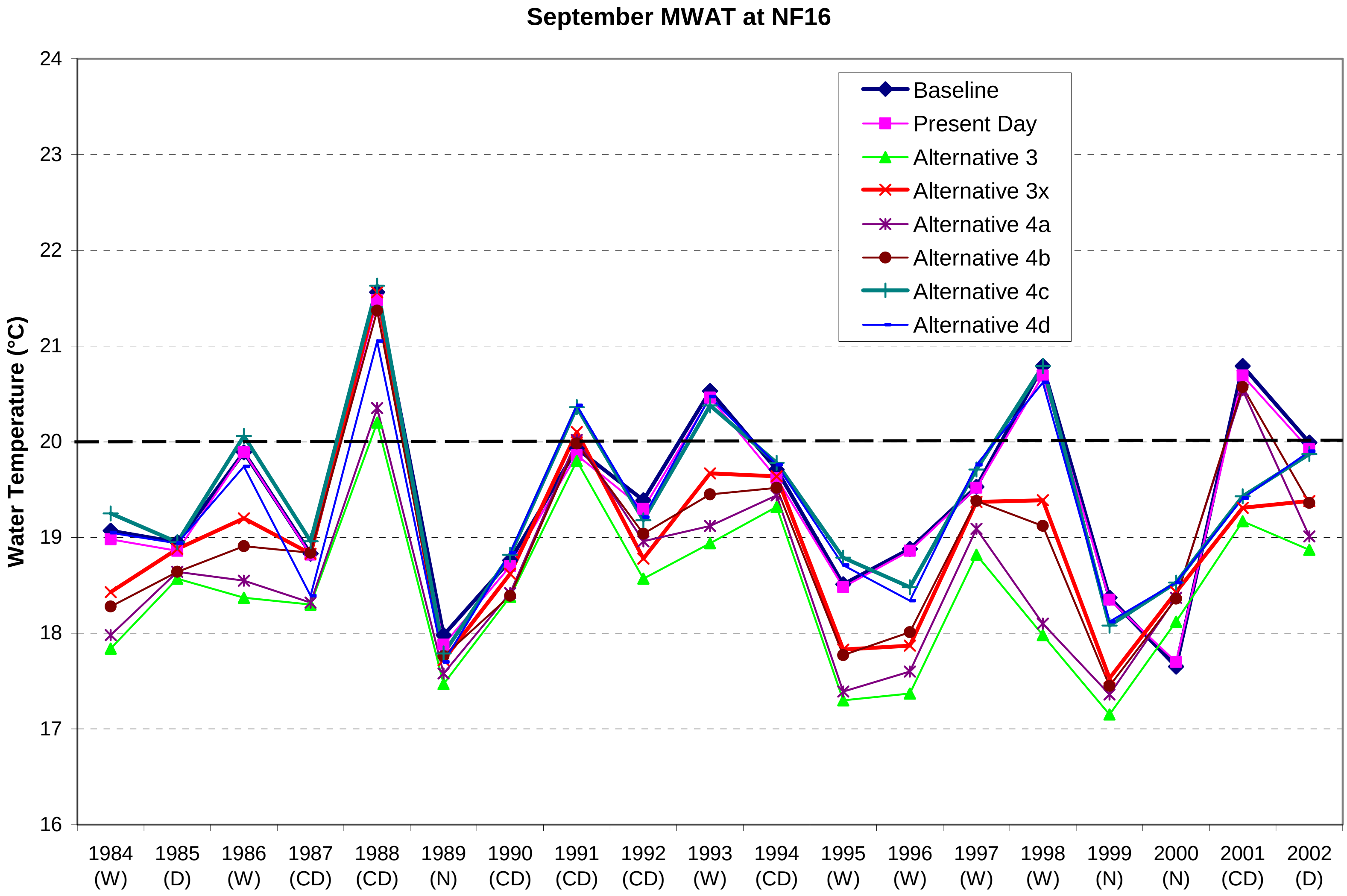


Figure 2-53d Comparison of Annual MWAT in Cresta Reach above Cresta PH (NF16) between Alternatives – Cresta Reach

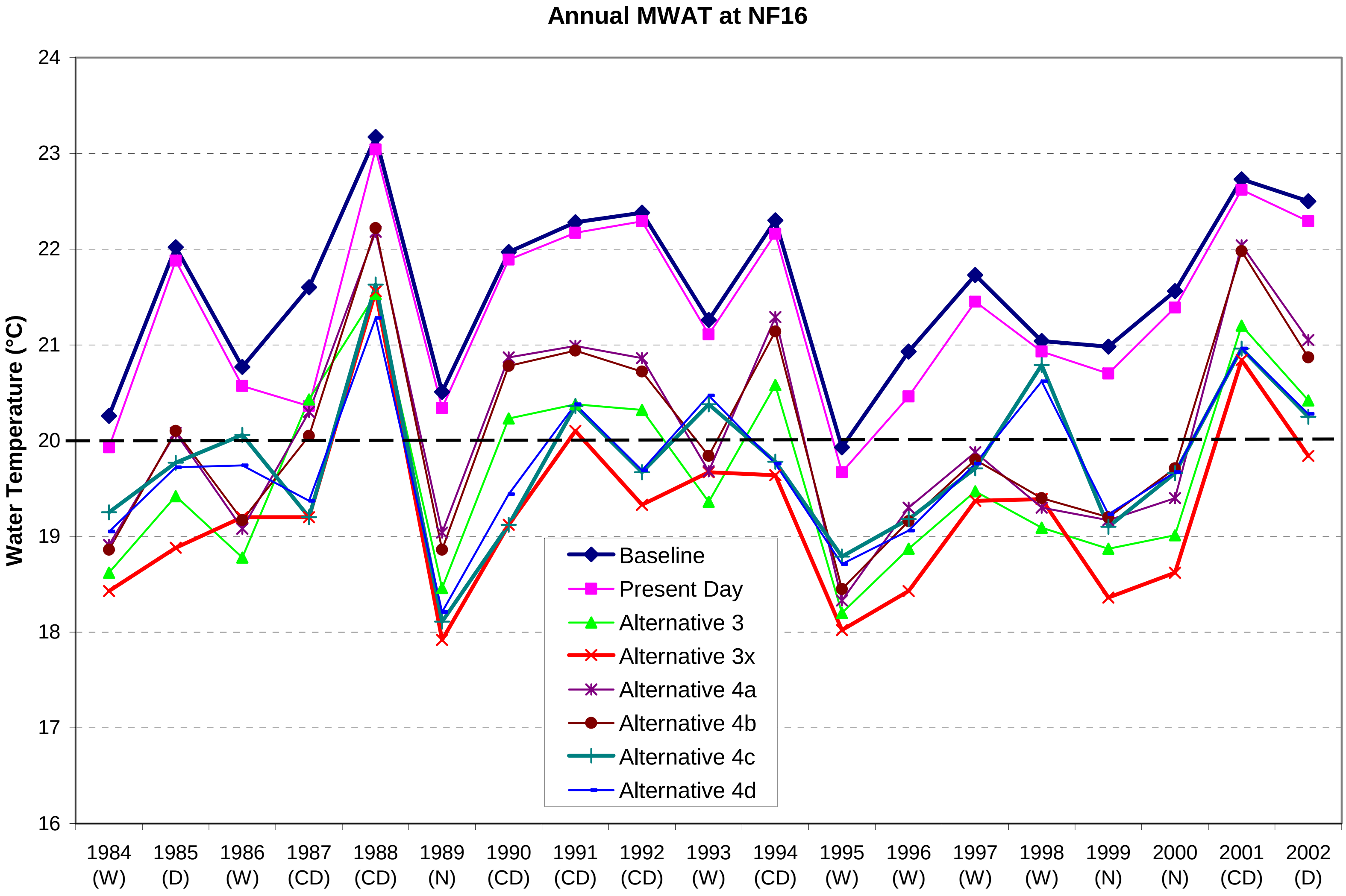


Figure 2-54a Comparison of July MWAT in Poe Reach above Poe PH (NF18) between Alternatives – Poe Reach

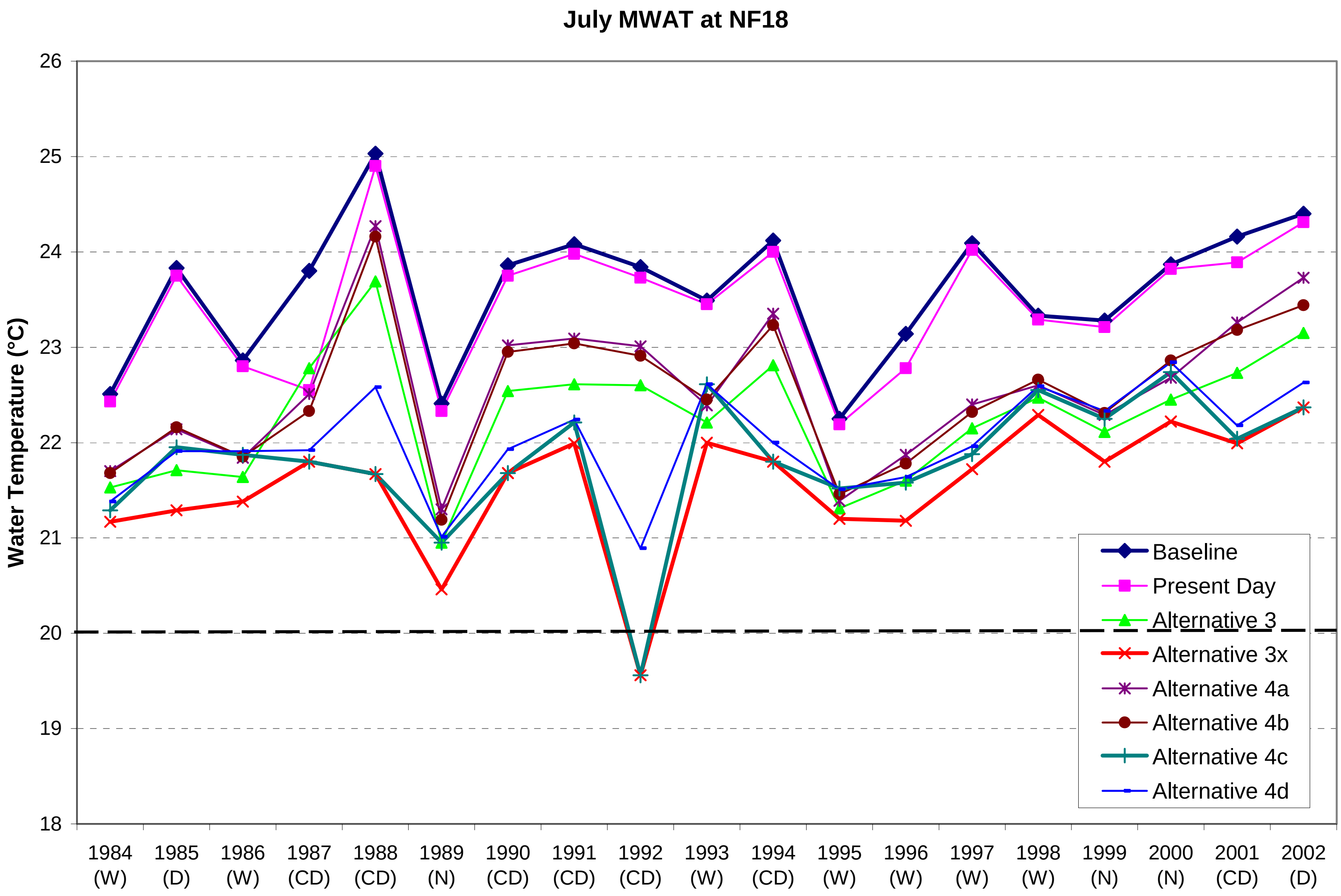


Figure 2-54b Comparison of August MWAT in Poe Reach above Poe PH (NF18) between Alternatives – Poe Reach

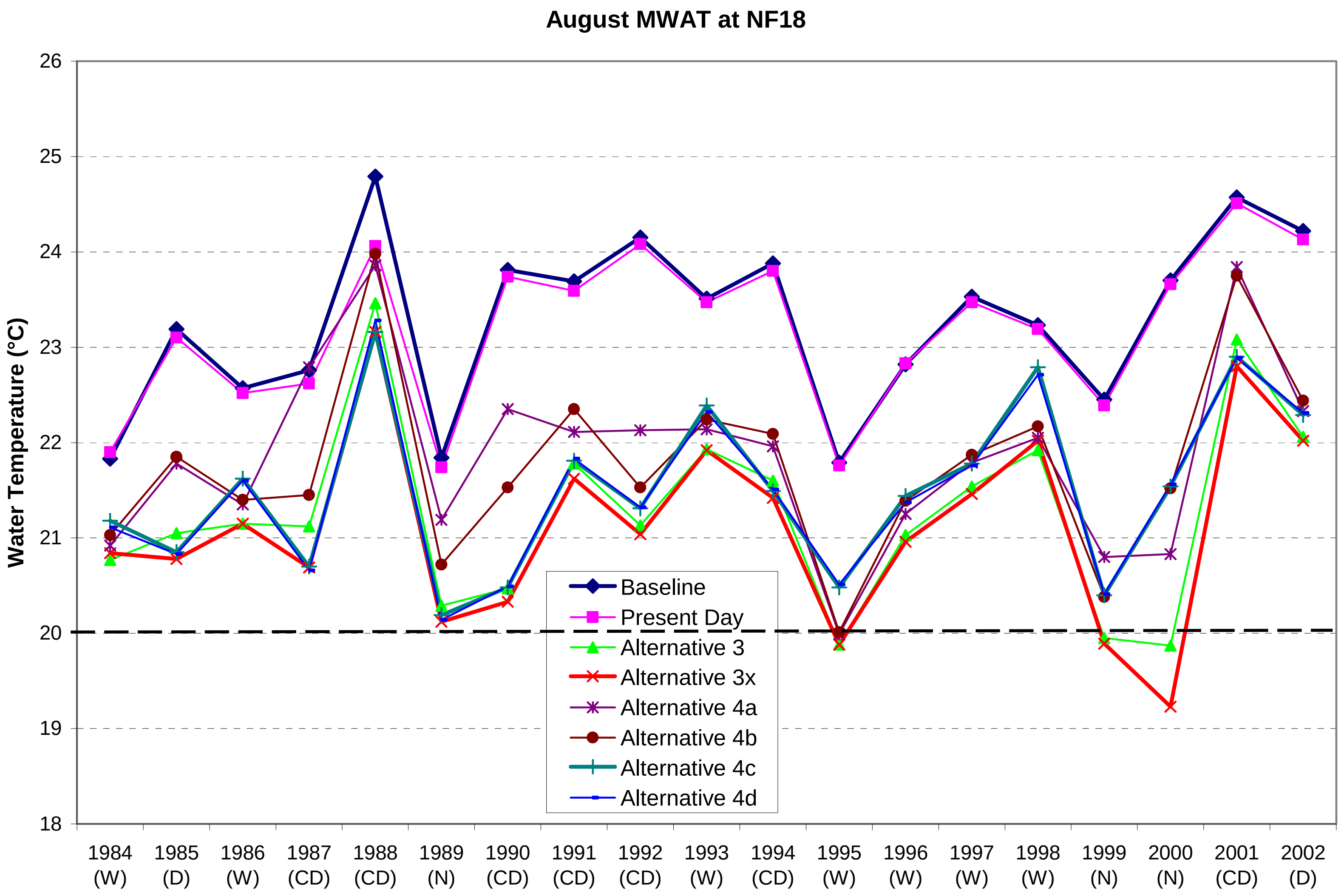


Figure 2-54c Comparison of September MWAT in Poe Reach above Poe PH (NF18) between Alternatives – Poe Reach

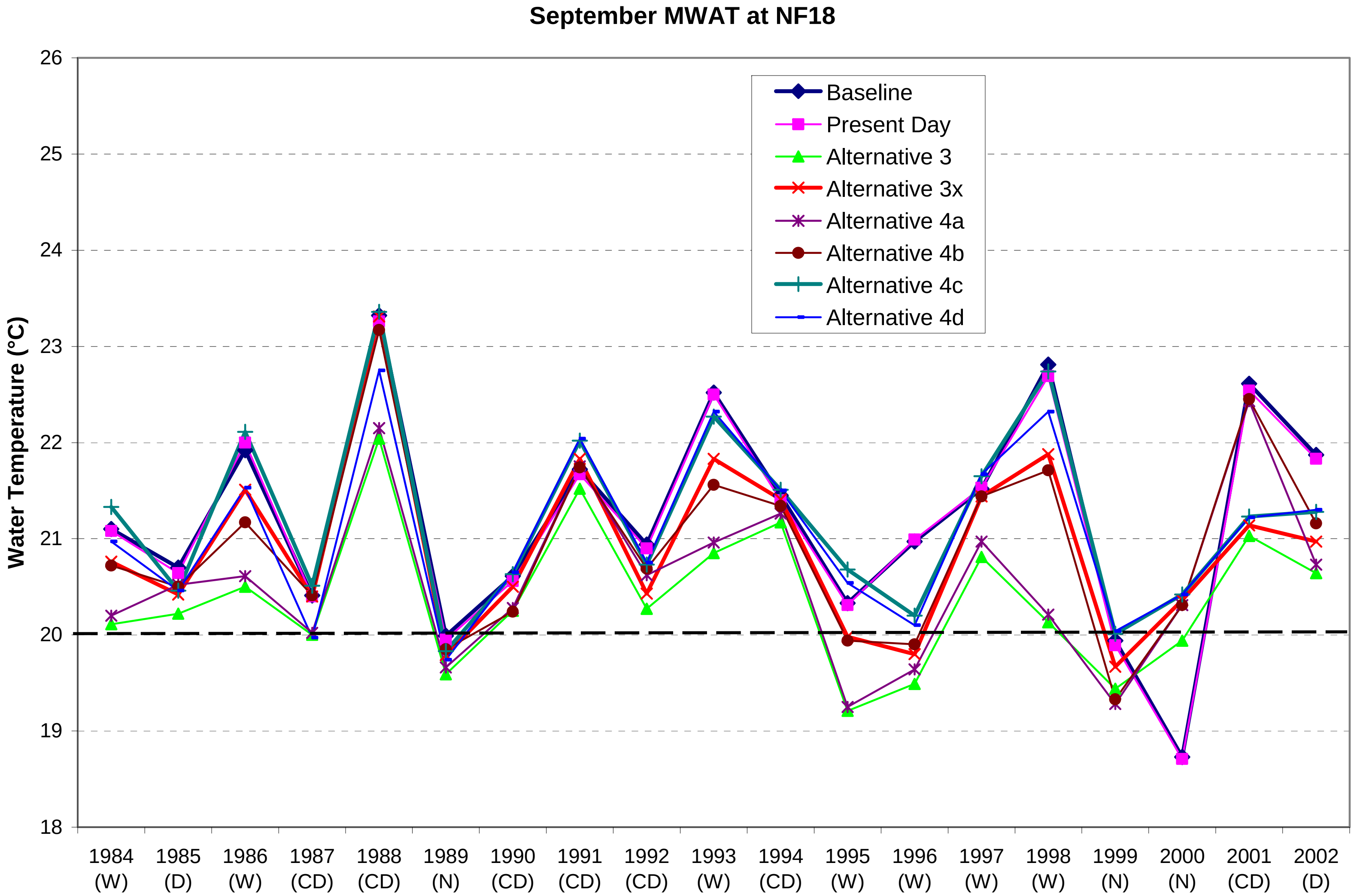


Figure 2-54d Comparison of Annual MWAT in Poe Reach above Poe PH (NF18) between Alternatives – Poe Reach

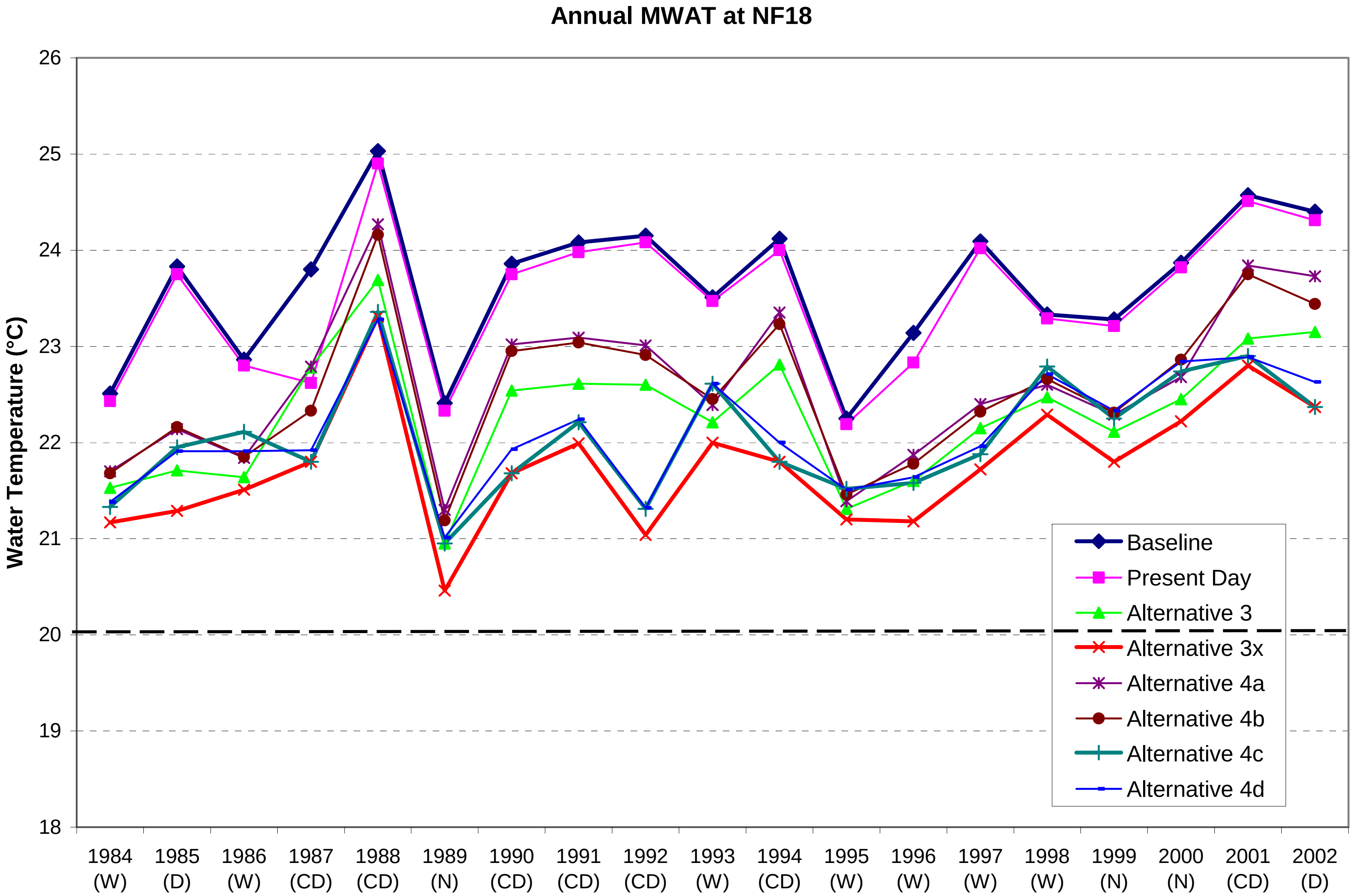


Figure 2-55a

Comparison of Monthly (Jul, Aug, Sep) MWAT in Rock Creek Reach above Bucks Creek (NF12) - Alternative 3x

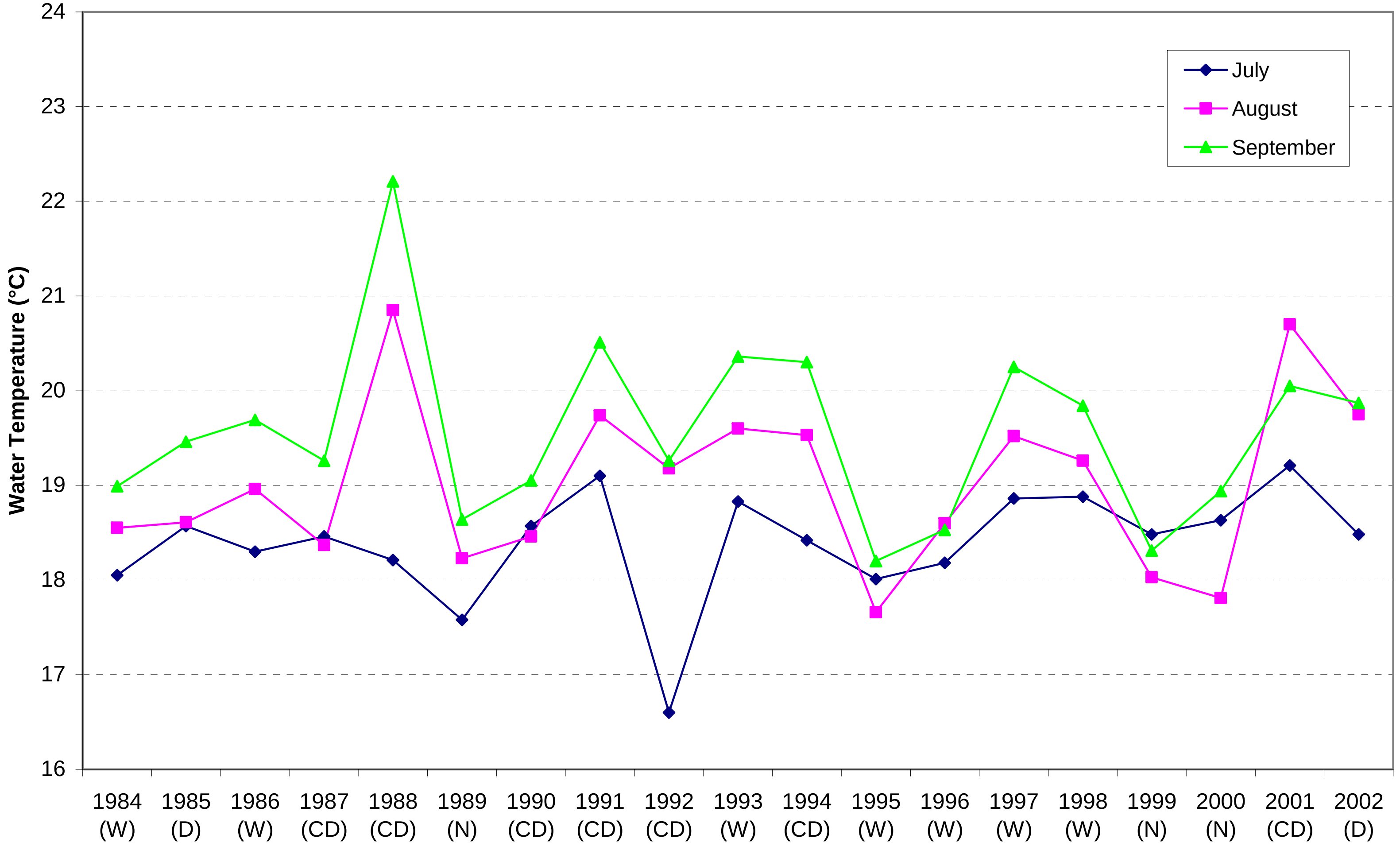


Figure 2-55b

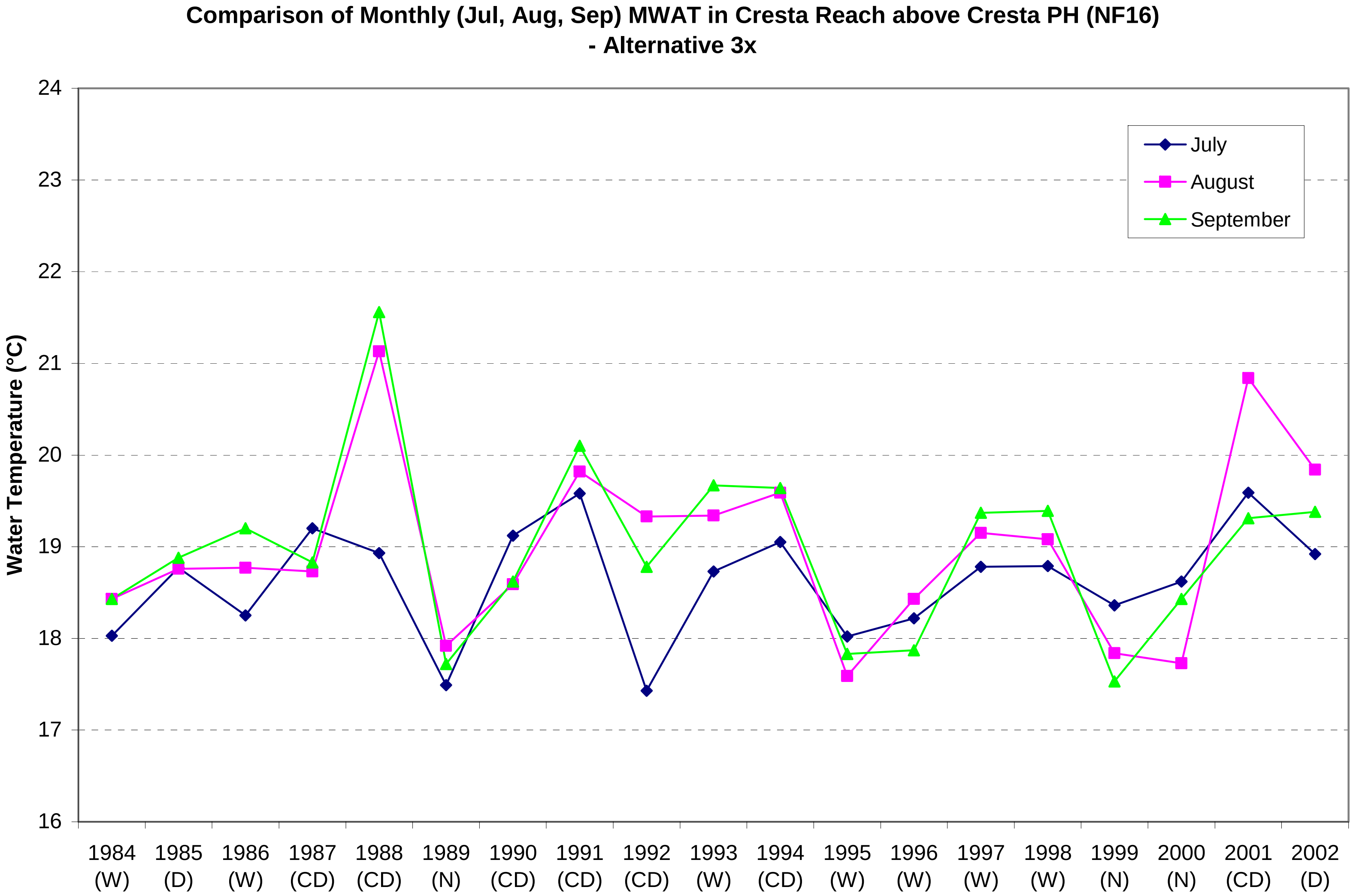
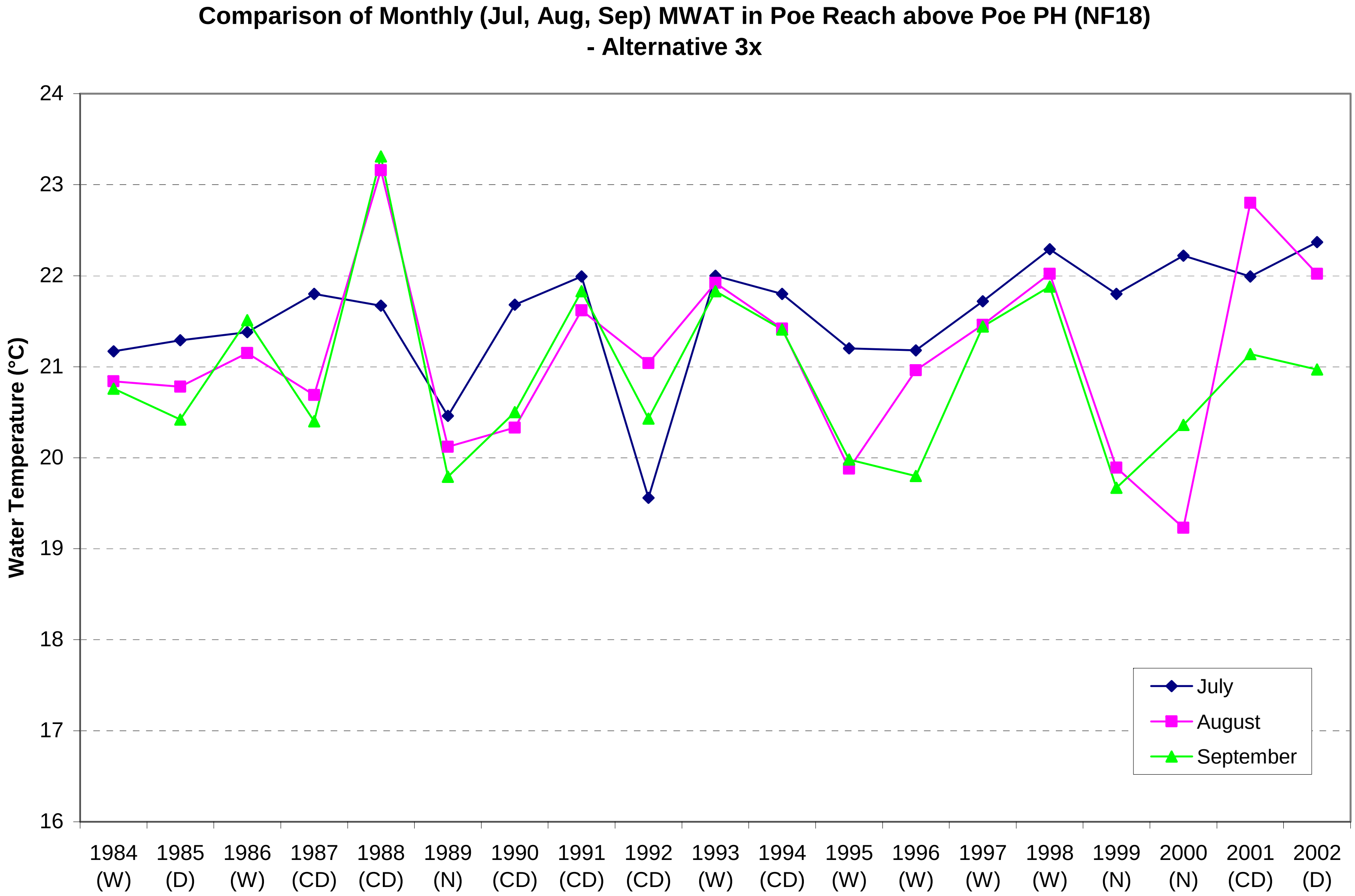

Comparison of Monthly (Jul, Aug, Sep) MWAT in Cresta Reach above Cresta PH (NF16)
- Alternative 3x
Water Temperature (°C)
24
23
22
21
20
19
18
17
16
1984 (W)
1985 (D)
1986 (W)
1987 (CD)
1988 (CD)
1989 (N)
1990 (CD)
1991 (CD)
1992 (CD)
1993 (W)
1994 (CD)
1995 (W)
1996 (W)
1997 (W)
1998 (W)
1999 (N)
2000 (N)
2001 (CD)
2002 (D)
July
August
September

Figure 2-55c



Comparison of Monthly (Jul, Aug, Sep) MWAT in Poe Reach above Poe PH (NF18)
- Alternative 3x
Water Temperature (°C)
24
23
22
21
20
19
18
17
16
1984 (W)
1985 (D)
1986 (W)
1987 (CD)
1988 (CD)
1989 (N)
1990 (CD)
1991 (CD)
1992 (CD)
1993 (W)
1994 (CD)
1995 (W)
1996 (W)
1997 (W)
1998 (W)
1999 (N)
2000 (N)
2001 (CD)
2002 (D)
July
August
September

Figure 2-56a

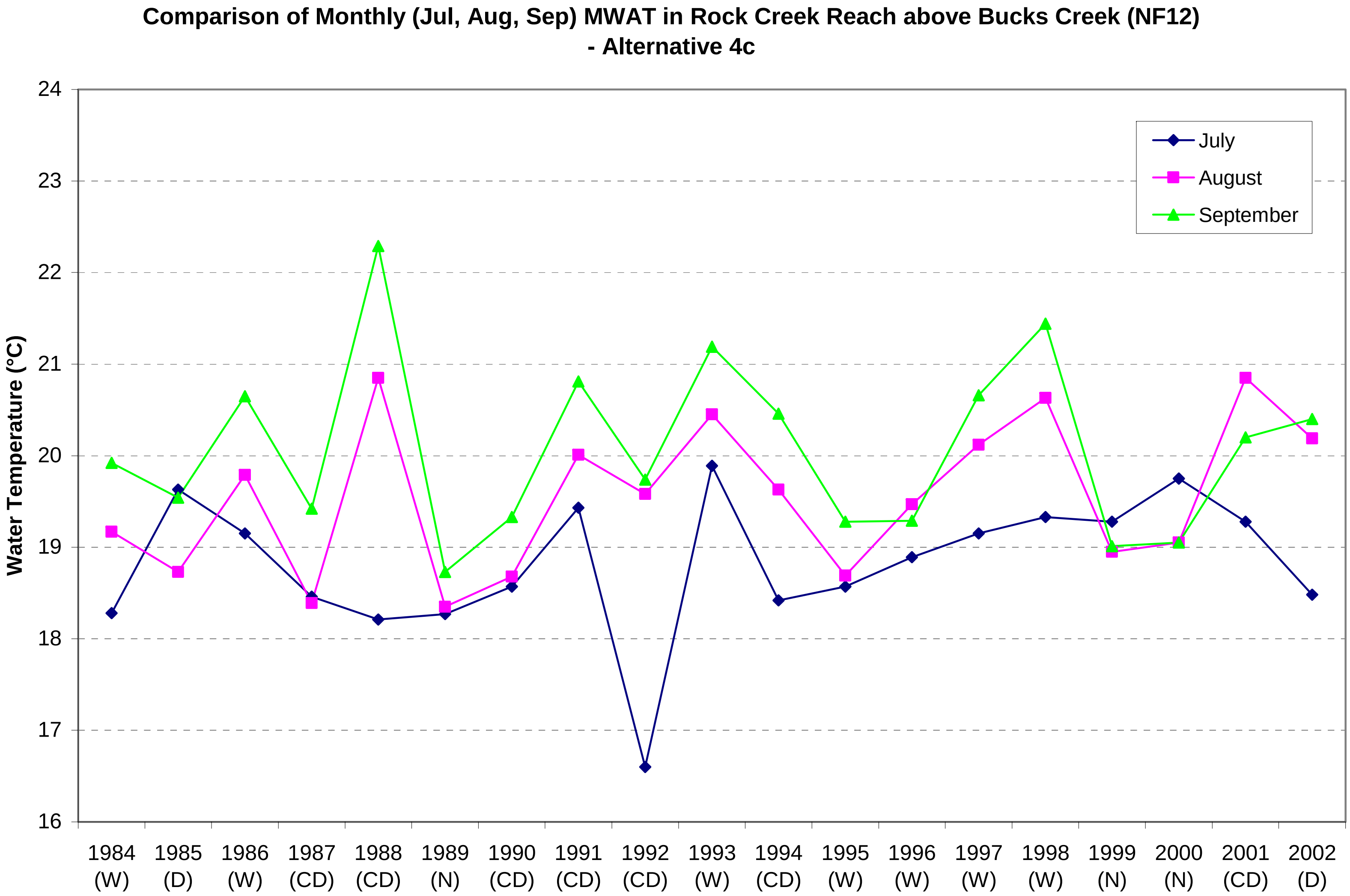

Comparison of Monthly (Jul, Aug, Sep) MWAT in Rock Creek Reach above Bucks Creek (NF12) - Alternative 4c
Water Temperature (°C)
24
23
22
21
20
19
18
17
16
1984 (W)
1985 (D)
1986 (W)
1987 (CD)
1988 (CD)
1989 (N)
1990 (CD)
1991 (CD)
1992 (CD)
1993 (W)
1994 (CD)
1995 (W)
1996 (W)
1997 (W)
1998 (W)
1999 (N)
2000 (N)
2001 (CD)
2002 (D)
July
August
September

Figure 2-56b

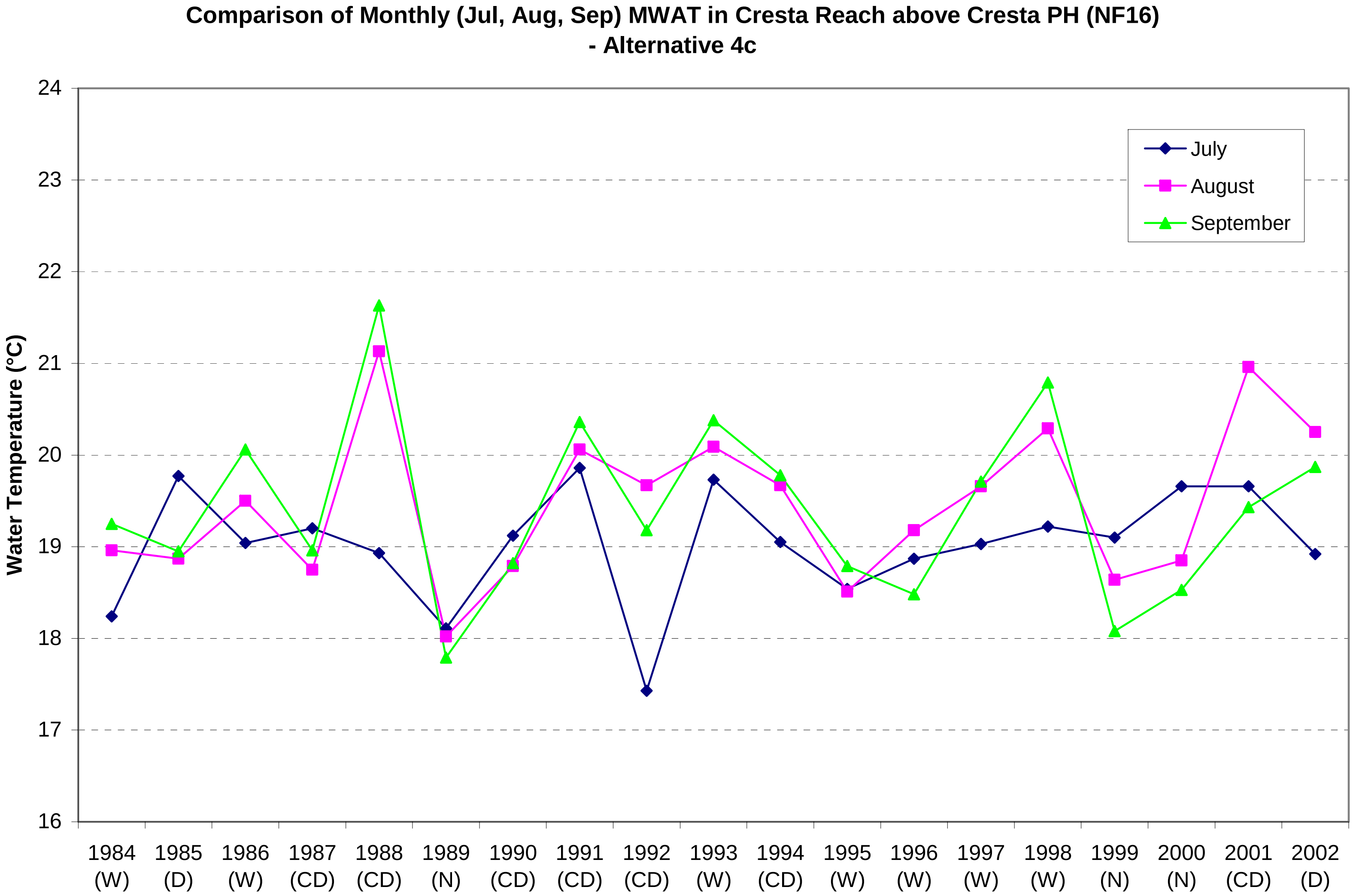

Comparison of Monthly (Jul, Aug, Sep) MWAT in Cresta Reach above Cresta PH (NF16) - Alternative 4c
Water Temperature (°C)
24
23
22
21
20
19
18
17
16
1984 (W)
1985 (D)
1986 (W)
1987 (CD)
1988 (CD)
1989 (N)
1990 (CD)
1991 (CD)
1992 (CD)
1993 (W)
1994 (CD)
1995 (W)
1996 (W)
1997 (W)
1998 (W)
1999 (N)
2000 (N)
2001 (CD)
2002 (D)
July
August
September

Figure 2-56c

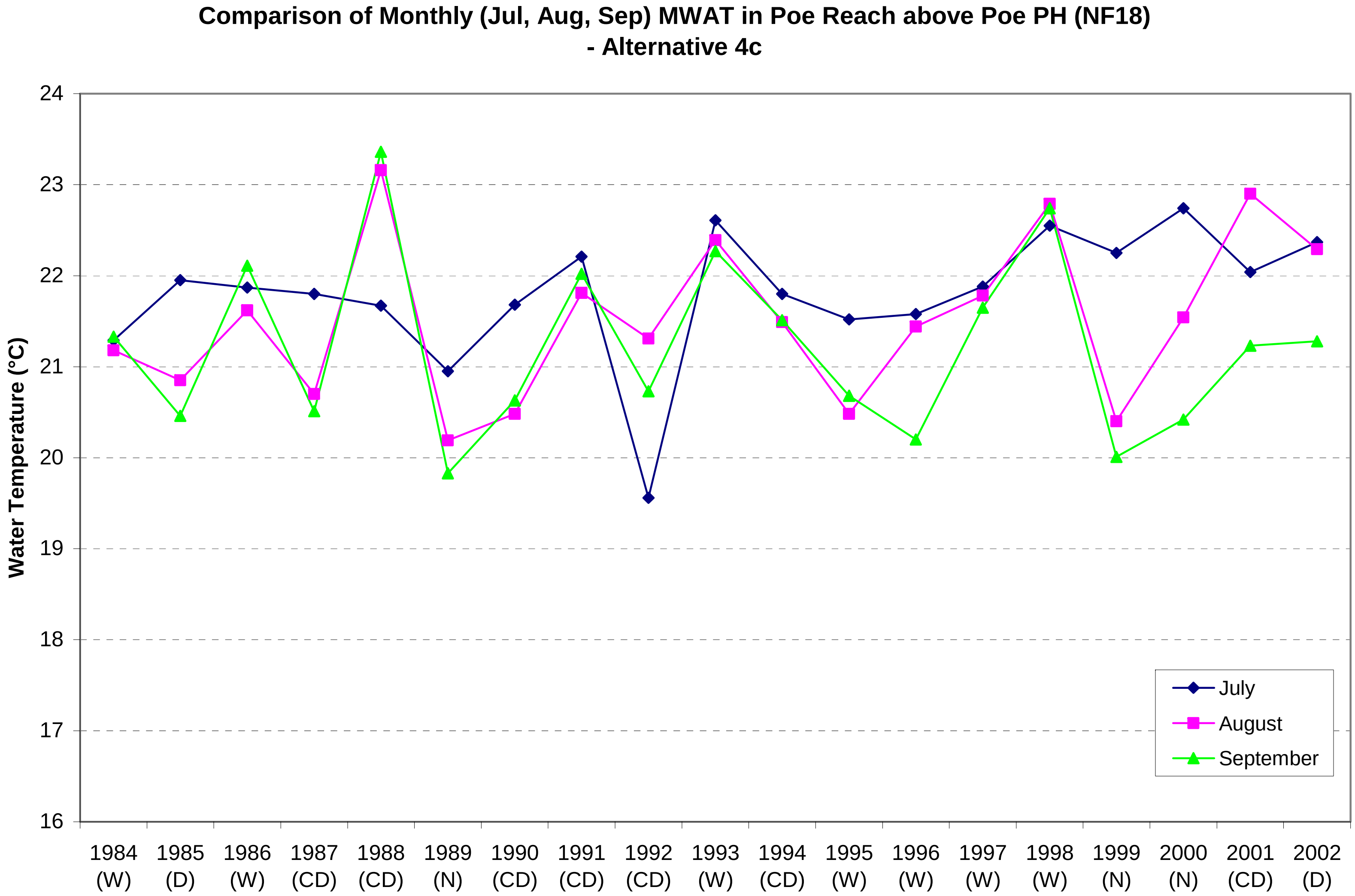

Comparison of Monthly (Jul, Aug, Sep) MWAT in Poe Reach above Poe PH (NF18)
- Alternative 4c
Water Temperature (°C)
24
23
22
21
20
19
18
17
16
1984 (W)
1985 (D)
1986 (W)
1987 (CD)
1988 (CD)
1989 (N)
1990 (CD)
1991 (CD)
1992 (CD)
1993 (W)
1994 (CD)
1995 (W)
1996 (W)
1997 (W)
1998 (W)
1999 (N)
2000 (N)
2001 (CD)
2002 (D)
July
August
September

Figure 2-57a

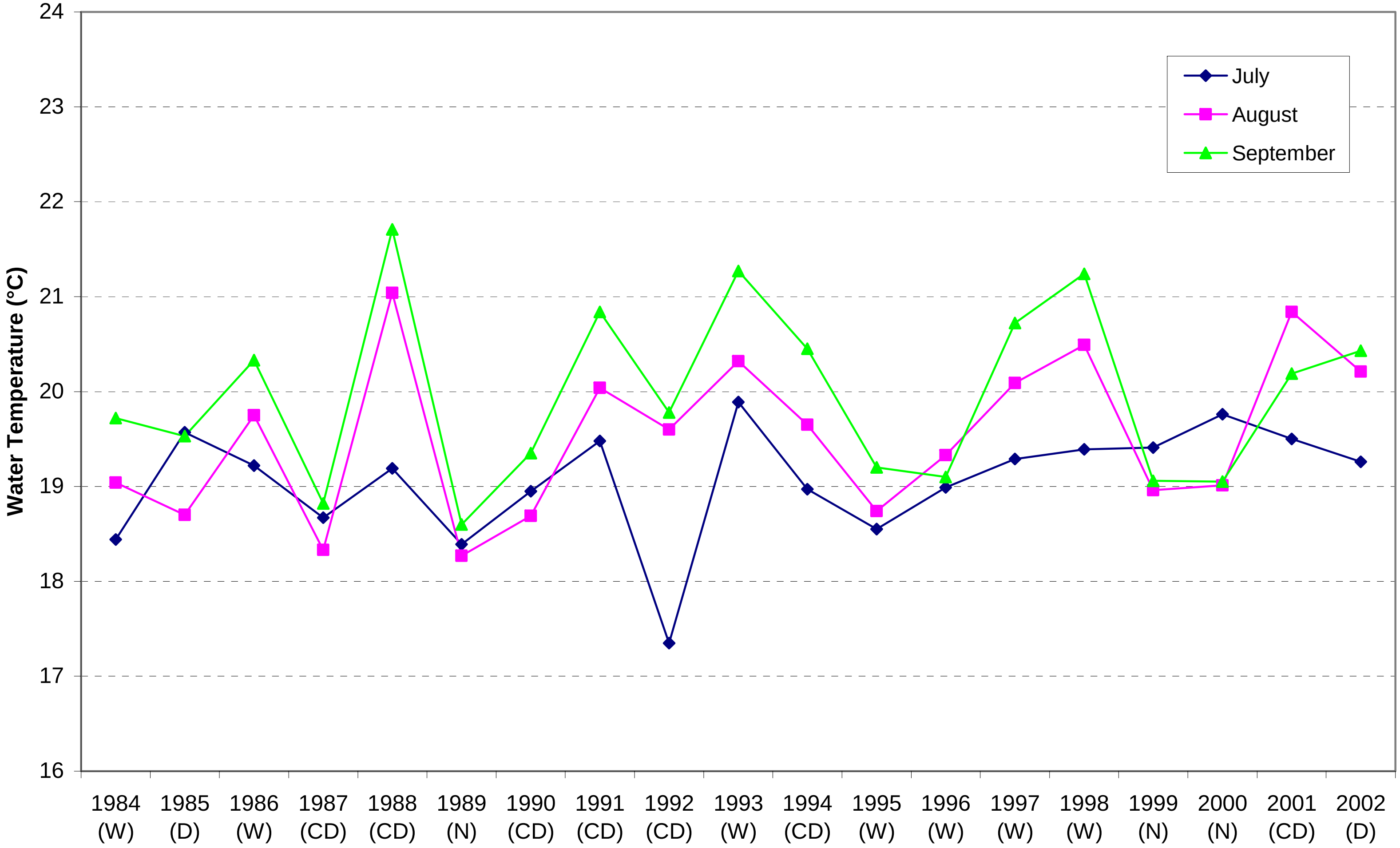

Comparison of Monthly (Jul, Aug, Sep) MWAT in Rock Creek Reach above Bucks Creek (NF12) - Alternative 4d
Water Temperature (°C)
24
23
22
21
20
19
18
17
16
1984 (W)
1985 (D)
1986 (W)
1987 (CD)
1988 (CD)
1989 (N)
1990 (CD)
1991 (CD)
1992 (CD)
1993 (W)
1994 (CD)
1995 (W)
1996 (W)
1997 (W)
1998 (W)
1999 (N)
2000 (N)
2001 (CD)
2002 (D)
July
August
September

Figure 2-57b

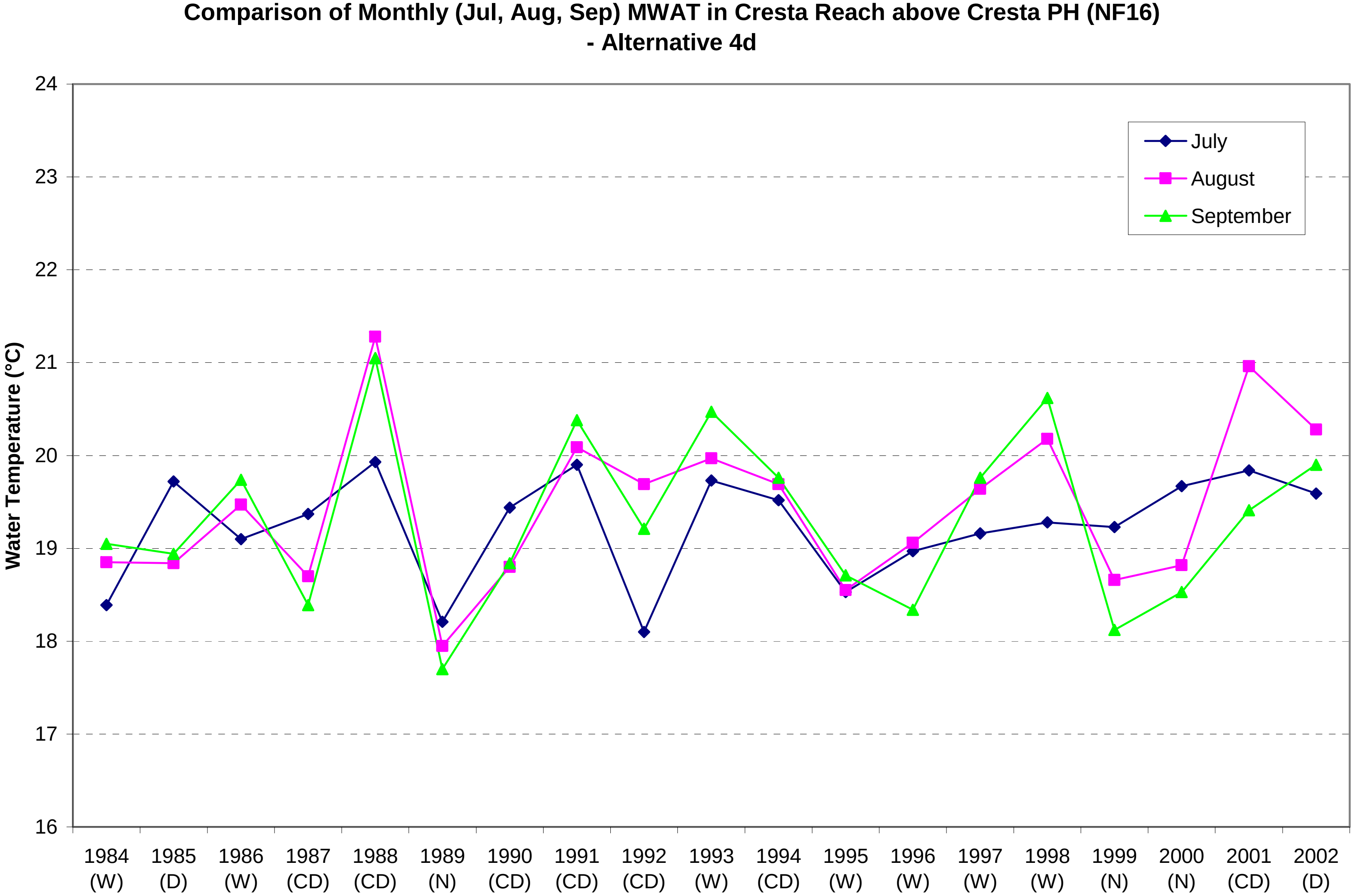
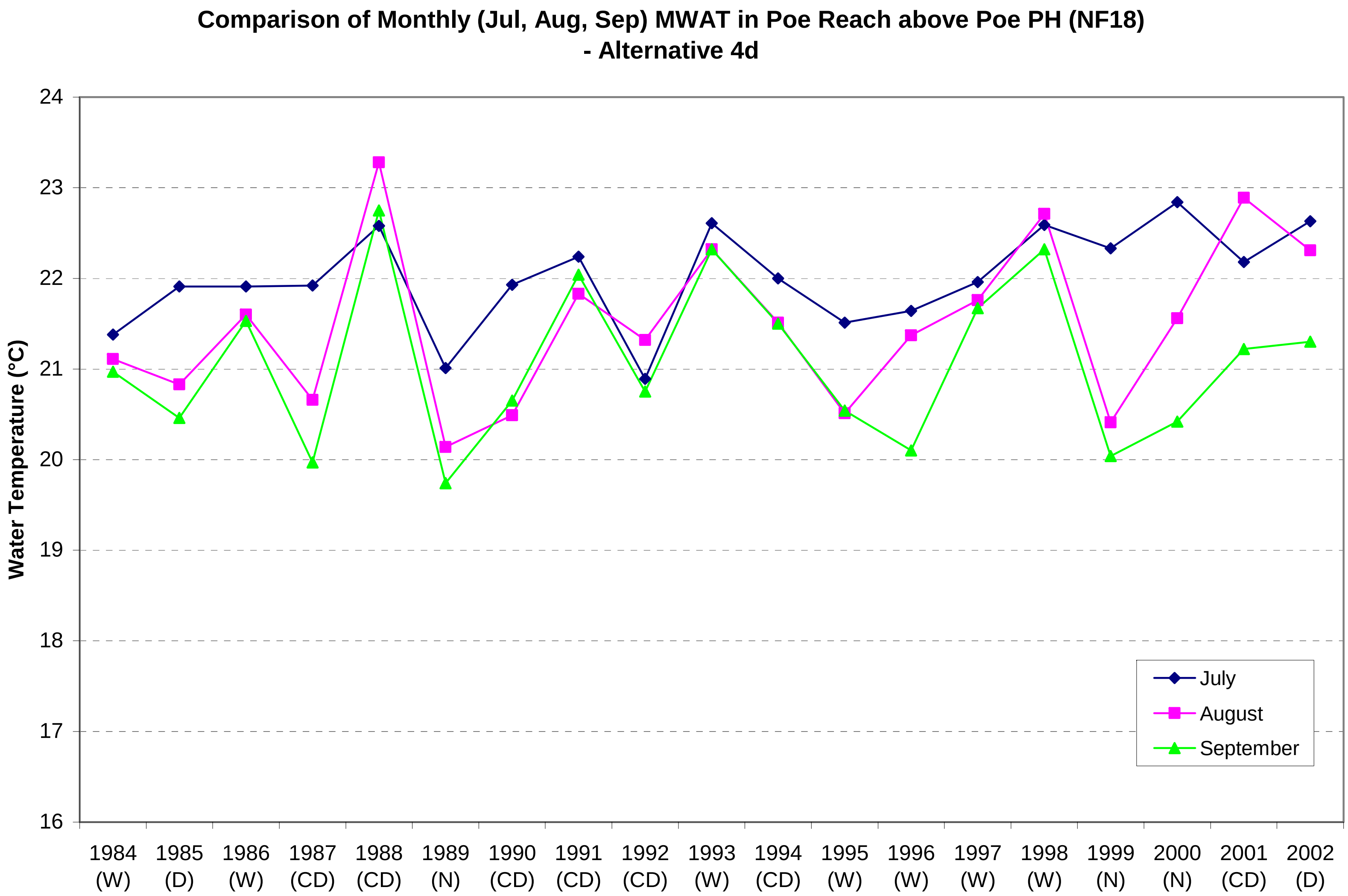

Comparison of Monthly (Jul, Aug, Sep) MWAT in Cresta Reach above Cresta PH (NF16) - Alternative 4d
Water Temperature (°C)
24
23
22
21
20
19
18
17
16
1984 (W)
1985 (D)
1986 (W)
1987 (CD)
1988 (CD)
1989 (N)
1990 (CD)
1991 (CD)
1992 (CD)
1993 (W)
1994 (CD)
1995 (W)
1996 (W)
1997 (W)
1998 (W)
1999 (N)
2000 (N)
2001 (CD)
2002 (D)
July
August
September

Figure 2-57c


Comparison of Monthly (Jul, Aug, Sep) MWAT in Poe Reach above Poe PH (NF18) - Alternative 4d
Water Temperature (°C)
24
23
22
21
20
19
18
17
16
1984 (W)
1985 (D)
1986 (W)
1987 (CD)
1988 (CD)
1989 (N)
1990 (CD)
1991 (CD)
1992 (CD)
1993 (W)
1994 (CD)
1995 (W)
1996 (W)
1997 (W)
1998 (W)
1999 (N)
2000 (N)
2001 (CD)
2002 (D)
July
August
September

2.3 DIEL WATER TEMPERATURE ANALYSIS

Diel water temperature provides an index for assessing the effects of acute thermal conditions in river reaches on cold freshwater habitat. This section characterizes the summer diel thermal regime of the NFFR based on historical hourly temperature data produced by PG&E through its annual NFFR monitoring efforts during the summer months of water years 2002, 2003, and 2004.

Water years 2002, 2003, and 2004 for the NFFR watershed were classified, in hydrologic terms, as “dry”, “normal”, and “normal” hydrologic years, respectively. The diel water temperature monitoring results for the Belden, Rock Creek, Cresta, and Poe Reaches for the three different years are shown Figures 2-58 to 2-50 and the diel temperature ranges for the summer months of the three years are summarized in Table 2-11. The monitoring results show that the diel water temperature fluctuations at the locations immediately below each dam (NF5, NF9, NF14, and NF17) were not as significant as the downstream points in each respective reach. This is not surprising because the reservoir behind each dam has much higher volume and water depth than the stream channel to attenuate the effects of diel changes in weather. The maximum diel water temperatures observed over the three years for the Belden Reach above East Branch (NF7), the Rock Creek Reach above Bucks Creek (NF12), the Cresta Reach above Cresta PH (NF16), and the Poe Reach above Poe PH were 24.0°C, 24.0°C, 24.0°C, and 26.6°C, respectively. Table 2-11 shows that the summertime diel water temperature ranges observed over the three years for the Belden Reach above East Branch, the Rock Creek Reach above Bucks Creek, the Cresta Reach above Cresta PH, and the Poe Reach above Poe PH were, on average, 4.8°C, 3.6°C, 2.9°C, and 3.2°C, respectively, in June, 4.8°C, 3.1°C, 2.8°C, and 3.1°C, respectively, in July, 4.1°C, 2.7°C, 2.5°C, and 2.7°C, respectively, in August, and 4.1°C, 2.5°C, 2.0°C, and 2.4°C, respectively, in September.

The diel water temperature monitoring results for water years 2002, 2003, and 2004 were observed under the <u>Baseline flow</u> conditions. For a given UNFFR Project-only alternative, the maximum or minimum diel water temperature can be estimated using the predicted mean daily temperature profile discussed in Section 2.1 plus or minus one half of the diel water temperature range shown in Table 2-11. For example, Figure 3-2a shows that the predicted mean daily water temperature at the downstream end of Poe Reach for Alternative 3c is about 21.5°C in July at the 50% exceedence level. Table 2-11 shows that the average diel water temperature range at NF18 in July is about 3.1°C (3.0°C in 2003 and 3.2°C in 2004). So the maximum diel water temperature at the downstream end of Poe Reach for Alternative 3c in July at the 50% exceedence level could be estimated at 23.0°C (i.e., 21.5 + (3.1 ÷ 2) = 23.0). However, further analysis would need to be conducted to estimate the diel water temperature for a reach if much higher dam releases (than the Baseline flow conditions) are used.

Table 2- 11 Summary of 2002 - 2004 Diel Temperature Ranges along the NFFR Reaches (°C)

Station	Month	2002			2003			2004		
		max	min	mean	max	min	mean	max	min	mean
Belden Reach										
NF5	June	1.4	0.3	0.6	1.1	0.2	0.6	0.8	0.2	0.5
	July	1.3	0.3	0.8	2.2	0.3	0.6	1.0	0.3	0.5
	Aug	0.7	0.2	0.5	1.9	0.3	0.7	1.4	0.2	0.4
	Sep	2.8	0.4	0.5	2.5	0.3	0.7	1.6	0.3	0.5
NF6	June	3.9	2.5	3.4	3.9	1.8	3.1	3.6	1.2	3.1
	July	4.2	2.6	3.3	3.7	2.5	3.2	3.6	2.7	3.1
	Aug	3.5	2.2	2.8	3.9	0.5	2.6	3.4	0.9	2.7
	Sep	4.7	2.4	3.5	4.6	2.2	3.4	4.0	1.7	3.0
NF7	June	5.6	3.6	5.0	5.7	2.1	4.7	5.4	1.5	4.7
	July	6.0	3.5	4.9	5.5	3.3	4.7	5.5	3.9	4.8
	Aug	5.4	3.4	4.3	4.8	0.6	3.8	5.1	1.6	4.1
	Sep	5.5	2.6	4.2	5.2	2.5	4.2	4.9	2.1	4.0
NF8	June	5.2	4.2	4.7	5.0	1.5	3.9	5.2	2.0	4.3
	July	5.3	3.5	4.6	5.2	3.1	4.4	5.0	3.7	4.5
	Aug	5.2	3.9	4.5	4.6	0.8	3.7	5.1	2.0	4.1
	Sep	4.4	2.2	3.4	4.2	2.0	3.1	4.5	1.8	3.3
Rock Creek Reach										
NF10	June	3.7	1.4	3.0	2.1	0.5	1.1	2.2	0.9	1.4
	July	2.5	0.6	1.7	1.7	0.9	1.4	1.6	0.5	1.2
	Aug	2.0	1.1	1.4	1.5	0.4	1.1	1.4	0.6	1.1
	Sep	1.4	0.3	1.0	1.3	0.4	1.0	1.4	0.6	1.1
NF11	June	5.1	3.0	3.9	4.6	2.0	3.8	4.8	1.8	3.8
	July	4.3	2.6	3.5	4.2	2.3	3.6	4.1	2.3	3.5
	Aug	4.1	2.7	3.2	3.7	0.8	3.1	3.6	1.0	3.0
	Sep	3.5	1.5	2.7	3.2	0.8	2.6	3.3	1.5	2.6
NF12	June	5.2	2.7	3.6	4.6	1.9	3.7	4.5	1.7	3.6
	July	3.8	2.2	2.9	3.7	1.9	3.2	3.8	2.5	3.2
	Aug	3.6	2.4	2.8	3.3	0.9	2.7	3.4	1.1	2.7
	Sep	3.7	1.3	2.5	3.0	1.1	2.5	3.2	1.7	2.4
NF13	June	4.6	2.0	3.1	3.9	1.8	2.7	3.3	1.2	2.6
	July	4.6	1.9	3.3	4.4	1.3	2.4	4.1	1.3	2.4
	Aug	5.3	1.9	3.7	4.2	1.5	2.7	3.3	0.9	1.7
	Sep	4.5	1.7	2.9	3.9	1.1	2.5	2.8	1.4	2.2
Cresta Reach										
NF14	June	1.5	0.7	1.1	1.8	0.6	1.1	1.8	0.6	1.1
	July	1.6	0.5	1.0	1.6	0.7	1.1	1.4	0.6	1.0
	Aug	1.6	0.5	1.1	1.3	0.3	1.0	1.3	0.5	0.8
	Sep	1.3	0.3	0.8	1.7	0.5	1.0	1.4	0.5	0.9
NF15	June	3.2	1.0	2.6	3.3	2.2	2.7	3.1	1.4	2.5
	July	3.2	1.8	2.5	3.1	1.6	2.6	3.0	1.9	2.5
	Aug	3.1	1.0	2.3	2.9	0.6	2.2	2.8	1.1	2.3
	Sep	2.6	0.9	3.1	4.8	0.6	2.1	2.5	0.8	2.0
NF16	June	3.5	2.1	3.1	3.7	2.3	2.9	3.5	1.8	2.8
	July	3.7	2.1	2.8	3.4	2.1	2.9	3.3	2.1	2.8
	Aug	3.1	1.6	2.4	2.9	0.6	2.4	3.2	1.6	2.6
	Sep	3.0	1.0	2.1	2.7	0.7	2.0	2.4	0.9	1.9

Table 2-11 Summary of 2002 - 2004 Diel Temperature Ranges along the NFFR Reaches (°C) (Continued)

Station	**Month**	**2002**			**2003**			**2004**		
		max	**min**	**mean**	**max**	**min**	**mean**	**max**	**min**	**mean**
Poe Reach										
NF17	June	1.8	1.1	1.4	1.6	0.5	1.1	1.5	0.2	0.7
	July	1.6	0.8	1.3	1.2	0.4	0.7	1.3	0.2	0.6
	Aug	1.7	0.8	1.2	1.0	0.2	0.6	0.9	0.3	0.6
	Sep	1.6	0.5	0.9	1.2	0.2	0.7	0.7	0.2	0.4
NF18	June	-	-	-	3.6	2.2	3.0	3.7	2.5	3.3
	July	-	-	-	3.3	2.2	3.0	3.6	2.8	3.2
	Aug	-	-	-	3.1	0.6	2.6	3.4	1.8	2.8
	Sep	-	-	-	2.8	1.1	2.2	3.0	2.0	2.6

Notes:

1) *Diel water temperature range is calculated from hourly temperature measurements for each day based on the diel maximum temperature minus the diel minimum temperature . Monthly statistics are based on these daily range values for each month.*
2) *Refer to Figure 2-28 for station locations.*
3) *NF17: NFFR below Poe Dam.*
4) *NF18: NFFR above Poe PH.*

Figure 5-58a Diel Water Temperatures in Belden Reach below Belden Dam (NF5), 2002

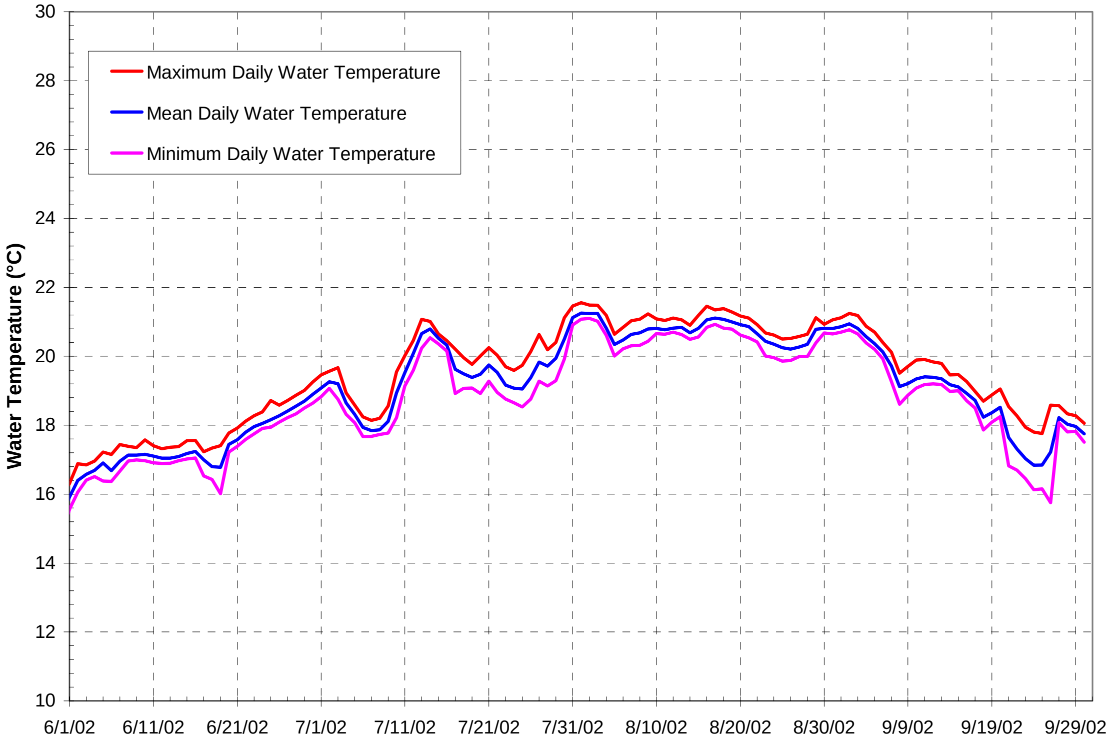


Figure 2-58b Diel Water Temperatures in Belden Reach above East Branch (NF7), 2002

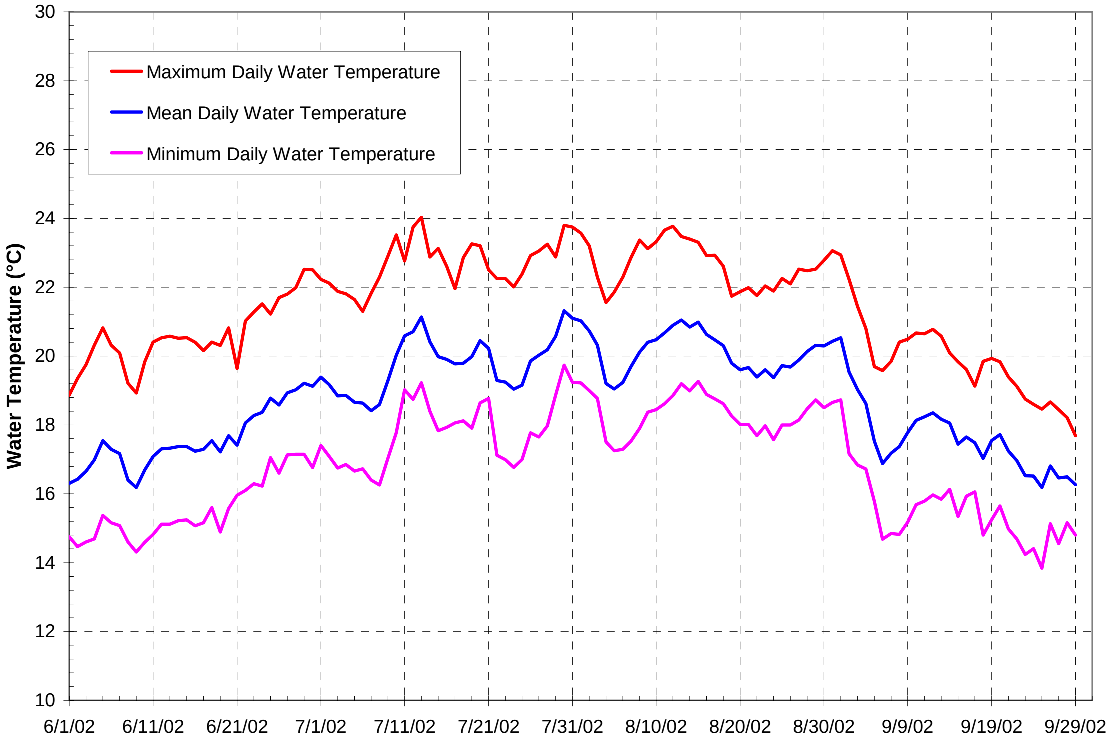


Figure 2-59a Diel Temperatures in Rock Ck. Reach below Rock Ck. Dam (NF9), 2002

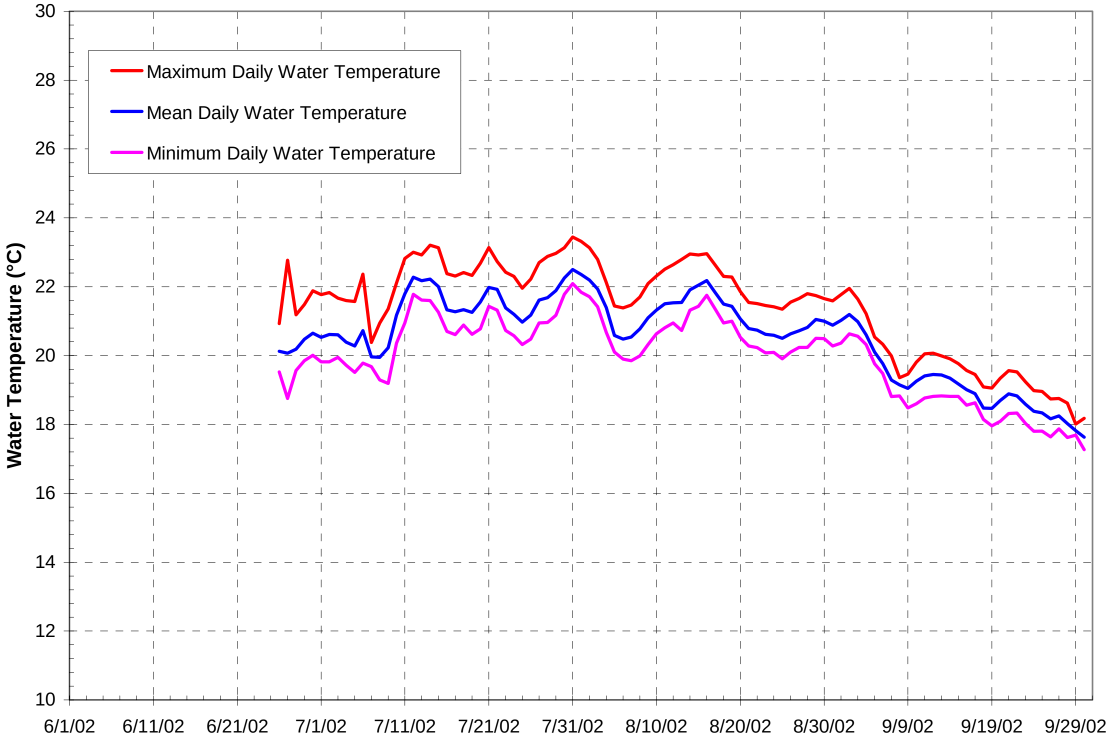


Figure 2-59b Diel Temperatures in Rock Creek Reach above Bucks Creek (NF12), 2002

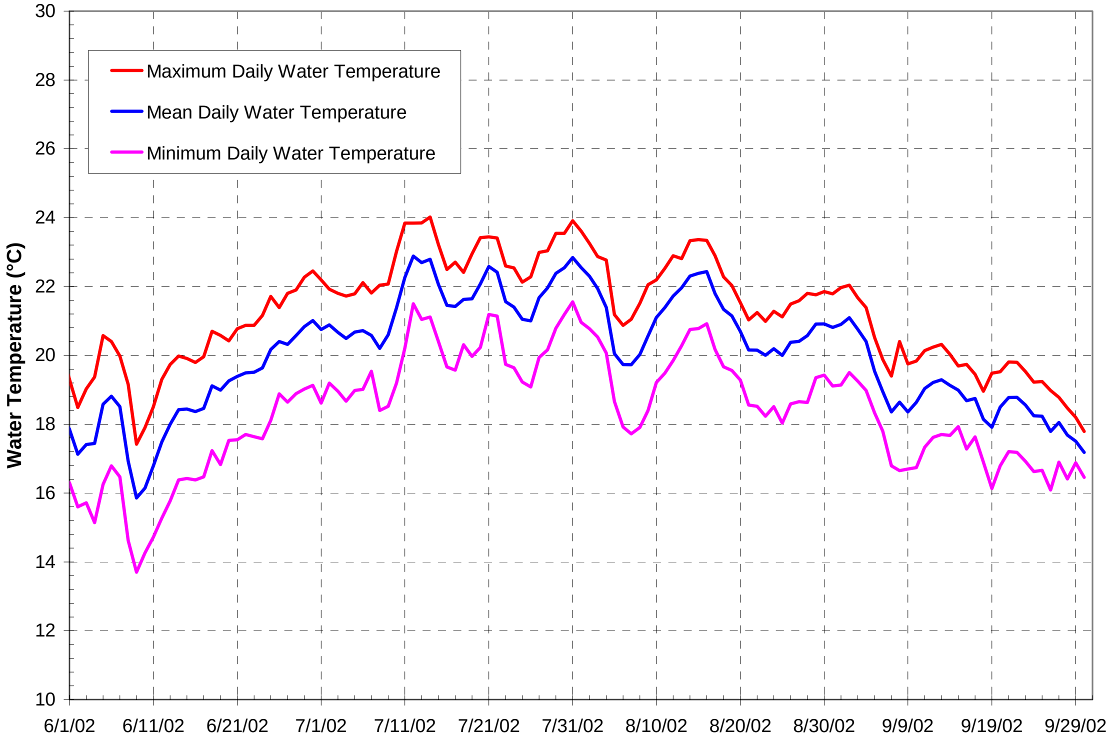


Figure 2-60a Diel Water Temperatures in Cresta Reach below Cresta Dam (NF14), 2002

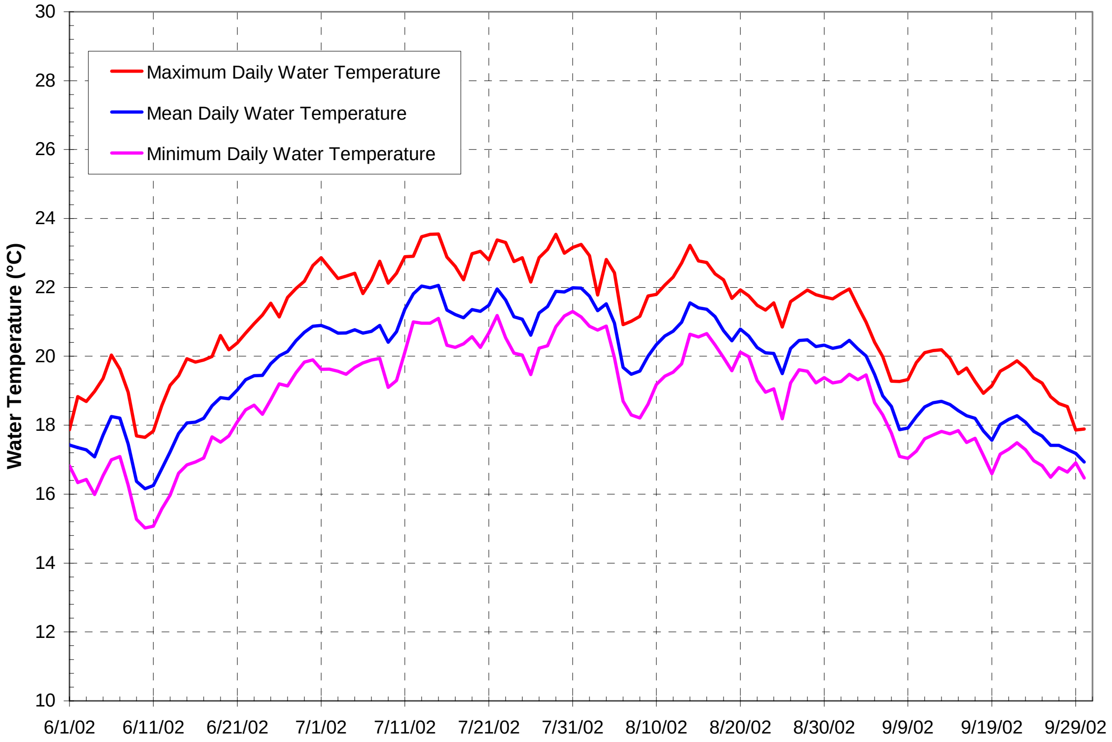


Figure 2-60b Diel Water Temperatures in Cresta Reach above Cresta PH (NF16), 2002

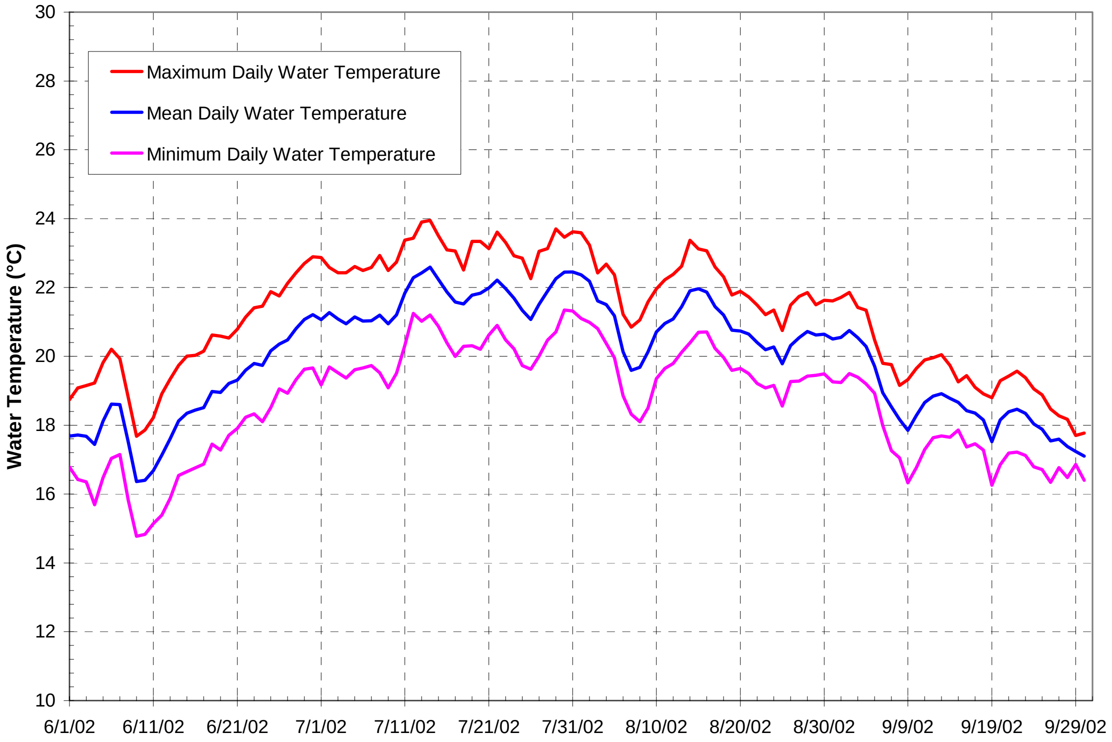


Figure 2-61a Diel Water Temperatures in Poe Reach below Poe Dam (NF17), 2002

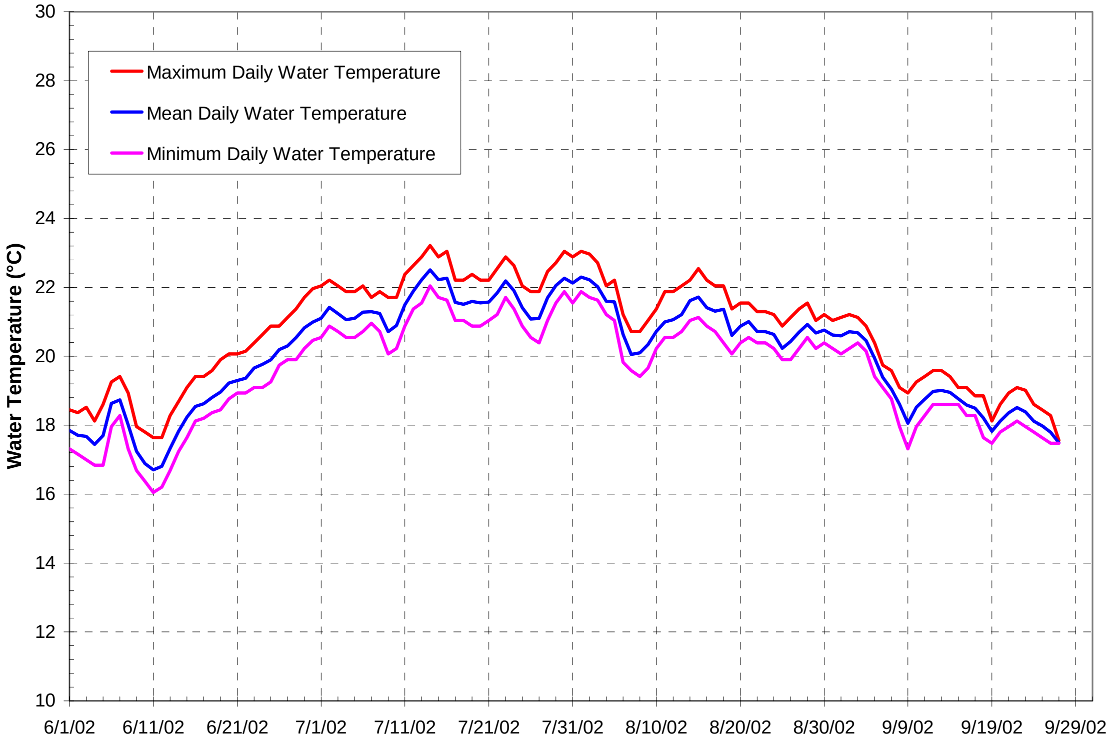


Figure 2-61b Diel Water Temperatures in Poe Reach above Poe PH (NF18), 2002

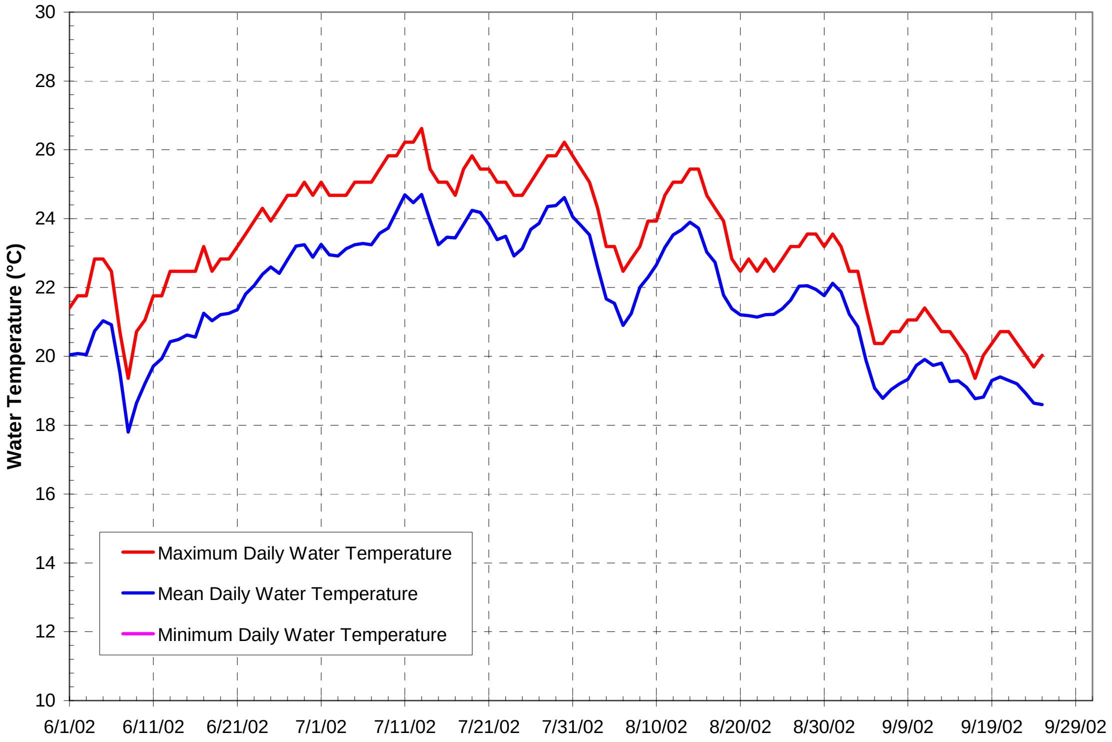


Figure 2-62a Diel Water Temperatures in Belden Reach below Belden Dam (NF5), 2003

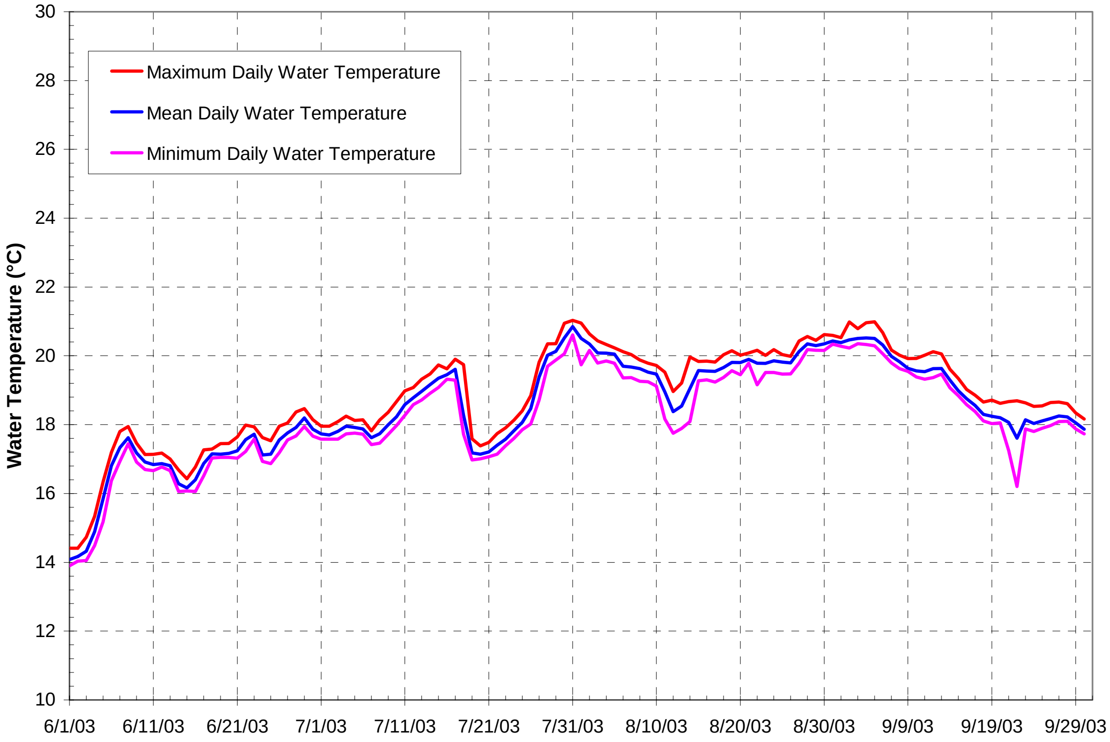


Figure 2-62b Diel Water Temperatures in Belden Reach above East Branch (NF7), 2003

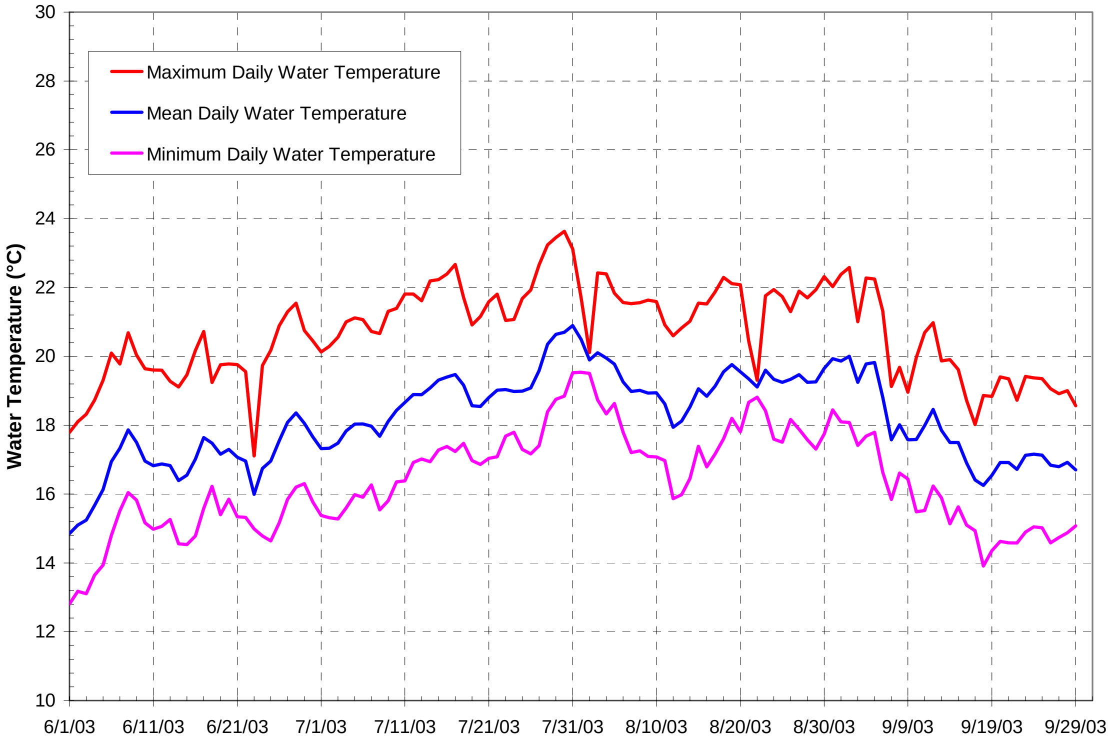


Figure 2-63a Diel Temperatures in Rock Ck. Reach below Rock Ck. Dam (NF9), 2003

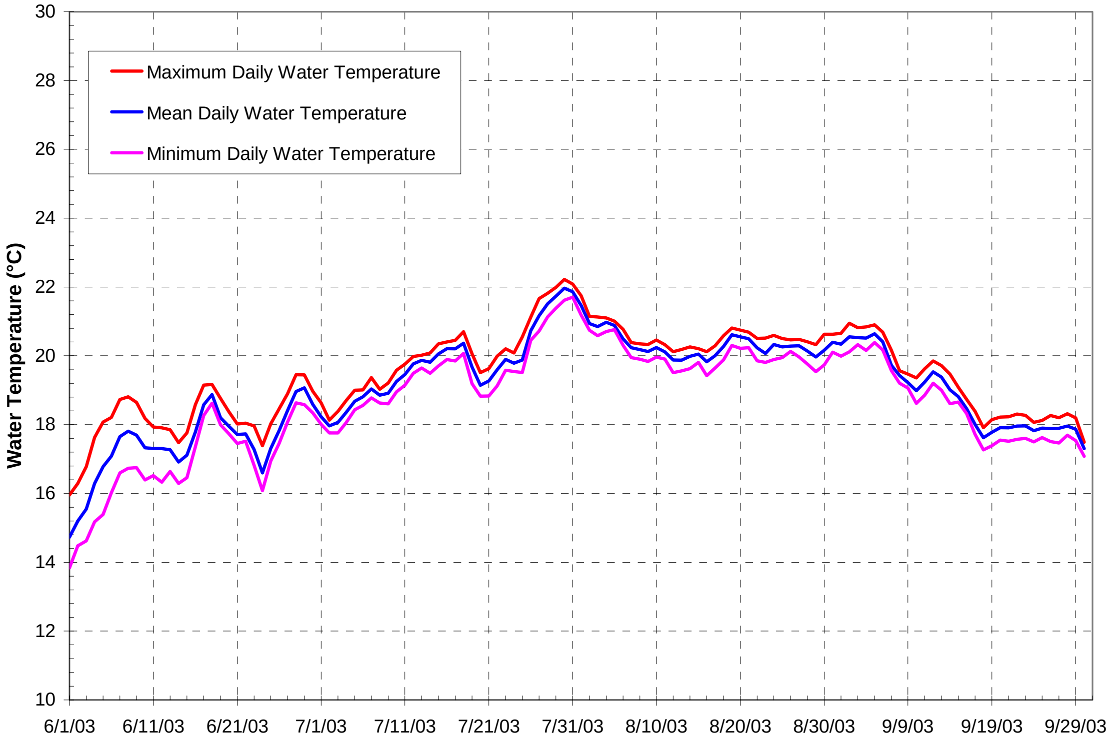


Figure 2-63b Diel Temperatures in Rock Creek Reach above Bucks Creek (NF12), 2003

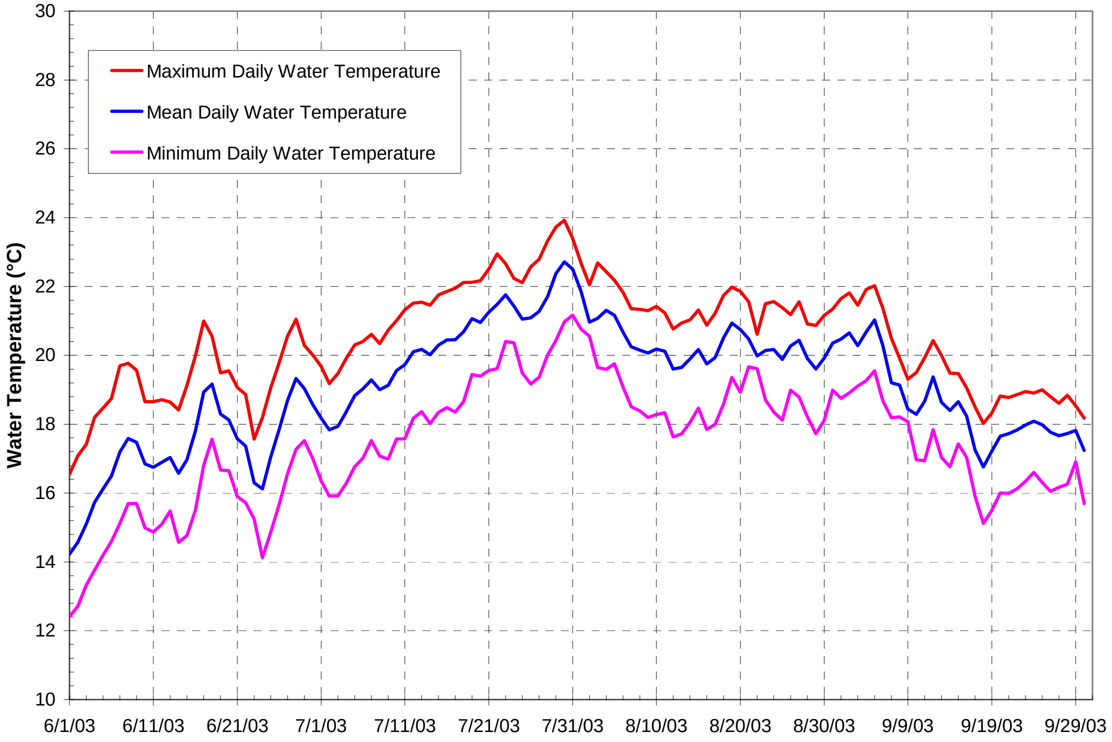


Figure 2-64a Diel Water Temperatures in Cresta Reach below Cresta Dam (NF14), 2003

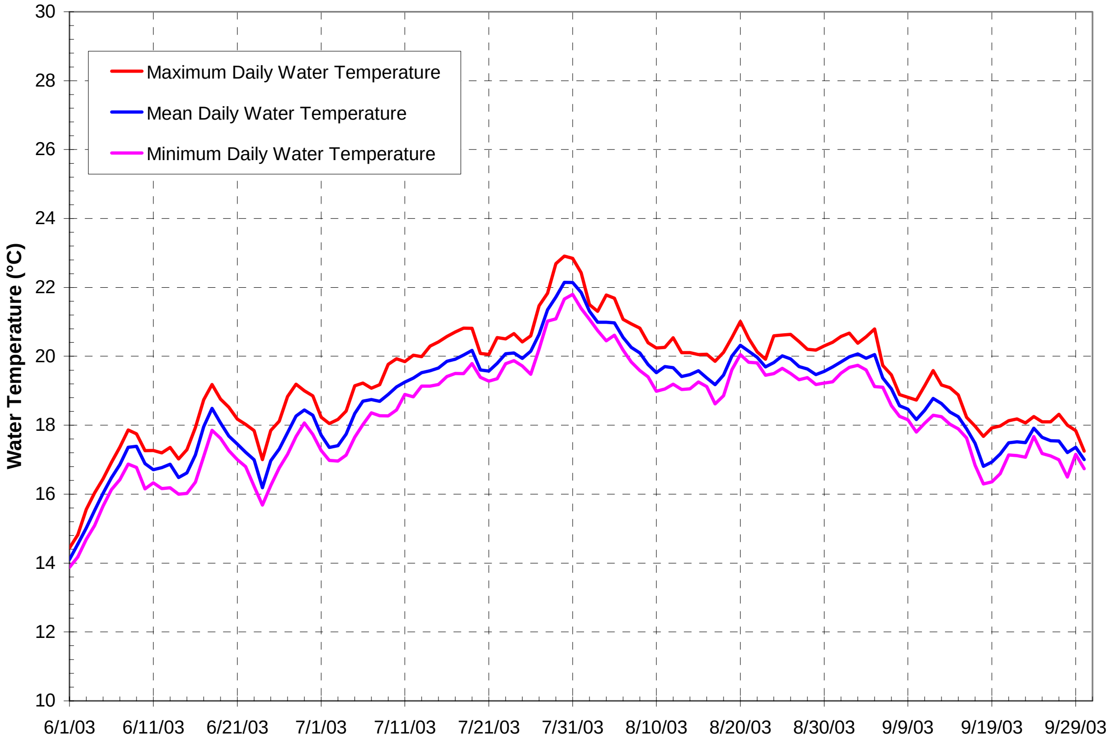


Figure 2-64b Diel Water Temperatures in Cresta Reach above Cresta PH (NF16), 2003

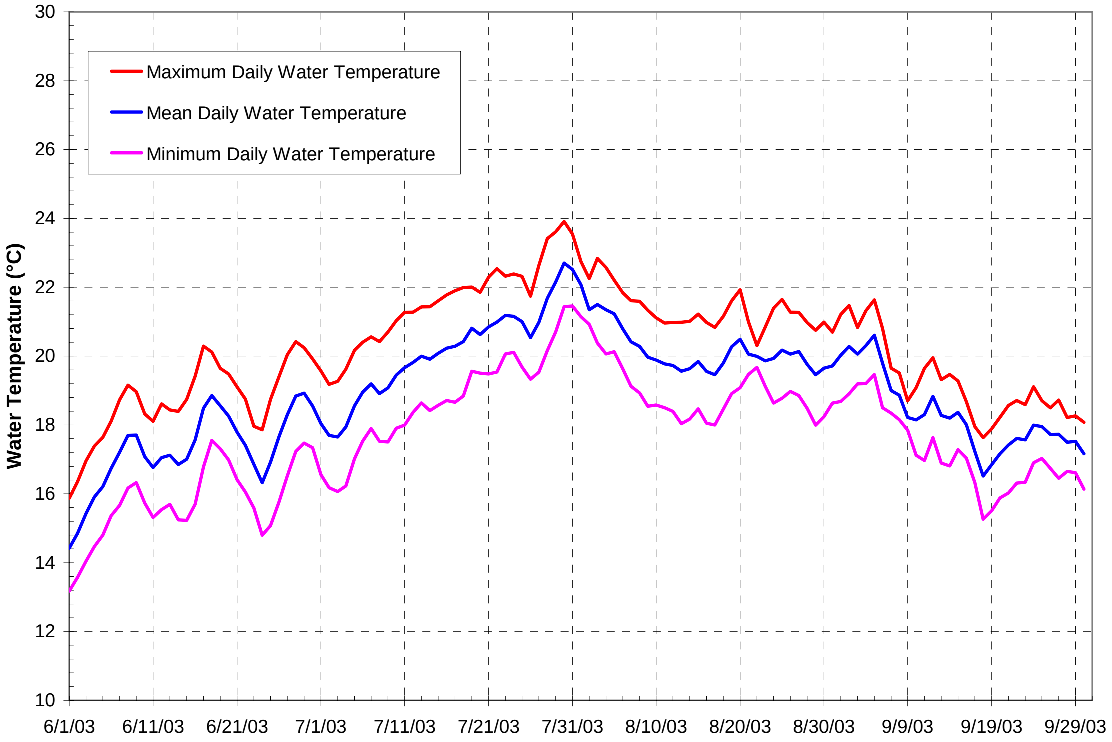


Figure 2-65a Diel Water Temperatures in Poe Reach below Poe Dam (NF17), 2003

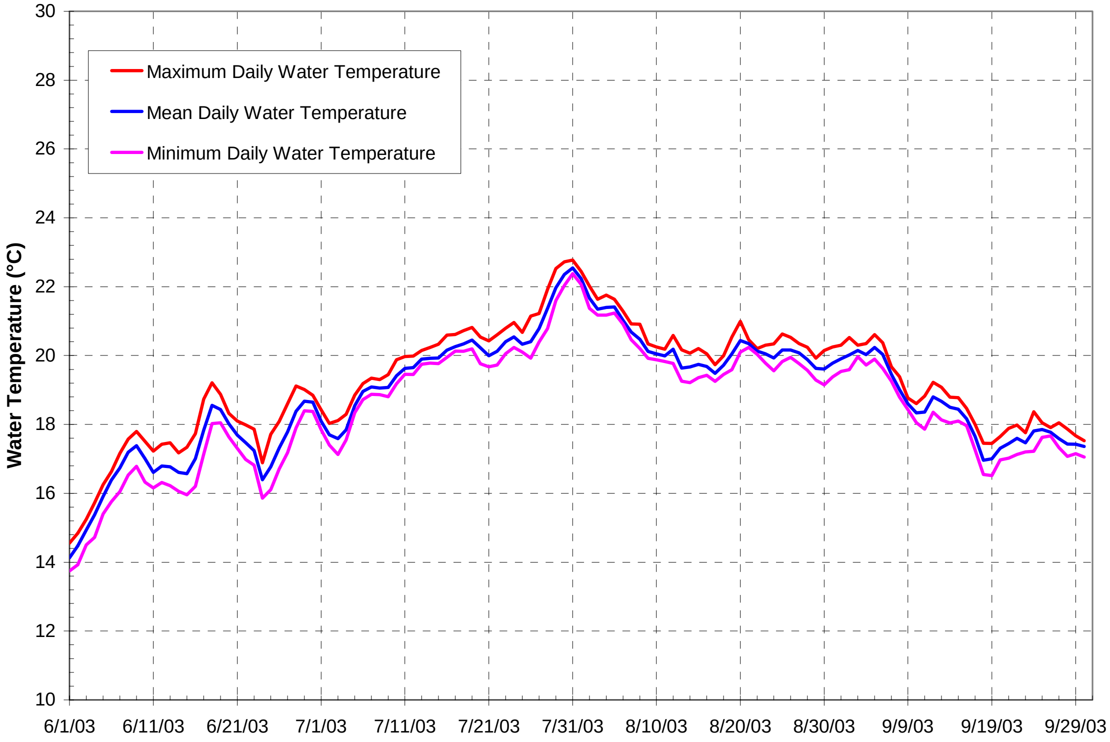


Figure 2-65b Diel Water Temperatures in Poe Reach above Poe PH (NF18), 2003

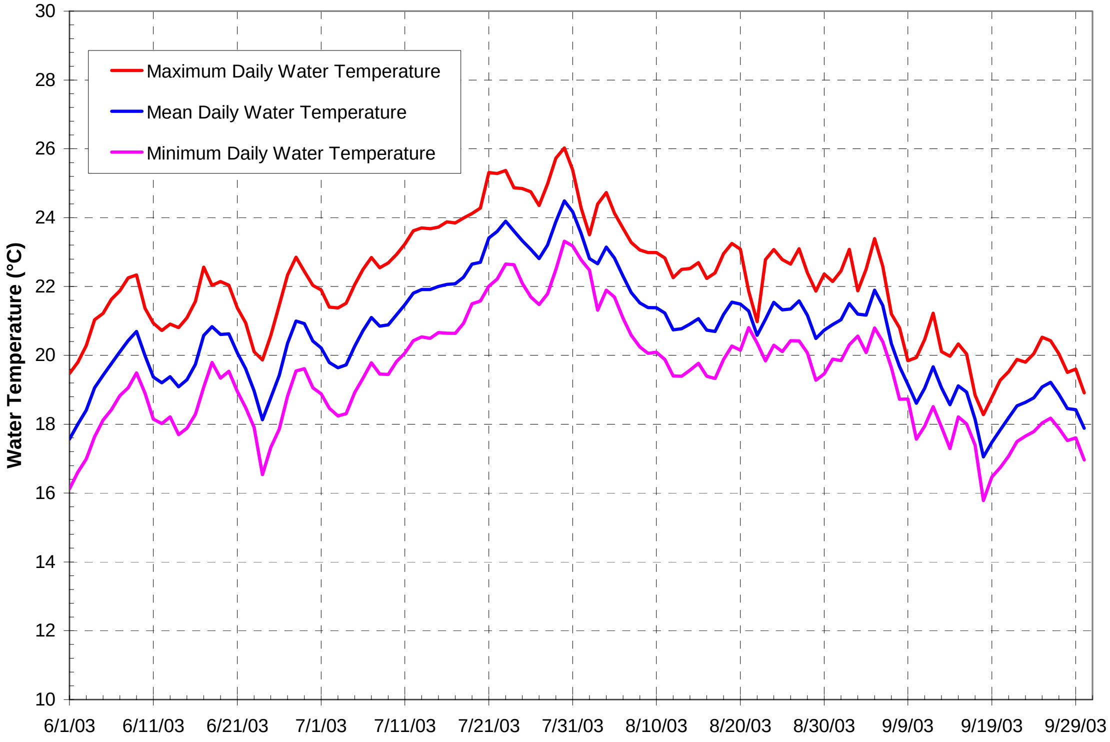


Figure 2-66a Diel Water Temperatures in Belden Reach below Belden Dam (NF5), 2004

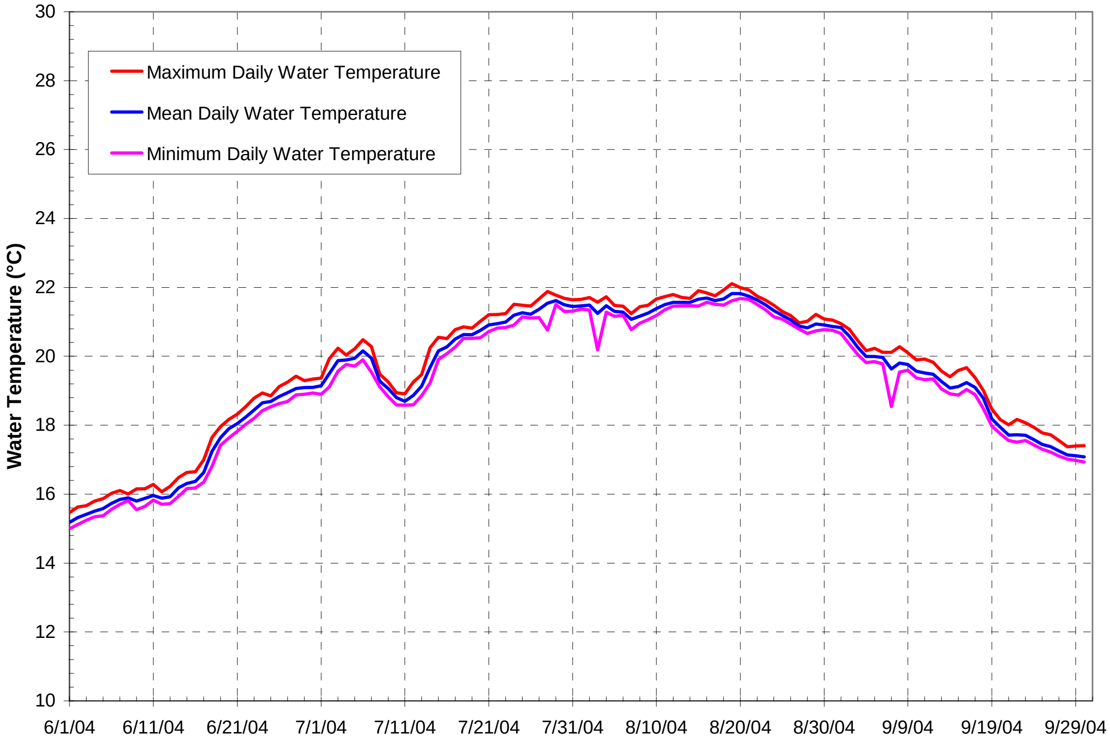


Figure 2-66b Diel Water Temperatures in Belden Reach above East Branch (NF7), 2004

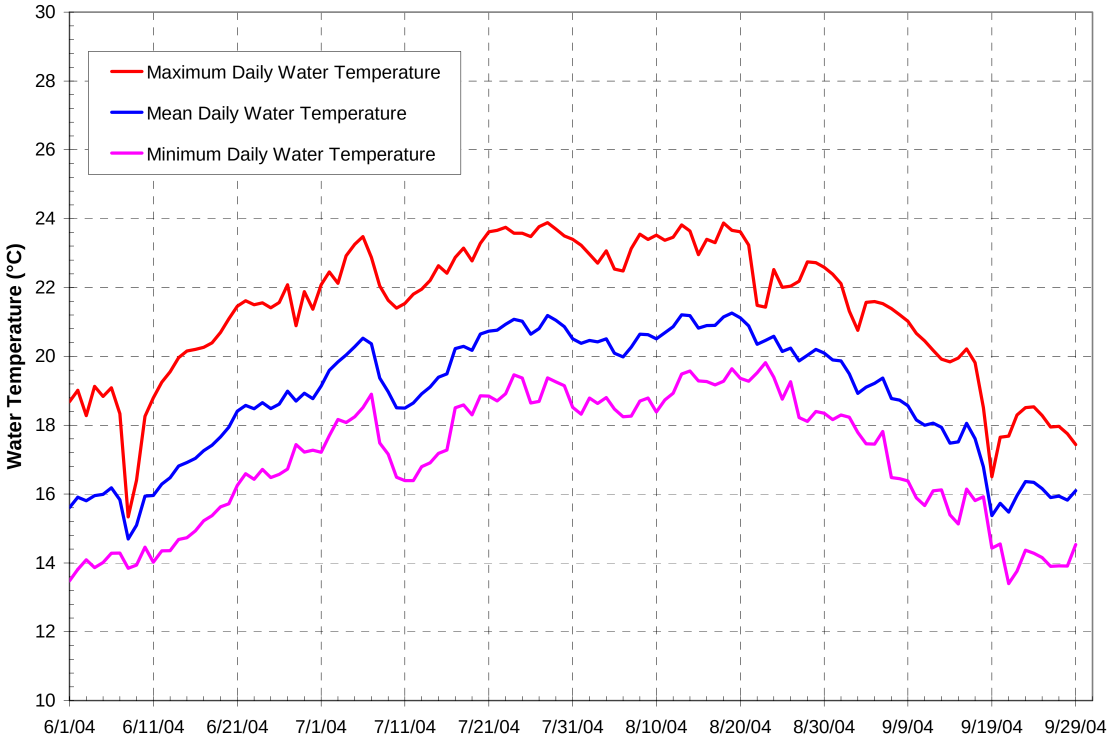


Figure 2-67a Diel Temperatures in Rock Ck. Reach below Rock Ck. Dam (NF9), 2004

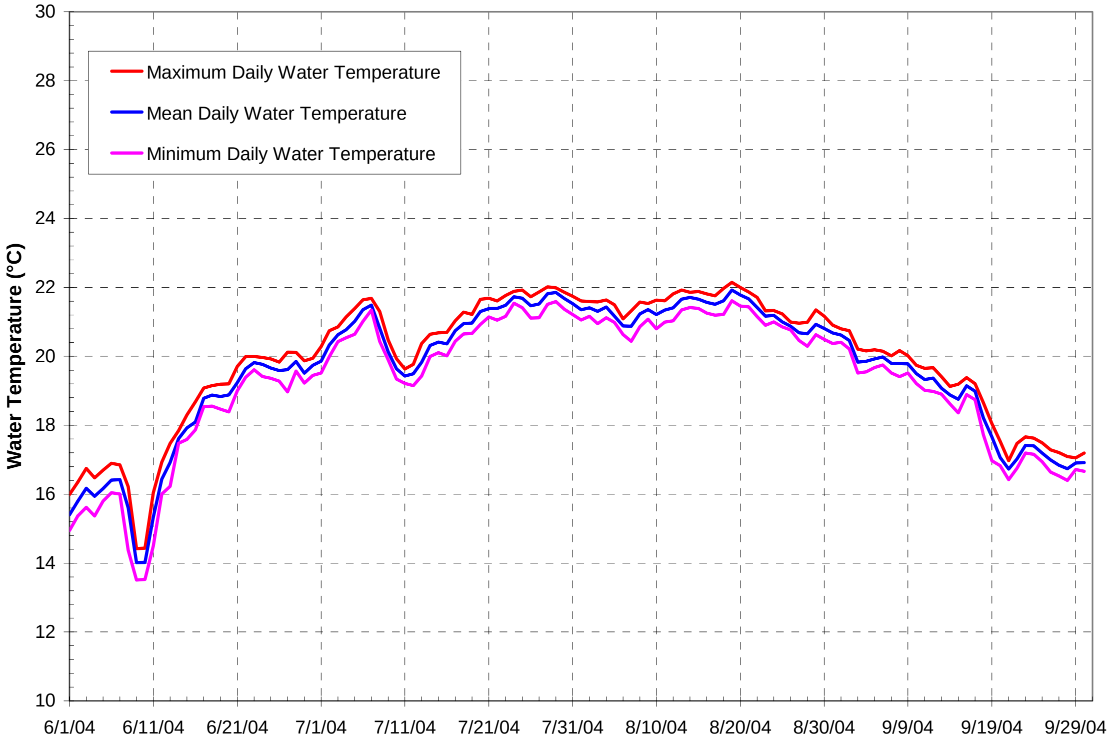


Figure 2-67b Diel Temperatures in Rock Ck. Reach above Bucks Creek (NF12), 2004

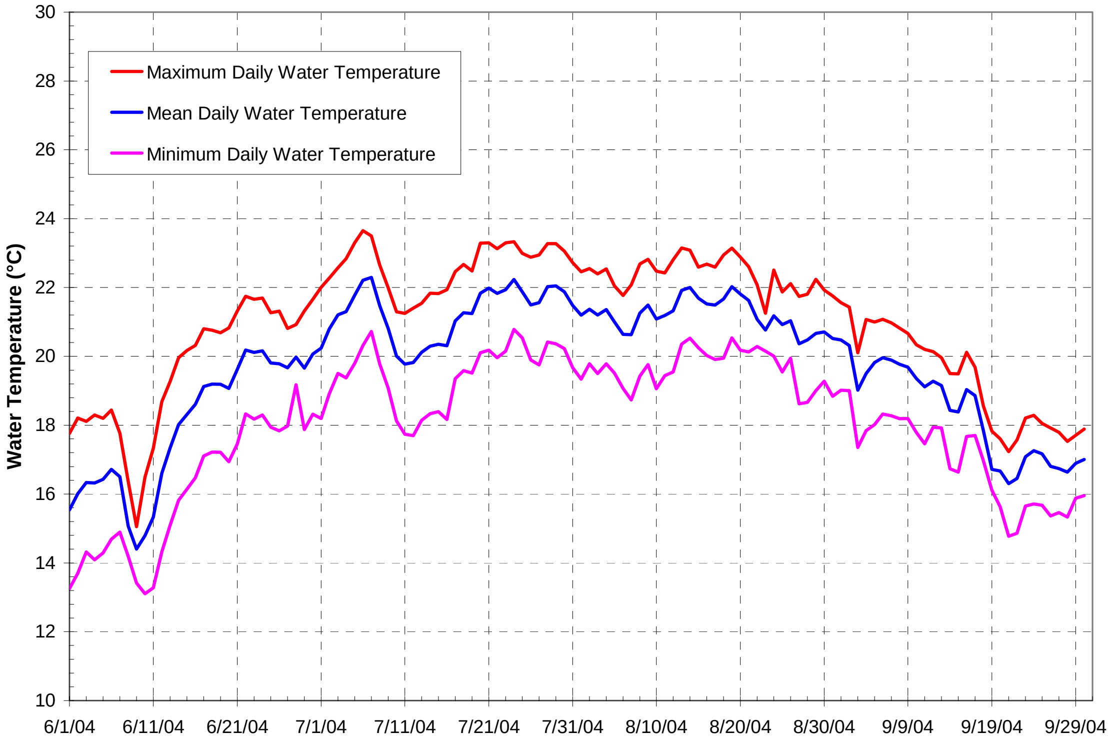


Figure 2-68a Diel Water Temperatures in Cresta Reach below Cresta Dam (NF14), 2004

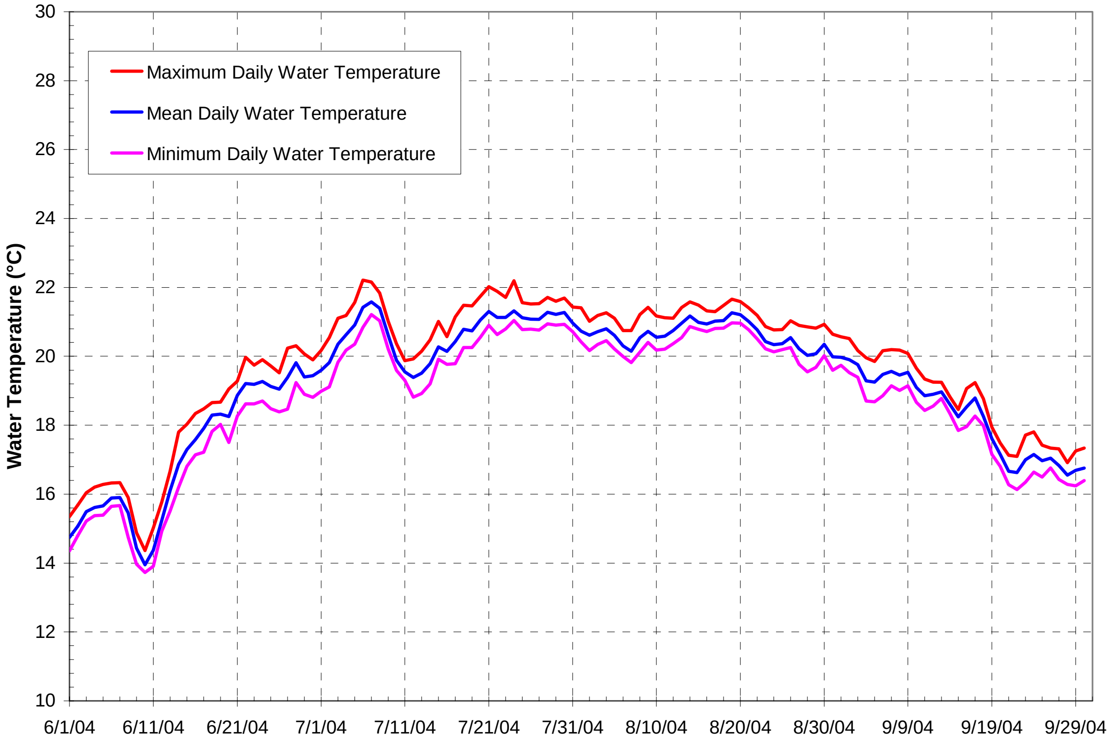


Figure 2-68b Diel Water Temperatures in Cresta Reach above Cresta PH (NF16), 2004

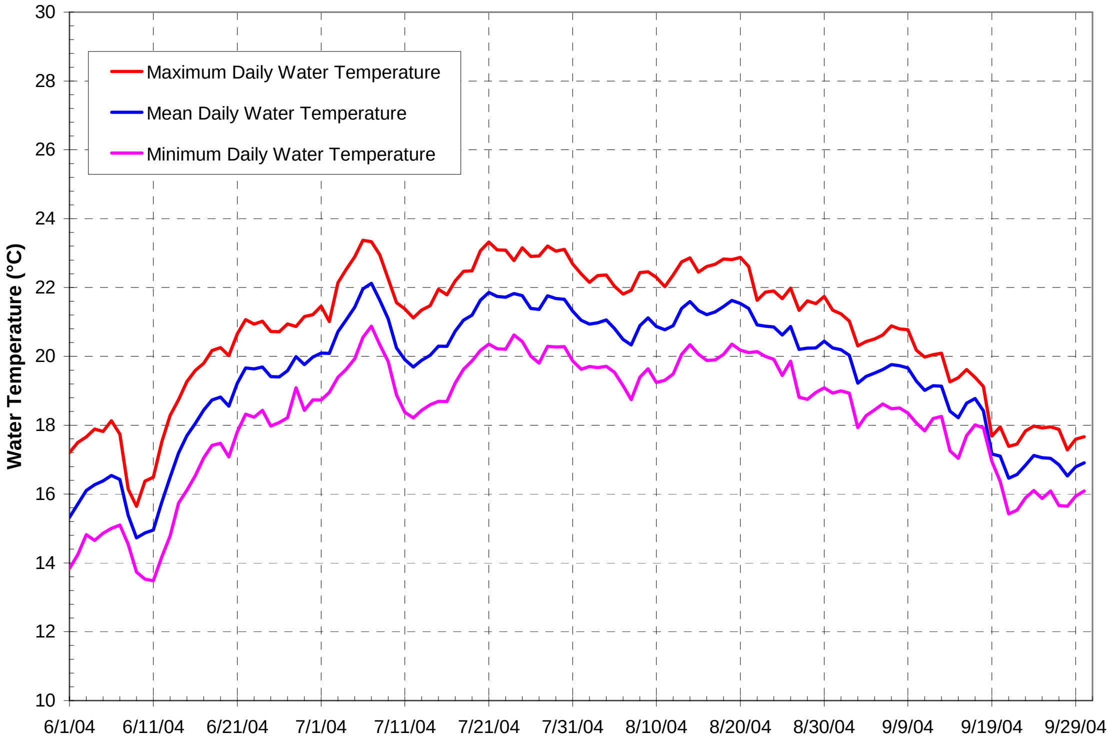


Figure 2-69a Diel Water Temperatures in Poe Reach below Poe Dam (NF17), 2004

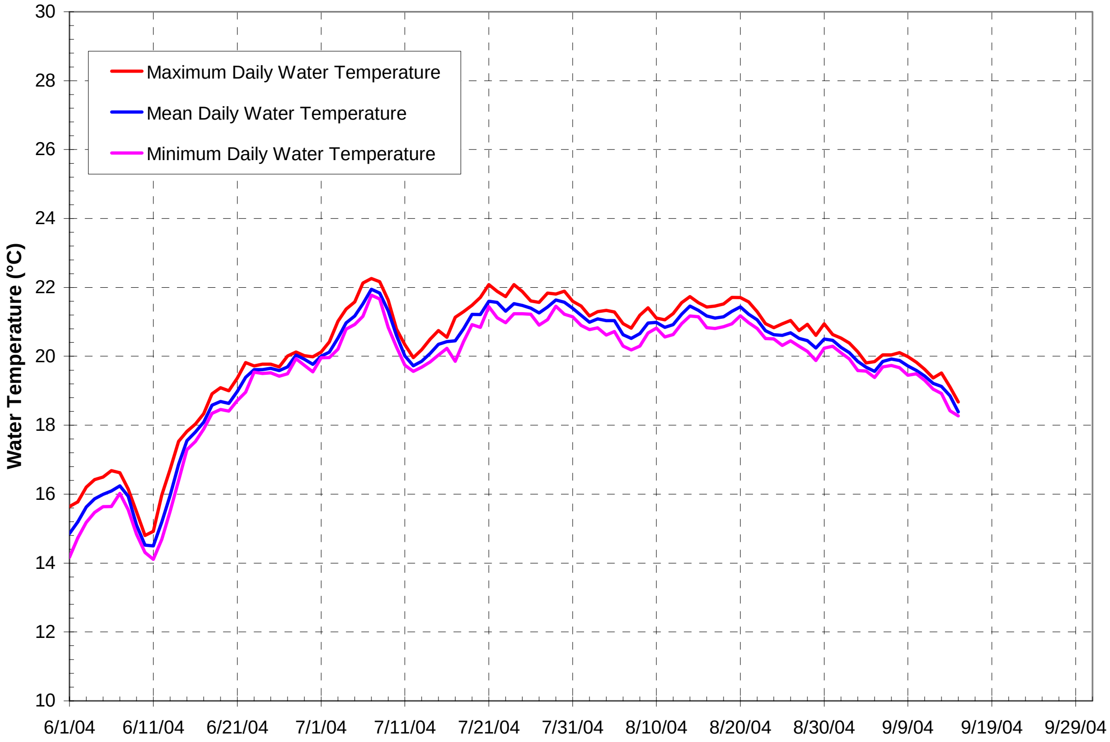
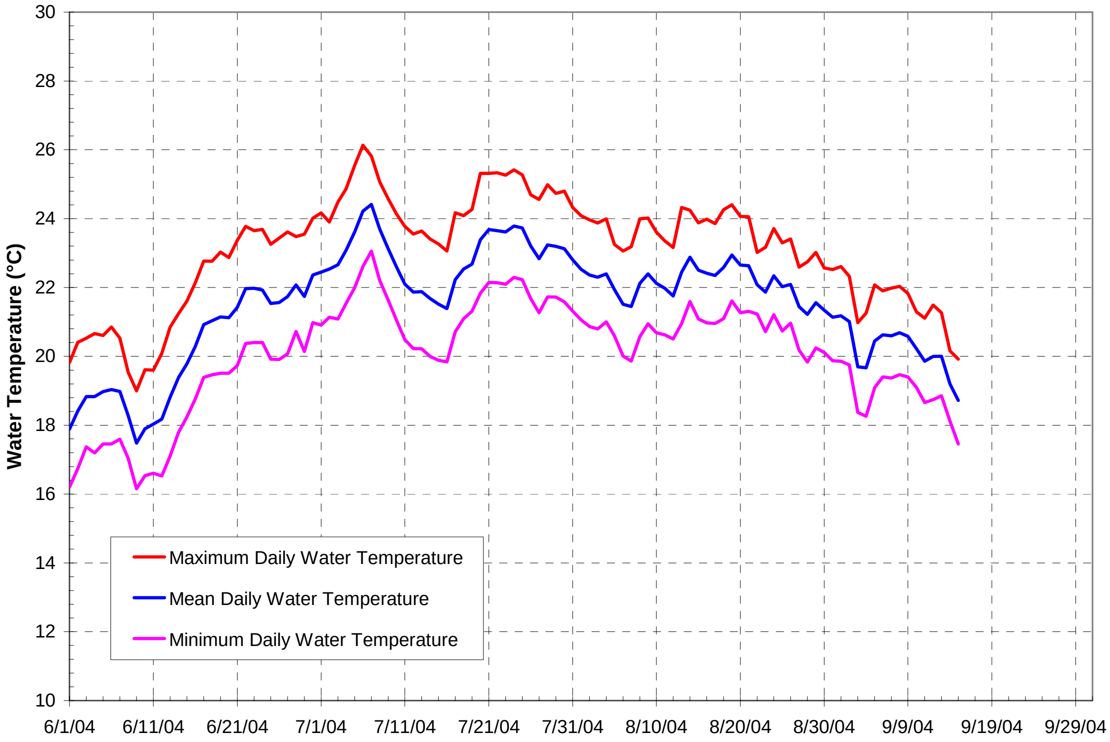


Figure 2-69b Diel Water Temperatures in Poe Reach above Poe PH (NF18), 2004



2.4 MODEL UNCERTAINTY AND ERROR PROPAGATION ANALYSIS

As described in Section 2.1, following is a list of models that were used in the Level 3 analysis for mean daily water temperature profiles along the NFFR and Figure 2-1 shows how these models were related.

- Lake Almanor: MITEMP as modified by Stetson
- Butt Valley Reservoir: Newly developed CE-QUAL-W2 by Stetson
- Belden Reservoir: Complete mixing method
- Rock Creek Reservoir: SNTEMP as modified by Stetson
- Cresta Reservoir and Poe Reservoir: Complete mixing method
- Five bypass reaches: SNTEMP for each reach.

No model is perfect and all models are subject to uncertainty. Sources of uncertainty have been classified into three main categories by researchers (Beck 1987): 1) uncertainty resulting from an imperfect model structure; 2) uncertainty resulting from estimation errors of model process parameters; and 3) uncertainty resulting from natural variability, such as environmental variability (which can be equated with uncertainty in the system input disturbances), spatial heterogeneity, and genetic variability. There are different methods to quantify the model uncertainty resulting from these individual sources.

The residual errors of mismatch between model output and the observed data reflect an amalgam of different sources of uncertainty. There are clearly cases in which it might be appropriate to quantify the error of prediction directly as a function of these residual errors of mismatch, one example being the application of Vollenweider's phosphorus-loading models reported by Reckhow and Chapra (1983).

In this uncertainty analysis of modeling of mean daily water temperatures, residual errors were used to quantify model uncertainty and probable error was used as a measure of model uncertainty. This is consistent with the SNTEMP program that uses probable error as a measure of model uncertainty. Statistically, probable error is equal to 0.6745 times the standard deviation for normally distributed model residuals. A normally distributed population has half of its elements within one probable error of the mean. In other words, each daily temperature prediction would be expected, on average, to be within ± the probable error. Table 2-12 summarizes probable errors of the NFFR models at the points of interest. It is worth noting that the Lake Almanor MITEMP model had three different bathymetry configurations: a) Baseline bathymetry condition; b) thermal curtain at the Prattville Intake with the submerged levees near the Intake in place; and c) thermal curtain at the Intake with the submerged levees removed. Efforts were made by Bechtel to calibrate the MITEMP model to the physical model observed test results for the Prattville Intake thermal curtain condition with and without the submerged levees removed (refer to Appendix A for more detailed information). The probable errors of the MITEMP model for these thermal curtain conditions were calculated based on comparison of the model calibration results and the physical model observed test results. The analysis shows that the probable errors of the MITEMP model for the Prattville Intake thermal curtain conditions (±0.26°C and ±0.43°C) and the Baseline bathymetry condition (±0.30°C) have similar magnitudes. As for the Caribou Intake thermal curtain condition, an internal weir was used to represent the thermal curtain in the Butt Valley Reservoir CE-QUAL-W2 model. It would be expected that the uncertainty of the Butt Valley Reservoir CE-QUAL-W2 model for the Caribou Intake thermal curtain condition would have a similar magnitude to that of the Baseline condition.

Error propagation analysis is a way of combining two or more random errors together to get a third. For example, in the NFFR Baseline modeling the calibrated/verified Butt Valley Reservoir CE-QUAL-W2 model had errors (±0.36°C) with respect to simulating the water temperatures at the Caribou #1 and #2 PH discharges (although the calibration/verification used the observed inflow temperatures (assuming no error) at the Butt Valley PH tailrace as model inputs). In a production run, the simulated discharge water temperatures at the Butt Valley PH tailrace by the Lake Almanor MITEMP model, which had errors at ±0.30°C, were used as the model inputs of the Butt Valley Reservoir CE-QUAL-W2 model. So the simulated water temperatures at the Caribou #1 and #2 PH discharges by the Butt Valley Reservoir CE-QUAL-W2 model in the production run included a combination of errors from both the Lake Almanor MITEMP model and the Butt Valley Reservoir CE-QUAL-W2 model.

Given the probable errors (δ_1 and δ_2) from two linked models, the following rule for the propagation of error was used to compute the addition of the probable errors (δ):

$$\delta = \sqrt{\delta_1^2 + \delta_2^2}$$

In mathematical terms, the square of the uncertainty in the sum of two imperfect numbers is the sum of the squares of individual uncertainties.

Table 2-13 summarizes the error propagation analysis for the mean daily water temperature modeling for the Baseline condition. The error propagation column in Table 2-13 can be regarded as the cumulative error for mean daily calculations for the system up to the respective points of interest. The analysis result shows that the uncertainty (in terms of the model-simulated absolute temperature values) is generally within ±0.5°C along the NFFR. For the alternative conditions, such as constructing a thermal curtain at the Prattville Intake with and without the submerged levees removed, because the magnitudes of model uncertainty of the Lake Almanor MITEMP model for the Prattville Intake thermal curtain conditions and the Baseline condition are similar, it would be expected that the uncertainties for the mean daily water temperature modeling for the alternative conditions would also generally be within ±0.5°C along the NFFR. Note that the uncertainty would have minimal effect on the analysis results of incremental changes in water temperature profiles between alternatives.

As for the results of maximum weekly average water temperature (MWAT) analysis, the uncertainty of the MWAT modeling results would be lower than the uncertainty of the mean daily water temperature modeling results. This is because, in general, it would be expected that longer time average modeling would be more accurate than shorter time average modeling.

Table 2-12 Summary of Model Uncertainty of NFFR Mean Daily Water Temperature Models

Model	Calibration/Validation Station and Time Period	Probable Error [1, 2]
Lake Almanor MITEMP (Existing bathymetry)	Summers of 2000 and 2001	
	Butt Valley PH Discharge Temperatures	±0.30°C
	Canyon Dam Outflow Temperatures	±0.20°C
Lake Almanor MITEMP (Prattville thermal curtain w/ levees)	Butt Valley PH Discharge Temperatures (Compared to the IIHR physical hydraulic model results)	±0.26°C
Lake Almanor MITEMP (Prattville thermal curtain w/o levees)	Butt Valley PH Discharge Temperatures (Compared to the IIHR physical hydraulic model results)	±0.43°C
Butt Valley Reservoir CE-QUAL-W2	Summers of 2000, 2001, and 2006	
	Caribou PH #1 Discharge Temperatures	±0.37°C
	Caribou PH #2 Discharge Temperatures	±0.34°C
	Combined Discharge Temperatures	±0.36°C
Seneca Reach SNTEP	Summers of 2000 and 2001	
	Seneca Reach above Caribou PH	±0.24°C
Belden Reach SNTEMP	Summers of 2000 and 2001	
	Belden Reach above East Branch (NF7)	±0.21°C
Rock Creek Reservoir SNTEMP	Summers of 2003 and 2006	
	Rock Creek Dam Release Temperatures (NF9)	±0.23°C
Rock Creek Reach SNTEMP	Summers of 2002 and 2003	
	Rock Creek Reach above Bucks Creek (NF12)	±0.19°C
Cresta Reach SNTEMP	Summers of 2002 and 2003	
	Cresta Reach above Cresta PH (NF16)	±0.16°C
Poe Reach SNTEMP	Summers of 1999, 2000, and 2003	
	Poe Reach above Poe PH (NF18)	±0.30°C

Notes:

1) Error is defined as the difference between model-simulated and observed daily discharge water temperatures. Probable error is a quantity used as a measure of model uncertainty: It is equal to 0.6745 times the standard deviation. A normally distributed population has half of its elements within one probable error of the mean. In other words, each daily temperature prediction would be expected, on average, to be within ± the probable error.
2) Sources of probable error calculations:
   a) Lake Almanor MITEMP model (Existing bathymetry): Bechtel's MITEMP calibration/validation report, 2002.
   b) Lake Almanor MITEMP model (Prattville thermal curtain): Stetson's calculations.
   c) Butt Valley Reservoir CE-QUAL-W2 model: Stetson's calculations.
   d) SNTEMP models for the Seneca, Belden, Rock Creek, and Cresta Reaches: PG&E's 2003 annual monitoring report.
   e) Rock Creek Reservoir SNTEMP model: Stetson's calculations.
   f) Poe Reach SNTEMP model: outputs from the Poe Reach SNTEMP calibration/validation models provided by PG&E.

Table 2-13 Summary of Error Propagation Analysis for the Mean Daily Water Temperature Modeling for the Baseline Condition

Water Body	**Upstream Inflow and Model Error in Inflow Temperature**				**Downstream Outflow and Model Error in Outflow Temperature**				**Error Propagation at Downstream**
	Inflow Location	Normal Discharge in Summer	Source Model/ Method	Source Error	Outflow	Normal Discharge in Summer	Waterbody Model/ Method	Model Error	
Butt Valley Reservoir	Butt Valley PH Discharge	1,600 cfs	Lake Almanor MITEMP	±0.30°C	Caribou #1 and #2	1,600 cfs	BV Reservoir CE-QUAL-W2	±0.36°C	±0.47°C
Seneca Reach	Canyon Dam Discharge	35 cfs	Lake Almanor MITEMP	±0.20°C	Seneca Reach above Caribou PH (NF4)	70 cfs [1]	Seneca Reach SNTEMP	±0.24°C	±0.31°C
Belden Reservoir	Mixed Seneca Reach inflow and Caribou Discharges	1,670 cfs	Full mixing method	±0.46°C	Downstream end of Belden Reservoir	1,670 cfs	Full mixing method	-	±0.46°C
Belden Reach	Belden Dam release	140 cfs	Full mixing method at Belden Reservoir	±0.46°C	Belden Reach above East Branch (NF7)	150 cfs [2]	Belden Reach SNTEMP	±0.21°C	±0.51°C
Rock Creek Reservoir	Mixed Belden Reach inflow, Belden PH discharge, and Yellow Creek inflow	1,840 cfs [3]	Full mixing method at the upstream end of Rock Creek Reservoir	±0.45°C	Downstream end of Rock Creek Reservoir	1,860 cfs [4]	Rock Creek Reservoir SNTEMP	±0.23°C	±0.51°C
Rock Creek Reach	Rock Creek Dam release	210 cfs	Rock Creek Reservoir SNTEMP	±0.51°C	Rock Creek Reach above Bucks Creek (NF12)	220 cfs [5]	Rock Creek Reach SNTEMP	±0.19°C	±0.54°C
Cresta Reservoir	Mixed Rock Creek Reach inflow and Rock Creek PH discharge	2,020 cfs [6]	Full mixing method	±0.52°C	Downstream end of Cresta Reservoir	2,020 cfs	Full mixing method	-	±0.52°C
Cresta Reach	Cresta Dam release	250 cfs	Full mixing method at Cresta Reservoir	±0.52°C	Cresta Reach above Cresta PH (NF16)	270 cfs [7]	Cresta Reach SNTEMP	±0.16°C	±0.54°C
Poe Reservoir	Mixed Cresta Reach inflow and Cresta PH discharge	2,040 cfs	Full mixing method	±0.52°C	Downstream end of Poe Reservoir	2,040 cfs	Full mixing method	-	±0.52°C
Poe Reach	Poe Dam release	100 cfs	Full mixing method at Poe Reservoir	±0.52°C	Poe Reach above Poe PH (NF16)	100 cfs	Poe Reach SNTEMP	±0.30°C	±0.60°C

Notes:

1) Seneca Reach accretion flow plus lower Butt Creek flow in summer was about 35 cfs; 2) Belden Reach accretion flow above East Branch was about 10 cfs; 3) East Branch flow and Yellow Creek flow was about 100 cfs and 60 cfs, respectively; 4) Chips Creek flow was about 20 cfs; 5) Rock Creek Reach accretion flow above Bucks Creek was about 10 cfs; 6) Bucks Creek/ Bucks Creek PH flow was about 150 cfs; 7) Grizzly Creek flow was about 20 cfs.

2.5 SUMMARY OF FINDINGS

The findings from the analyses in this chapter are summarized below:

1) All of the UNFFR Project-only alternatives can effectively, sustainably, and reliably reduce NFFR mean daily water temperatures, but to varying degrees. The ranking of alternatives in terms of mean daily water temperature reduction, from the greatest water temperature reduction to the least, is Alternative 3x, Alternative 4c, Alternative 4d, Alternative 3, Alternative 4b, and Alternative 4a. The highest ranked alternative (Alternative 3x) could reduce the mean daily water temperature by about 5.9°C in July and 4.3°C in August on average at the upstream end of Belden Reach over the 19-year analysis period (1984 – 2002), and by about 2.0°C in July and 1.6°C in August at the downstream end of Poe Reach. The lowest ranked alternative (Alternative 4a) could reduce the mean daily water temperature by about 2.5°C in July and 1.9°C in August at the upstream end of Belden Reach, and by about 0.8°C in July and 0.7°C in August at the downstream end of Poe Reach.

2) The water temperature reduction benefit of removing the submerged levees near the Prattville Intake is minimal, with a maximum temperature reduction of about 0.3°C in July and 0.6°C in August at the upstream end of Belden Reach. The benefit diminishes gradually downstream along the NFFR.

3) Mean daily water temperature modeling results indicate that preferential use of Caribou #1 over Caribou #2 (Alternatives 4b and 4c) appears to be more effective in reducing the NFFR water temperature than a thermal curtain at Butt Valley Reservoir near the Caribou Intakes (Alternatives 4a and 4d) in July, but these two measures have similar temperature reduction benefits in August.

4) All of the UNFFR Project-only alternatives infuse cold water from Lake Almanor to the NFFR through selective cold water withdrawal by way of either increased Canyon Dam low-level release and/or a Prattville Intake thermal curtain. Increasing Canyon Dam low-level releases would enhance water temperature reduction in Belden Reservoir, which would benefit all downstream reaches. Increasing Canyon Dam low-level releases would also reduce warming in the Seneca Reach, which would reduce inflow water temperature to Belden Reservoir. The amount of temperature reduction resulting from increased Canyon Dam low-level release depends on the magnitude of the release. Analysis of the relationship between increased Canyon Dam low-level release and water temperature reduction benefit at Belden Reservoir indicates that for every 100 cfs increased release above the "Present Day" conditions at Canyon Dam in July and August, the UNFFR Project-only alternatives could reduce the Belden Reservoir water temperature by about 0.5°C in July and 0.4°C in August. The monthly foregone power generation loss in July or August was estimated to be about 7.54×10^6 kwh for every 100 cfs of increased release. These developed relationships

together with the simulated mean daily temperature profiles for the UNFFR Project-only alternatives could be used to assist in the refinement of the analyzed alternatives if/when needed.

Constructing a thermal curtain at the Prattville Intake would also enhance water temperature reduction in Belden Reservoir and benefit all downstream reaches. But it would not have any foregone power generation loss.

5) The Level 3 analysis considered water temperature reduction along the Rock Creek, Cresta, and Poe Reaches by increasing dam releases. It is important to point out that increasing releases from these dams really only reduces warming along these reaches; it does not reduce the temperature of water at the starting point of the reach. Relationships between increased releases at these dams and warming reductions along these reaches were developed. These developed relationships together with the simulated temperature profiles can be used to assist in further, more refined management of water temperature along the Rock Creek, Cresta, and Poe Reaches if/when needed.

6) MWAT provides an index for assessing the effects of chronic thermal conditions in river reaches on cold freshwater habitat. Modeling the MWAT profile along the NFFR first required identifying the MWAT period (i.e., the 7-day period that had the warmest water temperature profile) that could be applied for different years. Analysis of the observed water temperatures at Belden Reservoir and along the NFFR and air temperatures in water years 2002, 2003, and 2004 was conducted to identify the MWAT period. The analysis found that the periods with the warmest 7-day average water temperature in Belden Reservoir in 2002, 2003, and 2004 could be used to identify the MWAT period for the downstream reaches.

7) MWAT analysis results also indicate that preferential use of Caribou #1 over Caribou #2 (Alternatives 4b and 4c) appears to be more effective in reducing the NFFR water temperature than a thermal curtain at Butt Valley Reservoir near the Caribou Intakes (Alternatives 4a and 4d) in July, but these two measures have similar temperature reduction benefits in August. This corroborates finding #3 above from the mean daily water temperature modeling results.

8) The MWAT analysis results indicate that some alternatives (Alternatives 3x, 4c, and 4d in particular) may shift the annual MWAT period from July/August under the Baseline condition to September under the alternative conditions. It is worth noting that, in the analyses of mean daily water temperature and MWAT profiles, the preferential use of Caribou #1 was assumed to operate in July and August, while the thermal curtain at Butt Valley Reservoir was assumed to operate in all year round. Apparently, preferential use of Caribou #1 would reduce the July and August MWATs but would have little effect on the September MWAT. This is one of the reasons that the September MWAT could be the highest MWAT in a year (i.e., annual MWAT) for the alternatives that include the preferential use of Caribou #1. Another factor that could cause the September MWAT to be the

highest MWAT in a year would be the increased Canyon Dam release measure. This measure was assumed to operate in July and August only. This measure would reduce the July and August MWATs but would have little effect on the September MWAT. The alternatives which could have higher September MWAT include Alternatives 3x, 4c, and 4d. September MWAT for these alternatives could be reduced further if the alternatives were allowed to operate in September. Comparison of the simulated monthly (Jul, Aug, and Sep) MWAT for Alternatives 3x, 4c, and 4d indicate that in general the three alternatives may have higher September MWAT in the Rock Creek Reach but lower September MWAT in the Poe Reach.

9) The MWAT analysis results indicate that the ranking of alternatives, in terms of MWAT reduction, is similar to the ranking of alternatives in terms of mean daily water temperature reduction (finding #1 above). The highest ranked alternative (Alternative 3x) would reduce the monthly MWAT by about 4.5°C in July and 3.0°C in August on average at the Belden Reach above the East Branch over the 19-year analysis period (1984 – 2002), and by about 2.0°C in July and 2.2°C in August at the downstream end of Poe Reach. The lowest ranked alternative (Alternative 4a) would reduce the monthly MWAT by about 2.2°C in July and 2.1°C in August at the Belden Reach above the East Branch, and by about 1.0°C in July and 1.4°C in August at the downstream end of Poe Reach.

10) Diel water temperature provides an index for assessing the effect of acute thermal conditions in river reaches. Analysis of the hourly temperature data produced by PG&E through its annual NFFR monitoring efforts during the summer months of water years 2002, 2003, and 2004 indicates that the maximum diel water temperatures observed over the three years for the Belden Reach above East Branch, the Rock Creek Reach above Bucks Creek, the Cresta Reach above Cresta PH, and the Poe Reach above Poe PH were 24.0°C, 24.0°C, 24.0°C, and 26.6°C, respectively.

11) The diel water temperature ranges (i.e., diel maximum minus diel minimum in any given day) shown in Table 2-11 was derived from the hourly water temperature monitoring results for water years 2002, 2003, and 2004 under <u>Baseline flow</u> conditions. The summertime diel water temperature ranges observed over the three years for the Belden Reach above East Branch, the Rock Creek Reach above Bucks Creek, the Cresta Reach above Cresta PH, and the Poe Reach above Poe PH were, on average, 4.8°C, 3.6°C, 2.9°C, and 3.2°C, respectively, in June, 4.8°C, 3.1°C, 2.8°C, and 3.1°C, respectively, in July, 4.1°C, 2.7°C, 2.5°C, and 2.7°C, respectively, in August, and 4.1°C, 2.5°C, 2.0°C, and 2.4°C, respectively, in September. For a given UNFFR Project-only alternative, the maximum or minimum diel water temperature could be estimated using the predicted mean daily temperature profile plus or minus one half of the diel water temperature range. However, further analysis would need to be conducted to estimate the diel water temperature for a reach if much higher dam releases (than the Baseline flow conditions) are used.

12) The uncertainty of the mean daily water temperature modeling results (in terms of the model-simulated absolute temperature values) for the Baseline condition and the alternative conditions are generally within ±0.5°C along the NFFR. The uncertainty of the MWAT modeling results would be expected to be lower than the uncertainty of the mean daily water temperature modeling results. The uncertainty would have minimal effect on the analysis results of incremental changes in water temperature profiles between alternatives.

3.0 ANALYSIS OF THE EFFECTS OF LEVEL 3 ALTERNATIVES ON COLD FRESHWATER HABITAT IN LAKE ALMANOR AND BUTT VALLEY RESERVOIR

Water temperature reduction measures at Lake Almanor include the withdrawal of cold water from the hypolimnion of Lake Almanor through use of a thermal curtain that would be installed near the Prattville Intake and/or through increased release from a modified low-level outlet at Canyon Dam. Extensive withdrawal of cold water from Lake Almanor could affect the thermal structure and dissolved oxygen (DO) distribution in Lake Almanor and, thus, alter volume of cold freshwater habitat of the lake. A CE-QUAL-W2 model of Lake Almanor was developed for PG&E by Jones & Stokes (2004) to simulate the effects that withdrawal of cold water from near the lake bottom could have on the distribution of DO and water temperature and, thus, cold freshwater habitat in the lake. Stetson conducted a peer review of the model and made modifications to the model (refer to Appendix A for detailed information). The Stetson-modified CE-QUAL-W2 model of Lake Almanor was used in this analysis.

The withdrawal of cold water from the hypolimnion of Lake Almanor at the Prattville Intake (through use of a thermal curtain) may produce low DO in the discharge of the Butt Valley PH. This cold water with low DO would plunge into the depths of Butt Valley Reservoir (as demonstrated in the 2006 special test) and could affect the cold freshwater habitat of Butt Valley Reservoir. A CE-QUAL-W2 model of Butt Valley Reservoir was recently developed by Stetson to assess the effects of this phenomenon on suitable cold freshwater habitat in the reservoir.

Table 3-1 summarizes the selected water temperature reduction alternatives that were selected for analysis of effects on cold freshwater habitat in Lake Almanor and Butt Valley Reservoir. Baseline was selected for analysis because it provides the CEQA baseline for comparing the effects of the alternatives. The “Present Day” alternative was selected for analysis because it provides a comparison with the proposed alternative by PG&E in its license application (essentially the same as the FERC Staff recommended alternative in the EIS). Alternative 4a was selected for analysis of the effects of cold water withdrawal using a thermal curtain at the Prattville Intake. Alternative 4c was selected for analysis of the effects of cold water withdrawal using a modified Canyon Dam low-level outlet. Alternative 3x was selected for analysis of the effects of cold water withdrawal using both the Prattville Intake thermal curtain and the modified Canyon Dam low-level outlet. The following describes the reasons that other alternatives were not selected for analysis:

Alternative 3: This alternative was not selected because it has similar water temperature reduction measures at Lake Almanor as Alternative 3x, but with lower releases at Canyon Dam (see Table 1-2). It would be expected that Alternative 3 would have less effect on Lake Almanor than Alternative 3x.

Alternative 4b: This alternative was not selected because it would have the same effect on Lake Almanor as Alternative 4a.

Alternative 4d: This alternative was not selected because it would have the same effect on Lake Almanor as Alternative 4c.

Table 3-1 Water Temperature Reduction Alternatives That Were Evaluated for Cold Freshwater Habitat Assessment

Alternative	Measures Included in the UNFFR Project-only Alternative	Remarks
Baseline	No action	• Baseline conditions are those that existed as of the NOP dated September 1, 2005.
"Present Day"	• Increase Canyon Dam releases to those given in the Partial Settlement (and decrease Prattville Intake release commensurately).	• The "Present Day" alternative is essentially the alternative proposed by PG&E in its license application and also the FERC Staff recommended alternative in the EIS.
Alternative 3x	• Install Prattville Intake thermal curtain and remove submerged levees near the Intake; • Modify Canyon Dam low-level outlet and increase release to 600 cfs (in July and August); • Operate Caribou #1 PH preferentially over Caribou #2 PH	• Alternative 3x was not examined in the Level 1 and 2 Report. • Alternative 3x is the alternative that would have the greatest water temperature reduction that could be achieved from the UNFFR Project-only. • Alternative 3x could have effects on cold freshwater habitat in both Lake Almanor and Butt Valley Reservoir.
Alternative 4a	• Install Prattville Intake thermal curtain (without removal of the submerged levees); • Install a single thermal curtain near Caribou #1 and #2 Intakes;	• Alternative 4a could have effects on cold freshwater habitat in both Lake Almanor and Butt Valley Reservoir.
Alternative 4c	• Modify Canyon Dam low-level outlet and increase release to 600 cfs (in July and August); • Operate Caribou #1 preferentially over Caribou #2.	• Alternative 4c could have effects on cold freshwater habitat in Lake Almanor only.

3.1 EVALUATION METRICS

The following two types of metrics were used to evaluate the potential effect of water temperature reduction alternatives on the suitable cold freshwater (also referred to as “preferred thermoxic”) habitat in Lake Almanor:

1) Cold freshwater habitat volume
   Cold freshwater habitat volume is defined as the lake-wide volume of water meeting the specified temperature and DO criteria. Three different criteria were considered:
   a) T ≤ 20°C and DO ≥ 5mg/L
   b) T ≤ 21°C and DO ≥ 5mg/L
   c) T ≤ 22°C and DO ≥ 5mg/L
   These criteria were used as indices of available optimal, preferred, or thermal refuge habitat throughout the summer reservoir stratification season.

2) Top of thermocline elevation and metalimnion surface area
   Top of thermocline is defined as the shallowest depth or highest elevation where the highest temperature gradient occurs. Metalimnion surface area is defined as the lake-wide surface area at the top of the thermocline.

   The metric of metalimnion surface area is proposed to augment the preferred thermoxic habitat analysis with a spatial index of the availability of the preferred thermoxic habitat used by the coldwater fish community of Lake Almanor.

As for Butt Valley Reservoir, only the metric of cold freshwater habitat volume was used to evaluate the potential effect. Metalimnion surface area was not applied to this reservoir because, due to its relatively small storage and shallow depth and relatively short residence time (about two weeks), reservoir stratification is not strong enough to have an apparent thermocline. This was demonstrated in the simulated water temperature profiles shown in Appendix D, Figures 7a - 8d.

Cold freshwater habitat volume and top of thermocline elevation/ metalimnion surface area for Lake Almanor were computed approximately bi-weekly for the years 2000 and 2001 (normal hydrologic year and critical dry year, respectively) for the following dates (the bold dates had observed profile data):

Year 2000	Year 2001
May 15, 2000	May 15, 2001
June 07, 2000	**June 06, 2001**
June 22, 2000	June 22, 2001
July 07, 2000	**July 10, 2001**
July 20, 2000	July 20, 2001
August 07, 2000	**August 9, 2001**
August 17, 2000	August 17, 2001

September 07, 2000	**September 12, 2001**
September 28, 2000	September 28, 2001
October 15, 2000	October 15, 2001

Cold freshwater habitat volume for <u>Butt Valley Reservoir</u> was computed approximately bi-weekly for the years 2000 and 2001 for the following dates (the bold dates had observed profile data):

Year 2000	Year 2001
May 15, 2000	May 15, 2001
June 07, 2000	**June 06, 2001**
June 22, 2000	June 22, 2001
July 07, 2000	**July 11, 2001**
July 20, 2000	July 20, 2001
August 07, 2000	August 07, 2001
August 17, 2000	**August 20, 2001**
September 07, 2000	September 07, 2001
September 28, 2000	September 28, 2001
October 15, 2000	October 15, 2001

Mid-May and mid-October were selected to represent the conditions of late spring and early fall. Two days were selected for each summer month to represent the summer month conditions (June – September). The days that had observed profile data were included so that the simulated results could be compared to the observed data. No days were selected for other seasons because the lake is generally well mixed during these times and little if any effects would be expected when the lake is well mixed.

3.2 METHOD USED TO CALCULATE SUITABLE COLD FRESHWATER HABITAT VOLUME

Suitable cold freshwater habitat, in terms of temperature and DO, was defined, for modeling purposes, to be the water layer that has temperature below a specified number (20°C, 21°C, or 22°C) and DO above 5 mg/L[1] (refer to Figure 3-1 for an example of a water layer of suitable cold freshwater habitat). The incremental change in the volume of suitable cold freshwater habitat for a given alternative relative to the "Baseline" habitat volume was the metric used to evaluate the effects of the alternative. Jones & Stokes (2004) used only one segment of the Lake Almanor CE-QUAL-W2 model (near Canyon Dam, Segment 9 of Figure 3-2) as a representative segment to evaluate the effects. Using only one segment to represent the entire lake assumed that the lake was completely and solely one-dimensional (vertical) in both water temperature and DO distributions. In our analysis, the model-simulated temperature and DO profiles in *all* model segments were examined to compute the suitable cold freshwater habitat volume. This approach, compared to Jones & Stokes approach, provided more detailed results by taking advantage of CE-QUAL-W2's capability to simulate the two-dimensional distribution (vertical and longitudinal) of temperature and DO. To facilitate the analysis, a cumulative elevation-volume curve was created for each model segment based on the bathymetry file of the model, and the curve was then used to compute the volume of the layer meeting the defined temperature and DO criteria in each segment using the model-simulated temperature and DO profiles for each segment.

Figure 3-2 shows the segmentation of Lake Almanor CE-QUAL-W2 model. The lake was modeled using segments of varying length (i.e., 1.1 – 2.8 miles) to represent the longitudinal pieces of the lake. Each segment was divided into multiple layers: each layer was 3.3 feet deep (or 1 meter). The lake was divided into two branches. Branch 1, which consisted of eight active segments, covered the western portion of the lake that is fed by the NFFR at Chester and terminates at Canyon Dam. Branch 2, which consisted of three active segments, covered the eastern portion of the lake that is fed by the Hamilton Branch.

Figure 3-3 shows the segmentation of Butt Valley Reservoir CE-QUAL-W2 model. The Butt Valley Reservoir CE-QUAL-W2 model divided the reservoir into 18 active segments of varying length from 560 ft to 3,800 ft (i.e., 171 m to 1,158 m) to represent the longitudinal pieces of the reservoir. Each segment was divided into multiple layers extending downward to the reservoir bottom; each layer was 2 feet deep (i.e., 0.61 m).

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[1] The summertime suitable cold freshwater habitat in Lake Almanor is generally vertically confined to the lake thermocline. The thermocline is the transition layer between the warm surface epilimnion water and the cold bottom hypolimnion water. In the thermocline, the temperature decreases rapidly from the well-mixed warm surface water temperature to the much colder deep water temperature. The thermocline water is generally suitable for cold freshwater habitat because it is where both the temperature and DO criteria can be met. Above the thermocline (i.e., epilimnion), water is generally not suitable for cold freshwater habitat because its temperature is too warm. Below the thermocline (i.e., hypolimnion), water is generally not suitable for cold freshwater habitat either because its DO is too low.

The analysis was conducted for years 2000 and 2001. Year 2000 was a "normal" hydrologic year and year 2001 was a "critical dry" hydrologic year. These two years were also used for calibration and verification of the Lake Almanor CE-QUAL-W2 model and the Butt Valley Reservoir CE-QUAL-W2 model. Using 2000 and 2001 for assessment of the cold freshwater habitat effect provided relatively more reliable modeling results because these two years were the same years used for model calibration and verification.

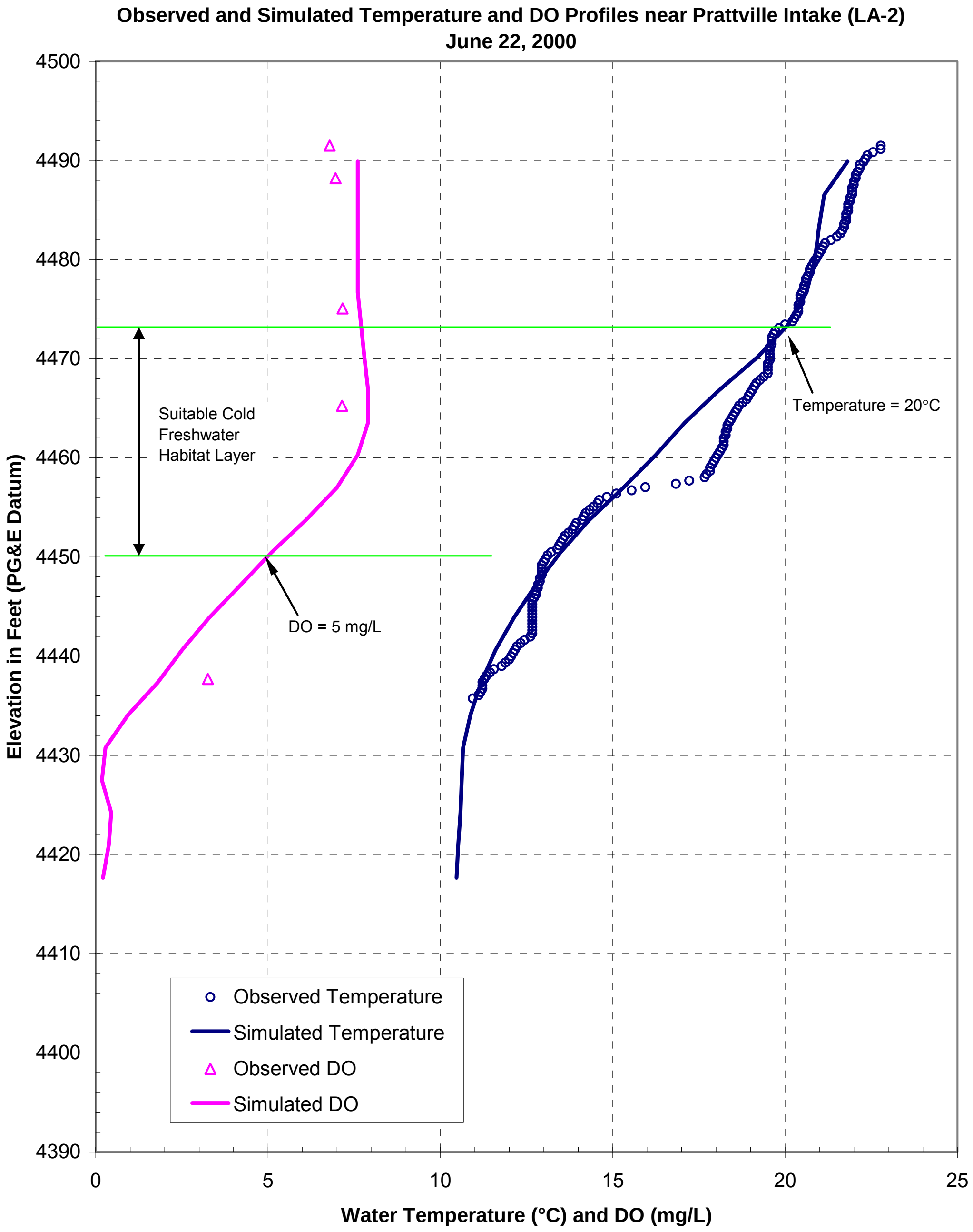
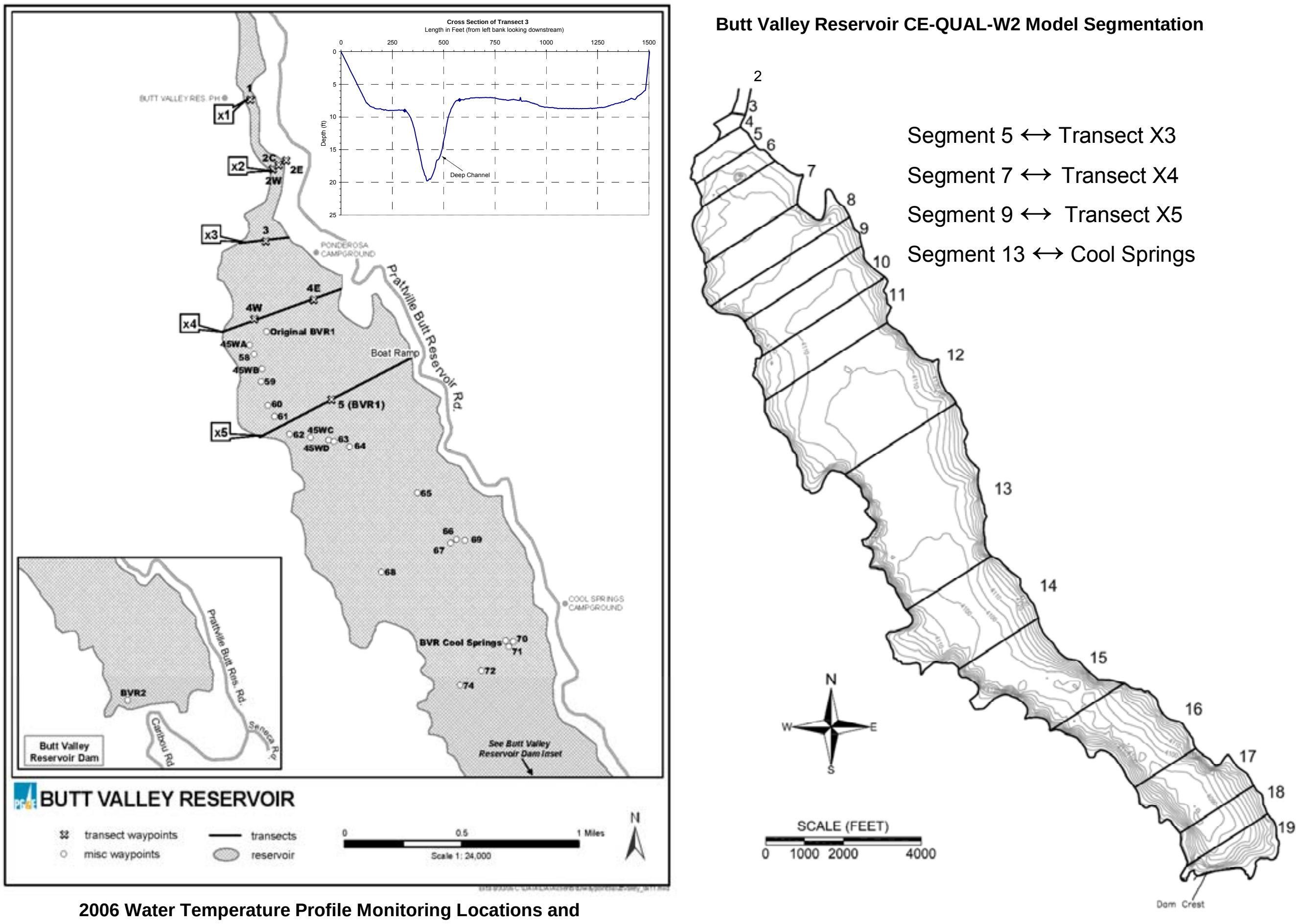


Figure 3-1 Example of Suitable Cold Freshwater Habitat Water Layer That has Temperature ≤ 20°C and DO ≥ 5 mg/L

Figure 3-2 Lake Almanor CE-QUAL-W2 Model Segmentation

(Notes: Segments 1 and 10 are the upstream and downstream boundary segments, respectively, for the Chester Branch and are not shown on the graph. Segment 11 is the upstream boundary segment for the Hamilton Branch and is not shown on the graph.)



Butt Valley Reservoir CE-QUAL-W2 Model Segmentation

2006 Water Temperature Profile Monitoring Locations and Water Velocity Transects – Butt Valley Reservoir

Figure 3-3 Butt Valley Reservoir CE-QUAL-W2 Model Segmentation

(Note: Segments 1 and 20 are the upstream and downstream boundary segments, respectively, and are not shown on the graph.)

3.3 RESULTS OF ANALYSIS OF LAKE ALMANOR

3.3.1 Results of Analysis of Lake Almanor Cold Freshwater Habitat Volume

The results of Lake Almanor cold freshwater habitat volume analysis for different alternatives and for the three different criteria (i.e., T ≤ 20°C and DO ≥ 5 mg/L; T ≤ 21°C and DO ≥ 5 mg/L; and T ≤ 22°C and DO ≥ 5 mg/L) for year 2000 are summarized in Tables 3-2a – 3-2c and shown in Figures 3-4a – 3-4c, and for year 2001 the results are summarized in Table 3-3a – 3-3c and shown in Figures 3-5a – 3-5c. Details on the computed elevation range and volume of the water layer by model segment that met the temperature and DO criteria for different alternatives are shown in Appendix C. If a segment had a water layer thickness meeting the temperature and DO criteria of more than 1 foot, then it was assumed that the segment had suitable cold freshwater habitat volume; otherwise, the segment had no suitable habitat volume.

In this analysis, only the model-simulated data, not the observed data, were used to compute the suitable cold freshwater habitat volume for the Baseline condition or existing condition[2]. Using the model-simulated Baseline condition as the basis was justified because the model was satisfactorily calibrated/verified to the observed data. Using the model-simulated Baseline condition as the basis to compute the incremental change in suitable cold freshwater habitat volume eliminated the small discrepancy between the model-simulated Baseline condition and the observed condition.

Based on the summary results in Tables 3-2a – 3-2c and Tables 3-3a – 3-3c, it is apparent that the magnitudes of the effects of the three alternatives (Alternatives 3x, 4a, and 4c) on the suitable cold freshwater habitat volume of Lake Almanor are sensitive to the temperature criterion used to define the suitable cold freshwater habitat. The following discusses the effects of the alternatives on the suitable cold freshwater habitat volume using the criteria of T ≤ 20°C and DO ≥ 5mg/L as an example:

Given the criteria of T ≤ 20°C and DO ≥ 5mg/L defined for the suitable cold freshwater habitat, compared to Baseline, the three alternatives (Alternatives 3x, 4a, and 4c) reduce the suitable cold freshwater habitat volume in August in the "normal" hydrologic year 2000 (Table 3-2a) and in July, August and early September in the "critical dry" hydrologic year 2001 (Table 3-3a). The results also show that Alternatives 3x and 4a increase the suitable cold freshwater habitat volume in June through October, except in August, in 2000 and in late September in 2001. Alternative 4c increases the suitable cold freshwater habitat volume in September and October in 2000 and in late September in 2001. As shown in Tables 3-2a and 3-3a, the "Present Day" alternative, which is essentially the alternative proposed by PG&E in its license application, also has some effect on the suitable cold freshwater habitat volume relative to the Baseline condition. The effect of the "Present Day" alternative results from the increased Canyon Dam

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[2] The Baseline condition is that which actually existed as of the NOP dated September 1, 2005. As for the analysis years of 2000 and 2001, the Baseline condition is also the existing condition in 2000 and 2001.

releases from the Baseline to those given in the Partial Settlement. However, in terms of percentage of the suitable cold freshwater habitat volume to the total lake storage, the change between each alternative and the Baseline in June, July, and August is within 1%.

During summertime, Lake Almanor is stratified. Warm water stays in the surface layer (i.e., epilimnion) and does not mix much with water in the deeper layer (i.e., hypolimnion). DO in the hypolimnion is reduced through the oxygen consumption during the breakdown of organic material and is not replenished by oxygen reaeration from the lake surface until late fall when de-stratification begins. Increased withdrawal of cold water from the hypolimnion of Lake Almanor during the summer would be expected to reduce the volume of cold water. On the other hand, the withdrawal of cold water would also induce the movement of lake bottom water and thereby increase the interfacial mixing between the hypolimnion water and the thermocline water. The increased mixing would in turn increase the DO concentration in the hypolimnion. So, the net effect on the suitable cold freshwater habitat volume of a given alternative depends on the relative reduction in cold water volume ($T \leq 20°C$) and the relative increase in water volume with DO ≥ 5 mg/L. As shown in Figures 3-6a and 3-6b, the cold water volumes ($T \leq 20°C$) in Lake Almanor in June, July, and August 2000 were considerably different (Figure 3-6a), with June having a much greater cold water volume than August. But the elevation at DO equal to 5 mg/L differed little over these three months (Figure 3-6b). The withdrawal of cold water from the hypolimnion of Lake Almanor would have a minimal effect on the lake's thermal structure in June and July but a considerable effect in August. As a result, the analysis shows that the alternatives increase the suitable cold freshwater habitat volume in June and July 2000 and reduce the habitat volume in August 2000. As demonstrated in Figures 3-7a and 3-7b, there is little difference in the simulated cold water volume below 20°C on June 22, 2000 between the Baseline condition and Alternative 3x (Figure 3-7a). But, compared to the Baseline condition, Alternative 3x increases the volume of water with DO above 5 mg/L. As a result Alternative 3x increases the suitable cold freshwater habitat volume in June 2000, as shown in Table 3-2a. Figure 3-7b shows the effect of Alternative 3x on August 17, 2000. It shows that Alternative 3x reduces the cold water volume below 20°C considerably but also considerably increases the volume of water with DO above 5 mg/L. The net effect is that Alternative 3x reduces the suitable cold freshwater habitat volume in August 2000, as shown in Table 3-2a.

As for September, depending on the water temperature and the hydrologic condition, the alternatives may increase the suitable cold freshwater habitat volume, as shown in Table 3-2a for the "normal" hydrologic year 2000. The alternatives may also reduce the habitat volume in early September and increase the habitat volume in late September, as shown in Table 3-3a for the "critical dry" year 2001.

In October, water temperature in the entire lake would be below 20°C although there may exist some stratification (refer to Appendix C, Figure 7f for October 2000 temperature profiles and Figure 8f for October 2001 temperature profiles). So water temperature at this time is not a limiting factor for cold freshwater habitat. Since the alternatives increase the DO concentration in the hypolimnion as discussed above, the alternatives would increase the suitable cold freshwater habitat volume in October, as shown in Tables 3-2a and 3-3a.

If the temperature criterion of T ≤ 20°C is relaxed to T ≤ 21°C or T ≤ 22°C, the computed absolute volumes of the suitable cold freshwater habitat for the Baseline and alternatives increase considerably in July and August. The high sensitivity of the suitable cold freshwater habitat volume to the temperature criterion arises from the fact that the top of the Lake Almanor thermocline during summer normally has a water temperature of about 20°C to 22°C. Above the thermocline, or in the epilimnion, a small change in water temperature can cause a great change in elevation or the suitable habitat volume because the water temperature profile in the epilimnion is relatively uniform. As shown in Appendix C, Figure 7c, the top of the thermocline had a water temperature at about 20.3°C on July 7, 2000 and about 21°C on July 20, 2000. Increasing the water temperature criterion from 20°C to 21°C would increase the habitat volume considerably for July 7, 2000 (see Tables 3-2a and 3-2b). Similarly, increasing the water temperature criterion from 21°C to 22°C would increase the habitat volume considerably for July 20, 2000 (see Tables 3-2b and 3-2c). On the other hand, given a water temperature criterion, the high incremental change in the suitable habitat volume between an alternative and the Baseline condition may not necessarily mean that the alternative has a considerable effect. For example, given the temperature criterion of T ≤ 22°C, Table 3-2c shows that there is a considerable reduction in the habitat volume for August 17, 2001. However, looking at Appendix C, Figure 8d, there is only a small difference in temperature between the alternatives and the Baseline condition and this small difference in temperature caused a large change in elevation and suitable habitat volume. More specifically, if the temperature criterion is relaxed to 22.1°C, there would be a minimal difference in the suitable habitat volume between the alternatives and the Baseline condition. This suggests that the temperature profiles presented in Appendix C, Figures 7a - 7f for year 2000 and Figures 8a - 8f for year 2001, need to be further examined to help identify the cause of the considerable change in the computed suitable habitat volume between the alternatives and the Baseline condition.

Based on the analysis results shown in Tables 3-2a – 3-2c and Tables 3-3a – 3-3c, it appears that increasing release of cold water at Canyon Dam low-level outlet (Alternative 4c) to 600 cfs or withdrawing cold water at the Prattville Intake through use of a thermal curtain (Alternative 4a) have similar effects on the suitable cold freshwater habitat of Lake Almanor.

Note that CE-QUAL-W2 is a generic two-dimensional (longitudinal and vertical), laterally-averaged hydrodynamic and water quality model. The model divides a waterbody into multiple segments in the longitudinal direction and multiple layers in the vertical direction. The model assumes uniform hydrodynamics and concentrations of water quality constituents in the lateral direction within the same segment and same layer. Figure 3-2 shows the segmentation of Lake Almanor CE-QUAL-W2 model. The Lake Almanor CE-QUAL-W2 model was discretized longitudinally and vertically, forming large cells. Due to the limitation of a two-dimensional model (compared to a three-dimensional model) and the spatial coarseness of the model segmentation (see Figure 3-

2), the Lake Almanor CE-QUAL-W2 model may not be able to capture the potentially small, isolated "pockets" of cold freshwater habitat that may occur in some local areas.

3.3.2 Results of Analysis of Lake Almanor Thermocline Elevation and Metalimnion Surface Area

The results of the analysis of the Lake Almanor thermocline elevation for different alternatives for year 2000 are summarized in Table 3-4 and shown in Figure 3-8, and for year 2001 the results are summarized in Table 3-5 and shown in Figure 3-9. The top of thermocline is defined as the shallowest depth or highest elevation where the highest temperature gradient occurs. After careful examination of the temperature profiles shown in Appendix C, Figures 7a - 7f for year 2000 and Figures 8a - 8f for year 2001, it was determined that a temperature gradient $\Delta T / \Delta d \geq 0.5°C/m$ would be a suitable criterion to identify the top of thermocline. As shown in Tables 3-4 and 3-5, the three alternatives (Alternatives 3x, 4a, and 4c) could lower the thermocline elevation by up to 3 feet in July and August when the lake epilimnion water temperature is relatively warm. Although the three alternatives could lower the thermocline elevation by up to 7 feet in September and October in 2000 and by up to 10 feet in September 2001, it may not be a meaningful effect because the lake water temperature at this time is generally cooler than the summer. As shown in Appendix C, Figures 7e and 8e, the entire lake had a water temperature lower than 19°C on September 7, 2000 and 20°C on September 12, 2001. At this time water temperature would not be a limiting factor for cold freshwater habitat for the given criteria of $T \leq 20°C$ and $DO \geq 5$ mg/L. So July and August should be the focus when using the thermocline elevation and metalimnion surface area as additional evaluation criteria.

Metalimnion surface area is defined as the lake-wide surface area at top of the thermocline. Once the top of thermocline elevation is identified, the metalimnion surface area can be estimated using the lake-wide elevation-surface area curve. The analysis results of Lake Almanor metalimnion surface area for different alternatives for year 2000 are summarized in Table 3-6 and shown in Figure 3-10, and for year 2001 the results are summarized in Table 3-7 and shown in Figure 3-11. In general, but to varying degrees, the three alternatives (Alternatives 3x, 4a, and 4c) reduce the metalimnion surface area from July to October in both years 2000 and 2001, with highest reduction in September or October. The "Present Day" alternative reduces the metalimnion surface area in October of 2000 and in September and October of 2001. In term of percentage of metalimnion surface area to the total lake surface area, the change between each of the three alternatives (Alternatives 3x, 4a, and 4c) and the Baseline condition is generally within 3% in July and August of year 2000 and 5% in July and August of year 2001.

Note that for the purpose of analyzing the Lake Almanor thermocline elevation and metalimnion surface area, a representative site near Canyon Dam (i.e., segment 9 of Lake Almanor CE-QUAL-W2 model shown in Figure 3-2) was used to conduct the analysis.

Table 3-2a Summary of Simulated Lake Almanor Habitat Volume (acre-ft) Having Water Temperature ≤ 20°C and DO ≥ 5 mg/L for Different Alternatives and Change in Habitat Volume Relative to Baseline Condition (2000, Normal Hydrologic Year)

Date	Total Reservoir Storage on Date (acre-ft)	Simulated Habitat Volume (acre-ft)					Change in Habitat Volume Relative to Baseline Condition (acre-ft)				% of Habitat Volume to Total Reservoir Storage on Date				
		Baseline	Present Day	Alt 3x	Alt 4a	Alt 4c	Present Day	Alt 3x	Alt 4a	Alt 4c	Base line	Present Day	Alt 3x	Alt 4a	Alt 4c
May 15	1,011,490	993,600	989,670	989,110	989,110	989,670	-3,930	-4,490	-4,490	-3,930	98%	98%	98%	98%	98%
June 7	1,015,410	876,500	874,470	883,350	881,800	874,470	-2,030	6,850	5,300	-2,030	86%	86%	87%	87%	86%
Jun 22	1,010,250	452,400	449,750	465,600	462,510	449,750	-2,650	13,200	10,110	-2,650	45%	45%	46%	46%	45%
July 7	993,780	216,200	214,940	230,770	227,740	214,950	-1,260	14,570	11,540	-1,250	22%	22%	23%	23%	22%
Jul 20	938,020	145,600	143,790	151,770	148,400	145,040	-1,810	6,170	2,800	-560	16%	15%	16%	16%	15%
Aug 7	913,180	65,000	63,690	63,410	61,150	63,110	-1,310	-1,590	-3,850	-1,890	7%	7%	7%	7%	7%
Aug 17	859,160	44,400	40,910	32,490	35,030	38,240	-3,490	-11,910	-9,370	-6,160	5%	5%	4%	4%	4%
Sep 7	836,720	636,600	639,480	698,340	683,250	661,180	2,880	61,740	46,650	24,580	76%	76%	83%	82%	79%
Sep 28	777,330	607,400	609,130	663,450	649,750	622,960	1,730	56,050	42,350	15,560	78%	78%	85%	84%	80%
Oct 15	761,020	676,200	678,940	712,080	702,680	694,830	2,740	35,880	26,480	18,630	89%	89%	94%	92%	91%

Note: The bold dates have observed profiles.

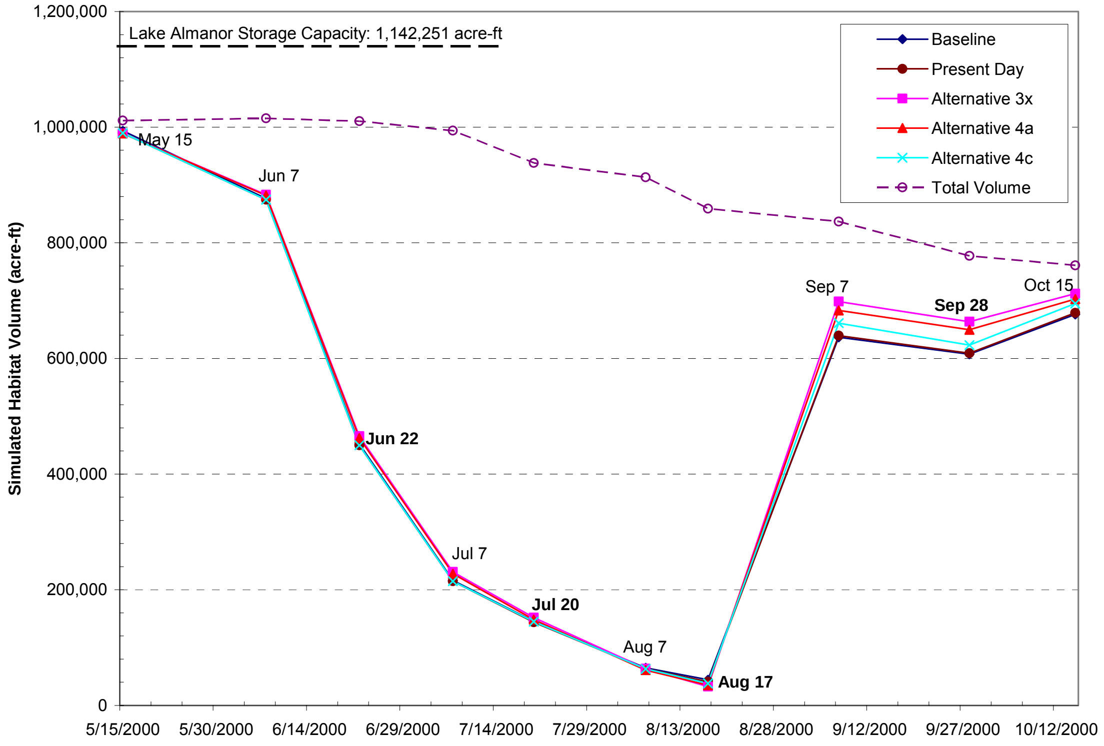

Figure 3-4a Comparison of Simulated Lake Almanor Habitat Volume Having Water Temperature ≤ 20°C and DO ≥ 5 mg/L for Different Alternatives (2000, Normal Hydrologic Year)

Table 3-2b Summary of Simulated Lake Almanor Habitat Volume (acre-ft) Having Water Temperature ≤ 21°C and DO ≥ 5 mg/L for Different Alternatives and Change in Habitat Volume Relative to Baseline Condition (2000, Normal Hydrologic Year)

Date	Total Reservoir Storage on Date (acre-ft)	Simulated Habitat Volume (acre-ft)					Change in Habitat Volume Relative to Baseline Condition (acre-ft)				% of Habitat Volume to Total Reservoir Storage on Date				
		Baseline	Present Day	Alt 3x	Alt 4a	Alt 4c	Present Day	Alt 3x	Alt 4a	Alt 4c	Base line	Present Day	Alt 3x	Alt 4a	Alt 4c
May 15	1,011,490	993,550	989,670	989,110	989,110	989,670	-3,880	-4,440	-4,440	-3,880	98%	98%	98%	98%	98%
June 7	1,015,410	876,510	874,470	883,350	881,800	874,470	-2,040	6,840	5,290	-2,040	86%	86%	87%	87%	86%
Jun 22	1,010,250	669,500	659,150	673,510	670,150	659,150	-10,350	4,010	650	-10,350	66%	65%	67%	66%	65%
July 7	993,780	584,410	585,350	598,010	594,810	587,100	940	13,600	10,400	2,690	59%	59%	60%	60%	59%
Jul 20	938,020	228,530	223,930	231,700	227,170	222,930	-4,600	3,170	-1,360	-5,600	24%	24%	25%	24%	24%
Aug 7	913,180	97,120	95,040	98,350	94,350	96,170	-2,080	1,230	-2,770	-950	11%	10%	11%	10%	11%
Aug 17	859,160	69,040	66,590	58,970	58,750	63,710	-2,450	-10,070	-10,290	-5,330	8%	8%	7%	7%	7%
Sep 7	836,720	636,600	639,480	698,340	683,250	661,180	2,880	61,740	46,650	24,580	76%	76%	83%	82%	79%
Sep 28	777,330	607,380	609,130	663,450	649,750	622,960	1,750	56,070	42,370	15,580	78%	78%	85%	84%	80%
Oct 15	761,020	676,160	678,940	712,080	702,680	694,830	2,780	35,920	26,520	18,670	89%	89%	94%	92%	91%

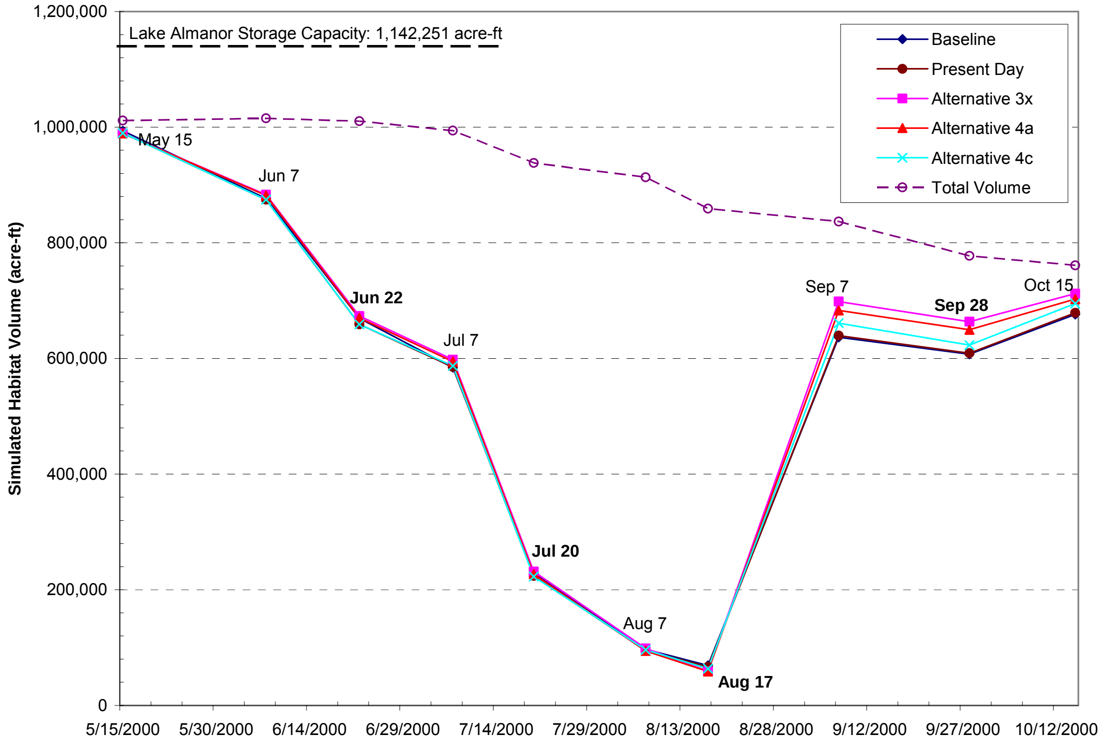

Figure 3-4b Comparison of Simulated Lake Almanor Habitat Volume Having Water Temperature ≤ 21°C and DO ≥ 5 mg/L for Different Alternatives (2000, Normal Hydrologic Year)

Table 3-2c Summary of Simulated Lake Almanor Habitat Volume (acre-ft) Having Water Temperature ≤ 22°C and DO ≥ 5 mg/L for Different Alternatives and Change in Habitat Volume Relative to Baseline Condition
(2000, Normal Hydrologic Year)

Date	Total Reservoir Storage on Date (acre-ft)	Simulated Habitat Volume (acre-ft)					Change in Habitat Volume Relative to Baseline Condition (acre-ft)				% of Habitat Volume to Total Reservoir Storage on Date				
		Baseline	Present Day	Alt 3x	Alt 4a	Alt 4c	Present Day	Alt 3x	Alt 4a	Alt 4c	Base line	Present Day	Alt 3x	Alt 4a	Alt 4c
May 15	1,011,490	993,550	989,670	989,110	989,110	989,670	-3,880	-4,440	-4,440	-3,880	98%	98%	98%	98%	98%
June 7	1,015,410	876,510	874,470	883,350	881,800	874,470	-2,040	6,840	5,290	-2,040	86%	86%	87%	87%	86%
Jun 22	1,010,250	798,650	798,700	818,190	815,210	798,700	50	19,540	16,560	50	79%	79%	81%	81%	79%
July 7	993,780	743,860	745,570	778,400	775,130	748,270	1,710	34,540	31,270	4,410	75%	75%	78%	78%	75%
Jul 20	938,020	632,400	631,140	661,580	657,470	638,300	-1,260	29,180	25,070	5,900	67%	67%	71%	70%	68%
Aug 7	913,180	144,170	143,320	155,090	149,440	147,300	-850	10,920	5,270	3,130	16%	16%	17%	16%	16%
Aug 17	859,160	458,170	440,650	345,350	342,380	406,800	-17,520	-112,820	-115,790	-51,370	53%	51%	40%	40%	47%
Sep 7	836,720	636,600	639,480	698,340	683,250	661,180	2,880	61,740	46,650	24,580	76%	76%	83%	82%	79%
Sep 28	777,330	607,380	609,130	663,450	649,750	622,960	1,750	56,070	42,370	15,580	78%	78%	85%	84%	80%
Oct 15	761,020	676,160	678,940	712,080	702,680	694,830	2,780	35,920	26,520	18,670	89%	89%	94%	92%	91%

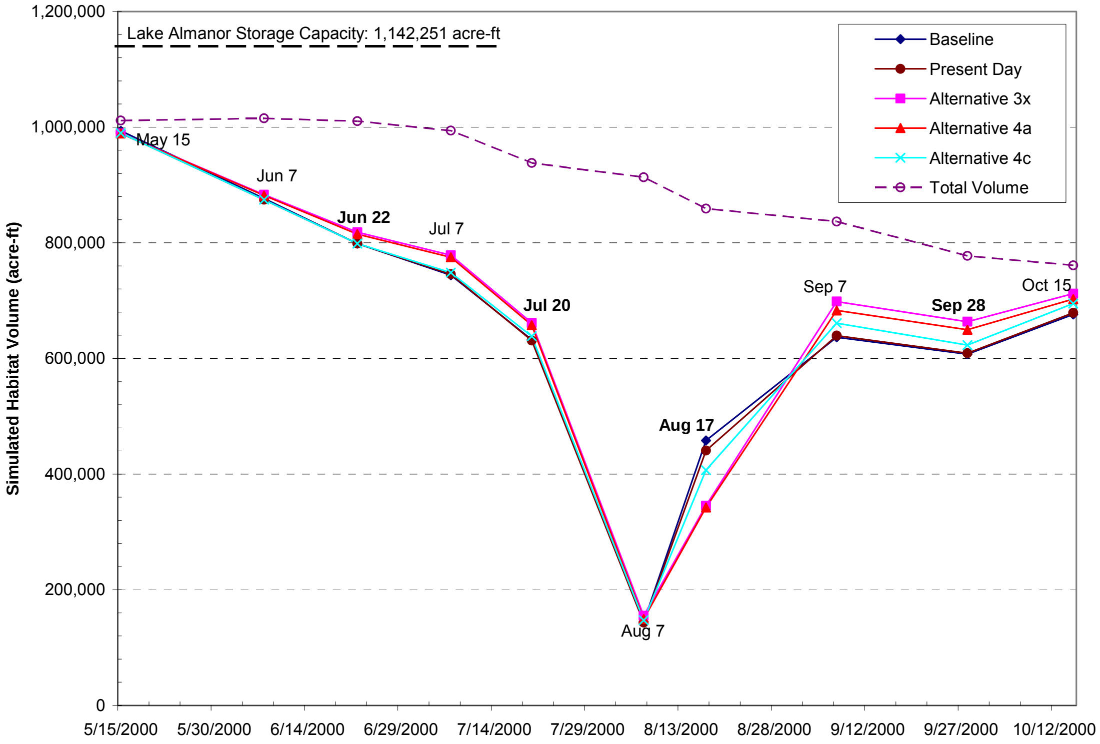

Figure 3-4c Comparison of Simulated Lake Almanor Habitat Volume Having Water Temperature ≤ 22°C and DO ≥ 5 mg/L for Different Alternatives (2000, Normal Hydrologic Year)

Table 3-3a Summary of Simulated Lake Almanor Habitat Volume (acre-ft) Having Water Temperature ≤ 20°C and DO ≥ 5 mg/L for Different Alternatives and Change in Habitat Volume Relative to Baseline Condition
(2001, Critical Dry Year)

Date	Total Reservoir Storage on Date (acre-ft)	Simulated Habitat Volume (acre-ft)					Change in Habitat Volume Relative to Baseline Condition (acre-ft)				% of Habitat Volume to Total Reservoir Storage on Date				
		Baseline	Present Day	Alt 3x	Alt 4a	Alt 4c	Present Day	Alt 3x	Alt 4a	Alt 4c	Base line	Present Day	Alt 3x	Alt 4a	Alt 4c
May 15	717,310	712,230	709,010	709,010	709,010	709,010	-3,220	-3,220	-3,220	-3,220	99%	99%	99%	99%	99%
June 6	721,260	588,900	585,970	590,050	589,390	585,970	-2,930	1,150	490	-2,930	82%	81%	82%	82%	81%
Jun 22	715,340	210,900	207,400	210,310	207,520	207,400	-3,500	-590	-3,380	-3,500	29%	29%	29%	29%	29%
July 10	702,590	85,420	82,720	84,830	82,900	84,240	-2,700	-590	-2,520	-1,180	12%	12%	12%	12%	12%
Jul 20	695,920	40,870	39,070	35,640	37,090	37,770	-1,800	-5,230	-3,780	-3,100	6%	6%	5%	5%	5%
Aug 9	648,010	360	0	0	0	0	-360	-360	-360	-360	0%	0%	0%	0%	0%
Aug 17	642,460	0	0	0	0	0	0	0	0	0	0%	0%	0%	0%	0%
Sep 12	634,800	490,230	493,040	352,170	463,000	442,000	2,810	-138,060	-27,230	-48,230	77%	78%	55%	73%	70%
Sep 28	625,800	543,700	545,630	575,920	558,700	565,360	1,930	32,220	15,000	21,660	87%	87%	92%	89%	90%
Oct 15	578,400	544,160	541,910	547,750	542,930	547,790	-2,250	3,590	-1,230	3,630	94%	94%	95%	94%	95%

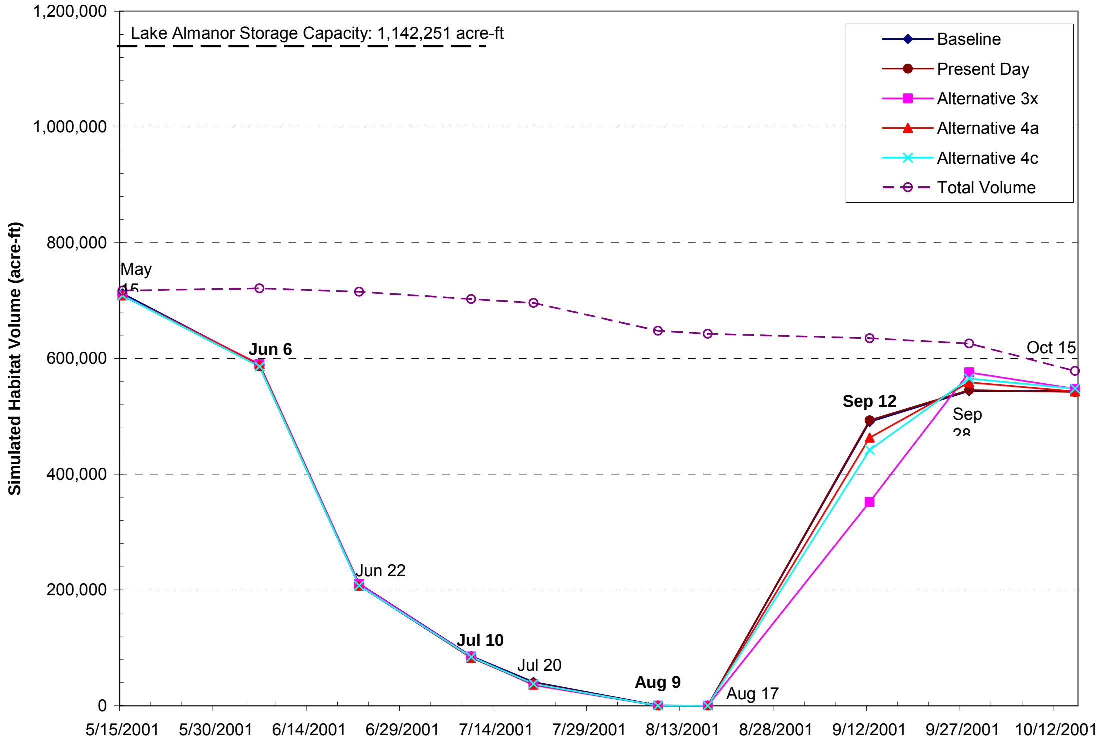

Figure 3-5a Comparison of Simulated Lake Almanor Habitat Volume Having Water Temperature ≤ 20°C and DO ≥ 5 mg/L for Different Alternatives (2001, Critical Dry Year)

Table 3-3b Summary of Simulated Lake Almanor Habitat Volume (acre-ft) Having Water Temperature ≤ 21°C and DO ≥ 5 mg/L for Different Alternatives and Change in Habitat Volume Relative to Baseline Condition (2001, Critical Dry Year)

Date	Total Reservoir Storage on Date (acre-ft)	Simulated Habitat Volume (acre-ft)					Change in Habitat Volume Relative to Baseline Condition (acre-ft)				% of Habitat Volume to Total Reservoir Storage on Date				
		Baseline	Present Day	Alt 3x	Alt 4a	Alt 4c	Present Day	Alt 3x	Alt 4a	Alt 4c	Base line	Present Day	Alt 3x	Alt 4a	Alt 4c
May 15	717,310	712,230	709,010	709,010	709,010	709,010	-3,220	-3,220	-3,220	-3,220	99%	99%	99%	99%	99%
June 6	721,260	588,900	585,970	590,050	589,390	585,970	-2,930	1,150	490	-2,930	82%	81%	82%	82%	81%
Jun 22	715,340	326,300	324,330	329,610	326,170	324,330	-1,970	3,310	-130	-1,970	46%	45%	46%	46%	45%
July 10	702,590	137,960	134,360	137,910	134,680	136,420	-3,600	-50	-3,280	-1,540	20%	19%	20%	19%	19%
Jul 20	695,920	74,230	73,060	69,690	68,900	72,360	-1,170	-4,540	-5,330	-1,870	11%	10%	10%	10%	10%
Aug 9	648,010	51,900	49,850	37,100	41,050	43,090	-2,050	-14,800	-10,850	-8,810	8%	8%	6%	6%	7%
Aug 17	642,460	23,260	20,250	8,160	14,730	12,930	-3,010	-15,100	-8,530	-10,330	4%	3%	1%	2%	2%
Sep 12	634,800	505,370	509,840	545,620	524,010	533,150	4,470	40,250	18,640	27,780	80%	80%	86%	83%	84%
Sep 28	625,800	543,700	545,630	575,920	558,700	565,360	1,930	32,220	15,000	21,660	87%	87%	92%	89%	90%
Oct 15	578,400	544,160	541,910	547,750	542,930	547,790	-2,250	3,590	-1,230	3,630	94%	94%	95%	94%	95%

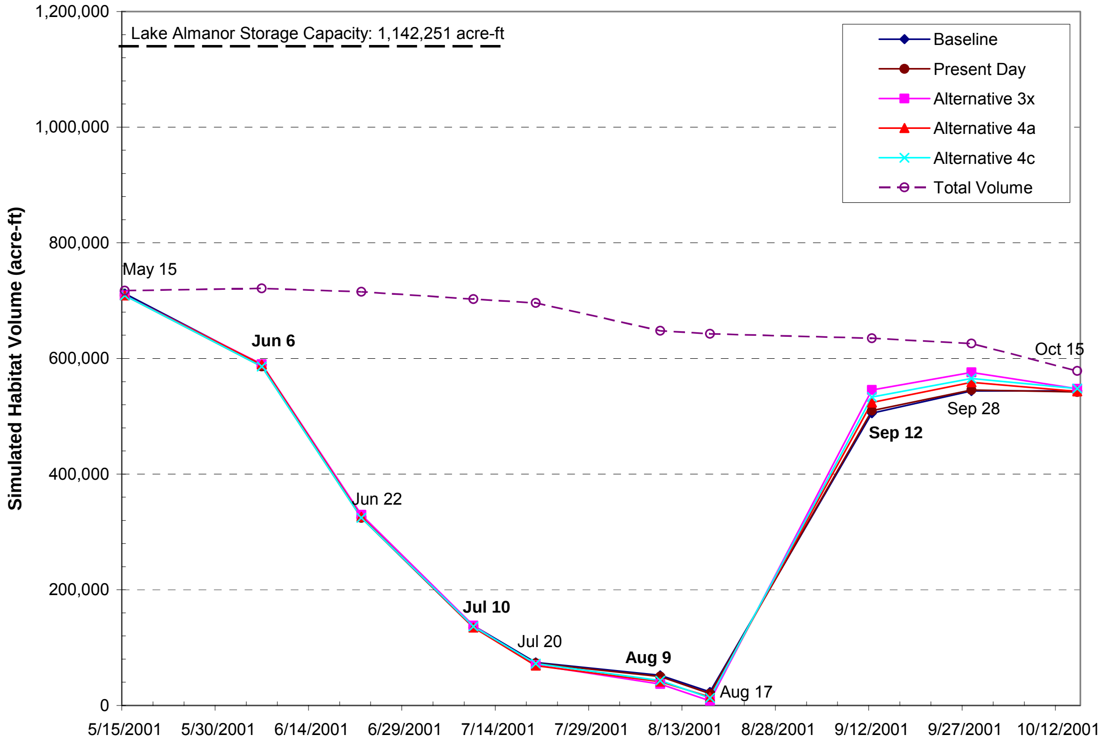

Figure 3-5b Comparison of Simulated Lake Almanor Habitat Volume Having Water Temperature ≤ 21°C and DO ≥ 5 mg/L for Different Alternatives (2001, Critical Dry Year)

Table 3-3c Summary of Simulated Lake Almanor Habitat Volume (acre-ft) Having Water Temperature ≤ 22°C and DO ≥ 5 mg/L for Different Alternatives and Change in Habitat Volume Relative to Baseline Condition

(2001, Critical Dry Year)

Date	Total Reservoir Storage on Date (acre-ft)	Simulated Habitat Volume (acre-ft)					Change in Habitat Volume Relative to Baseline Condition (acre-ft)				% of Habitat Volume to Total Reservoir Storage on Date				
		Baseline	Present Day	Alt 3x	Alt 4a	Alt 4c	Present Day	Alt 3x	Alt 4a	Alt 4c	Base line	Present Day	Alt 3x	Alt 4a	Alt 4c
May 15	717,310	712,230	709,010	709,010	709,010	709,010	-3,220	-3,220	-3,220	-3,220	99%	99%	99%	99%	99%
June 6	721,260	588,900	585,970	590,050	589,390	585,970	-2,930	1,150	490	-2,930	82%	81%	82%	82%	81%
Jun 22	715,340	544,990	542,240	553,650	550,580	542,240	-2,750	8,660	5,590	-2,750	76%	76%	77%	77%	76%
July 10	702,590	427,730	428,850	426,390	420,380	435,440	1,120	-1,340	-7,350	7,710	61%	61%	61%	60%	62%
Jul 20	695,920	420,180	421,170	410,020	405,990	422,840	990	-10,160	-14,190	2,660	60%	61%	59%	58%	61%
Aug 9	648,010	160,750	153,060	149,100	146,780	152,710	-7,690	-11,650	-13,970	-8,040	25%	24%	23%	23%	24%
Aug 17	642,460	282,590	254,640	103,720	124,360	142,530	-27,950	-178,870	-158,230	-140,060	44%	40%	16%	19%	22%
Sep 12	634,800	505,370	509,840	545,620	524,010	533,150	4,470	40,250	18,640	27,780	80%	80%	86%	83%	84%
Sep 28	625,800	543,700	545,630	575,920	558,700	565,360	1,930	32,220	15,000	21,660	87%	87%	92%	89%	90%
Oct 15	578,400	544,160	541,910	547,750	542,930	547,790	-2,250	3,590	-1,230	3,630	94%	94%	95%	94%	95%

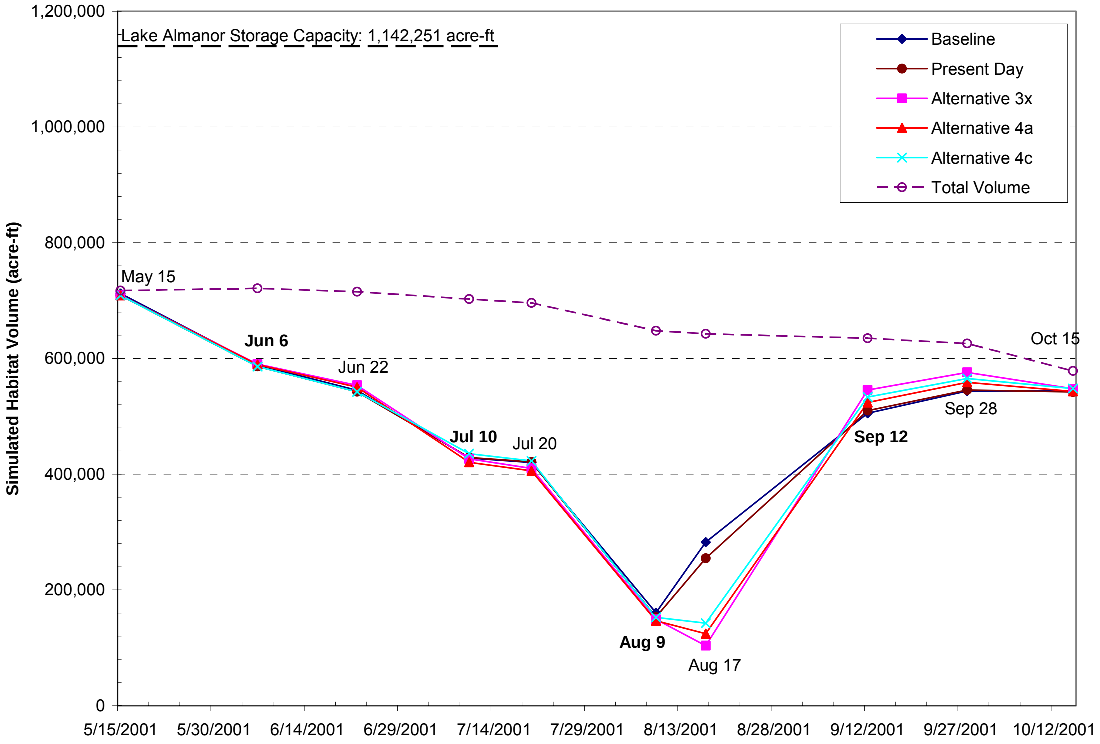

Figure 3-5c Comparison of Simulated Lake Almanor Habitat Volume Having Water Temperature ≤ 22°C and DO ≥ 5 mg/L for Different Alternatives (2001, Critical Dry Year)

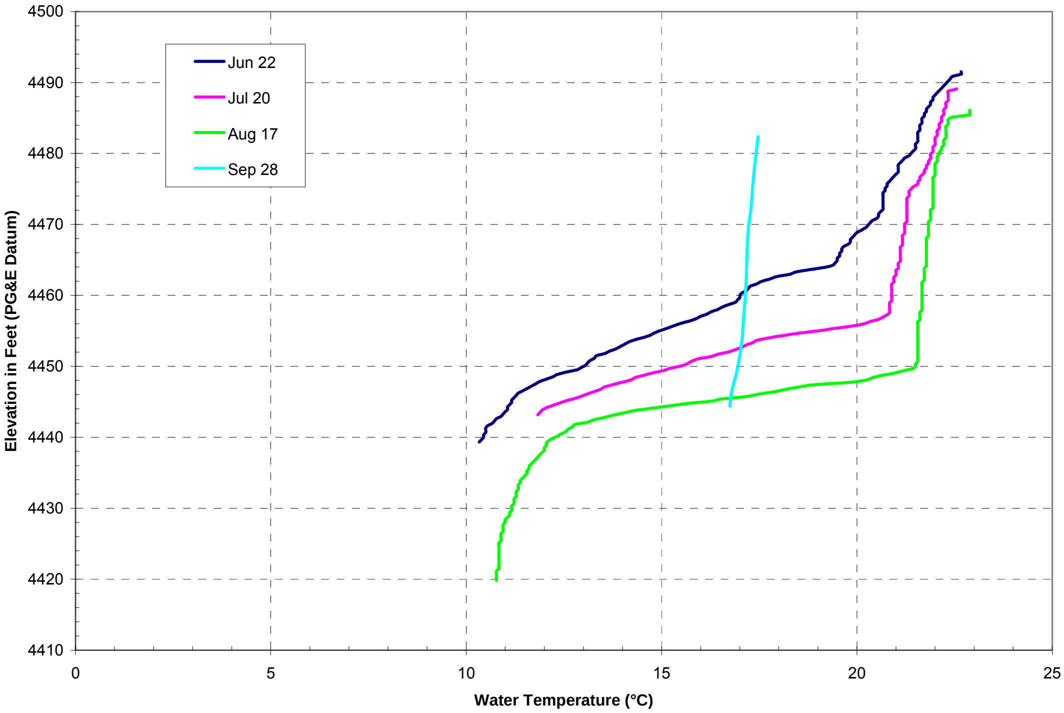

Figure 3-6a Observed Temperature Profiles in Lake Almanor near Canyon Dam, 2000

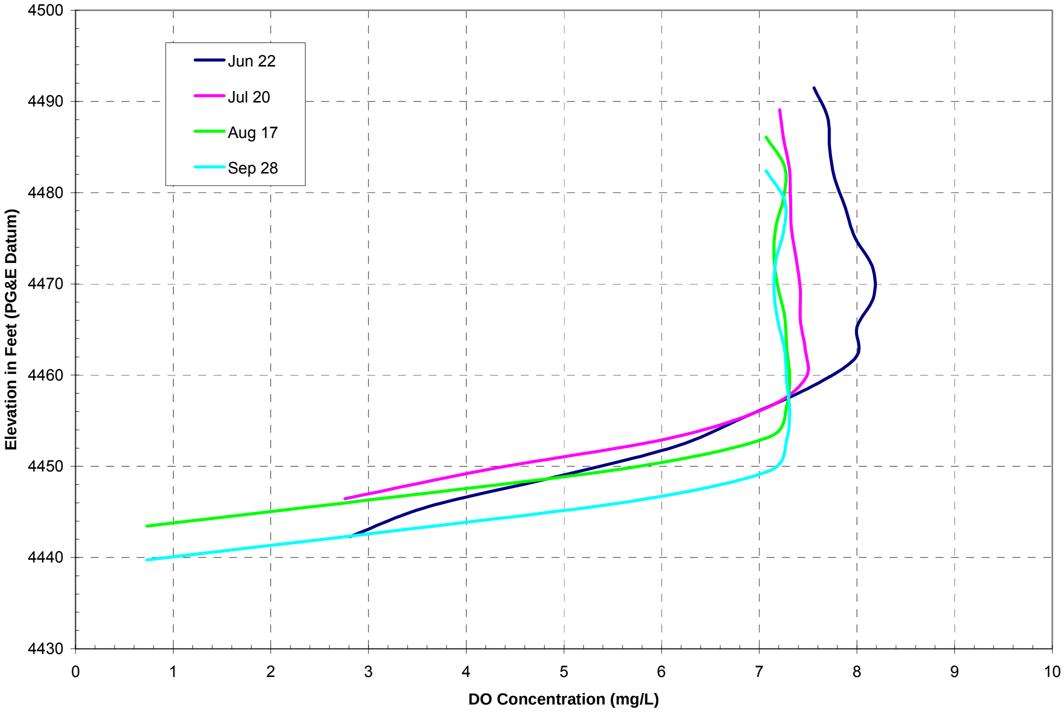

Figure 3-6b Observed DO Profiles in Lake Almanor near Canyon Dam, 2000

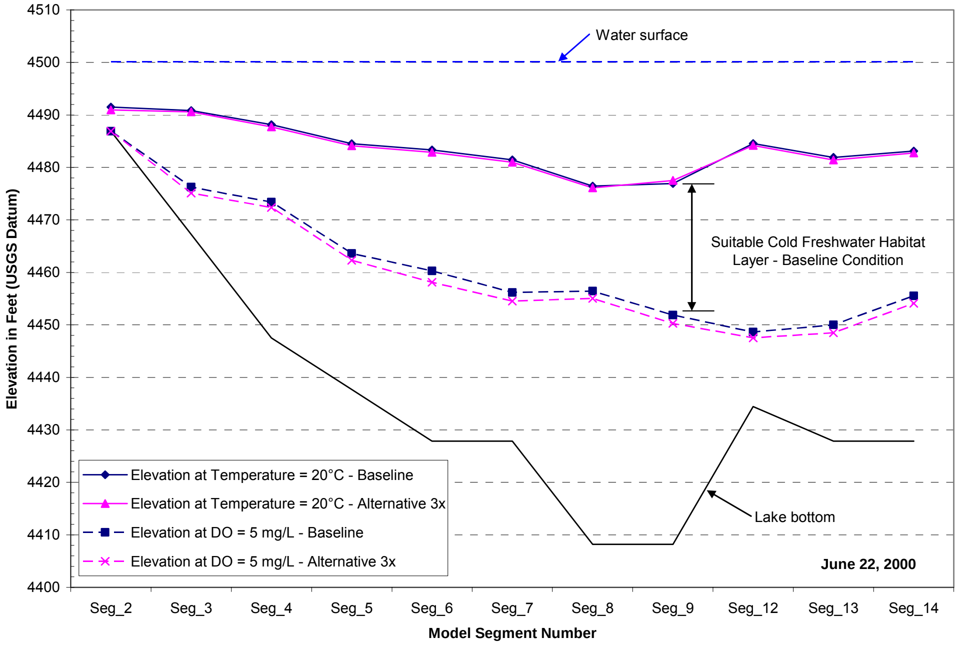

Figure 3-7a Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, June 22, 2000

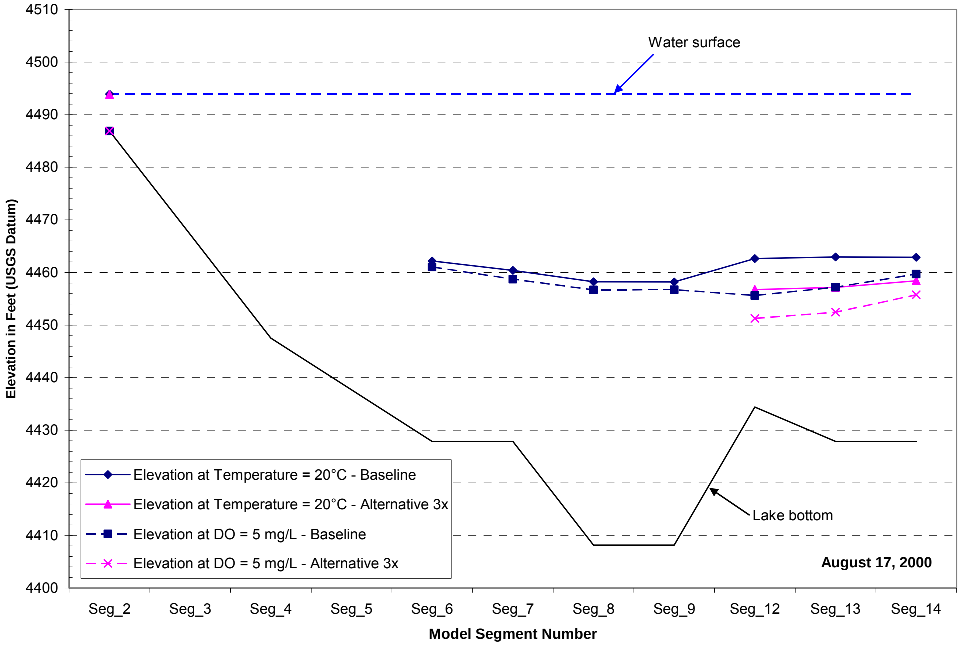

Figure 3-7b Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, August 17, 2000

Table 3-4 Summary of Simulated Lake Almanor Thermocline Elevation for Different Alternatives and Change in Thermocline Elevation Relative to Baseline Condition
(2000, Normal Hydrologic Year)

Date	Water Surface Elevation	Simulated Thermocline Elevation (feet in USGS Datum)					Change in Thermocline Elevation Relative to Baseline Condition (ft)			
		Baseline	**Present Day**	**Alt 3x**	**Alt 4a**	**Alt 4c**	**Present Day**	**Alt 3x**	**Alt 4a**	**Alt 4c**
5/15/2000	4,500.2									
6/7/2000	4,500.3	4,473.8	4,473.8	4,473.8	4,473.8	4,473.8	0	0	0	0
6/22/2000	4,500.1	4,480.3	4,480.3	4,480.3	4,480.3	4,480.3	0	0	0	0
7/7/2000	4,499.5	4,463.9	4,463.9	4,463.9	4,463.9	4,463.9	0	0	0	0
7/20/2000	4,497.2	4,467.2	4,467.2	4,463.9	4,463.9	4,463.9	0	-3	-3	-3
8/7/2000	4,496.2	4,467.2	4,467.2	4,463.9	4,463.9	4,467.2	0	-3	-3	0
8/17/2000	4,493.9	4,460.7	4,460.7	4,460.7	4,460.7	4,460.7	0	0	0	0
9/7/2000	4,492.9	4,454.1	4,454.1	4,447.5	4,450.8	4,450.8	0	-7	-3	-3
9/28/2000	4,490.3	4,454.1	4,454.1	4,447.5	4,447.5	4,450.8	0	-7	-7	-3
10/15/2000	4,489.6	4,444.3	4,441.0	4,437.7	4,441.0	4,441.0	-3	-7	-3	-3

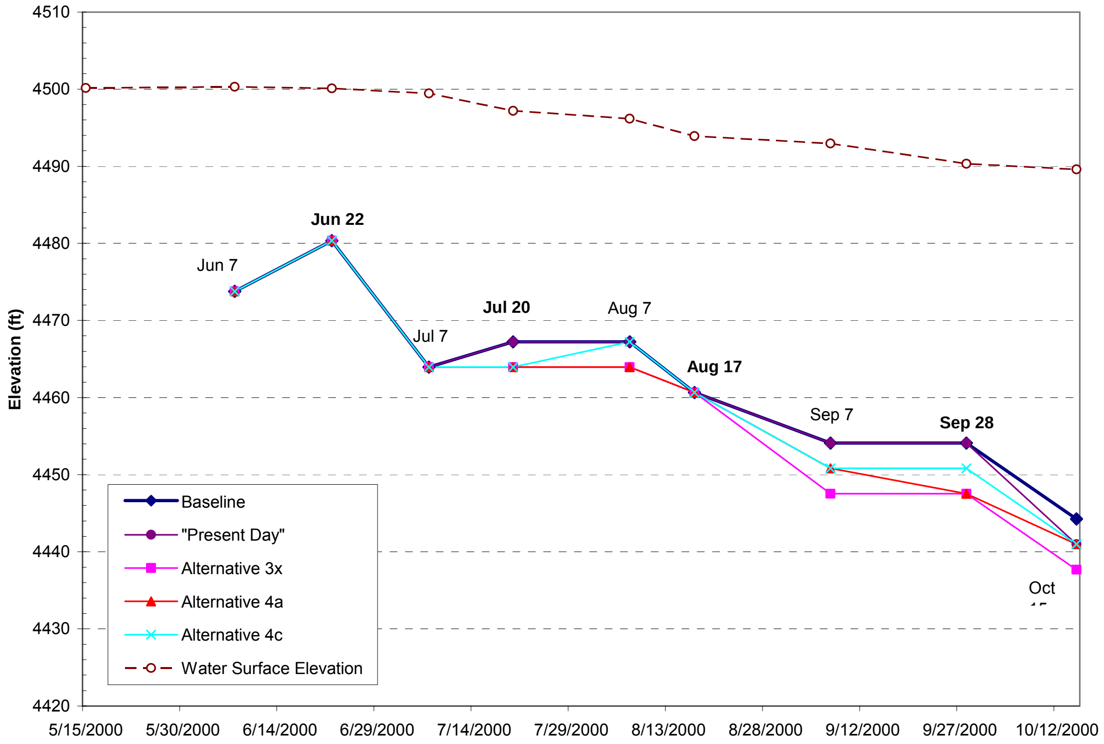

Figure 3-8 Comparison of Simulated Lake Almanor Thermocline Elevation for Different Alternatives
(2000, Normal Hydrologic Year)

Table 3-5 Summary of Simulated Lake Almanor Thermocline Elevation for Different Alternatives and Change in Thermocline Elevation Relative to Baseline Condition (2001, Critical Dry Year)

Date	Water Surface Elevation	Simulated Thermocline Elevation (feet in USGS Datum)					Change in Thermocline Elevation Relative to Baseline Condition (ft)			
		Baseline	**Present Day**	**Alt 3x**	**Alt 4a**	**Alt 4c**	**Present Day**	**Alt 3x**	**Alt 4a**	**Alt 4c**
5/15/2001	4,487.6	4,450.8	4,450.8	4,450.8	4,450.8	4,450.8	0	0	0	0
6/6/2001	4,487.8	4,467.2	4,467.2	4,467.2	4,467.2	4,467.2	0	0	0	0
6/22/2001	4,487.5	4,470.5	4,470.5	4,470.5	4,470.5	4,470.5	0	0	0	0
7/10/2001	4,486.9	4,457.4	4,457.4	4,454.1	4,454.1	4,454.1	0	-3	-3	-3
7/20/2001	4,486.6	4,463.9	4,463.9	4,463.9	4,460.7	4,463.9	0	0	-3	0
8/9/2001	4,484.3	4,457.4	4,457.4	4,457.4	4,457.4	4,457.4	0	0	0	0
8/17/2001	4,484.0	4,457.4	4,457.4	4,454.1	4,457.4	4,454.1	0	-3	0	-3
9/12/2001	4,483.6	4,444.3	4,444.3	4,441.0	4,444.3	4,441.0	0	-3	0	-3
9/28/2001	4,483.2	4,447.5	4,444.3	4,437.7	4,444.3	4,437.7	-3	-10	-3	-10
10/15/2001	4,480.8	4,427.9	4,424.6	4,421.3	4,424.6	4,421.3	-3	-7	-3	-7

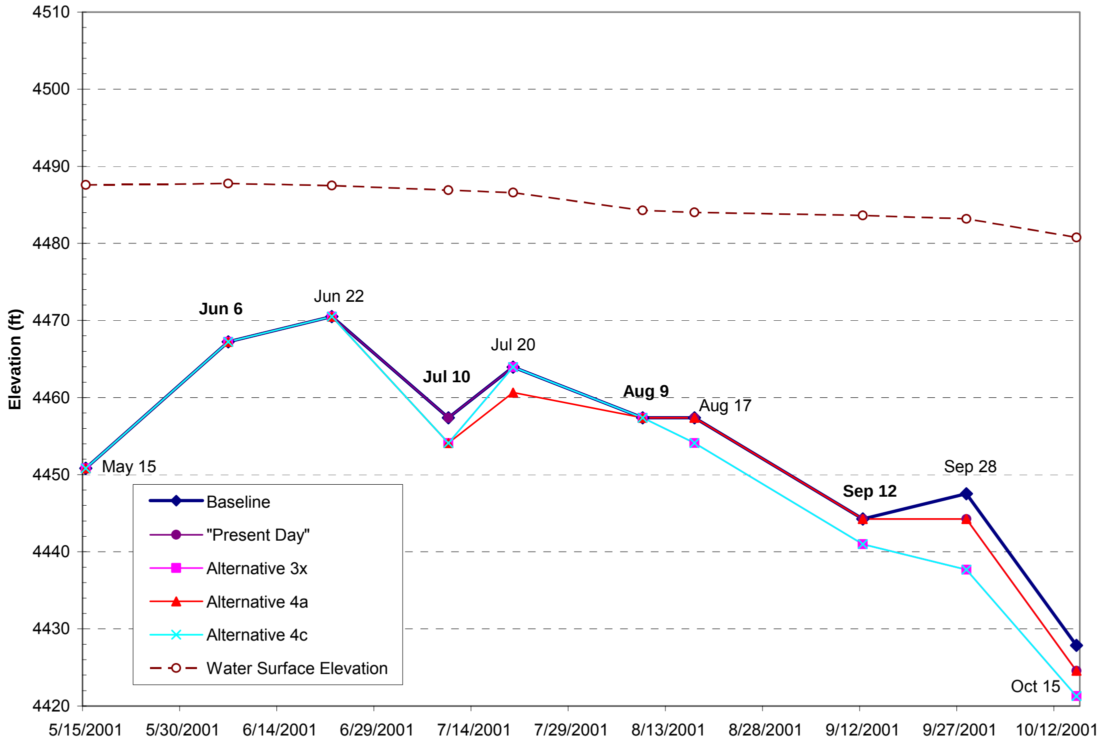

Figure 3-9 Comparison of Simulated Lake Almanor Thermocline Elevation for Different Alternatives (2001, Critical Dry Year)

Table 3-6 Summary of Simulated Lake Almanor Metalimnion Surface Area (acre) for Different Alternatives and Change in Thermocline Surface Area Relative to Baseline Condition
(2000, Normal Hydrologic Year)

Date	Lake Surface Area on Date (acre)	Simulated Metalimnion Surface Area (acre)					Change in Metalimnion SA Relative to Baseline Condition (acre)				% of Metalimnion SA to Total Lake SA on Date				
		Baseline	**Present Day**	**Alt 3x**	**Alt 4a**	**Alt 4c**	**Present Day**	**Alt 3x**	**Alt 4a**	**Alt 4c**	**Base line**	**Present Day**	**Alt 3x**	**Alt 4a**	**Alt 4c**
May 15	25,280														
June 7	25,330	17,320	17,320	17,320	17,320	17,320	0	0	0	0	68%	68%	68%	68%	68%
Jun 22	25,260	19,370	19,370	19,370	19,370	19,370	0	0	0	0	77%	77%	77%	77%	77%
July 7	25,030	14,220	14,220	14,220	14,220	14,220	0	0	0	0	57%	57%	57%	57%	57%
Jul 20	24,240	15,080	15,080	14,220	14,220	14,220	0	-860	-860	-860	62%	62%	59%	59%	59%
Aug 7	23,890	15,080	15,080	14,220	14,220	15,080	0	-860	-860	0	63%	63%	60%	60%	63%
Aug 17	23,140	13,460	13,460	13,460	13,460	13,460	0	0	0	0	58%	58%	58%	58%	58%
Sep 7	22,830	11,560	11,560	9,210	10,410	10,410	0	-2,350	-1,150	-1,150	51%	51%	40%	46%	46%
Sep 28	22,020	11,560	11,560	9,210	9,210	10,410	0	-2,350	-2,350	-1,150	52%	52%	42%	42%	47%
Oct 15	21,790	7,900	6,540	5,070	6,540	6,540	-1,360	-2,830	-1,360	-1,360	36%	30%	23%	30%	30%

Note: The bold dates have observed profiles.

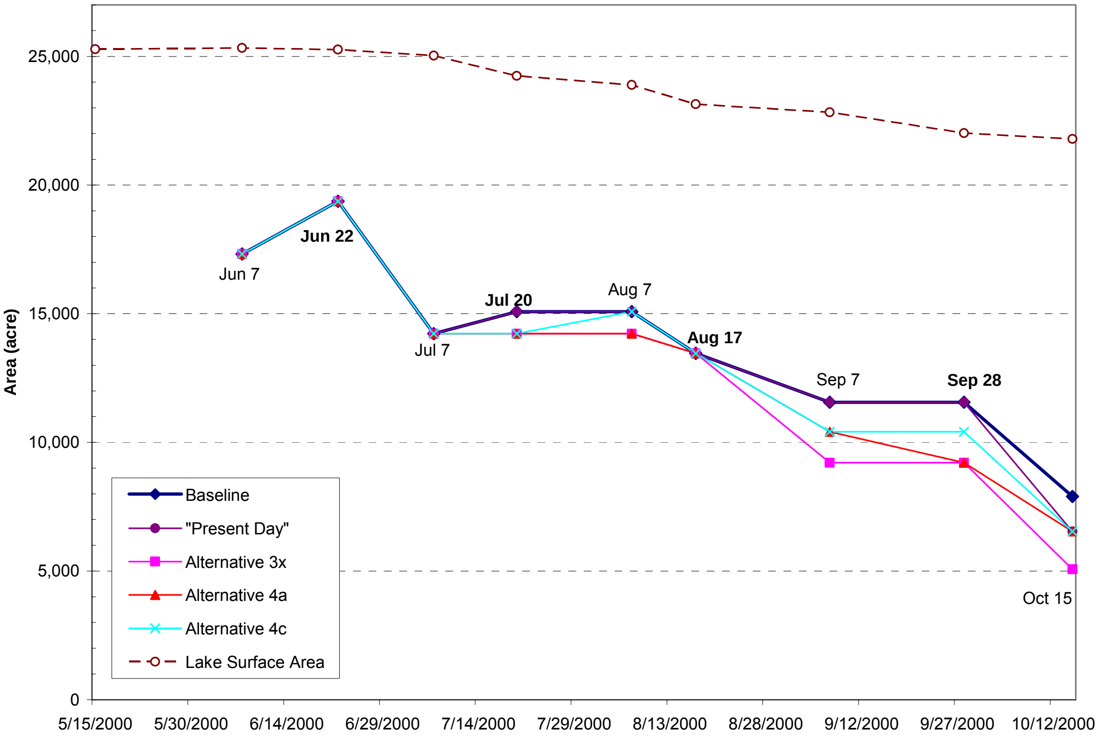

Figure 3-10 Comparison of Simulated Lake Almanor Metalimnion Surface Area for Different Alternatives
(2000, Normal Hydrologic Year)

Table 3-7 Summary of Simulated Lake Almanor Metalimnion Surface Area (acre) for Different Alternatives and Change in Thermocline Surface Area Relative to Baseline Condition

(2001, Critical Dry Year)

Date	Lake Surface Area on Date (acre)	Simulated Metalimnion Surface Area (acre)					Change in Metalimnion SA Relative to Baseline Condition (acre)				% of Metalimnion SA to Total Lake SA on Date				
		Baseline	Present Day	Alt 3x	Alt 4a	Alt 4c	Present Day	Alt 3x	Alt 4a	Alt 4c	Base line	Present Day	Alt 3x	Alt 4a	Alt 4c
May 15	21,190	10,410	10,410	10,410	10,410	10,410	0	0	0	0	49%	49%	49%	49%	49%
June 6	21,240	15,080	15,080	15,080	15,080	15,080	0	0	0	0	71%	71%	71%	71%	71%
Jun 22	21,160	16,150	16,150	16,150	16,150	16,150	0	0	0	0	76%	76%	76%	76%	76%
July 10	20,980	12,610	12,610	11,560	11,560	11,560	0	-1,050	-1,050	-1,050	60%	60%	55%	55%	55%
Jul 20	20,890	14,220	14,220	14,220	13,460	14,220	0	0	-760	0	68%	68%	68%	64%	68%
Aug 9	20,220	12,610	12,610	12,610	12,610	12,610	0	0	0	0	62%	62%	62%	62%	62%
Aug 17	20,150	12,610	12,610	11,560	12,610	11,560	0	-1,050	0	-1,050	63%	63%	57%	63%	57%
Sep 12	20,040	7,900	7,900	6,540	7,900	6,540	0	-1,360	0	-1,360	39%	39%	33%	39%	33%
Sep 28	19,910	9,210	7,900	5,070	7,900	5,070	-1,310	-4,140	-1,310	-4,140	46%	40%	25%	40%	25%
Oct 15	19,230	510	420	360	420	360	-90	-150	-90	-150	3%	2%	2%	2%	2%

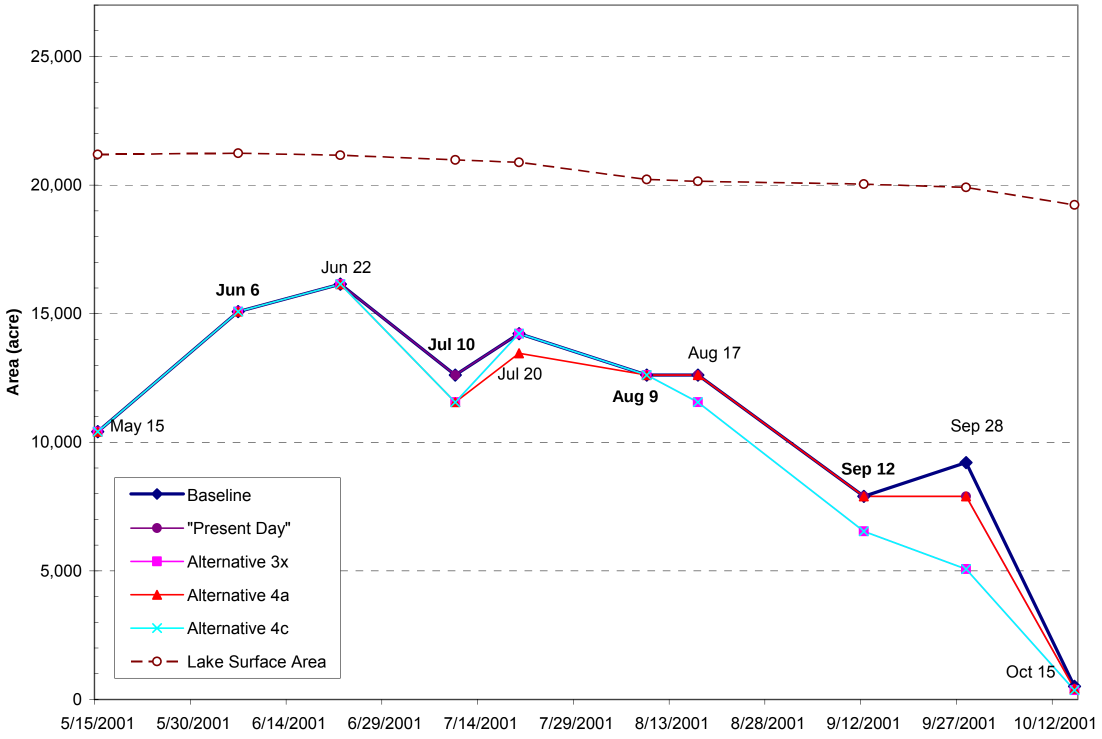

Figure 3-11 Comparison of Simulated Lake Almanor Metalimnion Surface Area for Different Alternatives (2001, Critical Dry Year)

3.4 RESULTS OF ANALYSIS OF BUTT VALLEY RESERVOIR

3.4.1 Results of Analysis of Butt Valley Reservoir Cold Freshwater Habitat Volume

As mentioned earlier, cold water withdrawn from the hypolimnion of Lake Almanor at the Prattville Intake (through use of a thermal curtain) may produce low DO in the discharge of the Butt Valley PH. This cold water with low DO would plunge into Butt Valley Reservoir and could affect the cold freshwater habitat of Butt Valley Reservoir. A CE-QUAL-W2 model of Butt Valley Reservoir was recently developed by Stetson to assess the effects of this phenomenon on suitable cold freshwater habitat in the reservoir.

Figures 3-12 and 3-13 show the simulated discharge water temperatures and DO concentrations at the Butt Valley PH in 2000 and 2001, respectively, for the alternatives that use the Prattville Intake thermal curtain (i.e., Alternatives 3x and 4a). The results show that the Prattville Intake thermal curtain would reduce both the discharge water temperatures and DO concentrations at the Butt Valley PH discharge. The reason that Alternative 3x causes a higher reduction than Alternative 4a in terms of both water temperature and DO at the Butt Valley PH discharge is that Alternative 3x includes removal of the submerged levees near the Prattville Intake, while Alternative 4a does not (see Table 3-1). Since the simulated discharge water temperatures and DO concentrations at the Butt Valley PH discharge for Alternatives 3x and 4a are similar, it would be expected that Alternatives 3x and 4a have similar effects on Butt Valley Reservoir because the outflow hydraulics between the Caribou Intake thermal curtain in Alternative 4a and the preferential use of Caribou #1 in Alternative 3x are also expected to be similar. So, in this analysis the computation of suitable cold freshwater habitat volume was conducted for Alternative 4a only.

The results of Butt Valley Reservoir cold freshwater habitat analysis for the Baseline condition and Alternative 4a for the three different criteria (i.e., T ≤ 20°C and DO ≥ 5 mg/L; T ≤ 21°C and DO ≥ 5 mg/L; and T ≤ 22°C and DO ≥ 5 mg/L) for year 2000 are summarized in Tables 3-8a – 3-8c and shown in Figures 3-14a – 3-14c, and for year 2001 the results are summarized in Tables 3-9a – 3-9c and shown in Figures 3-15a – 3-15c. Details on the computed elevation ranges and volumes of the water layers by model segment that meet the temperature and DO criteria are shown in Appendix D. Similar to the computation of suitable cold freshwater habitat volume for Lake Almanor, a minimum thickness of 1 foot meeting the temperature and DO criteria was used in calculating the suitable cold freshwater habitat volume of Butt Valley Reservoir. Note that the analysis did not consider any oxygen reaeration at the Butt Valley PH discharge. Oxygen reaeration under actual Baseline conditions would not be expected to be high because the Prattville Intake mainly withdraws epilimnion water which has relatively high concentrations of DO. If a thermal curtain near the Prattville Intake is used to cause hypolimnion cold water withdrawal (with low DO), oxygen reaeration under this condition may be more pronounced. Thus, these results for Butt Valley Reservoir represent a “worst case” condition.

If T ≤ 20°C and DO ≥ 5mg/L are defined as the criteria for the suitable cold freshwater habitat, it appears that Alternative 4a generally increased the suitable cold freshwater habitat in Butt Valley Reservoir in both years 2000 and 2001. The increase was due to the low temperature produced by the Prattville Intake thermal curtain at the Butt Valley PH discharge, which, overall, cooled the reservoir and increased the volume of water cooler than 20°C. Although the Prattville Intake thermal curtain also produced low DO, this was more than offset by its cooling effect, as demonstrated in Figures 3-16a and 3-16b. As shown in Figures 3-16a and 3-16b, compared to the Baseline condition, Alternative 4a increased the cold water volume (T ≤ 20°C) downstream of segment 7, but also reduced the water volume with DO ≥ 5 mg/L. The net effect was that Alternative 4a increased the suitable freshwater habitat in Butt Valley Reservoir as shown in Table 3-8a for the given criteria of T ≤ 20°C and DO ≥ 5mg/L.

In the Butt Valley Reservoir CE-QUAL-W2 model, an internal weir representing the Caribou Intake thermal curtain was added at model segment 17[3]. It would be expected that the water behind the thermal curtain (i.e., segments 18 and 19) would be cold with low DO. This was also demonstrated in Figures 3-16a and 3-16b.

If the temperature criterion is relaxed from T ≤ 20°C to T ≤ 21°C, Alternative 4a reduced the suitable cold freshwater habitat in July and August of 2000 and increased the habitat in July and August of 2001. In July and August of 2000, Butt Valley Reservoir water temperature was generally lower than 21°C (see Appendix D, Figures 7c and 7d), water temperature was not a limiting factor for cold freshwater habitat if the temperature criterion is T ≤ 21°C. The decreased DO was the factor that caused the reduction of suitable habitat volume. In contrast, in July and August of 2001 Butt Valley Reservoir surface water temperature was higher than 21°C (see Appendix D, Figures 8c and 8d), with both the increased cold water and reduced DO affecting the habitat volume. The net effect was that Alternative 4a increased the habitat volume in July and August of 2001.

If the temperature criterion is relaxed from T ≤ 20°C to T ≤ 22°C, Alternative 4a generally reduced the suitable cold freshwater habitat in both years 2000 and 2001. This is because decreased DO was the limiting factor.

The analysis results indicate that the effect of installing a thermal curtain at Prattville Intake on the suitable cold freshwater habitat in Butt Valley Reservoir is highly correlated to the temperature criterion. If the temperature criterion is set at T ≤ 20°C, the effect is small and measures may not be needed. If the temperature criterion is set at T ≤ 21°C or T ≤ 22°C, measures to increase DO in the Butt Valley PH discharge appear to be needed.

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[3] The bottom elevation of the internal weir in the model was set at 4100 ft in USGS datum. This elevation is the same bottom elevation of the designed Caribou Intake thermal curtain shown in Figure 4-9.

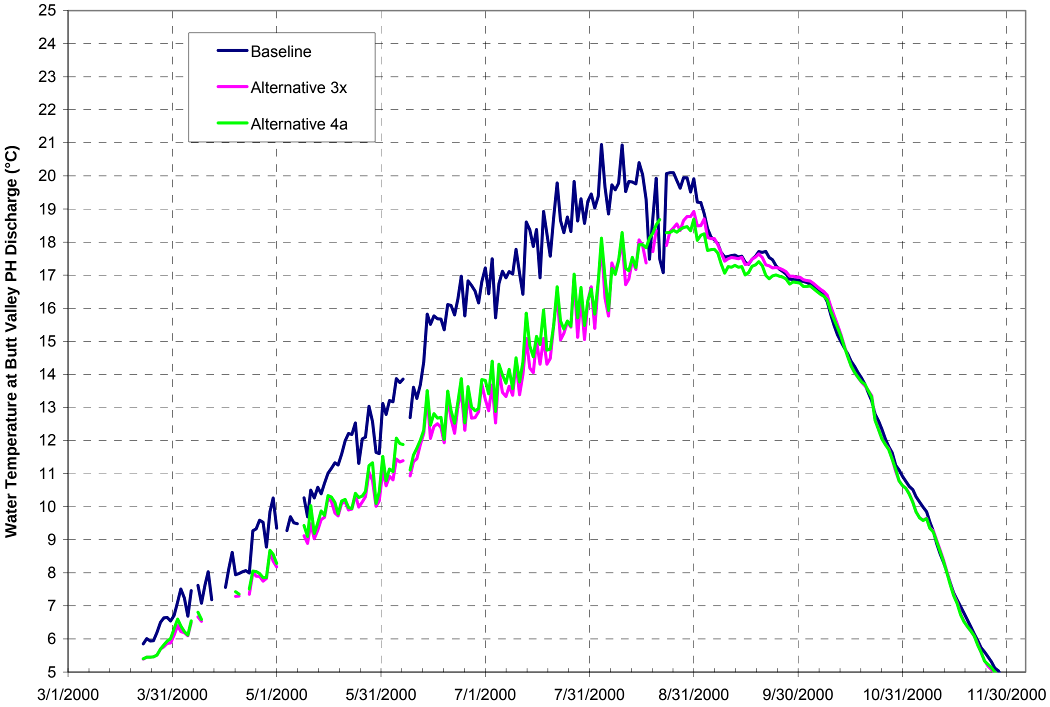


Figure 3-12a Simulated Discharge Water Temperatures at the Butt Valley Discharge Under Different Alternatives, 2000

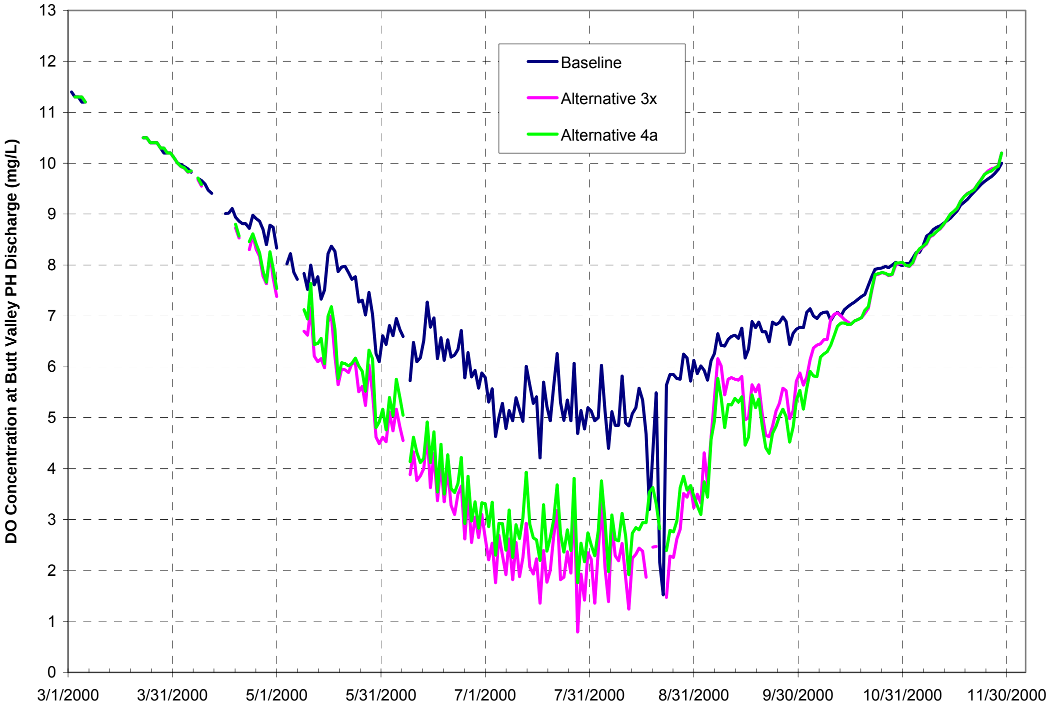


Figure 3-12b Simulated Discharge DO Concentrations at the Butt Valley PH Discharge Under Different Alternatives, 2000

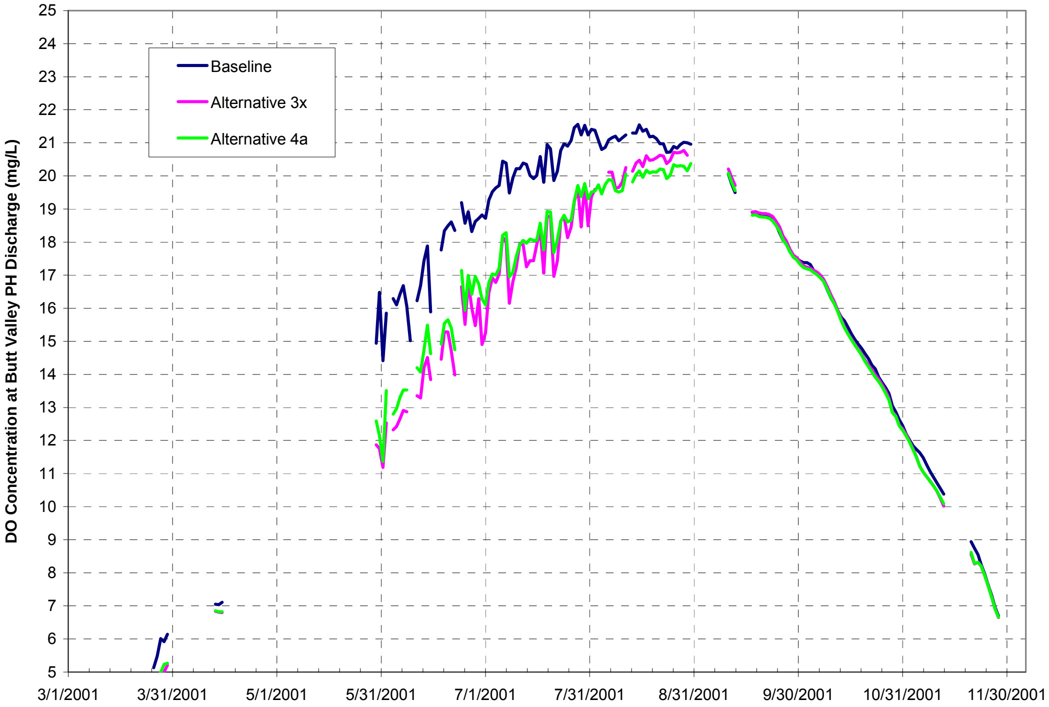


Figure 3-13a Simulated Discharge Water Temperatures at the Butt Valley Discharge Under Different Alternatives, 2001

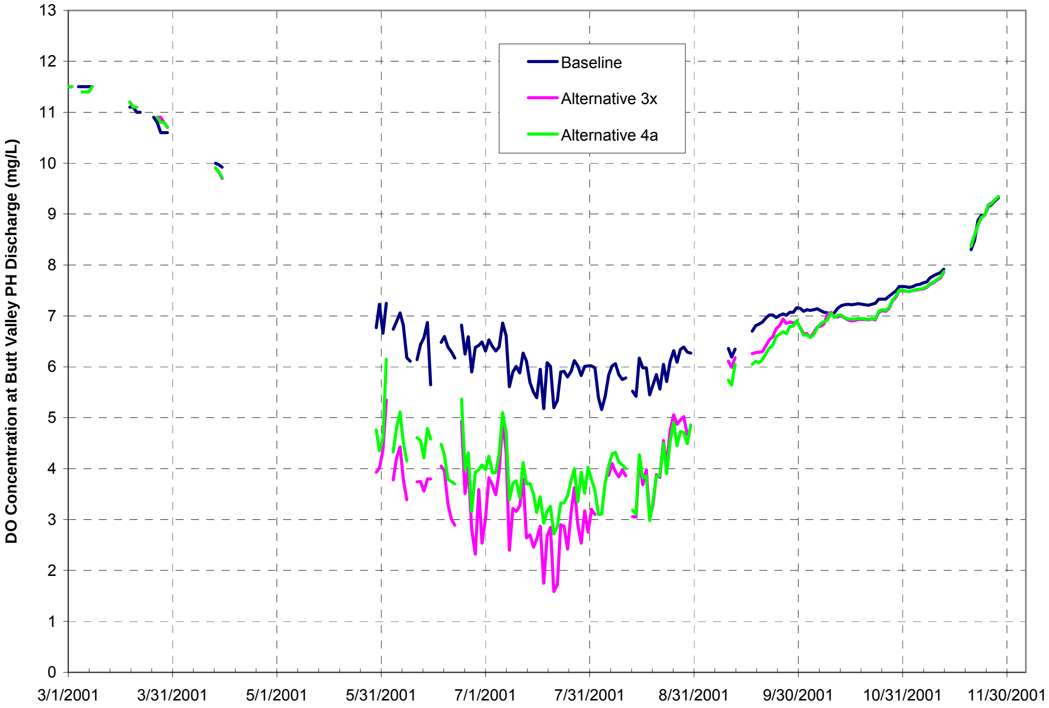


Figure 3-13b Simulated Discharge DO Concentrations at the Butt Valley PH Discharge Under Different Alternatives, 2001

Table 3-8a Summary of Simulated Butt Valley Reservoir Habitat Volume (acre-ft) Having Water Temperature ≤ 20°C and DO ≥ 5 mg/L for Different Alternatives and Change in Habitat Volume Relative to Baseline Condition

(2000, Normal Hydrologic Year)

Date	Total Reservoir Storage on Date (acre-ft)	Simulated Habitat Volume (acre-ft)		Change in Alt 4a Habitat Volume Relative to Baseline Condition (acre-ft)	% of Habitat Volume to Total Reservoir Storage	
		Baseline	Alt 4a		Baseline	Alt 4a
May 15	34,270	33,980	34,270	290	99%	100%
June 7	33,790	31,420	33,420	2,000	93%	99%
Jun 22	32,410	24,190	21,500	-2,690	75%	66%
July 7	36,790	33,510	26,460	-7,050	91%	72%
Jul 20	37,390	17,690	22,680	4,990	47%	61%
Aug 7	37,190	2,970	7,710	4,740	8%	21%
Aug 17	38,570	2,170	12,310	10,140	6%	32%
Sep 7	41,260	41,090	41,110	20	100%	100%
Sep 28	34,710	34,600	34,710	110	100%	100%

Note: The bold dates have observed profiles.

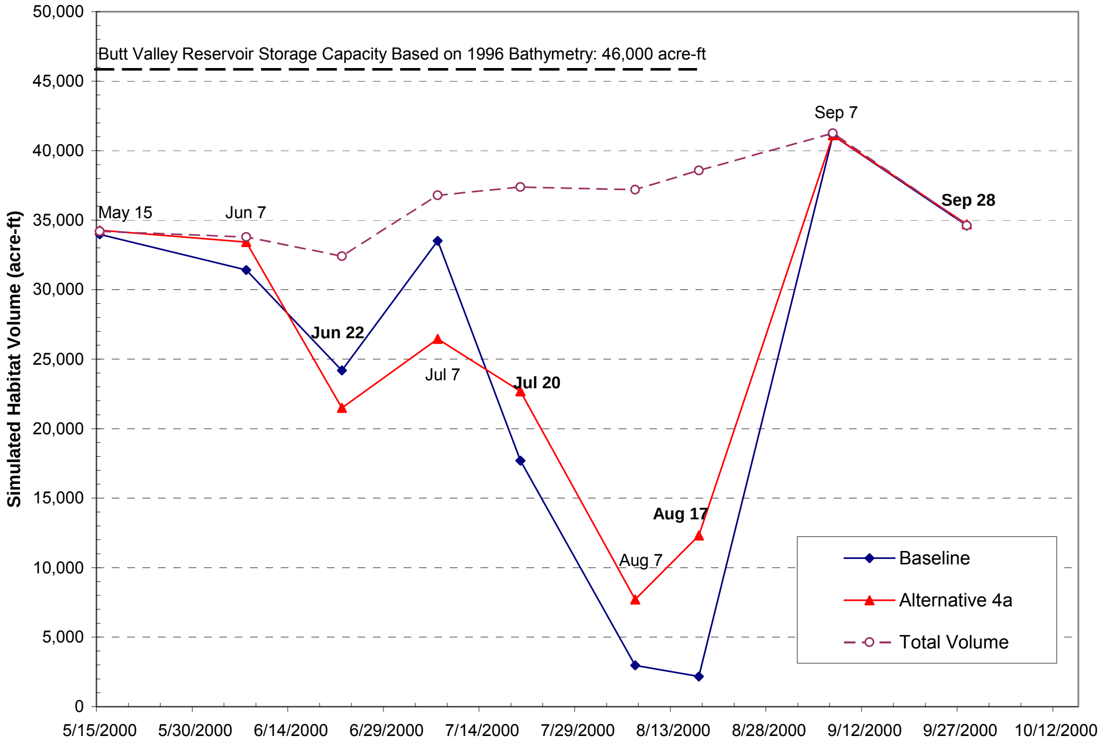


Figure 3-14a Comparison of Simulated Butt Valley Reservoir Habitat Volume Having Water Temperature ≤ 20°C and DO ≥ 5 mg/L for Different Alternatives (2000, Normal Hydrologic Year)

Table 3-8b Summary of Simulated Butt Valley Reservoir Habitat Volume (acre-ft) Having Water Temperature ≤ 21°C and DO ≥ 5 mg/L for Different Alternatives and Change in Habitat Volume Relative to Baseline Condition

(2000, Normal Hydrologic Year)

Date	Total Reservoir Storage on Date (acre-ft)	Simulated Habitat Volume (acre-ft)		Change in Alt 4a Habitat Volume Relative to Baseline Condition (acre-ft)	% of Habitat Volume to Total Reservoir Storage	
		Baseline	Alt 4a		Baseline	Alt 4a
May 15	34,270	33,980	34,270	290	99%	100%
June 7	33,790	31,420	33,420	2,000	93%	99%
Jun 22	32,410	28,400	24,980	-3,420	88%	77%
July 7	36,790	34,380	27,080	-7,300	93%	74%
Jul 20	37,390	32,360	26,250	-6,110	87%	70%
Aug 7	37,190	16,340	16,010	-330	44%	43%
Aug 17	38,570	34,170	27,290	-6,880	89%	71%
Sep 7	41,260	41,090	41,110	20	100%	100%
Sep 28	34,710	34,600	34,710	110	100%	100%

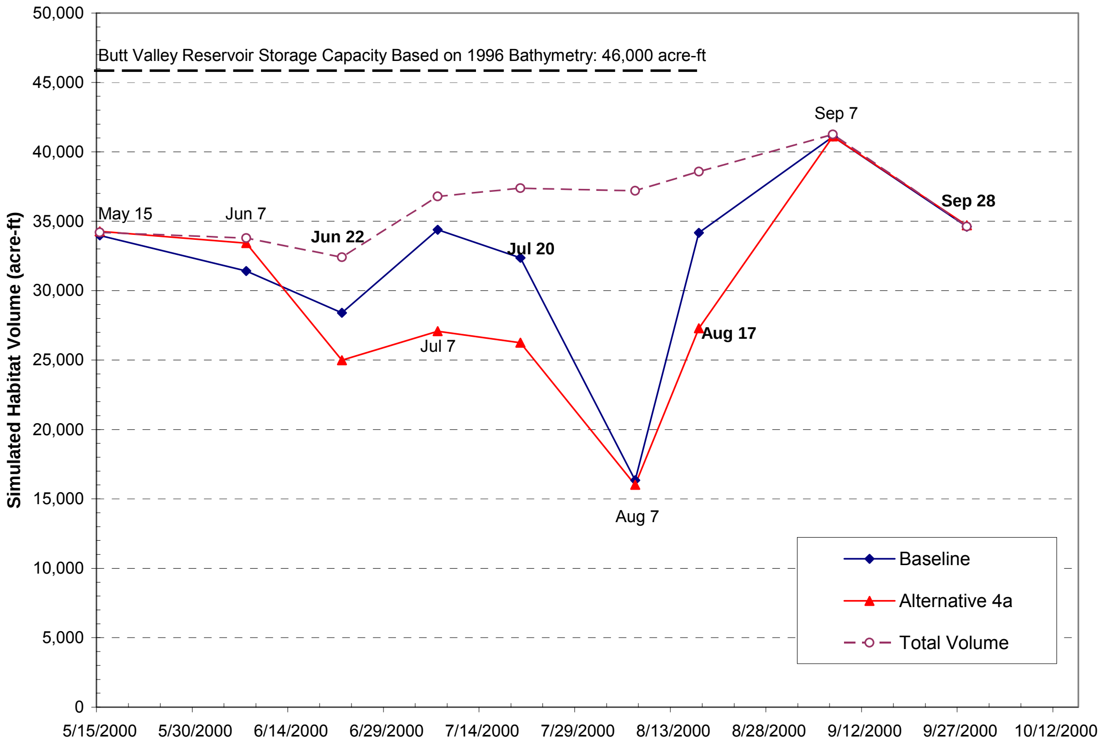


Figure 3-14b Comparison of Simulated Butt Valley Reservoir Habitat Volume Having Water Temperature ≤ 21°C and DO ≥ 5 mg/L for Different Alternatives (2000, Normal Hydrologic Year)

Table 3-8c Summary of Simulated Butt Valley Reservoir Habitat Volume (acre-ft) Having Water Temperature ≤ 22°C and DO ≥ 5 mg/L for Different Alternatives and Change in Habitat Volume Relative to Baseline Condition
(2000, Normal Hydrologic Year)

Date	Total Reservoir Storage on Date (acre-ft)	Simulated Habitat Volume (acre-ft)		Change in Alt 4a Habitat Volume Relative to Baseline Condition (acre-ft)	% of Habitat Volume to Total Reservoir Storage	
		Baseline	Alt 4a		Baseline	Alt 4a
May 15	34,270	33,980	34,270	290	99%	100%
June 7	33,790	31,420	33,420	2,000	93%	99%
Jun 22	32,410	29,980	28,700	-1,280	93%	89%
July 7	36,790	34,380	27,080	-7,300	93%	74%
Jul 20	37,390	33,340	26,250	-7,090	89%	70%
Aug 7	37,190	32,420	26,740	-5,680	87%	72%
Aug 17	38,570	36,120	27,290	-8,830	94%	71%
Sep 7	41,260	41,090	41,110	20	100%	100%
Sep 28	34,710	34,600	34,710	110	100%	100%

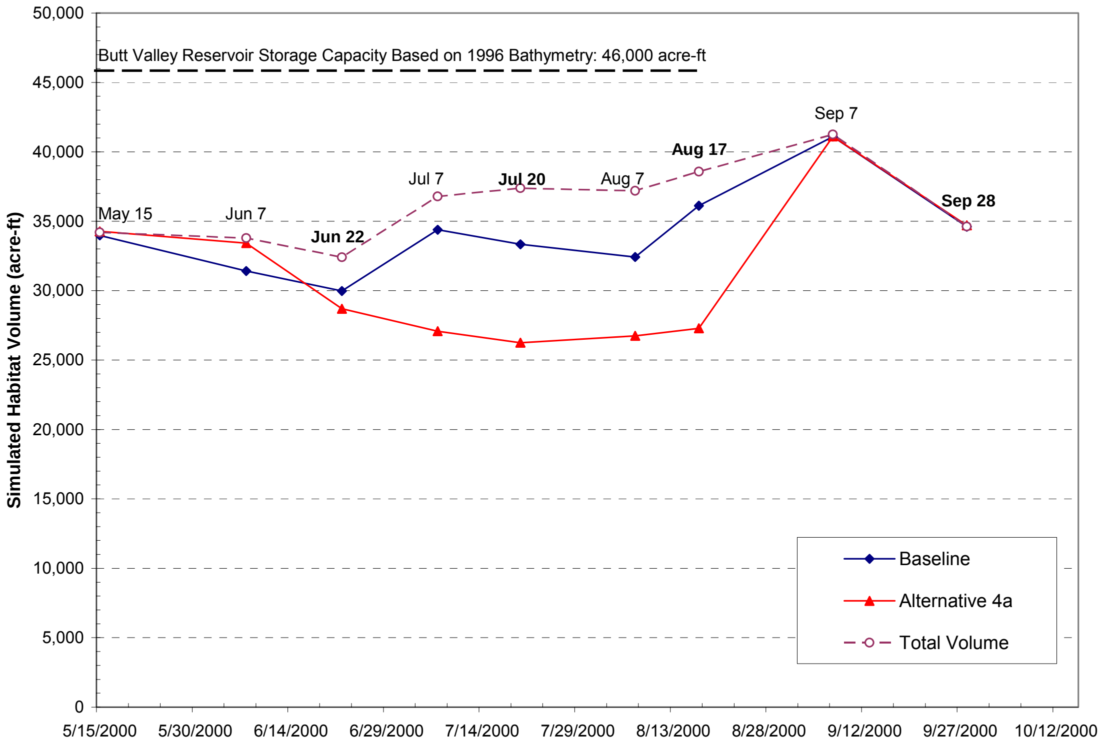
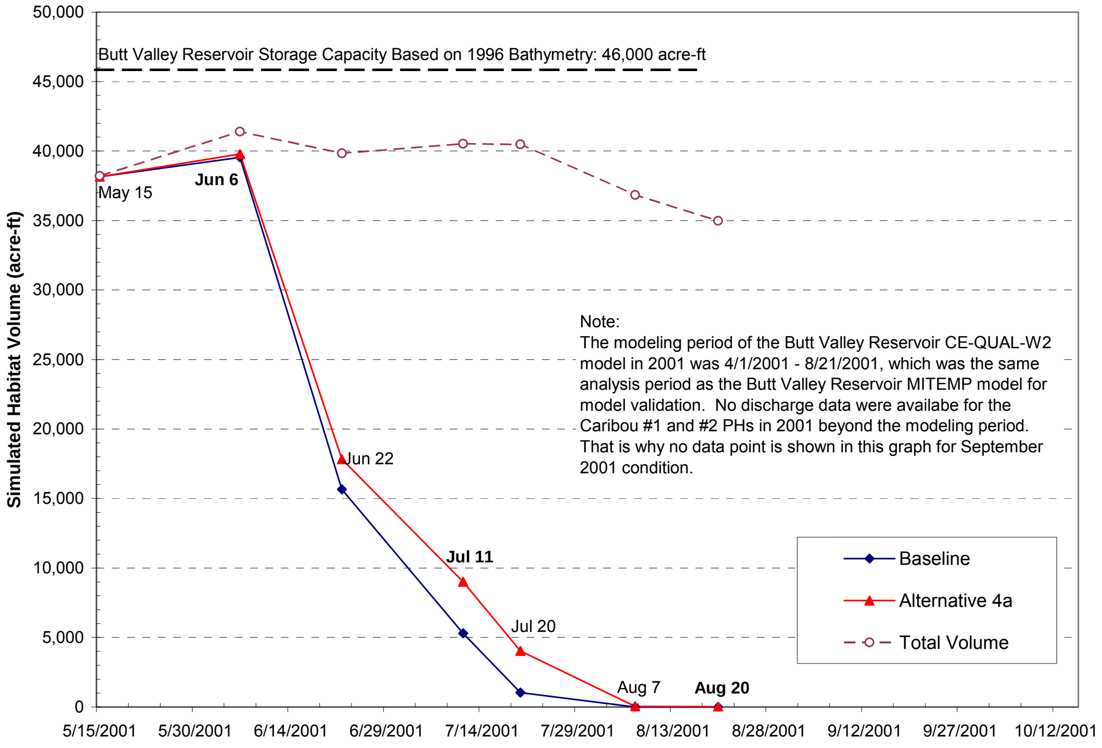


Figure 3-14c Comparison of Simulated Butt Valley Reservoir Habitat Volume Having Water Temperature ≤ 22°C and DO ≥ 5 mg/L for Different Alternatives
(2000, Normal Hydrologic Year)

Table 3-9a Summary of Simulated Butt Valley Reservoir Habitat Volume (acre-ft) Having Water Temperature ≤ 20°C and DO ≥ 5 mg/L for Different Alternatives and Change in Habitat Volume Relative to Baseline Condition

(2001, Critical Dry Year)

Date	Total Reservoir Storage on Date (acre-ft)	Simulated Habitat Volume (acre-ft)		Change in Alt 4a Habitat Volume Relative to Baseline Condition (acre-ft)	% of Habitat Volume to Total Reservoir Storage	
		Baseline	Alt 4a		Baseline	Alt 4a
May 15	38,210	38,160	38,150	-10	100%	100%
June 6	41,400	39,550	39,780	230	96%	96%
Jun 22	39,840	15,660	17,830	2,170	39%	45%
July 11	40,530	5,290	9,010	3,720	13%	22%
Jul 20	40,490	1,040	4,030	2,990	3%	10%
Aug 7	36,840	0	50	50	0%	0%
Aug 20	34,980	0	20	20	0%	0%



Note:
The modeling period of the Butt Valley Reservoir CE-QUAL-W2 model in 2001 was 4/1/2001 - 8/21/2001, which was the same analysis period as the Butt Valley Reservoir MITEMP model for model validation. No discharge data were availabe for the Caribou #1 and #2 PHs in 2001 beyond the modeling period. That is why no data point is shown in this graph for September 2001 condition.

Figure 3-15a Comparison of Simulated Butt Valley Reservoir Habitat Volume Having Water Temperature ≤ 20°C and DO ≥ 5 mg/L for Different Alternatives (2001, Critical Dry Year)

Table 3-9b Summary of Simulated Butt Valley Reservoir Habitat Volume (acre-ft) Having Water Temperature ≤ 21°C and DO ≥ 5 mg/L for Different Alternatives and Change in Habitat Volume Relative to Baseline Condition

(2001, Critical Dry Year)

Date	Total Reservoir Storage on Date (acre-ft)	Simulated Habitat Volume (acre-ft)		Change in Alt 4a Habitat Volume Relative to Baseline Condition (acre-ft)	% of Habitat Volume to Total Reservoir Storage	
		Baseline	Alt 4a		Baseline	Alt 4a
May 15	38,210	38,160	38,150	-10	100%	100%
June 6	41,400	40,220	39,950	-270	97%	96%
Jun 22	39,840	24,890	24,690	-200	62%	62%
July 11	40,530	14,980	20,010	5,030	37%	49%
Jul 20	40,490	10,870	17,370	6,500	27%	43%
Aug 7	36,840	210	4,670	4,460	1%	13%
Aug 20	34,980	910	4,330	3,420	3%	12%

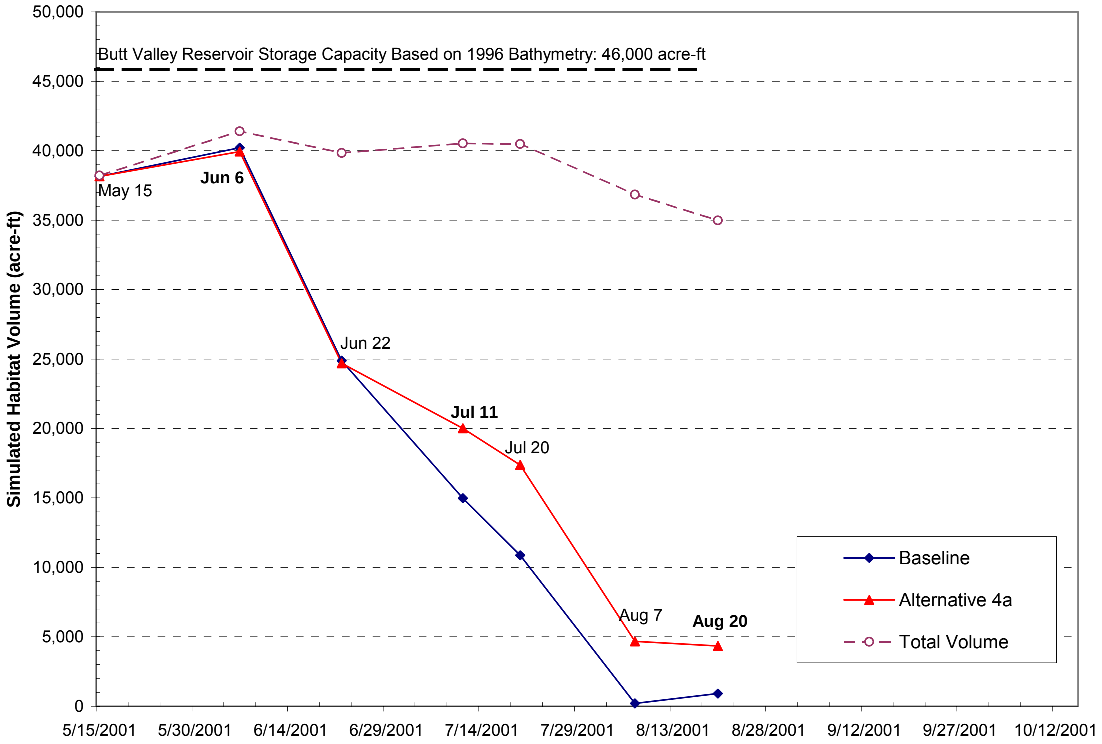


Figure 3-15b Comparison of Simulated Butt Valley Reservoir Habitat Volume Having Water Temperature ≤ 21°C and DO ≥ 5 mg/L for Different Alternatives (2001, Critical Dry Year)

Table 3-9c Summary of Simulated Butt Valley Reservoir Habitat Volume (acre-ft) Having Water Temperature ≤ 22°C and DO ≥ 5 mg/L for Different Alternatives and Change in Habitat Volume Relative to Baseline Condition

(2001, Critical Dry Year)

Date	Total Reservoir Storage on Date (acre-ft)	Simulated Habitat Volume (acre-ft)		Change in Alt 4a Habitat Volume Relative to Baseline Condition (acre-ft)	% of Habitat Volume to Total Reservoir Storage	
		Baseline	Alt 4a		Baseline	Alt 4a
May 15	38,210	38,160	38,150	-10	100%	100%
June 6	41,400	40,220	39,950	-270	97%	96%
Jun 22	39,840	35,140	35,020	-120	88%	88%
July 11	40,530	37,560	36,210	-1,350	93%	89%
Jul 20	40,490	35,920	35,680	-240	89%	88%
Aug 7	36,840	21,110	29,070	7,960	57%	79%
Aug 20	34,980	31,210	30,970	-240	89%	89%

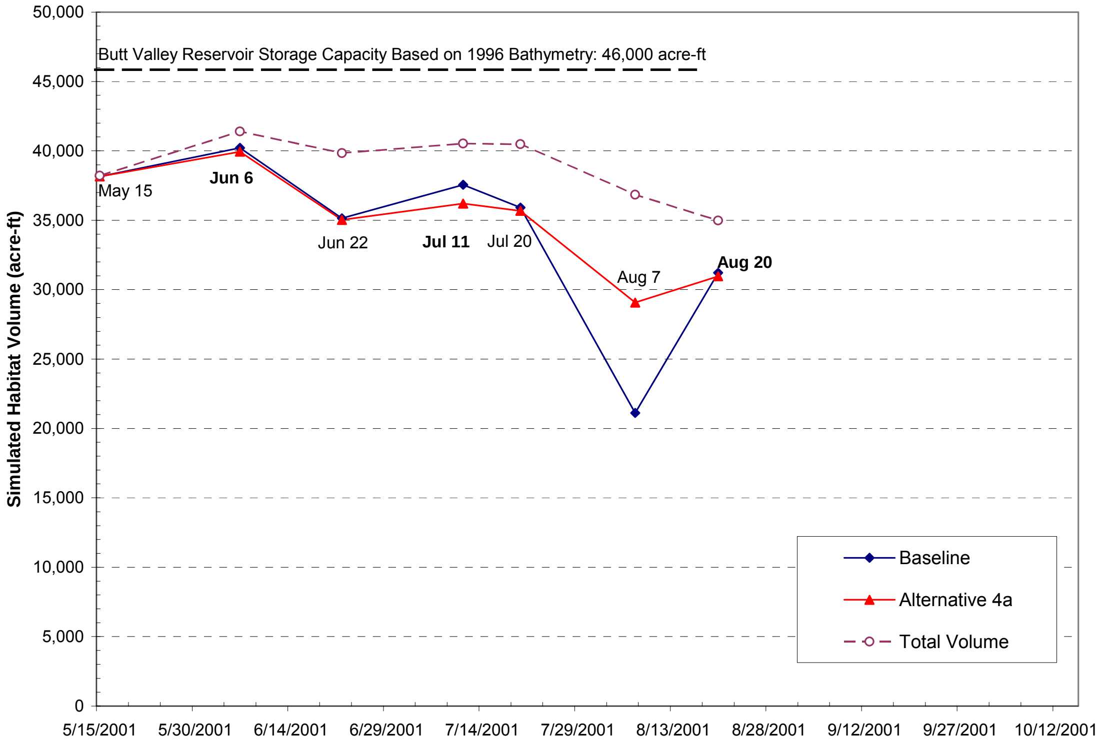


Figure 3-15c Comparison of Simulated Butt Valley Reservoir Habitat Volume Having Water Temperature ≤ 22°C and DO ≥ 5 mg/L for Different Alternatives (2001, Critical Dry Year)

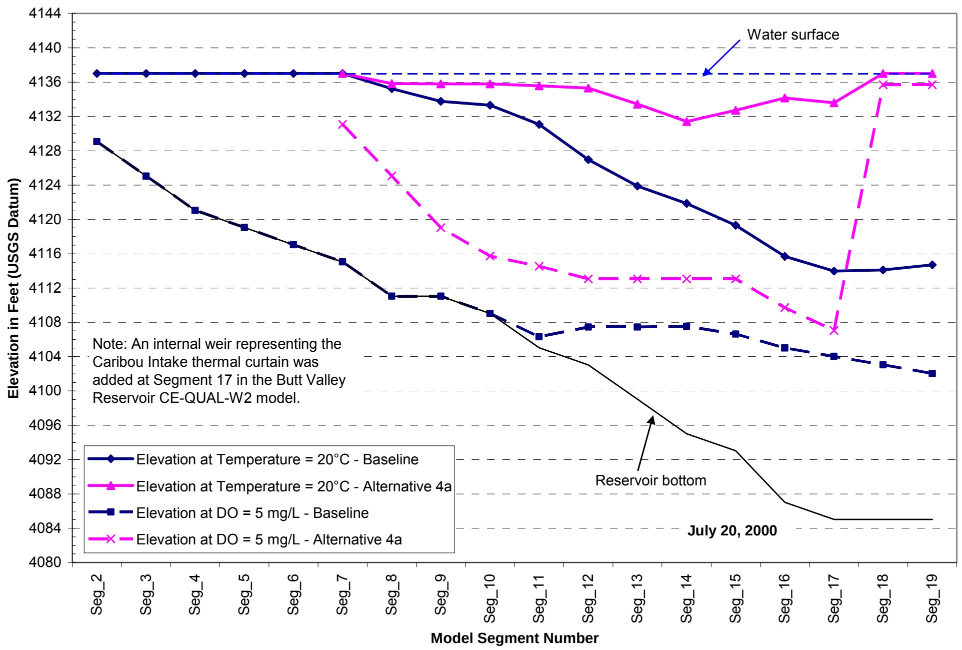


Figure 3-16a Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, July 20, 2000

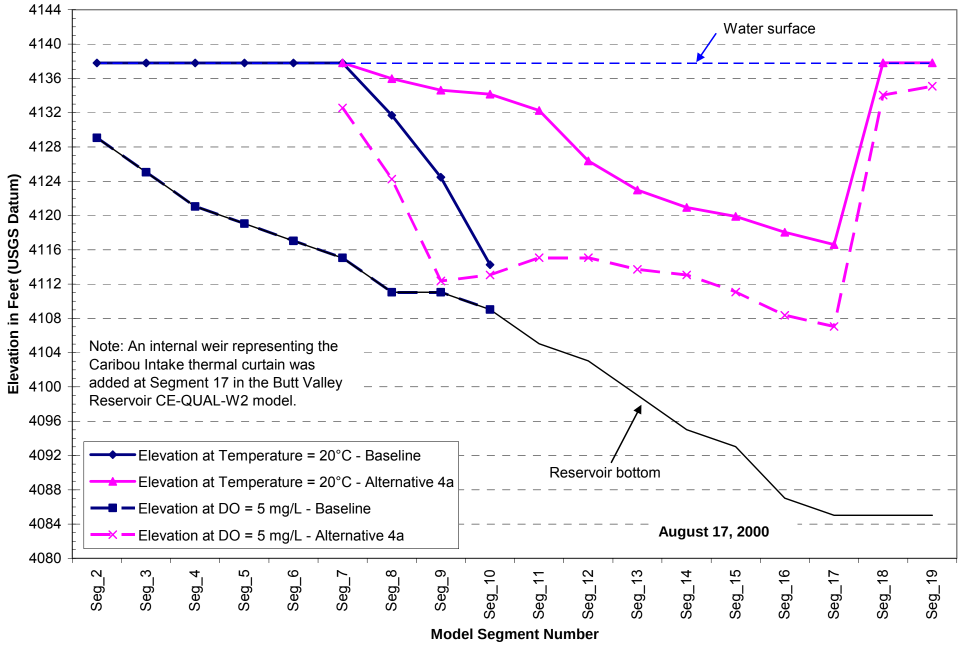


Figure 3-16b Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, August 17, 20

3.5 SUMMARY OF FINDINGS

Following is a summary of findings based on CE-QUAL-W2 modeling analyses of selected UNFFR Project-only alternatives, including Baseline, the "Present Day" alternative, and Alternatives 3x, 4a, and 4c, for the "normal" hydrologic year 2000 and the "critical dry" hydrologic year 2001. Baseline was selected for analysis because it provided the CEQA baseline for comparing the effects of the alternatives. The "Present Day" alternative was selected for analysis because it provided a comparison with the proposed alternative by PG&E in its license application (essentially the same as the FERC Staff recommended alternative in the EIS). Alternative 4a was selected for analysis of the effects of cold water withdrawal using a thermal curtain at the Prattville Intake. Alternative 4c was selected for analysis of the effects of cold water withdrawal using a modified Canyon Dam low-level outlet. Alternative 3x was selected for analysis of the effects of cold water withdrawal using both the Prattville Intake thermal curtain and the modified Canyon Dam low-level outlet. Alternatives 3, 4b, and 4d were not analyzed because: (a) It would be expected that Alternative 3 would have less effect on Lake Almanor than Alternative 3x since Alternative 3 has similar water temperature reduction measures at Lake Almanor as Alternative 3x, but has lower releases at the Canyon Dam low-level outlet (see Table 1-2); (b) Alternative 4b would have the same effect on Lake Almanor as Alternative 4a; and (c) Alternative 4d would have the same effect on Lake Almanor as Alternative 4c.

1) In terms of percentage of the suitable cold freshwater habitat volume to the total lake storage, the changes between each alternative and Baseline in June, July, and August are all within 1%. The magnitudes of the effects of the three water temperature reduction alternatives (Alternatives 3x, 4a, and 4c) on the suitable cold freshwater habitat volume of Lake Almanor are sensitive to the criteria used to define the suitable cold freshwater habitat. Three different criteria were analyzed: a) T ≤ 20°C and DO ≥ 5 mg/L; b) T ≤ 21°C and DO ≥ 5 mg/L; and c) T ≤ 22°C and DO ≥ 5 mg/L. Analysis results of the selected alternatives were compared to those for Baseline and are summarized in Tables 3-10a and 3-10b.

   If the suitable cold freshwater habitat is defined as the water layer that has water temperature ≤ 20°C and DO ≥ 5mg/L, then, compared to Baseline, the three water temperature reduction alternatives selected for analysis (Alternatives 3x, 4a, and 4c) *reduce* the suitable cold freshwater habitat volume of Lake Almanor in August of the normal hydrologic year 2000 and in July, August, and early September of the critical dry year 2001. Alternatives 3x and 4a increase the suitable cold freshwater habitat volume in June through October, except in August, in 2000 and in late September in 2001. Alternative 4c increases the suitable cold freshwater habitat volume in September and October in 2000 and in late September in 2001. The "Present Day" alternative, which is essentially the alternative proposed by PG&E in its license application, also has some effect on the suitable cold freshwater habitat volume relative to Baseline. The effect of the "Present Day" alternative results from the increased Canyon Dam releases from Baseline to those given in the Partial Settlement.

Increased withdrawal of cold water from the hypolimnion of Lake Almanor in summer (e.g., through Prattville thermal curtain and increased Canyon Dam low-level release) has two effects on water temperature and dissolved oxygen (DO) in the lake: 1) it reduces the volume of cold water (compared to Baseline conditions); and 2) it induces the movement of lake bottom water which increases interfacial mixing between hypolimnion water and thermocline water and, in turn, increases DO concentrations in the hypolimnion. So, the net effect on the suitable cold freshwater habitat of a given water temperature reduction alternative depends on the relative reduction in cold water volume and the increase in water volume with DO ≥ 5 mg/L. In June and July, Lake Almanor generally has sufficient cold water volume available for withdrawal and, thus, DO is the limiting factor for determining the incremental change in suitable cold freshwater habitat for a given alternative relative to Baseline conditions. In August, both water temperature and DO are important factors but water temperature appears to be the more limiting factor. In September, depending on the water temperature and the hydrologic condition, either water temperature or DO may be the limiting factor. Generally speaking, by September the ambient air temperature is decreasing and Lake Almanor is subject to mixing as the thermocline begins breaking down. In October, air temperatures have reduced substantially, water temperature in the entire lake is typically cold, so water temperature is not a limiting factor for cold freshwater habitat.

If the temperature criterion of T ≤ 20°C is relaxed to T ≤ 21°C or T ≤ 22°C, the computed absolute volumes of the suitable cold freshwater habitat for the Baseline and the alternatives increase considerably in July and August. The high sensitivity of the suitable cold freshwater habitat volume to the temperature criterion arises from the fact that the top of the Lake Almanor thermocline in summer normally has a water temperature of about 20°C to 22°C. Above the thermocline (or in the epilimnion), where DO ≥ 5 mg/L, a small increase in water temperature can cause a great change in elevation and suitable habitat volume because the water temperature profile in the epilimnion is relatively uniform. On the other hand, given a water temperature criterion, the high incremental change in the suitable habitat volume between an alternative and the Baseline condition may not necessarily mean the alternative has a considerable effect. This is because a small difference in temperature between the alternative and the Baseline condition can cause a considerable change in elevation and suitable habitat volume. So, it is necessary to further examine the water temperature profiles to help identify the cause of the considerable change in the computed suitable habitat volume between the alternative and the Baseline condition.

2) Increasing the release of cold water at the Canyon Dam low-level outlet (Alternative 4c) to 600 cfs or withdrawing cold water at the Prattville Intake through use of a thermal curtain (Alternative 4a) appears to have similar effects on the suitable cold freshwater habitat of Lake Almanor.

3) The CE-QUAL-W2 model, due to its inherent coarseness, is not able to capture the potentially small, isolated “pockets” of cold freshwater habitat that may occur in some local areas.

4) The top of thermocline is defined as the shallowest depth (i.e., highest elevation) where the highest temperature gradient occurs. After careful examination of Lake Almanor temperature profiles at the representative site near Canyon Dam, it was determined that a temperature gradient $\Delta T / \Delta d \geq 0.5$°C/m would be a suitable criterion to identify the top of Lake Almanor thermocline. The analysis results indicate that the three alternatives (Alternatives 3x, 4a, and 4c) could lower the thermocline elevation by up to 3 feet in July and August (in both years 2000 and 2001) when the lake epilimnion water temperature is relatively warm. Although the three alternatives could lower the thermocline elevation by up to 7 feet in September and October in 2000 and by up to 10 feet in September 2001, it may not be a meaningful effect because the lake water temperature at these times is generally cooler than the summer and below 20°C.

5) Metalimnion surface area is defined as the lake-wide surface area at the top of the thermocline. Once the top of thermocline elevation is identified, the metalimnion surface area can be estimated using the lake-wide elevation-surface area curve. The analysis results of Lake Almanor metalimnion surface area indicate that in general, but to varying degrees, the three alternatives (Alternatives 3x, 4a, and 4c) reduce the metalimnion surface area from July to October in both years 2000 and 2001, with highest reduction in September or October. The “Present Day” alternative reduces the metalimnion surface area in October of 2000 and in September and October of 2001. In term of percentage of the metalimnion surface area to total lake surface area, the change between each of the three alternatives (Alternatives 3x, 4a, and 4c) and the Baseline condition is generally within 3% in July and August of year 2000 and 5% in July and August of year 2001.

6) The effect of installing a thermal curtain at the Prattville Intake on the suitable cold freshwater habitat volume in Butt Valley Reservoir is highly correlated to the temperature criterion. If the temperature criterion for the reservoir is set at $T \leq$ 20°C, installing a thermal curtain at the Prattville Intake generally increases the suitable cold freshwater habitat. The increase is due to the low water temperature produced by the Prattville Intake thermal curtain at the Butt Valley PH discharge, which, overall, cools the reservoir and increases the volume of water less than 20°C. Although the Prattville Intake thermal curtain also produces low DO, this is more than offset by its cooling effect, which suggests that water temperature is the more limiting factor under a temperature criterion of $T \leq 20$°C. If the temperature criterion is relaxed to $T \leq 21$°C, depending on the reservoir water temperature and the hydrologic condition, either water temperature or DO may be the limiting factor. If the temperature criterion is relaxed to $T \leq 22$°C, DO would be the limiting factor. Therefore, if the temperature criterion is relaxed to either $T \leq 21$°C or $T \leq 22$°C, measures that increase DO in the Butt Valley PH discharge

to offset the effect of the Prattville Intake thermal curtain on the suitable cold freshwater habitat of Butt Valley Reservoir would be needed.

Table 3-10a Summary of Simulated Lake Almanor Habitat Volume for Different Alternatives and Change in Habitat Volume Relative to Baseline Condition for Different Criteria Defined for Cold Freshwater Habitat

(2000, Normal Hydrologic Year)

Date	Total Reservoir Storage on Date (acre-ft)	Simulated Habitat Volume (acre-ft)					Change in Habitat Volume Relative to Baseline Condition (acre-ft)				% of Habitat Volume to Total Reservoir Storage on Date				
		Baseline	Present Day	Alt 3x	Alt 4a	Alt 4c	Present Day	Alt 3x	Alt 4a	Alt 4c	Base line	Pres. Day	Alt 3x	Alt 4a	Alt 4c
Criteria: Water Temperature ≤ 20°C and DO ≥ 5 mg/L															
May 15	1,011,490	993,600	989,670	989,110	989,110	989,670	-3,930	-4,490	-4,490	-3,930	98%	98%	98%	98%	98%
June 7	1,015,410	876,500	874,470	883,350	881,800	874,470	-2,030	6,850	5,300	-2,030	86%	86%	87%	87%	86%
Jun 22	1,010,250	452,400	449,750	465,600	462,510	449,750	-2,650	13,200	10,110	-2,650	45%	45%	46%	46%	45%
July 7	993,780	216,200	214,940	230,770	227,740	214,950	-1,260	14,570	11,540	-1,250	22%	22%	23%	23%	22%
Jul 20	938,020	145,600	143,790	151,770	148,400	145,040	-1,810	6,170	2,800	-560	16%	15%	16%	16%	15%
Aug 7	913,180	65,000	63,690	63,410	61,150	63,110	-1,310	-1,590	-3,850	-1,890	7%	7%	7%	7%	7%
Aug 17	859,160	44,400	40,910	32,490	35,030	38,240	-3,490	-11,910	-9,370	-6,160	5%	5%	4%	4%	4%
Sep 7	836,720	636,600	639,480	698,340	683,250	661,180	2,880	61,740	46,650	24,580	76%	76%	83%	82%	79%
Sep 28	777,330	607,400	609,130	663,450	649,750	622,960	1,730	56,050	42,350	15,560	78%	78%	85%	84%	80%
Oct 15	761,020	676,200	678,940	712,080	702,680	694,830	2,740	35,880	26,480	18,630	89%	89%	94%	92%	91%
Criteria: Water Temperature ≤ 21°C and DO ≥ 5 mg/L															
May 15	1,011,490	993,550	989,670	989,110	989,110	989,670	-3,880	-4,440	-4,440	-3,880	98%	98%	98%	98%	98%
June 7	1,015,410	876,510	874,470	883,350	881,800	874,470	-2,040	6,840	5,290	-2,040	86%	86%	87%	87%	86%
Jun 22	1,010,250	669,500	659,150	673,510	670,150	659,150	-10,350	4,010	650	-10,350	66%	65%	67%	66%	65%
July 7	993,780	584,410	585,350	598,010	594,810	587,100	940	13,600	10,400	2,690	59%	59%	60%	60%	59%
Jul 20	938,020	228,530	223,930	231,700	227,170	222,930	-4,600	3,170	-1,360	-5,600	24%	24%	25%	24%	24%
Aug 7	913,180	97,120	95,040	98,350	94,350	96,170	-2,080	1,230	-2,770	-950	11%	10%	11%	10%	11%
Aug 17	859,160	69,040	66,590	58,970	58,750	63,710	-2,450	-10,070	-10,290	-5,330	8%	8%	7%	7%	7%
Sep 7	836,720	636,600	639,480	698,340	683,250	661,180	2,880	61,740	46,650	24,580	76%	76%	83%	82%	79%
Sep 28	777,330	607,380	609,130	663,450	649,750	622,960	1,750	56,070	42,370	15,580	78%	78%	85%	84%	80%
Oct 15	761,020	676,160	678,940	712,080	702,680	694,830	2,780	35,920	26,520	18,670	89%	89%	94%	92%	91%
Criteria: Water Temperature ≤ 22°C and DO ≥ 5 mg/L															
May 15	1,011,490	993,550	989,670	989,110	989,110	989,670	-3,880	-4,440	-4,440	-3,880	98%	98%	98%	98%	98%
June 7	1,015,410	876,510	874,470	883,350	881,800	874,470	-2,040	6,840	5,290	-2,040	86%	86%	87%	87%	86%
Jun 22	1,010,250	798,650	798,700	818,190	815,210	798,700	50	19,540	16,560	50	79%	79%	81%	81%	79%
July 7	993,780	743,860	745,570	778,400	775,130	748,270	1,710	34,540	31,270	4,410	75%	75%	78%	78%	75%
Jul 20	938,020	632,400	631,140	661,580	657,470	638,300	-1,260	29,180	25,070	5,900	67%	67%	71%	70%	68%
Aug 7	913,180	144,170	143,320	155,090	149,440	147,300	-850	10,920	5,270	3,130	16%	16%	17%	16%	16%
Aug 17	859,160	458,170	440,650	345,350	342,380	406,800	-17,520	-112,820	-115,790	-51,370	53%	51%	40%	40%	47%
Sep 7	836,720	636,600	639,480	698,340	683,250	661,180	2,880	61,740	46,650	24,580	76%	76%	83%	82%	79%
Sep 28	777,330	607,380	609,130	663,450	649,750	622,960	1,750	56,070	42,370	15,580	78%	78%	85%	84%	80%
Oct 15	761,020	676,160	678,940	712,080	702,680	694,830	2,780	35,920	26,520	18,670	89%	89%	94%	92%	91%

Note: The bold dates have observed profiles.

Table 3-10b Summary of Simulated Lake Almanor Habitat Volume for Different Alternatives and Change in Habitat Volume Relative to Baseline Condition for Different Criteria Defined for Cold Freshwater Habitat

(2001, Critical Dry Hydrologic Year)

Date	Total Reservoir Storage on Date (acre-ft)	Simulated Habitat Volume (acre-ft)					Change in Habitat Volume Relative to Baseline Condition (acre-ft)				% of Habitat Volume to Total Reservoir Storage on Date				
		Baseline	Present Day	Alt 3x	Alt 4a	Alt 4c	Present Day	Alt 3x	Alt 4a	Alt 4c	Base line	Pres. Day	Alt 3x	Alt 4a	Alt 4c
Criteria: Water Temperature ≤ 20°C <u>and</u> DO ≥ 5 mg/L															
May 15	717,310	712,230	709,010	709,010	709,010	709,010	-3,220	-3,220	-3,220	-3,220	99%	99%	99%	99%	99%
June 6	721,260	588,900	585,970	590,050	589,390	585,970	-2,930	1,150	490	-2,930	82%	81%	82%	82%	81%
Jun 22	715,340	210,900	207,400	210,310	207,520	207,400	-3,500	-590	-3,380	-3,500	29%	29%	29%	29%	29%
July 10	702,590	85,420	82,720	84,830	82,900	84,240	-2,700	-590	-2,520	-1,180	12%	12%	12%	12%	12%
Jul 20	695,920	40,870	39,070	35,640	37,090	37,770	-1,800	-5,230	-3,780	-3,100	6%	6%	5%	5%	5%
Aug 9	648,010	360	0	0	0	0	-360	-360	-360	-360	0%	0%	0%	0%	0%
Aug 17	642,460	0	0	0	0	0	0	0	0	0	0%	0%	0%	0%	0%
Sep 12	634,800	490,230	493,040	352,170	463,000	442,000	2,810	-138,060	-27,230	-48,230	77%	78%	55%	73%	70%
Sep 28	625,800	543,700	545,630	575,920	558,700	565,360	1,930	32,220	15,000	21,660	87%	87%	92%	89%	90%
Oct 15	578,400	544,160	541,910	547,750	542,930	547,790	-2,250	3,590	-1,230	3,630	94%	94%	95%	94%	95%
Criteria: Water Temperature ≤ 21°C <u>and</u> DO ≥ 5 mg/L															
May 15	717,310	712,230	709,010	709,010	709,010	709,010	-3,220	-3,220	-3,220	-3,220	99%	99%	99%	99%	99%
June 6	721,260	588,900	585,970	590,050	589,390	585,970	-2,930	1,150	490	-2,930	82%	81%	82%	82%	81%
Jun 22	715,340	326,300	324,330	329,610	326,170	324,330	-1,970	3,310	-130	-1,970	46%	45%	46%	46%	45%
July 10	702,590	137,960	134,360	137,910	134,680	136,420	-3,600	-50	-3,280	-1,540	20%	19%	20%	19%	19%
Jul 20	695,920	74,230	73,060	69,690	68,900	72,360	-1,170	-4,540	-5,330	-1,870	11%	10%	10%	10%	10%
Aug 9	648,010	51,900	49,850	37,100	41,050	43,090	-2,050	-14,800	-10,850	-8,810	8%	8%	6%	6%	7%
Aug 17	642,460	23,260	20,250	8,160	14,730	12,930	-3,010	-15,100	-8,530	-10,330	4%	3%	1%	2%	2%
Sep 12	634,800	505,370	509,840	545,620	524,010	533,150	4,470	40,250	18,640	27,780	80%	80%	86%	83%	84%
Sep 28	625,800	543,700	545,630	575,920	558,700	565,360	1,930	32,220	15,000	21,660	87%	87%	92%	89%	90%
Oct 15	578,400	544,160	541,910	547,750	542,930	547,790	-2,250	3,590	-1,230	3,630	94%	94%	95%	94%	95%
Criteria: Water Temperature ≤ 22°C <u>and</u> DO ≥ 5 mg/L															
May 15	717,310	712,230	709,010	709,010	709,010	709,010	-3,220	-3,220	-3,220	-3,220	99%	99%	99%	99%	99%
June 6	721,260	588,900	585,970	590,050	589,390	585,970	-2,930	1,150	490	-2,930	82%	81%	82%	82%	81%
Jun 22	715,340	544,990	542,240	553,650	550,580	542,240	-2,750	8,660	5,590	-2,750	76%	76%	77%	77%	76%
July 10	702,590	427,730	428,850	426,390	420,380	435,440	1,120	-1,340	-7,350	7,710	61%	61%	61%	60%	62%
Jul 20	695,920	420,180	421,170	410,020	405,990	422,840	990	-10,160	-14,190	2,660	60%	61%	59%	58%	61%
Aug 9	648,010	160,750	153,060	149,100	146,780	152,710	-7,690	-11,650	-13,970	-8,040	25%	24%	23%	23%	24%
Aug 17	642,460	282,590	254,640	103,720	124,360	142,530	-27,950	-178,870	-158,230	-140,060	44%	40%	16%	19%	22%
Sep 12	634,800	505,370	509,840	545,620	524,010	533,150	4,470	40,250	18,640	27,780	80%	80%	86%	83%	84%
Sep 28	625,800	543,700	545,630	575,920	558,700	565,360	1,930	32,220	15,000	21,660	87%	87%	92%	89%	90%
Oct 15	578,400	544,160	541,910	547,750	542,930	547,790	-2,250	3,590	-1,230	3,630	94%	94%	95%	94%	95%

Note: The bold dates have observed profiles.

4.0 FEASIBILITY-LEVEL DESIGN LAYOUTS, OPERATIONAL REQUIREMENTS, AND ESTIMATED COSTS OF LEVEL 3 ALTERNATIVES

This chapter documents the feasibility-level designs, operational requirements, and cost estimates for the measures comprising the UNFFR Project-only alternatives formulated for Level 3 analysis. Cost estimates considered capital cost, annual operation and maintenance (O&M) cost, and annual foregone power generation loss[1]. Capital cost estimates were developed based on unit costs given in Means 2009, budgetary quotes from vendors, and costs derived from Black & Veatch estimates.

To allow for comparison of costs across water temperature alternatives, capital costs were amortized and converted to an equivalent uniform annual cost based on a Fixed Charge Rate (FCR) of 12.25% and useful lives that varied depending on the capital component. The FCR of 12.25% consists of a discount rate of 9% and taxes and insurance of 3.25% which are consistent with the EIS prepared by FERC (FERC, 2005). New facilities, such as thermal curtains[2], modified low-level outlets at Canyon Dam, and the hypothetical hydropower facility below Canyon Dam, were assumed to have useful lives of 50 years.

Annual O&M costs were estimated to be a percentage of capital costs as listed in Table 4-1:

Table 4-1 Percentages Used in Annual O&M Cost Estimates

Facility	O&M Percentage of Capital Cost
Thermal Curtain	1.00%
Low-Level Outlet	0.50%
Hydropower Facility	2.00%

PG&E is a net importer of power, potentially during the high demand summertime period during which the temperature reduction measures would operate, so any forgone power generation resulting from a particular measure must be replaced by purchased power from an outside supplier. Annual foregone power generation loss was estimated based on the potential commensurate flow reduction and/or turbine efficiency reduction in each respective powerhouse resulting from a particular measure, static head of the powerhouse, and normal operating efficiency of the powerhouse turbines. The unit purchase price of \$0.065/KWh[3] was used in the foregone power generation estimates.

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[1] Costs presented in this report are used as an evaluation tool of alternatives and do not reflect profit to PG&E on power and PG&E's ability to recover cost through rate increases.

[2] The Hypalon fabric, used for thermal curtain applications, is a reinforced flexible geomembrane, a synthetic rubber product manufactured into plies that are combined over a reinforcing polyester scrim fabric. It has a demonstrated long life in harsh environments such as industrial wastes, sewage lagoons, and reservoir linings. It resists flexural cracking and abrasion as well as damaging effects of weather and heat.

[3] The use of \$0.06358/KWh purchase price was derived from the FERC EIS (FERC 2005).

Table 4-2 lists static heads and turbine efficiencies that were used in the foregone power generation loss estimates.

Table 4-2 Powerhouse Static Head and Turbine Efficiencies Used in Foregone Power Generation Loss Estimates

Powerhouse	Static Head (ft)	Turbine Efficiency
Butt Valley PH	362	80.6%
Caribou #1 PH	1,151	69.1%
Caribou #2 PH	1,150	84.2%
Oak Flat PH	137	80.1%
Belden PH	770	79.6%
Rock Creek PH	535	85.9%
Cresta PH	290	80.1%
Poe PH	488	78.6%
Bucks Creek PH	2,558	78.1%

4.1 FEASIBILITY-LEVEL DESIGN LAYOUTS, OPERATIONAL REQUIREMENTS, AND ESTIMATED COSTS OF INDIVIDUAL MEASURES COMPRISING THE UNFFR PROJECT-ONLY ALTERNATIVES FORMULATED FOR LEVEL 3 ANALYSIS

The UNFFR Project-only alternatives formulated for this Level 3 analysis include a combination of the following measures at Lake Almanor and Butt Valley Reservoir:

Lake Almanor:

- Install Prattville Intake thermal curtain with removal of submerged levees by dredging;
- Install Prattville Intake thermal curtain without removal of submerged levees;
- Repair/modify Canyon Dam low-level outlet and increase release (and decrease Prattville Intake discharge commensurately).

Butt Valley Reservoir:

- Install a single thermal curtain near Caribou #1 and #2 Intakes;
- Use Caribou #1 preferentially over Caribou #2[4].

In addition to the above measures, constructing a hydroelectric powerhouse below Canyon Dam was considered to partially recover power loss caused by the increased dam release. Note that constructing a hydroelectric powerhouse below Canyon Dam is not a water temperature reduction measure.

The following sections provide detailed descriptions, feasibility-level engineering designs and cost estimates, operational requirements, and discussions for the individual measures comprising the UNFFR Project-only alternatives formulated for this Level 3 analysis.

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[4] Preferential use of Caribou #1 over Caribou #2 is an operational modification measure. It does not require physical modifications. Accordingly, no design was prepared for this measure.

1. Prattville Intake Thermal Curtain and Dredging

Description of Measure: Install a U-shaped “long upper curtain” at Prattville Intake (referred to as curtain #4 in Black and Veatch, 2004a) and dredge the lake bottom to remove levees near the intake area to enhance cool water flow into the intake. The purpose of the thermal curtain is to create a barrier that prevents the flow of warm surface water into the intake. Warm water is retained behind the curtain while cool water is drawn into the intake from the lake bottom through the open area under the curtain.

Description of Operations: This measure does not affect operations. Implement normal operations at Prattville Intake and Butt Valley PH.

Detailed Description of Facilities Improvements and Design Criteria:
To be effective, the curtain must be designed such that the velocities in the open area under the curtain are relatively low, in the range of 0.10 - 0.25 fps. This objective is achieved with a Hypalon fabric curtain approximately 2,570 ft long by 50 ft deep (total area = 108,000 sq ft) extending about 900 ft offshore from the high shoreline. The curtain is “fixed,” meaning that as the lake level fluctuates the level of the lower lip of the curtain, which is set about 5 ft above the lake bottom, remains constant with respect to the lake bottom. In this way, the total open area under the curtain is maintained at the required 5,280 sq ft. Galvanized steel bin-type walls extend about 300 ft offshore from the shoreline and connect to the curtain endpoints. To enhance cool water inflow into the intake, submerged levees that impede cool water flow are removed by dredging about 23,000 cy of lake bottom material comprising the levees.

List of Figures:

Discussion:
Black and Veatch prepared reports for PG&E documenting the design and estimated cost for the thermal curtain at the Prattville Intake (Black and Veatch, 2004a; 2004b). The Black and Veatch report (2004b) also contained modifications prepared in November 2004 which increased the strength of the thermal curtain construction in order to withstand wind and wave forces. Stetson evaluated the design and estimated cost documented in the Black and Veatch reports.

Evaluation of Black and Veatch design

The design size and layout of the fixed U-shaped “long upper curtain” at Prattville Intake in the Black and Veatch 2004 reports were based on results of physical prototype hydraulic model testing at the Iowa Institute of Hydraulic Research (IIHR, 2003). IIHR evaluated six thermal curtains of different sizes and layouts and conducted physical prototype model tests to compare and select the most effective and viable thermal curtain. The most effective thermal curtain configuration was determined to be U-shaped, 900-feet x 770-feet x 900-feet (i.e., curtain #4). The most effective elevation of the curtain bottom was determined to be 4,455 ft (USGS datum). According to IIHR (2004), with the U-shaped long upper curtain in place and with the dredging of submerged levees at the Prattville Intake area, the Butt Valley PH discharge water temperature could be reduced by about 5.8°C and 5.2°C during July and August respectively at its normal operating discharge of 1,600 cfs. Dredging alone would provide about 1.4°C and 1.6°C water temperature reduction at the Butt Valley PH during July and August, respectively, at its normal operating discharge of 1,600 cfs. IIHR also evaluated the effectiveness of installing a submerged hooded pipeline at the existing Prattville Intake to cause colder water to enter the intake. The thermal curtain measure was determined to be more effective.

Stetson concludes that the basis of designing the fixed U-shaped “long upper curtain” at Prattville Intake for controlling the temperature of water entering the intake is technically-sound and acceptable.

<u>Evaluation of Black and Veatch cost estimate</u>

Initially, Black and Veatch estimated the cost of the “long upper curtain” (2,570 ft) and dredging at $8.3 million (2004a). After meeting with PG&E staff and discussing the report and design assumptions, Black and Veatch modified the design to strengthen the curtain against large wave forces and revised the estimated cost to about $17.8 million (2004b). The revision to the estimated cost was due to the modified design, changes in disposal site for the dredging material and other dredging-related costs, changes to costs for scuba diving for installation, prolonging of the construction schedule, and an increase in contingency from 25% to 35%.

In the Level 1 and 2 Report, Stetson reviewed the design concept and evaluated the cost estimate prepared by Black and Veatch against other similar thermal curtain projects. Stetson found that the design and cost estimates prepared by Black and Veatch were reasonable. As part of this feasibility level review, Stetson revisited the design and prepared a current cost estimate for installation of the thermal curtain at the Prattville Intake.

The cost estimates prepared by Black and Veatch had sufficient detail for a feasibility analysis and were mostly based on R.S. Means Heavy Construction Costs 2004. Stetson therefore adjusted these 2004 costs to 2009 costs using the Engineering News Record (ENR) Construction Cost Index (CCI) from June 2004 (index value =7109.40) and March 2009 (index value =8534.05). The ENR CCI increased approximately 20% from June 2004 to March 2009. The estimated cost for the Prattville thermal curtain and dredging in 2009 dollars is approximately $21,338,000. Table 4-3 shows the Black and Veatch opinion of cost of Prattville Intake thermal curtain in 2004 dollars and Table 4-4 shows a summary of the Black and Veatch cost estimate and Stetson’s adjustment to 2009 dollars.

Table 4-3 Black and Veatch Opinion of Cost of Prattville Intake Thermal Curtain #4 and Dredging in 2004 Dollars (2004b)

					Labor						Material		Equipment							
CSI Div. / Sect.	DESCRIPTION	Quantity	Unit	Unit Cost	Crew Code	M-H per Unit	Man Hours	Duration Days	Avg. Wage Rate	Labor Cost	Unit Cost	Material Cost	Code	No.	Avg. Cost ($/hr)	Equipment Cost	Sub-contract	Other	Total Cost	Remarks
1	General Requirements																			
	Mobilization	1	LS	95,515				0.0		0.00		0.00			0.00	0.00		95,515	95,515	
	Supervision	1	LS	349,638				0.0		0.00		0.00			0.00	0.00		349,638	349,638	
	Temporary construction facilities	1	LS	139,855				0.0		0.00		0.00			0.00	0.00		139,855	139,855	
	Temporary utilities	1	LS	104,892				0.0		0.00		0.00			0.00	0.00		104,892	104,892	
	Safety	1	LS	174,819				0.0		0.00		0.00			0.00	0.00		174,819	174,819	
	Miscellaneous	1	LS	139,855				0.0		0.00		0.00			0.00	0.00		139,855	139,855	
	Subtotal Mobilization									0		0				0.00	0	1,004,575	1,004,575	
2	Site Work																			
02240	Dewatering																			
	1 Decant Basin (Excavation And Restoration)	300	CY	16	H	0.246	74	0.6	58.77	4,336.88		0.00	6	4	35.53	349.57			4,686	Excavation & Demo Conc. Basin
	1 Decant Basin (Concrete)	182	CY	249	E	1.499	273	2.3	58.77	16,041.41	112.00	20,390.22	8	2	47.66	867.38	0	8,000	45,299	Other Is Filters for Fines
02300	Earthwork																			
	1 Dredge disposal area prep	1	LS	15,000	A	0.000	0	0.0	55.00	0.00	0.00	0.00				0.00		15,000	15,000	
	1 Dredge Disposal Area Restoration	1	LS	20,000	A	0.000	0	0.0	55.00	0.00	0.00	0.00				0.00		20,000	20,000	
	1 Silt curtains	76,000	SF	1.27	C	0.004	269	11.2	48.33	12,996.00	0.89	67,640.00	3	1	96.65	8,662.91		7,300	96,599	
	1 Dredging	22,750	CY	60	A	0.448	10,200	63.8	55.00	561,000.00	0.00	0.00	1	1	294.12	375,000.20	79,000	360,900	1,375,900	Other is special mob/demob
	1 Crane	1	LS	155,373.81	B	2,040	2,040	63.8	52.00	106,080.00	0.00	0.00	3	1	96.65	49,293.81		0	155,374	Fourth Additional Crane
	2 Bin wall backfill (rock)	3,750	CY	31	A	0.000	0	0.0	55.00	0.00	31.00	116,250.00				0.00		0	116,250	
	1 Skinner Flat - Machine Loading & Hauling 5 Miles	22,750	CY	13.69	H	0.274	6,234	194.8	47.75	297,649.63		0.00	6	4	35.53	13,840.32			311,490	
	1 Skinner Flat - Level Site	22,750	CY	4.17	C	0.082	1,866	77.7	48.33	90,165.83		0.00	7	2	46.00	4,767.39			94,933	
02480	Marine Work																			
	3 Work boat	1	EA	150,000	F	0.000	0	0.0	51.75	0.00	**150,000.00**	150,000.00			0.00	0.00		0	150,000	
	Subcontract For Divers																			
	Curtain Anchors																			
	3 Windward Main Anchors	1	LS	271,397	E	0.000	0	0.0	56.00	0.00	0.00	0.00				0.00	271,397	0	271,397	Was $210K Divers For 53.7 MD
	3 Leeward Main Anchors	1	LS	155,251	E	0.000	0	0.0	56.00	0.00	0.00	0.00				0.00	155,251	0	155,251	Adj. for 39.7 MD $210K Divers
	Bin Walls																			
	3 Water Installation, Including Fill	1	LS	150,000	A	0	0	0.0	55.00	0.00		0.00	1	1	335.81	0.00	150,000	0	150,000	Subcontract for Diving
	Curtain Wall																			
	3 Hypalon Curtain (60 mils)	1	LS	210,000	G	0.000	0	0.0	49.20	0.00	0.00	0.00				0.00	210,000		210,000	Subcontract for Diving
	Subtotal Site Construction						20,955			1,088,270		354,280				452,782	865,648	411,200	3,172,180	
3	Concrete																			
03400	Precast Concrete																			
	Curtain Anchors																			
	4 Windward Main Anchors	1,244	CY	250	E	1.786	2,221	69.4	56.00	124,400.00	150.00	186,600.00				0.00	0	0	311,000	Caissons
	4 Leeward Main Anchors	711	CY	250	E	1.786	1,270	39.7	56.00	71,100.00	150.00	106,650.00				0.00	0	0	177,750	Caissons
	4 Chain Anchors For Bottom Of Curtain	1,444	CY	250	E	1.786	2,579	80.6	56.00	144,400.00	150.00	216,600.00				0.00		0	361,000	Caissons
	Subtotal Concrete						6,070			339,900		509,850				0	0	0	849,750	
5	Metals																			
05050	Basic Materials & Methods																			
	Curtain Anchors																			
	4 Windward Main Anchor Frame	33,600	LBS	2.40	B	0.012	388	12.1	52.00	20,160.26	1.80	60,480.00				0.00		0	80,640	
	4 Leeward Anchor Frames	24,000	LBS	2.40	B	0.012	277	8.7	52.00	14,400.19	1.80	43,200.00				0.00		0	57,600	
	4 Chain Anchors (For BOC) Frames	65,000	LBS	1.80	B	0.012	750	23.4	52.00	38,999.99	1.20	78,000.00				0.00		0	117,000	
	4 Miscellaneous	23,800	LBS	3.20	B	0.015	366	11.4	52.00	19,040.01	2.40	57,120.00				0.00		0	76,160	
05100	Structural Metal Framing																			
	Bin Walls																			
	2 east and west walls	8,400	sf	29	A	0.060	502	7.9	55.00	27,636.00	24.00	201,600.00	1	1	192.58	12,095.56		0	241,332	
	2 Water Installation, Including Fill	1	LS	373,975	A	3,856	3,856	60.3	55.00	212,100.00		0.00	1	1	335.81	161,874.52	0	0	373,975	
	4 Curtain cables (Galv.)																			
	4 Windward Main Anch. To Stabilizing Buoy, 1-1/4" Dia.	5,250	ft	15.63	D	0.070	368	5.7	52.88	19,431.56	11.90	62,475.00	3	0	96.65	138.97		0	82,046	

Table 4-3 Black and Veatch Opinion of Cost of Prattville Intake Thermal Curtain #4 and Dredging in 2004 Dollars (2004b) (Continued)

					Labor						Material		Equipment							
CSI Div. / Sect.	DESCRIPTION	Quantity	Unit	Unit Cost	Crew Code	M-H per Unit	Man Hours	Duration Days	Avg. Wage Rate	Labor Cost	Unit Cost	Material Cost	Code	No.	Avg. Cost ($/hr)	Equipment Cost	Sub-contract	Other	Total Cost	Remarks
	4 Leeward Main Anch. To Stabilizing Buoy, 1-1/8" Dia.	4,200	ft	12.78	D	0.056	235	3.7	52.88	12,436.20	9.80	41,160.00	3	0	96.65	88.94		0	53,685	
	4 Windward Main Anch. To Bottom Tanks, 7/8" Dia.	4,200	ft	8.31	D	0.033	139	2.2	52.88	7,328.48	6.55	27,510.00	3	0	96.65	52.41		0	34,891	
	4 Leeward Main Anch. To Bottom Tanks, 1" Dia.	3,150	ft	10.40	D	0.046	145	2.3	52.88	7,661.59	7.95	25,042.50	3	0	96.65	54.80		0	32,759	
	Curtain chains (1" Extra Strength Galv.)																			
	4 Windward Stabilizing Buoy To Top Tanks	1,050	ft	29.61	D	0.154	162	2.5	52.88	8,557.49	21.41	22,480.50	3	0	96.65	53.30		0	31,091	
	4 Leeward Stabilizing Buoy To Top Tanks	1,050	ft	29.61	D	0.154	162	2.5	52.88	8,557.49	21.41	22,480.50	3	0	96.65	53.30		0	31,091	
	4 Between Top Tanks	390	ft	29.61	D	0.154	60	0.9	52.88	3,178.50	21.41	8,349.90	3	0	96.65	19.80		0	11,548	
	4 Between Bottom Tanks	195	ft	29.61	D	0.154	30	0.5	52.88	1,589.25	21.41	4,174.95	3	0	96.65	9.90		0	5,774	
	4 Anchors To Bottom Tanks	1,950	ft	29.61	D	0.154	301	4.7	52.88	15,892.49	21.41	41,749.50	3	0	96.65	98.05		0	57,740	
	4 Ropes (3/4" Polyester)																			
	4 Top Of Curtain	1,750	ft	2.16	D	0.017	30	0.5	52.88	1,573.03	1.25	2,187.50	3	0	96.65	11.25		0	3,772	
	4 Bottom Of Curtain	1,750	ft	2.16	D	0.017	30	0.5	52.88	1,573.03	1.25	2,187.50	3	0	96.65	11.25		0	3,772	
	Floatable Tanks																			
	4 Top Of Curtain - 15' Long	132	LS	3,186	D	0.000	0	0.0	52.88	0.00	3,186	420,495.54	3		96.65	0.00		0	420,496	
	4 Bottom Of Curtain - 30' Long	66	LS	5,734	D	0.000	0	0.0	52.88	0.00	5,734	378,445.98	3		96.65	0.00		0	378,446	
	Stabilizing buoys																			
	4 Windward Stabilizing Buoys	21	ea	3,290	D	0.000	0	0.0	52.88	0.00	3,136.00	65,856.00	3		96.65	0.00		3,231	69,087	
	4 Leeward Stabilizing Buoys	21	ea	3,290	D	0.000	0	0.0	52.88	0.00	3,136.00	65,856.00	3		96.65	0.00		3,231	69,087	
	2 Trolley Beams At Ends Of Bin Wall	2	ea	17,320	D	6.998	14	0.2	52.88	740.00	13,800.00	27,600.00	1	1	742.85	1,299.55	5,000	0	34,640	
	2 Duct Pipe At Ends of Bin Wall	2	ea	4,420	D	6.998	14	0.2	52.88	740.00	900.00	1,800.00	1	1	742.85	1,299.55	5,000	0	8,840	
	Subtotal Metals						7,828			421,596		1,660,251				177,161	10,000	6,462	2,275,470	
8	Doors																			
089xx	4 Curtain Wall																			
	Hypalon Or XR-5 Curtain (60 mils)	108,000	SF	6.24	G	0.046	5,020	62.7	49.20	246,960.19	2.15	232,200.00	5	4	96.75	194,250.02		1,000	674,410	
	Subtotal Doors						5,020			246,960		232,200				194,250	0	1,000	674,410	
10	Specialties																			
	4 Cable Break Warning Buoys - foam	84	EA	100.00	F	0.000	0	0.0	51.75	0.00	100.00	8,400.00			0.00	0.00		0	8,400	
	4 Marine Warning And Signs Around Curtain	1	LS	12,560.00	F	0.000	0	0.0	51.75	0.00	12,560.00	12,560.00			0.00	0.00		0	12,560	
	Subtotal Specialties						0			0		20,960				0	0	0	20,960	
16	Electrical																			
	4 Off Shore Temporary Floating Lighting	1	LS	36,381				0.0		0.00		0.00			0.00	0.00	36,381		36,381	Subcontract Furnish and Install
	1 On Shore Temporary Lighting	1	LS	29,191				0.0		0.00		0.00			0.00	0.00	29,191		29,191	Subcontract Furnish and Install
	Subtotal Electrical						0			0		0				0	65,572	0	65,572	
17	Instrumentation																			
	4 Trash rack blockage warning system	1	EA	5,000	F	0.000	0	0.0	51.75	0.00	0.00	0.00	4	2	81.29	5,000.00		0	5,000	
	Subtotal Instrumentation						0	0		0		0				5,000	0	0	5,000	
	Construction Subtotal (Direct Costs)						39,872			2,096,725		2,777,542				829,193	941,220	1,423,236	8,067,916	

Indirect Costs			
Sales Tax	8%	of purchased materials	222,203
Overhead and Profit	20%	of construction cost + general requirements	1,613,583
Bonds and Insurance	4%	of construction cost + general requirements + sales tax + overhead and profit	396,148
Escalation	8%	of construction cost	645,433
Contingency	35%	of construction cost + general conditions + sales tax + overhead and profit + bonds and insurance + escalation	3,830,849
Construction Subtotal Indirects			**6,708,217**
Total Construction (directs and Indirects)			**14,776,133**
Permits			50,000
Design	10%	of construction cost	1,477,613
Construction Management	10%	of construction cost	1,477,613
Total			**17,781,359**

Table 4-4 Summary of the Black and Veatch Cost Estimate for the Prattville Intake Thermal Curtain and Dredging in 2004 Dollars (2004b) and Stetson's Adjustment to 2009 Dollars

Item No.	Description	Quantity	Unit	Unit Cost	Man-Hours	Labor Cost	Material Cost	Equipment Cost	Subcontract Cost	Other Cost	**Direct Total Cost**	**Indirects Mark-ups**	**Indirect Total Costs**	**Total**
1	**Dredging**													
	Materials & Methods				20,955	1,088,270	88,030	452,782	108,191	411,200	2,148,473	1.5174	3,260,123	5,408,596
	Subtotal Dredging				20,955	$ 1,088,270	$ 88,030	$ 452,782	$ 108,191	$ 411,200	$ 2,148,473		$ 3,260,123	$ 5,408,596
2	**Bin Wall**													
	Materials & Methods				4,387	241,216	347,250	176,569	10,000	-	775,035	1.5174	1,176,050	1,951,085
	Subtotal Bin Wall				4,387	$ 241,216	$ 347,250	$ 176,569	$ 10,000	$ -	$ 775,035		$ 1,176,050	$ 1,951,085
3	**Marine Work (Diving Work)**													
	Materials & Methods				-	-	150,000	-	786,648	-	936,648	1.5174	1,421,284	2,357,932
	Subtotal Marine Work				0	$ -	$ 150,000	$ -	$ 786,648	$ -	$ 936,648		$ 1,421,284	$ 2,357,932
4	**Curtains**													
	Materials & Methods				14,530	767,240	2,192,261	199,842	36,381	7,462	3,203,186	1.5174	4,860,561	8,063,747
	Subtotal Curtains				14,530	$ 767,240	$ 2,192,261	$ 199,842	$ 36,381	$ 7,462	$ 3,203,186		$ 4,860,561	$ 8,063,747
	Total				**39,872**	**$ 2,096,726**	**$ 2,777,541**	**$ 829,193**	**$ 941,220**	**$ 418,662**	**$ 7,063,342**		**$ 10,718,017**	**$ 17,781,359**

1 ENR construction costs	June 2004 CCI	7109.40	2009 dollars	**$ 21,338,000**
	March 2009 CCI	8534.05		
2 Original Cost estimate prepared by Black and Veatch (2004b)	percent change	20%		

3 The cost for the Prattville Intake thermal curtain only (without dredging) is estimated to be approximately $14,847,000 in 2009 dollars (i.e., ($17,781,359 – $5,408,596)*(1 + 20%) = $14,847,000).

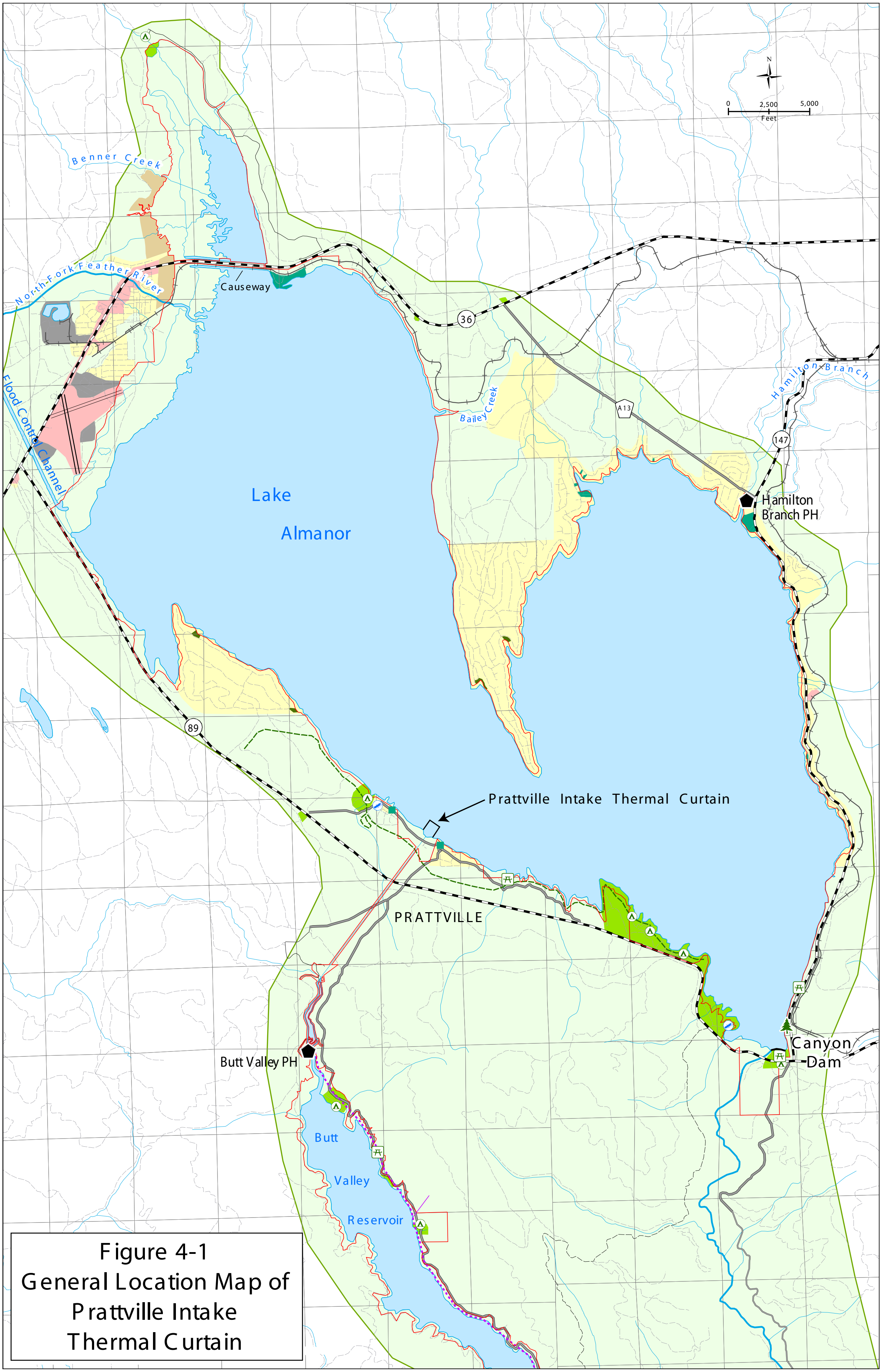
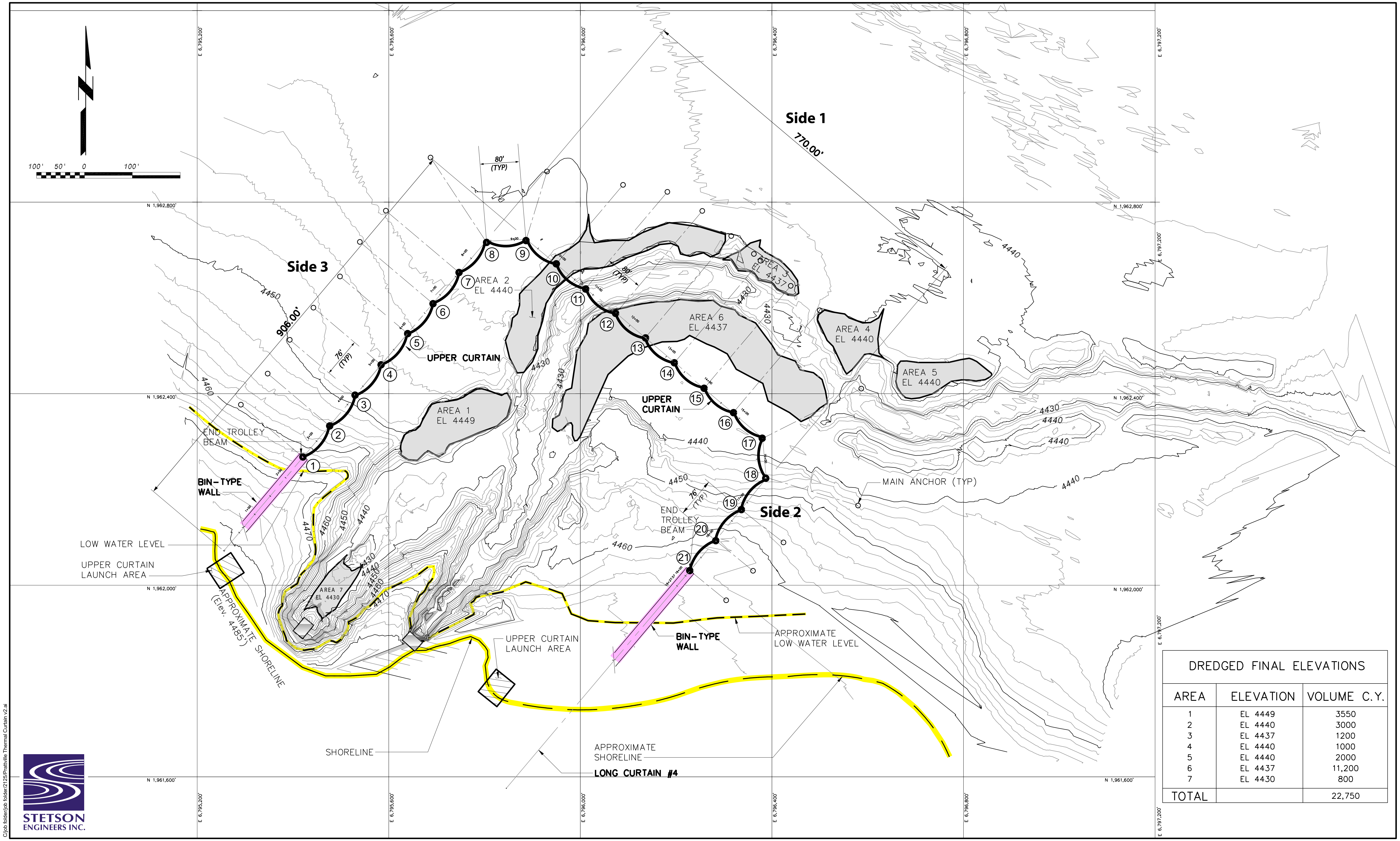


Figure 4-1
General Location Map of
Prattville Intake
Thermal Curtain



DREDGED FINAL ELEVATIONS

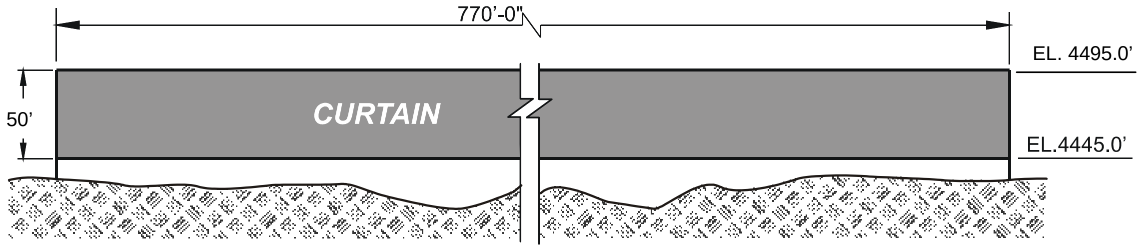
AREA	ELEVATION	VOLUME C.Y.
1	EL 4449	3550
2	EL 4440	3000
3	EL 4437	1200
4	EL 4440	1000
5	EL 4440	2000
6	EL 4437	11,200
7	EL 4430	800
TOTAL		22,750

Figure 4-2: Plan View of Prattville Intake Thermal Curtain Site Layout

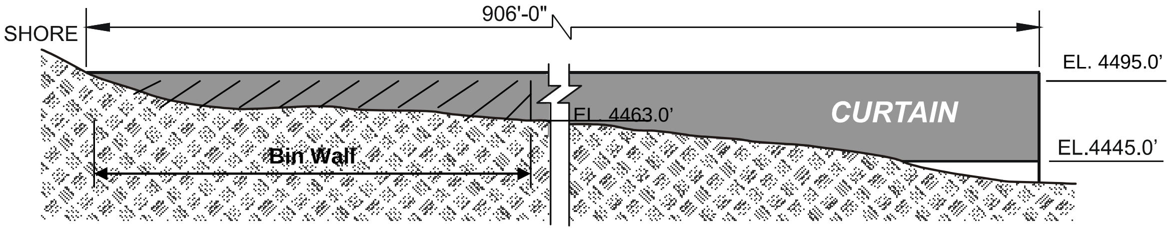
ELEVATIONS ARE PG&E DATUM

HORIZONTAL DATUM IS BASED ON THE CALIFORNIA STATE PLANE
COORDINATE SYSTEM, ZONE 1 (NAD 1983)

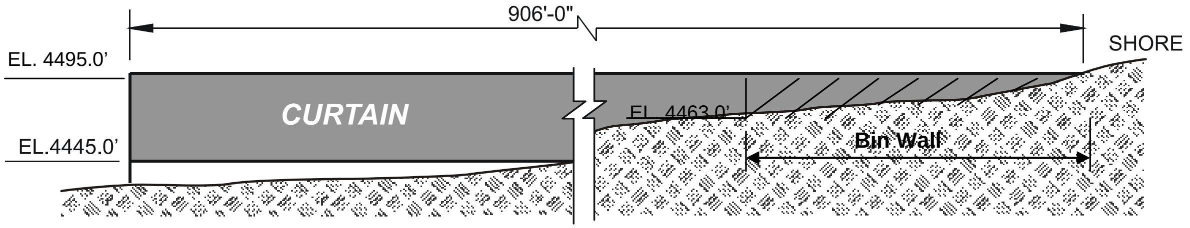
Source: Black & Veatch, 2004: Prattville Intake modifications, Phase 3.



SIDE 1



SIDE 2



SIDE 3

Note: Bin walls extend from the shoreline to where the bottom of the lake is at el. 4463 ft (PG&E datum)

Figure 4-3 Elevation Views of Prattville Intake Thermal Curtain (Curtain #4)

(Adapted from Figure 7-8 of IIHR, 2004)

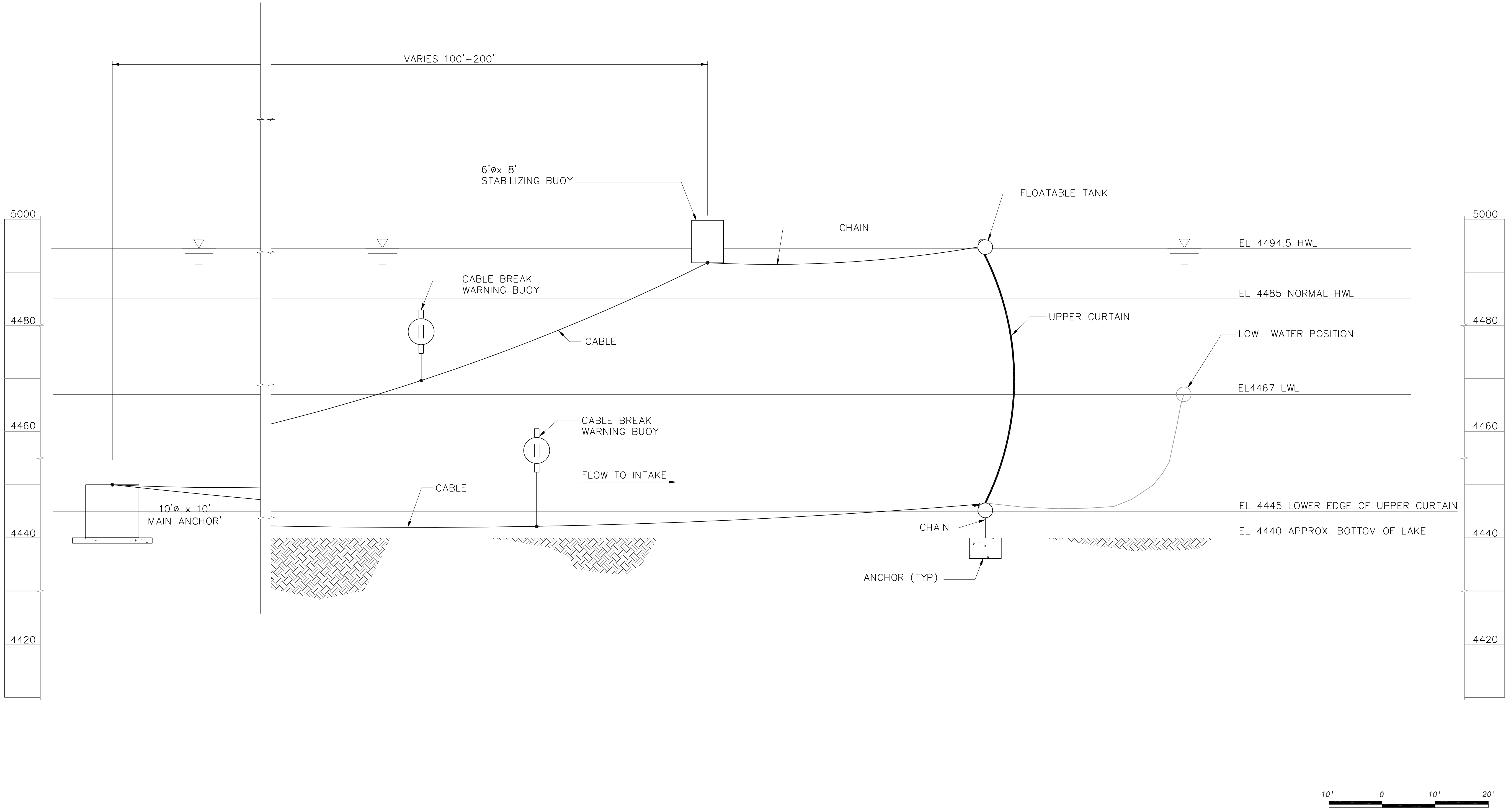


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Figure 4-4: Profile View of Prattville Intake Thermal Curtain

Elevation datum: PG&E datum
Source: Black & Veatch, 2004: Prattville Intake modifications, Phase 3.

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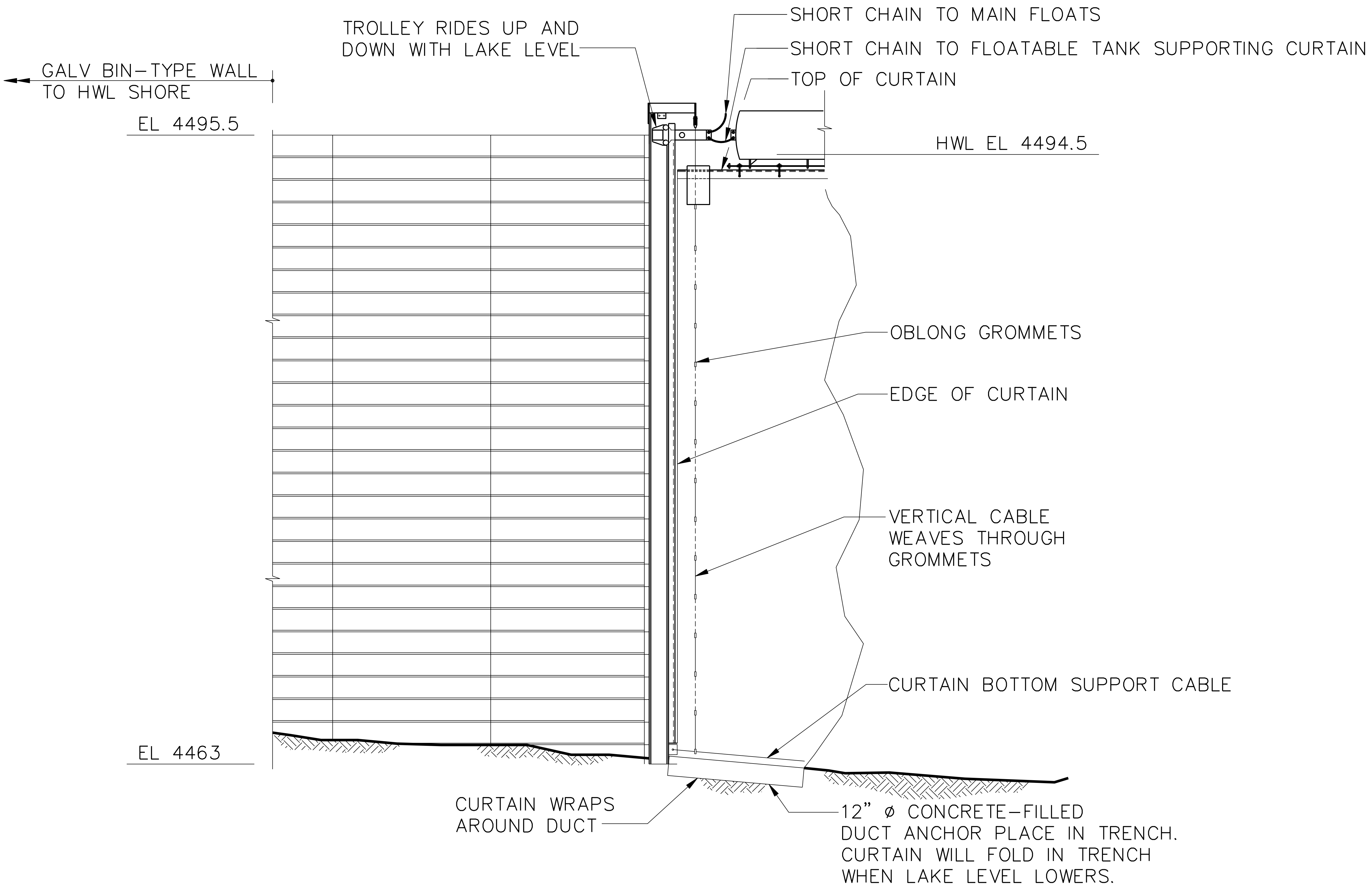

Figure 4-5: Trolley Beam at End of Bin-Type Wall of Prattville Intake Thermal Curtain

Elevation datum: PG&E datum
Source: Black & Veatch, 2004: Prattville Intake modifications, Phase 3.

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2. Modify/Repair Canyon Dam Low-Level Outlet and Increase Release

Description of Measure: Modify/repair the Canyon Dam low-level outlet and increase cool water release from the low-level outlet as needed during the summer. At present, the low-level outlet can safely release up to only 73 cfs. The purpose of this measure is to increase the cool water release from the hypolimnion of Lake Almanor to the NFFR.

Description of Operations: Depending upon the alternative, the release rate of the Canyon Dam low-level outlet ranges from about 60 cfs to 600 cfs. The maximum allowable discharge to avoid potential adverse impacts arising from velocity and scour to aquatic habitat along the Seneca Reach is estimated at about 700 cfs[5]. Increasing Canyon Dam release would require decreasing Prattville Intake release commensurately to avoid lake level fluctuations or changes from the operating rules agreed to in the Partial Settlement Agreement.

High release from the Canyon Dam low-level outlet would cause hydropower generation loss. The feasibility of hydropower generation to recover the foregone power by constructing a powerhouse below Canyon Dam was investigated in this Level 3 analysis.

Detailed Description of Facilities Improvements and Design Criteria:
Modify and repair two (Gates #1 and #5) of the three low level outlets by connecting two pre-fabricated steel bulkheads with built-in slide gates to the existing outlets to enable controllable releases up to 600 cfs. Modifying and repairing Gate #1 only can release up to about 340 cfs.

List of Figures:

- Figure 4-6: Location map of Canyon Dam
- Figure 4-7: Flow Improvement Modifications/ Plan & Sections/ Canyon Dam Intake Tower (intentionally not shown)

Discussion:
The Canyon Dam Intake Tower has three low level outlets gates – Gates #1, #3, #5 – all are set at elevation 4432 ft, about 72 ft below the maximum lake level elevation of 4504

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[5] At 700 cfs, the river stage is approximately at bankfull in the lower half of the Seneca reach near the Seneca Resort and China Bar areas. Flows exceeding about 700 cfs result in over bank flows in this reach (PG&E 2002), which should, therefore, be avoided. Flows between 600 and 700 cfs begin to mobilize spawning gravel and flows greater than 700 cfs can result in significant movement of streambed materials in the Seneca reach (PG&E 2002). Since most trout spawning and egg incubation is completed by July (PG&E 2002), any minor movement of gravel at flows as high as 700 cfs would not disturb fish nests. Habitat area for adult trout increases with flow to near a maximum between 300 and 800 cfs, but it gradually decreases for rearing juvenile trout from a maximum habitat area at about 50 cfs to about 70% of the maximum at 700 cfs (PG&E 2002). However, juvenile trout rearing habitat provided at a flow of 700 cfs would result in about 80% of that provided by the FERC-recommended minimum stream flows during the same season (13,000 ft^2/1000 ft vs. 16,000 ft^2/1000 ft) (PG&E 2002). Although some variable decrease in juvenile rearing habitat area could occur during periods when river temperature management would be needed, it is not likely to limit trout production (Source: Keith. Marine, Fisheries Scientist, NSR, June 8, 2007).

ft USGS datum[6]. These three low level gates are damaged or are in poor condition due to corrosion and long-term hydrostatic loading on the gates and gate-stems. PG&E's inspections revealed bad gate-stems, gate connections, and bolts. In August-October 2005 PG&E did repair work on Gate #5 and rehabilitated the gate and gate-stem connection at a cost of about $860,000 (which included construction costs of $619,000 and indirect costs of $241,000). Gate #5 is the only low level gate that is currently operable, but its operation is limited and it can reliably and safely release only up to about 73 cfs.

To comply with FERC requirements, PG&E is currently investigating the need for additional modifications and repairs to the overall Canyon Dam Outlet Tower and Tunnel Works to address concerns about vibrations during high discharges and outlet capacity limitations. It may be possible to incorporate the modification and repair work to Gates #1 and #5 described herein into this overall workplan.

The concept design for modifying the outlet structure for the Canyon Dam on Lake Almanor was prepared by Black and Veatch. Although the current configuration of the outlet structure is functional and suitable for PG&E's current needs, the purpose of the modification of the outlet structure is to allow greater flexibility and range of flows between 60 cfs and 600 cfs for discharging through the outlet structure to the downstream reaches of the NFFR. In addition, the overall capacity of the system (outlet structure and tunnel) must be maintained so that up to 2,000 cfs can be released for emergency conditions. Stetson has evaluated the modification concept developed by Black and Veatch and developed a cost estimate to perform the work.

The concept design for modifying the outlet structure consists of two components. The first component is rehabilitating Gate #1 in a similar fashion to what was done to Gate #5 in 2005. The second component is to fit Gates #1 and #5 with bulkheads. Each bulkhead would be fitted with various size head gates which could be opened and closed to allow for varying releases from 60 cfs to 600 cfs. These bulkheads would be pre-fabricated offsite and then installed using barges for cranes and diving platforms. The bulkheads would be attached to the existing concrete structure.

Additionally, PG&E staff expressed concern about the existing outlet tunnel[7] and its suitability for continuous discharge of high flows. PG&E has suggested that a liner may need to be installed in the concrete section of the tunnel in order to guard against pressurized flows[8]. While no data was available for Stetson to evaluate the condition of

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[6] There are two additional gates that are set even lower, Gates #2 and #4, at el. 4410. But these two gates are buried under about 20 ft of sediment and are considered unrepairable and permanently inoperable.

[7] The existing low-level outlet facility is comprised of a 115 ft tall vertical tower leading to a 1,350 ft long horseshoe shape tunnel which passes through the earthen Canyon Dam and discharges into the downstream river channel. The upstream portion of the outlet tunnel (about 550 ft long) was steel-lined and the remaining portion is a 10 ft diameter concrete conduit.

[8] According to the physical hydraulic model test results conducted by Northwest Hydraulic Consultants (NHC) in 2006 on flow conditions and air entrainment in the Canyon Dam tunnel under different flow rates

the tunnel and the need for a tunnel liner, Stetson nevertheless investigated the cost of lining the concrete section of the tunnel in the event that this is necessary.

For estimating the rehabilitation cost of the existing Gate #1, PG&E provided Stetson with copies of the cost breakdown associated with the rehabilitation of Gate #5. Using the cost breakdown for the rehabilitation of Gate #5, Stetson estimated the construction cost for similar rehabilitation of Gate #1 at about $619,000 in 2005 dollars. Construction costs were increased by 11% based on the Engineering News Record Construction Cost Index. The estimated construction cost for the Gate #1 rehabilitation is approximately $686,000 in 2009 dollars.

For determining the expected construction costs for the modification of the Canyon Dam outlet structure, Stetson contacted various contractors specializing in underwater construction and fabrication of gate structures. Each contractor provided budget level cost estimates for this work. Where possible, Stetson also compared the budget level costs provided by contractors with costs from the Means Heavy Construction 2009 in order to help confirm that the estimated costs are appropriate. The estimated total cost for modifying the outlet structure is approximately $4,894,000 (Table 4-5).

For the tunnel lining, Stetson contacted several contractors regarding various methods of lining the tunnel. The curved tunnel layout would be difficult to install for rigid lining systems such as steel. The use of steel liners would also require reduction of the tunnel diameter and thus reduce the hydraulic capacity of the tunnel. Costs for construction of a steel liner were not available. Flexible lining systems, on the other hand, have limitations on the maximum velocities that can flow through the tunnel. This issue would need to be examined closer in order to determine whether a flexible liner would be feasible. The estimated total cost for lining the tunnel with a flexible liner is approximately $5,808,000 (Table 4-6). This is based on the costs for installation of a similar flexible liner in PG&E's Belden tunnel.

(60cfs, 600cfs, 800cfs, 1,500cfs, 2,000cfs, and 2,400cfs), at flow rate of 600 cfs, the tunnel is generally open channel flow from the entrance to about 1,150 ft and then fully pressurized flow to the tunnel exit.

Table 4-5 Cost Estimate for Modifying the Canyon Dam Outlet Structure

Description	Quantity	Unit	Unit Cost	**Total Cost**	Remarks
1 General Requirements					
Mobilization	1	LS	19,950	19,950	
Supervision	1	LS	71,250	71,250	
Temporary construction facilities	1	LS	28,500	28,500	Set at same percentage as was used in the Caribou Intake curtain cost estimate.
Temporary utilities	1	LS	21,375	21,375	
Safety	1	LS	35,625	35,625	
Miscellaneous	1	LS	28,500	28,500	
Subtotal General Requirements				$ 205,200	
2 Site Construction					
Installation of #1 & #5 bulkheads (diving, barges & etc)	1	LS	400,000	400,000	Based on email from Aaron of C&W Diving Services.
Modify Existing Trash Racks of #1 & #5	2	EA	200,000	400,000	
Rehab of existing Gate #1	1	EA	686,000	686,000	Based on info from PG&E for rehab of Gate #5.
Subtotal Site Construction				$ 1,486,000	
3 Concrete					
Deck Modifications					
Outlet Deck Additions	1	LS	100,000	100,000	
Subtotal Concrete				$ 100,000	
5 Metals					
Structural Metal Framing					
Bulk Head	23,000	LBS	3.00	69,000	From a metal fabricator
New Trash Racks	2	EA	20,000	40,000	Converted from bulk head work, assuming 1/2 as much iron
Valve stems and structure modification	8	EA	5,000	40,000	Converted from bulk head work, assuming 1/2 as much iron
Subtotal Metals				$ 149,000	
8 Doors					
36" Gate with elec actuator	1	EA	37,000	37,000	Rounded up from quote by Waterman
18" Gate with elec actuator	3	EA	21,000	63,000	Rounded up from quote by Waterman
10" Gate with elec actuator	4	EA	20,000	80,000	Rounded up from quote by Waterman
Subtotal Doors				$ 180,000	
16 Electrical					
Power for motors	1	LS	10,000	10,000	
Subtotal Electrical				$ 10,000	
17 Instrumentation					
Controls for Gates	1	EA	40,000	40,000	
Subtotal Instrumentation				$ 40,000	
Construction Subtotal (Direct Costs)				**$ 2,170,200**	
Indirect Costs					
Sales Tax: 8% purchased materials				104,170	
Overhead and Profit: 20% of construction cost				434,040	Set at same percentage as was used for the Prattville curtain by Black & Veatch.
Bonds and Insurance: 4% of construction cost + sales tax + overhead and profit				108,336	
Escalation: 8% construction cost				173,616	
Contingency: 35% construction cost + sales tax + overhead & profit + bonds & insurance+ escalation				1,046,627	
Construction Subtotal (Direct Costs)				**$ 1,866,789**	
Total Construction (directs and indirects)				**$ 4,036,989**	
Permits				50,000	Set at same percentage as was used for the Prattville curtain by Black & Veatch.
Design: 10% of construction cost				403,699	
Construction Management: 10% of construction cost				403,699	
Total				**$ 4,894,000**	

Table 4-6 Cost Estimate for Lining the Canyon Dam Tunnel with Flexible Liner

	Description	Quantity	Unit	Unit Cost	**Total Cost**
1	**General Requirements**				
	Mobilization	1	LS	16,800	16,800
	Supervision	1	LS	60,000	60,000
	Temporary construction facilities	1	LS	24,000	24,000
	Temporary utilities	1	LS	18,000	18,000
	Safety	1	LS	30,000	30,000
	Miscellaneous	1	LS	24,000	24,000
	Subtotal General Requirements				$ 173,000
2	**Site Construction**				
	Installation of Tunnel Liner	40,200	SF	60	2,412,000
	Subtotal Site Construction				$2,412,000
	Construction Subtotal (Direct Costs)				**$2,585,000**
	Indirect Costs				
	Sales Tax: 8% purchased materials				116,000
	Overhead and Profit: 20% of construction cost				517,000
	Bonds and Insurance: 4% of construction cost + sales tax + overhead and profit				129,000
	Escalation: 8% construction cost				207,000
	Contingency: 35% construction cost + sales tax + overhead & profit + bonds & insurance+ escalation				1,244,000
	Construction Subtotal (Direct Costs)				**$2,213,000**
	Total Construction (directs and indirects)				**$4,798,000**
	Permits				50,000
	Design: 10% of construction cost				480,000
	Construction Management: 10% of construction cost				480,000
	Total				**$5,808,000**

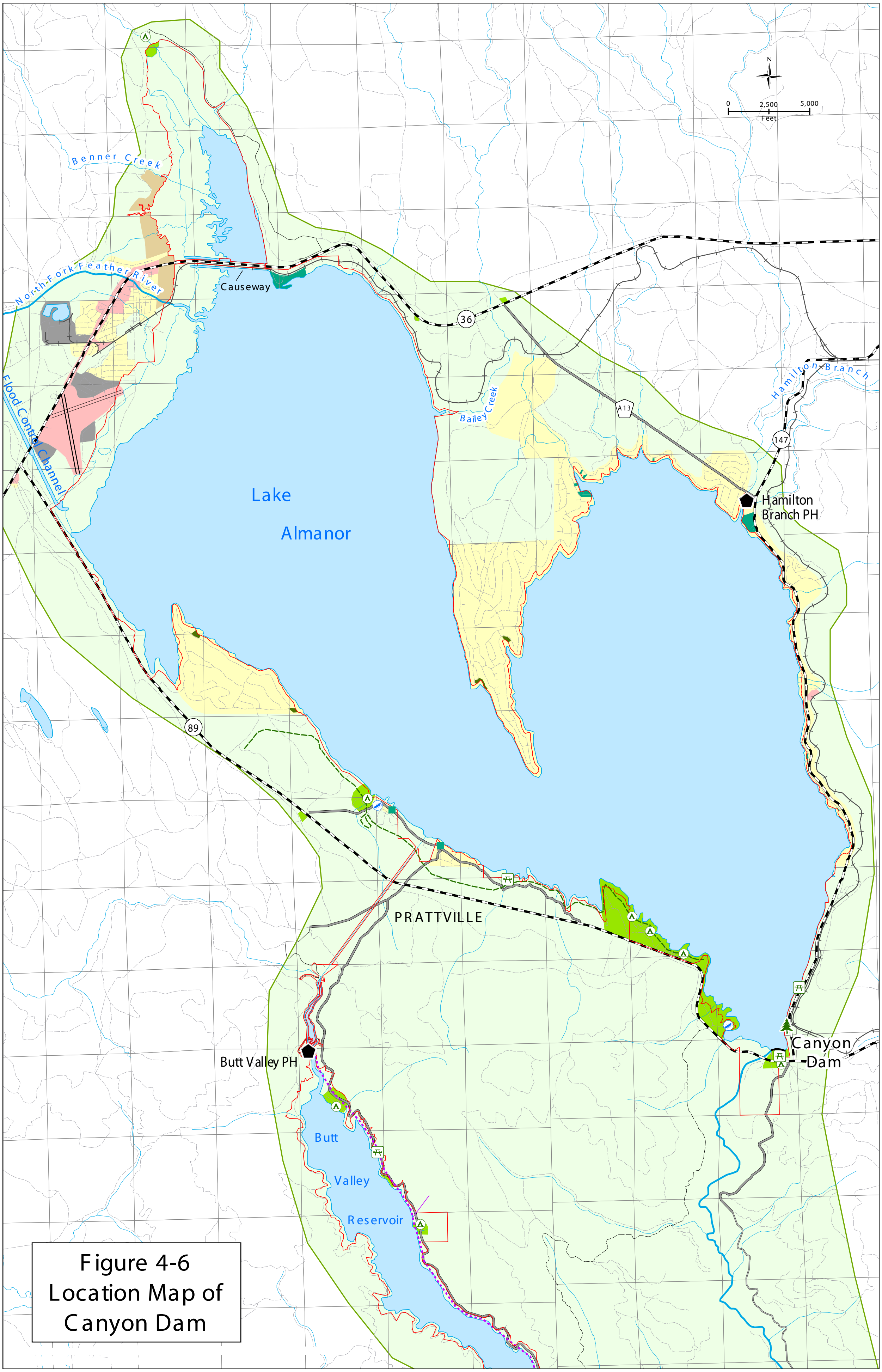

Figure 4-6
Location Map of
Canyon Dam

Figure 4-7: Flow Improvement Modifications/ Plan & Sections/ Canyon Dam Intake Tower

(Intentionally Not Shown)

3. Caribou Intake Thermal Curtain

Description of Measure: Install a fixed Γ-shaped "long upper curtain" near the Caribou Intakes. The purpose of the thermal curtain is to create a barrier that prevents the flow of warm surface water into the intakes. Warm water is retained behind the curtain while cool water is drawn from the lake bottom into the intakes through the open area under the curtain. The Γ-shaped curtain does not affect flow to the spillway at Butt Valley Dam.

Description of Operations: This measure does not affect operations. Implement normal operations at Caribou Intakes and Caribou PHs.

Detailed Description of Facilities Improvements and Design Criteria:
To be effective, the curtain must be designed such that the velocities in the open area under the curtain are relatively low, in the range of 0.10 - 0.25 fps. This objective is achieved with a Hypalon fabric curtain approximately 1,960 ft long by 42 ft deep (total area = 63,000 sq ft) extending about 980 ft offshore from the high shoreline. The curtain is "fixed," meaning that as the reservoir level fluctuates the level of the lower lip of the curtain, which is set about 10 ft above the reservoir bottom, remains constant with respect to the reservoir bottom. In this way, the total open area under the curtain is maintained at the required 5,930 sq ft. Galvanized steel bin-type walls extend about 200 ft offshore from the shoreline and connect to the curtain endpoints.

List of Figures:

Discussion:
Butt Valley Reservoir has a storage capacity of 49,897 acre-feet. Water surface elevations fluctuate by about 10 to 15 feet from the maximum water surface elevation of 4,142 feet (USGS datum) on an annual basis. The reservoir serves as the afterbay to Butt Valley PH and the forebay for the Caribou No.1 and No. 2 PHs. Some additional flow enters Butt Valley Reservoir through Butt Creek and possibly through seepage. Water is delivered to the two Caribou powerhouses through two separate intake structures near Butt Valley Dam and there are no low-level outlets constructed at the dam. The Caribou No. 1 Intake is located at an invert elevation of 4,077 feet (USGS datum) in Butt Valley Reservoir and delivers up to 1,100 cfs to the Caribou #1 PH. The Caribou No. 2 Intake is located in a shallow cove area with an entrance elevation of 4,110 feet (USGS datum) and normally delivers up to 1,460 cfs to the Caribou No. 2 PH. Both Caribou No. 1 and No. 2 PHs discharge to Belden Reservoir located in the NFFR approximately 10 river miles downstream of Canyon Dam Outlet. Caribou No. 2 PH is the preferred generating PH because it has higher turbine efficiency than Caribou No. 1 PH by about 15%.

Historical water temperature measurements indicate that Caribou No. 1 Intake mainly draws cold hypolimnion water while Caribou No. 2 Intake mainly draws warm surface water. To cause Caribou No. 2 Intake to draw cold hypolimnion water, installing a thermal curtain is necessary. Bin-type walls would be constructed at the two ends of the curtain from the high water line to about 30 ft beyond the low water level to reduce localized damage to the curtain arising from water level fluctuations of the reservoir. When the water elevation is drawn down a significant amount of the curtain would be exposed making the curtain vulnerable to damage from vandalism, wind, and debris similar to the conditions observed at the Bureau of Reclamation's Whiskeytown Reservoir in Shasta County. At Whiskeytown, the curtain tore at these exposed curtain locations, was vandalized, and was buried by sand preventing it from floating when the water rose. Similar to Black and Veatch's design for the Prattville Intake thermal curtain, a trolley system is proposed at the end of the bin walls. This system allows the top of the curtain to slide up and down as the water surface varies preventing stresses in the curtain. It prevents the curtain from being exposed and buried in the sand and discourages vandalism. This system also eliminates the periodic maintenance that may be necessary to free the curtain buried by sand and prevents the curtain from floating.

Stetson prepared a conceptual design to construct a thermal curtain in front of the Caribou Intakes in the Butt Valley Reservoir. Using the conceptual design Stetson prepared a cost estimate. This design and cost estimate are based largely on the design and associated cost estimate prepared by Black and Veatch for the Prattville Intake thermal curtain as presented in the Prattville Intake Modifications Phase 3 Feasibility Study – Final Report (Black and Veatch, January 28, 2004) and the associated Attachment 6 dated November 22, 2004.

The plan view of conceptual design is provided in Figure 4-8. It should be noted that the design presented considers less loading for wind and wave compared to the modified design by Black and Veatch for the Prattville Intake thermal curtain. This was deemed reasonable due to the sheltered location of the Butt Valley Reservoir compared to the Prattville Intake at Lake Almanor. The design does, however, use the heavier weight cables, chains, and fasteners included in the conceptual design of the Prattville Intake thermal curtain.

In preparing the design, Stetson took into consideration potential curtain damage at the shore line caused by rising and falling lake levels. This was addressed by using tapered bin walls to hold the curtain end from the high water level to the low water level. The end of the curtain rides up and down on a rail system at the end of each bin wall. Conceptual drawings of the bin walls are included in Figure 4-11. This is the same concept that was applied the Prattville thermal curtain design by Black and Veatch.

Stetson used the Prattville thermal curtain cost estimate prepared by Black and Veatch as the basis for preparing the cost estimate for the Caribou Intakes thermal curtain. Quantities of items were adjusted to reflect the design of the Caribou Intakes Thermal Curtain. Notable differences were as follows:

a) There was no dredging needed for the Caribou Intakes so this cost was eliminated.
b) Anchors were placed at 120 ft intervals as was originally proposed on the Prattville Intake thermal curtain by Black and Veatch (2004a). The modified

design for the Prattville Intake thermal curtain by Black and Veatch had an anchoring space at 80 ft intervals (see Figure 4-2).

c) The size/quantities of the bin walls were reduced since the sides of the Butt Valley reservoir are much steeper than those at Lake Almanor.

Once the quantities were adjusted for the Caribou Intakes thermal curtain, the costs were adjusted from 2004 dollars to March 2009 dollars using the Engineering News Record (ENR) Construction Cost Index (CCI) from the two dates and adjusting the final values by the percent change. The ENR CCI increased approximately 20% from June 2004 to March 2009. The estimated cost for the Caribou Intakes thermal curtain is approximately $8,720,000 (Table 4-7).

The initial design and evaluation of the Prattville Intake thermal curtain prepared by Black and Veatch (2004a) is similar in scope and cost to the Caribou Intakes thermal curtain. The length and height of the curtains are similar and they are both designed for minimal wind and wave forces. At Prattville, however, some dredging is required while at Caribou this is not anticipated. The initial cost estimate for the Prattville Intake thermal curtain was $8.3 million in 2004 dollars which is equivalent to approximately $10 million in 2009 dollars. This is consistent with the estimated cost of $8.7 million (in 2009 dollars) for the Caribou Intakes thermal curtain.

Note that the Caribou Intake thermal curtain design is conceptual, particularly the curtain location and curtain depth. Further analysis would be needed to develop details for the design and operation of the curtain, including physical prototype hydraulic testing and/or detailed mathematical hydrodynamic modeling. The current CE-QUAL-W2 modeling for Butt Valley Reservoir used an internal weir to represent the thermal curtain and the bottom elevation of the internal weir was set at 4100 ft. This elevation is the same bottom elevation of the designed thermal curtain shown in Figure 4-9.

Table 4-7 Cost Estimate for the Caribou Intake Thermal Curtain

CSI Div/	Description	Quantity	Unit	Unit Cost	Total Cost
1	**General Requirements**				
	Mobilization	1	LS	47,758	47,758
	Supervision	1	LS	174,819	174,819
	Temporary construction facilities	1	LS	69,928	69,928
	Temporary utilities	1	LS	52,446	52,446
	Safety	1	LS	87,410	87,410
	Miscellaneous	1	LS	69,928	69,928
	Subtotal General Requirements				$ 502,287
2	**Site Construction**				
	2 Bin Wall Backfill (rock)	1,400	CY	31	43,400
	Marine Work				
	3 Work Boat	1	EA	150,000	150,000
	Subcontract for Divers				-
	Bin Walls				-
	3 Water Installation, Including Fill	1	LS	56,000	56,000
	Subtotal Site Construction				$ 249,400
3	**Concrete**				
	Curtain Anchors				
	4 Windward Main Anchors	830	CY	250	207,500
	4 Chain Anchrs for bottom of curtain (BOC)	960	CY	250	240,000
	Subtotal Concrete				$ 447,500
5	**Metals**				
	Basic Material and Methods				
	Curtain Anchors				
	4 Main Anchor Frame	33,600	LBS	2.40	80,660
	4 Chain Anchors (For BOC) Frames	65,000	LBS	1.80	117,005
	4 Miscellaneous	23,800	LBS	3.20	76,055
	Structural Metal Framing				-
	Bin Walls				-
	2 east and west walls	3,100	sf	29	89,107
	2 Water Installation, including fill	1	LS	139,000	139,000
	Curtain Cables (galv.)				-
	4 Main Anch. To stabilizing buoy, 1-1/4" dia	3,500	ft	15.63	54,698
	4 Main Anch. To bottom tanks, 7/8" dia	2,800	ft	8.31	23,261
	Curtain Chains (1" Extra Strength Galv)				-
	4 Stabilizing Buoy to Top Tanks	700	ft	29.60	20,723
	4 Between Top Tanks	280	ft	29.60	8,289
	4 Between Bottom Tanks	140	ft	29.60	4,145
	4 Anchors to Bottom Tanks	140	ft	29.60	4,145
	Ropes (3/4") Polyester)				-
	4 Top of Curtain	1,615	ft	2.16	3,481
	4 Bottom of Curtain	1,615	ft	2.16	3,481
	Floatable Tanks				-
	4 Top of Curtain - 15' long	108	LS	3,186	344,088
	4 Bottom of Curtain - 30' long	54	LS	5,734	309,636
	Stabilizing Buoys				-
	4 Windward Stabilizing Buoy	14	EA	3,405	47,674
	2 Trolley Beams at ends of Bin Walls	2	EA	17,320	34,640
	2 Duct Pipe at ends of Bin Walls	2	EA	4,420	8,840
	Subtotal Metals				$ 1,368,928
8	**Doors**				
	4 Curtain Wall				
	Hypalon Or XR-5 Curtain (60 mils)	90,000	SF	6.25	562,846
	Subtotal Doors				$ 562,846
10	**Specialties**				
	4 Cable Break Waring Buoys - foam	84	EA	100	8,400
	4 Marine Warning and Signs around Curtian	1	LS	12,560	12,560
	Subtotal Specialties				$ 20,960
17	**Instrumentation**				
	4 Trash rack blockage warning system	1	EA	5,000	5,000
	Subtotal Instrumentation				$ 5,000
	Construction Subtotal (Direct Costs)				**$ 3,156,921**
	Indirect Costs				
	Sales Tax: 8% purchased materials				252,554
	Overhead and Profit: 20% of construction cost				631,384
	Bonds and Insurance: 4% of construction cost + sales tax + overhead and profit				161,634
	Escalation: 8% construction cost				252,554
	Contingency: 35% construction cost + sales tax + overhead & profit + bonds & insurance+ escalation				1,559,266
	Construction Subtotal (Direct Costs)				**$ 2,857,392**
	Total Construction (directs and indirects)				**$ 6,014,313**
	Permits				50,000
	Design: 10% of construction cost				601,431
	Construction Management: 10% of construction cost				601,431
	Total				**$ 7,267,000**

ENR construction costs	
June 2004 CCI	7109.4
March 2009 CCI	8534.05
percent change	20%
March 2009 Budget	**$ 8,720,000**

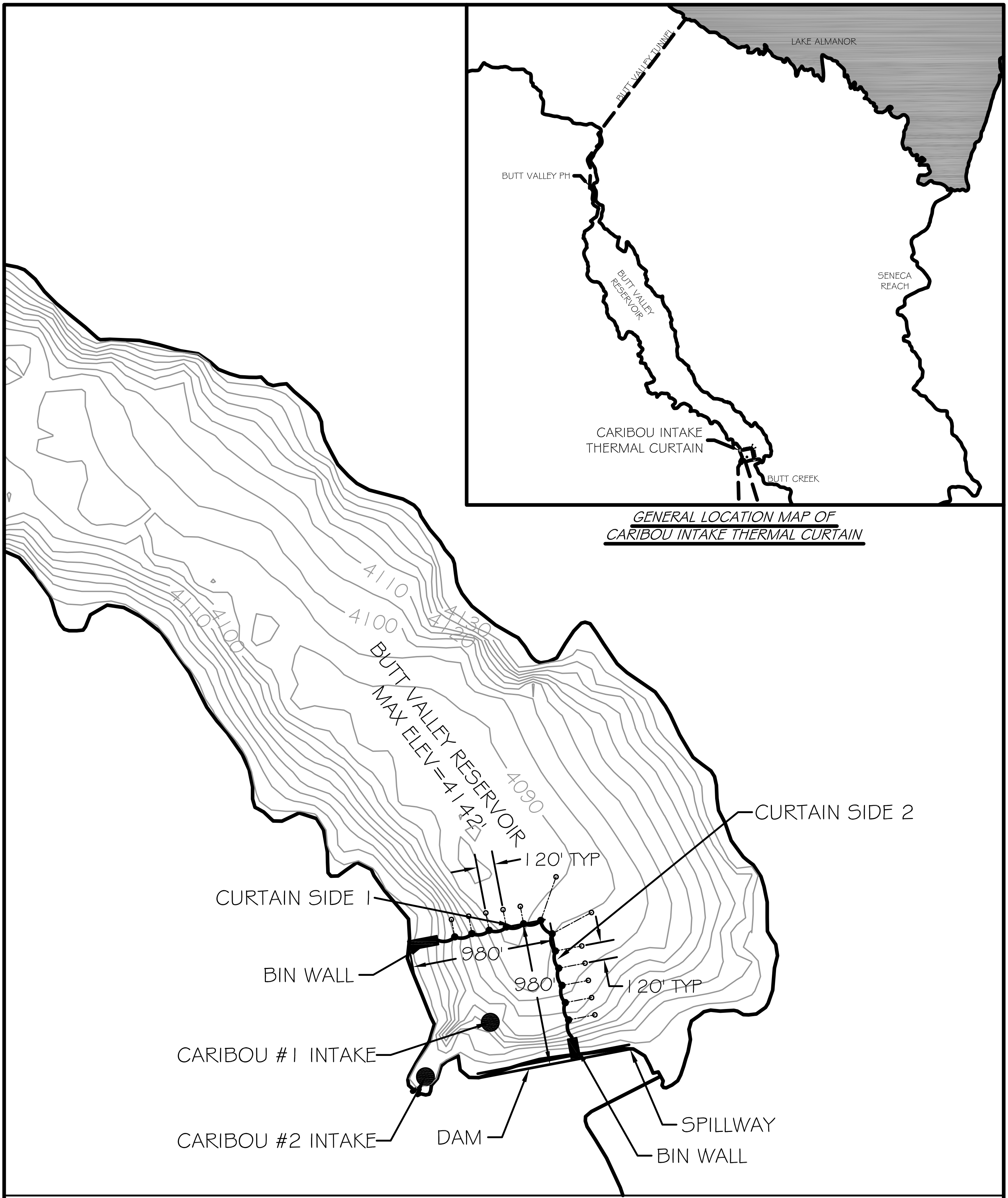

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FIGURE 4-8: PLAN VIEW OF CARIBOU INTAKE THERMAL CURTAIN SITE LAYOUT

SCALE (FEET)
0 450 900 1800

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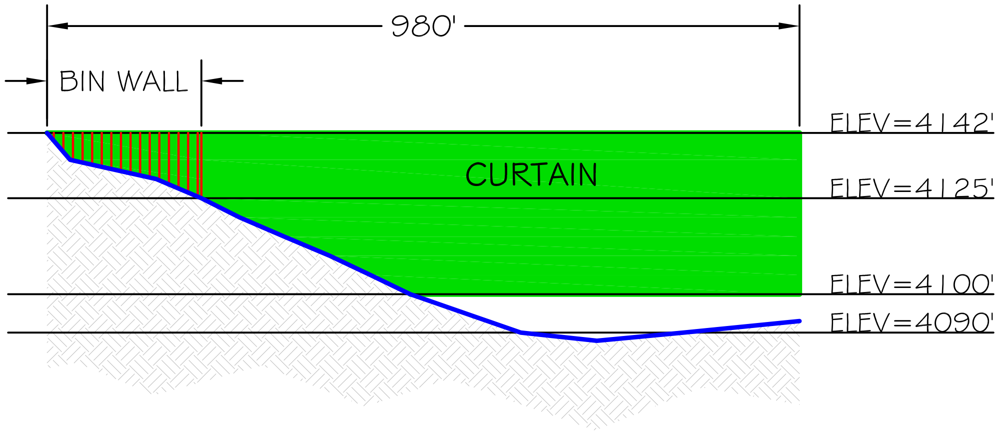

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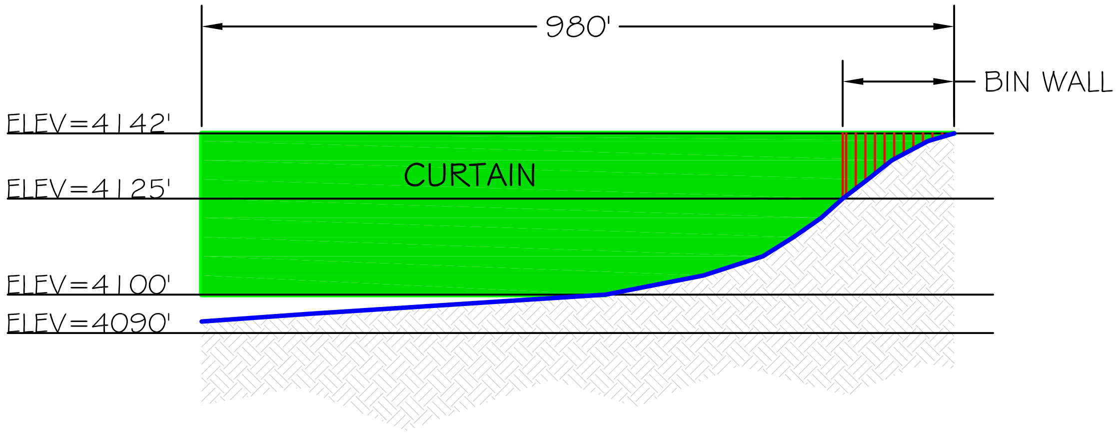

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FIGURE 4-9: ELEVATION VIEW OF CARIBOU INTAKE THERMAL CURTAIN

UPPER FIXED THERMAL CURTAIN

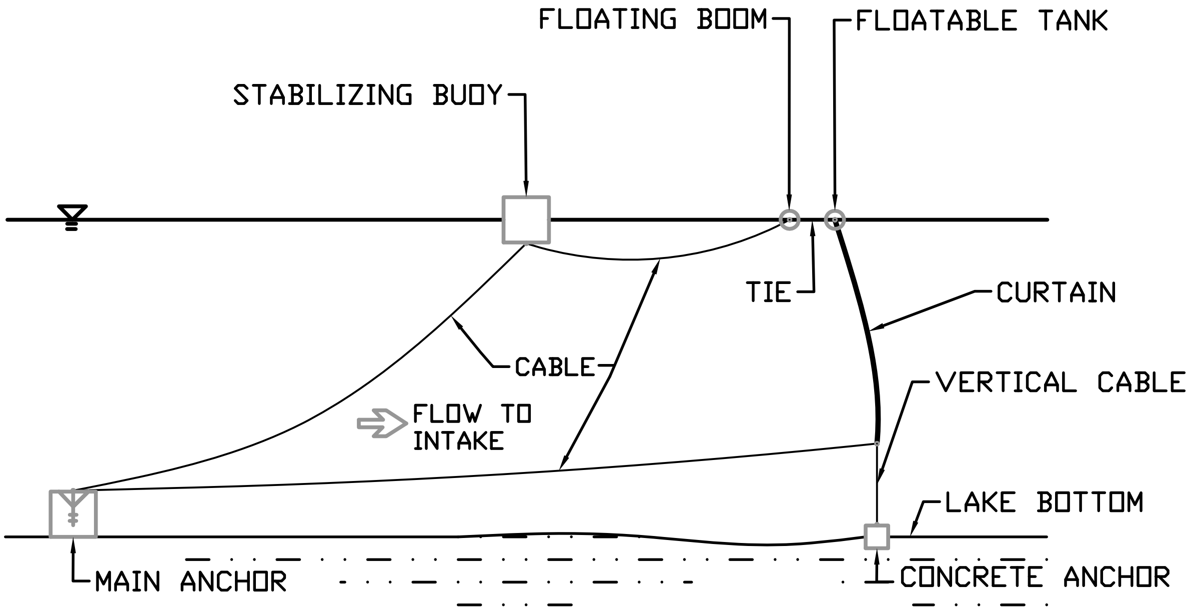

FIGURE 4-10: PLAN VIEW OF CARIBOU INTAKE THERMAL CURTAIN

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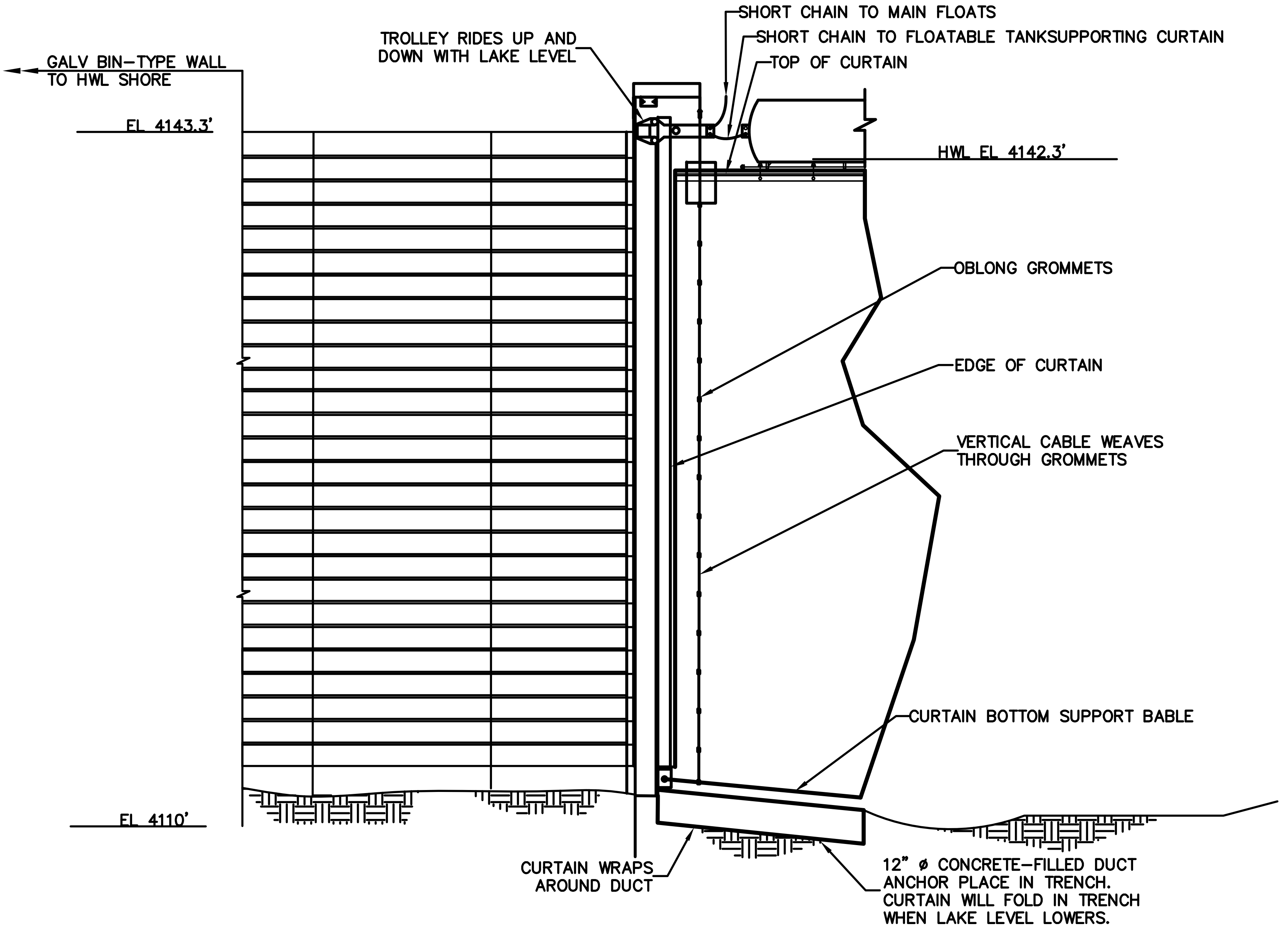
CARIBOU INTAKE MODIFICATIONS

UPPER CURTAIN TIED TO FLOATING BOOM
AND TO LAKE BOTTOM



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CARIBOU INTAKE MODIFICATIONS

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TROLLEY BEAM AT END OF BIN - TYPE WALL

FIGURE 4-11: TROLLEY BEAM AT END OF BIN-TYPE WALL OF CARIBOU INTAKE THERMAL CURTAIN

4. Hypothetical Canyon Dam Outlet Hydroelectric Generation Plant

Description of Project: Investigate the feasibility of installing a hydroelectric generation plant at the discharge at the Canyon Dam Outlet to partially recover the power generation lost due increased low-level releases for NFFR water temperature reduction.

Description of Operations: The range of flow for power generation would be from 60 cfs to 600 cfs with a bypass sized to pass 2,000 cfs under emergency flow conditions. The system was laid out to provide maximum power output which meant sizing the power generation facilities for the maximum flow of 600 cfs.

Detailed Description of Facilities Improvements and Design Criteria:
This project would require construction of the powerhouse, reconfiguration of the tunnel outlet to include a bypass to the powerhouse and connection to the powerhouse, and a transmission line to carry power to the Butt Valley PH or Hamilton Branch PH.

This project would also require that the improvements on the outlet gate structure and the tunnel lining be conducted first in order to provide adequate flow control and stability of the tunnel which would convey the flows to the hypothetical powerhouse. The costs for these additional improvements were discussed under the evaluation of Canyon Dam outlet structure modification.

List of Figures:

- Figure 4-12: View of hypothetical hydroelectric generation plant site below Canyon Dam Outlet
- Figure 4-13: Plan view of hypothetical Canyon Dam hydroelectric generation plant site layout

Discussion:
The total head on the hypothetical powerhouse is approximately 91 feet and was calculated based on the normal maximum water level in Lake Almanor (4504 ft in USGS datum) and the top of the conduit at the existing outlet works (4413 ft in USGS datum). Assuming a system efficiency of 80%, the capacity of the powerhouse would be approximately 3.7 MW at the flow rate of 600 cfs. The maximum annual power generation under Alternatives 3x or 4c is estimated to be about 9.6×10^6 KWh. This is equivalent to $624,000 per year based on the unit power purchase price of $0.065/KWh.

Stetson reviewed costs obtained from the Federal Energy Regulatory Commission (FERC) application for a proposed Pit 3 powerhouse (also a PG&E facility) on Pit River (FERC #233). The proposed Pit 3 powerhouse is comparable to the hypothetical Canyon Dam powerhouse. The proposed Pit 3 powerhouse was sized for 420 cfs at 88 feet of net head and would produce 2.8 MW. The total estimated cost of the Pit 3 powerhouse is approximately $20M. The cost for the hypothetical Canyon Dam powerhouse was calculated based on component costs of the proposed Pit 3 powerhouse. Costs for the hypothetical Canyon Dam powerhouse transmission lines were obtained from publicized sources for transmission lines of the same voltage. The total estimated cost for the hypothetical Canyon Dam powerhouse is approximately $48.9M. A breakdown of these costs is shown in Table 4-8. The amortized annual capital cost is estimated to be about $6,000,000 per year. The amortized annual capital cost is about 10 times higher than the annual power generation benefit.

Table 4-8 Cost Estimate for a Hypothetical Hydroelectric Generation Plant below Canyon Dam

CSI Div/	Description	Quantity	Unit	Unit Cost	Total Cost	Remarks
1	**General Requirements**					
	Mobilization	1	LS	154,000	154,000	
	Supervision	1	LS	550,000	550,000	Set at same percentage as was used in the Caribou Intake curtain cost estimate.
	Temporary construction facilities	1	LS	220,000	220,000	
	Temporary utilities	1	LS	165,000	165,000	
	Safety	1	LS	275,000	275,000	
	Miscellaneous	1	LS	220,000	220,000	
	Subtotal General Requirements				$ 1,584,000	
2	**Site Construction**					
	Structures and Improvemetns	1	LS	3,571,000	3,571,000	Prorated from Pit 3 PH
	Diversion Structure & Tail Race	1	LS	2,100,000	2,100,000	Prorated from Pit 3 PH
	Subtotal Site Construction				$ 3,571,000	
16	**Electrical**					
	Turbine, Generator	1	LS	10,286,000	10,286,000	Prorated from Pit 3 PH
	Switchyard Equipment	1	LS	1,714,000	1,714,000	Prorated from Pit 3 PH
	Transmission Line	6	MI	771,000	4,626,000	
	Subtotal Electrical				$ 16,626,000	
	Construction Subtotal (Direct Costs)				**$ 21,781,000**	
	Indirect Costs					
	Sales Tax: 8% purchased materials				1,045,000	Set at same percentage as was used for the Prattville curtain by Black & Veatch.
	Overhead and Profit: 20% of construction cost				4,356,000	
	Bonds and Insurance: 4% of construction cost + sales tax + overhead and profit				1,087,000	
	Escalation: 8% construction cost				1,742,000	
	Contingency: 35% construction cost + sales tax + overhead & profit + bonds & insurance+ escalation				10,504,000	
	Construction Subtotal (Direct Costs)				**$ 18,734,000**	
	Total Construction (directs and indirects)				**$ 40,515,000**	
	Permits				300,000	Same as Pit 3 PH
	Design: 10% of construction cost				4,052,000	
	Construction Management: 10% of construction cost				4,052,000	
	Total				**$ 48,919,000**	

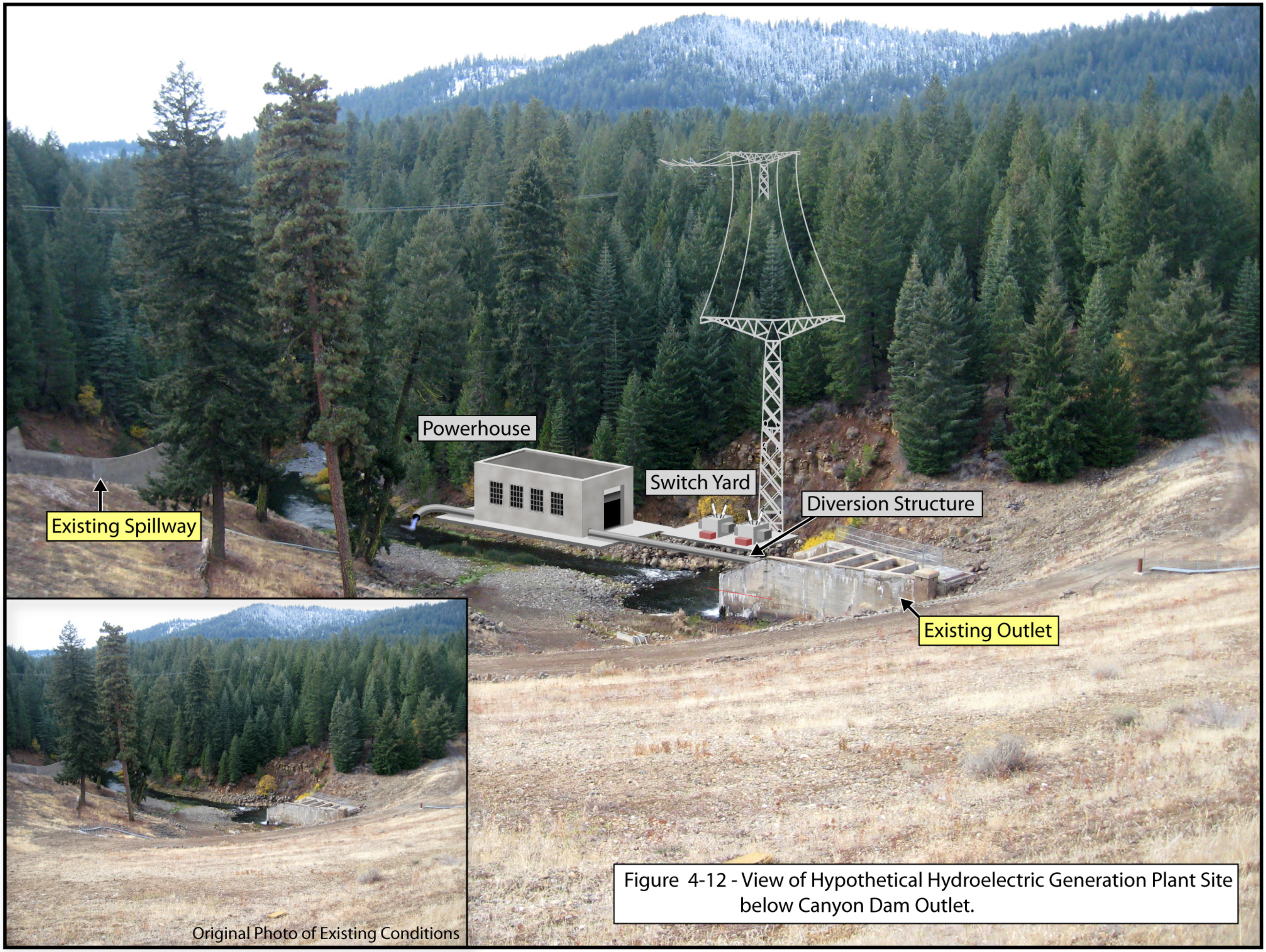
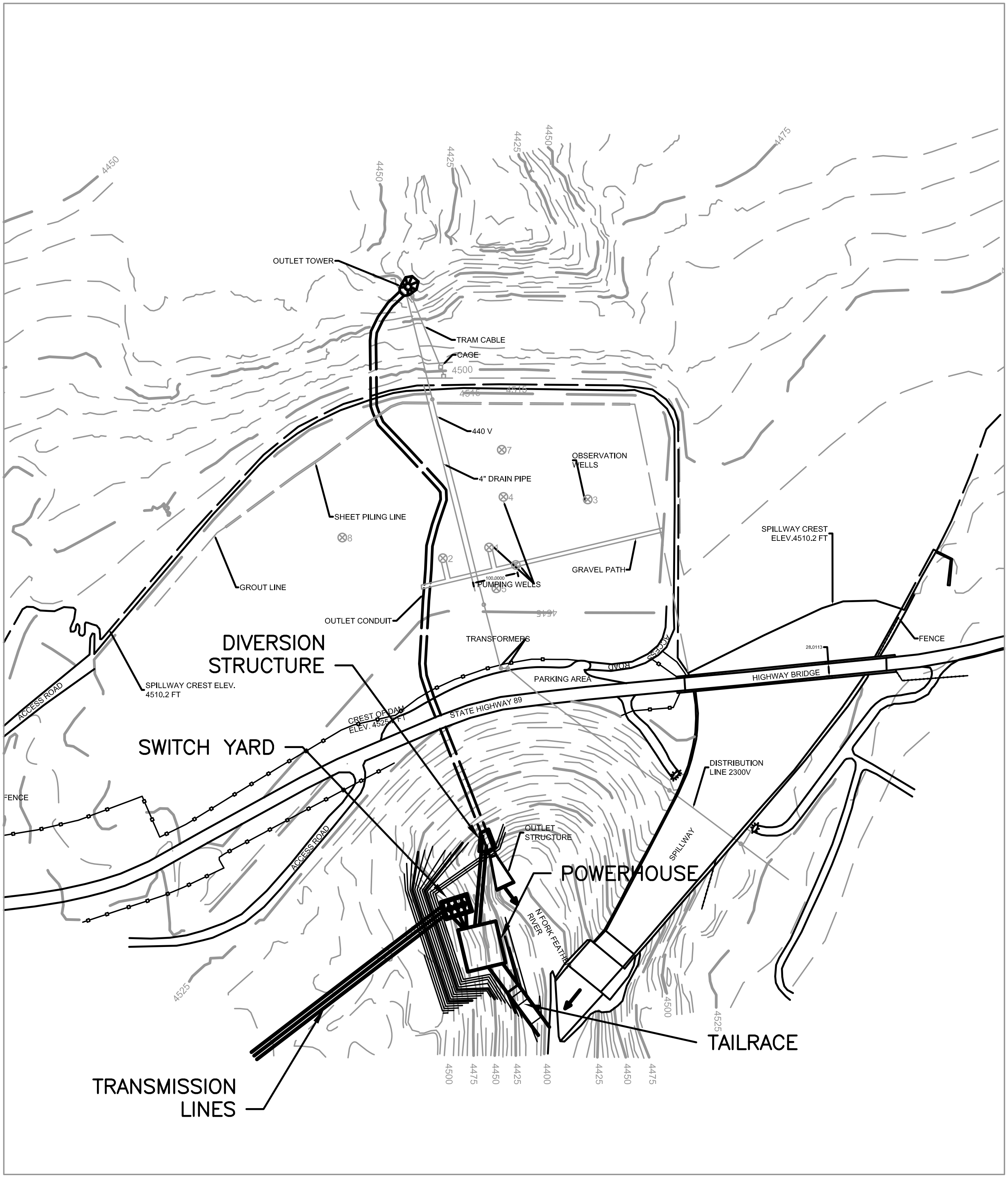


Figure 4-12 - View of Hypothetical Hydroelectric Generation Plant Site below Canyon Dam Outlet.



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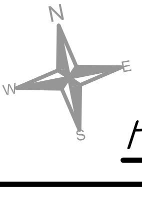


FIGURE 4-13: PLAN VIEW OF
CANYON DAM OUTLET
HYDROELECTRIC PLAN SITE LAYOUT

SCALE (FEET)
0 100 200 400

4.2 ESTIMATED TOTAL COSTS OF LEVEL 3 ALTERNATIVES

Table 4-9 summarizes the estimated total costs of the Level 3 alternatives. The cost estimates derive from the design layouts and detailed descriptions of the individual water temperature reduction measures that comprise the water temperature reduction alternatives. Figures 4-14 and 4-15 compare the estimated capital costs and the annualized costs among the Level 3 alternatives, respectively.

Tables 4-10a and 4-10b summarize the estimated total annualized costs of Level 3 alternatives, the mean daily water temperature reduction benefits in July and August estimated based on the 25% exceedence temperature profiles, and the estimated annualized costs for each degree Celsius water temperature reduction at the points of interest.

Illustrative layouts for the Level 3 alternatives are presented in Figures 4-16 through 4-22. Each figure includes a table summarizing the estimated cost of the alternative and a graph showing the resulting water temperature profile along the NFFR.

Table 4-9 Estimated Costs of Level 3 Alternatives

Alternative	**Measures**	**Capital Cost ($)**	**Annualized Cost ($/year)**				
			Amortized Capital (50 years)	**Annual O&M**	**Foregone Power Generation Loss**		**Total ($/year)**
					KWh ×10^6/ year	**$/year**	
Baseline	None	-	-	-	-	-	**0**
"Present Day"	Modify Canyon Dam Low-Level Outlet to Increase Canyon Dam Release to Those Given in the Partial Settlement	4,894,000	601,000	24,000	47.94 [1]	3,116,000	**3,741,000**
Alternative 3	Install Prattville Intake Thermal Curtain and Remove Submerged Levees	21,338,000	2,622,000	213,000	0.00	0	2,835,000
	Install Caribou Intake Thermal Curtain	8,720,000	1,072,000	87,000	0.00	0	1,159,000
	Modify Canyon Dam Low-Level Outlet to Increase Canyon Dam Release to 250 cfs (in July and August)	4,894,000	601,000	24,000	26.39 [2]	1,715,000	2,340,000
					47.94 [1]	3,116,000	3,116,000
	Total	**34,952,000**	**4,295,000**	**324,000**	**74.33**	**4,831,000**	**9,450,000**
Alternative 3x	Install Prattville Intake Thermal Curtain and Remove Submerged Levees	21,338,000	2,622,000	213,000	0.00	0	2,835,000
	Operate Caribou #1 PH Preferentially	0	0	0	11.32 [3]	736,000	736,000
	Modify Canyon Dam Low-Level Outlet to Increase Canyon Dam Release to 600 cfs (in July and August)	10,702,000	1,315,000	54,000	79.17 [2]	5,146,000	6,515,000
					47.94 [1]	3,116,000	3,116,000
	Total	**32,040,000**	**3,937,000**	**267,000**	**138.43**	**8,998,000**	**13,202,000**
Alternative 4a	Install Prattville Intake Thermal Curtain	14,847,000	1,824,000	148,000	0.00	0	1,972,000
	Install Caribou Intake Thermal Curtain	8,720,000	1,072,000	87,000	0.00	0	1,159,000
					47.94 [1]	3,116,000	3,116,000
	Total	**23,567,000**	**2,896,000**	**235,000**	**47.94**	**3,116,000**	**6,247,000**
Alternative 4b	Install Prattville Intake Thermal Curtain	14,847,000	1,824,000	148,000	0.00	0	1,972,000
	Operate Caribou #1 PH Preferentially	0	0	0	13.91 [3]	904,000	904,000
					47.94 [1]	3,116,000	3,116,000
	Total	**14,847,000**	**1,824,000**	**148,000**	**61.85**	**4,020,000**	**5,992,000**
Alternative 4c	Modify Canyon Dam Low-Level Outlet to Increase Canyon Dam Release to 600 cfs (in July and August)	10,702,000	1,315,000	54,000	79.17 [2]	5,146,000	6,515,000
	Operate Caribou #1 PH Preferentially	0	0	0	11.32 [3]	736,000	736,000
					47.94 [1]	3,116,000	3,116,000
	Total	**10,702,000**	**1,315,000**	**54,000**	**138.43**	**8,998,000**	**10,367,000**
Alternative 4d	Modify Canyon Dam Low-Level Outlet to Increase Canyon Dam Release to 600 cfs (in July and August)	10,702,000	1,315,000	54,000	79.17 [2]	5,146,000	6,515,000
	Install Caribou Intake Thermal Curtain	8,720,000	1,072,000	87,000	0.00	0	1,159,000
					47.94 [1]	3,116,000	3,116,000
	Total	**19,422,000**	**2,387,000**	**141,000**	**127.11**	**8,262,000**	**10,790,000**

1) Foregone power generation loss is due to increased Canyon Dam releases to those given in the Partial Settlement and commensurate flow reductions through the Butt Valley, Caribou #1, and Caribou #2 PHs.

2) Additional foregone power generation loss is due to the increased Canyon Dam release in July and August under the alternative and commensurate flow reductions through the Butt Valley, Caribou #1, and Caribou #2 PHs.

3) Additional foregone power generation loss is due to the lower turbine efficiency of Caribou #1 PH relative to Caribou #2 PH (by about 15%).

Table 4-10a Summary of Total Annualized Costs, Mean Daily Water Temperature Reduction Benefit in July, and Estimated Annualized Costs per Unit Temperature Reduction of Level 3 Alternatives

Alternatives	**Total Annualized Cost [1] ($/year)**	**Mean Daily Water Temperature Reduction Benefit (°C) – July (25% Exceedence Profile)**				**Annualized Cost per Unit Temperature Reduction ($/year/°C)**			
		Belden Reach above East Branch (NF7)	Rock Creek Reach above Bucks Creek (NF12)	Cresta Reach above Cresta PH (NF16)	Poe Reach above Poe PH (NF18)	Belden Reach above East Branch (NF7)	Rock Creek Reach above Bucks Creek (NF12)	Cresta Reach above Cresta PH (NF16)	Poe Reach above Poe PH (NF18)
Alternative 3	9,450,000	2.58	2.09	1.99	1.17	3,663,000	4,522,000	4,749,000	8,077,000
Alternative 3x	13,202,000	4.61	3.80	3.61	2.22	2,864,000	3,474,000	3,657,000	5,947,000
Alternative 4a	6,247,000	1.97	1.60	1.53	0.88	3,171,000	3,904,000	4,083,000	7,099,000
Alternative 4b	5,992,000	2.43	1.97	1.88	1.10	2,466,000	3,042,000	3,187,000	5,447,000
Alternative 4c	10,367,000	3.91	3.23	3.08	1.88	2,651,000	3,210,000	3,366,000	5,514,000
Alternative 4d	10,790,000	3.27	2.71	2.59	1.57	3,300,000	3,982,000	4,166,000	6,873,000

1). Total annualized cost includes amortized annual capital cost, annual O&M cost, and annual foregone power generation loss. Amortized annual capital cost was calculated in 50 years based on a Fixed Charge Rate (FCR) of 12.25%.

Table 4-10b Summary of Total Annualized Costs, Mean Daily Water Temperature Reduction Benefit in August, and Estimated Annualized Costs per Unit Temperature Reduction of Level 3 Alternatives

Alternatives	**Total Annualized Cost [1] ($/year)**	**Mean Daily Water Temperature Reduction Benefit (°C) – August (25% Exceedence Profile)**				**Annualized Cost per Unit Temperature Reduction ($/year/°C)**			
		Belden Reach above East Branch (NF7)	Rock Creek Reach above Bucks Creek (NF12)	Cresta Reach above Cresta PH (NF16)	Poe Reach above Poe PH (NF18)	Belden Reach above East Branch (NF7)	Rock Creek Reach above Bucks Creek (NF12)	Cresta Reach above Cresta PH (NF16)	Poe Reach above Poe PH (NF18)
Alternative 3	9,450,000	2.24	1.88	1.81	1.13	4,219,000	5,027,000	5,221,000	8,363,000
Alternative 3x	13,202,000	3.17	2.73	2.63	1.65	4,165,000	4,836,000	5,020,000	8,001,000
Alternative 4a	6,247,000	1.44	1.16	1.13	0.69	4,338,000	5,385,000	5,528,000	9,054,000
Alternative 4b	5,992,000	1.52	1.24	1.20	0.74	3,942,000	4,832,000	4,993,000	8,097,000
Alternative 4c	10,367,000	2.65	2.27	2.19	1.38	3,912,000	4,567,000	4,734,000	7,512,000
Alternative 4d	10,790,000	2.56	2.18	2.10	1.32	4,215,000	4,950,000	5,138,000	8,174,000

1). Total annualized cost includes amortized annual capital cost, annual O&M cost, and annual foregone power generation loss. Amortized annual capital cost was calculated in 50 years based on a Fixed Charge Rate (FCR) of 12.25%.

Figure 4-14 Comparison of Capital Cost among Level 3 Alternatives

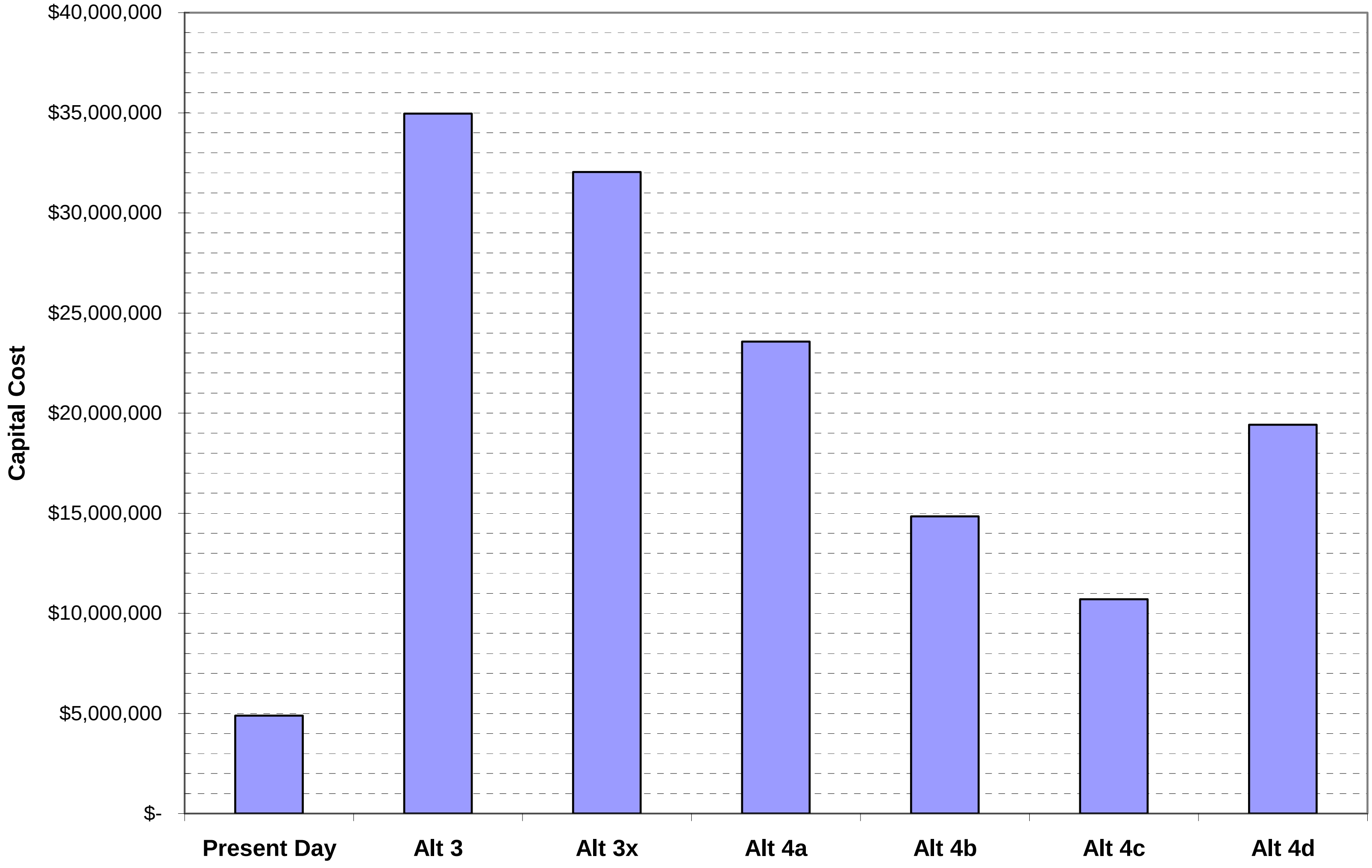
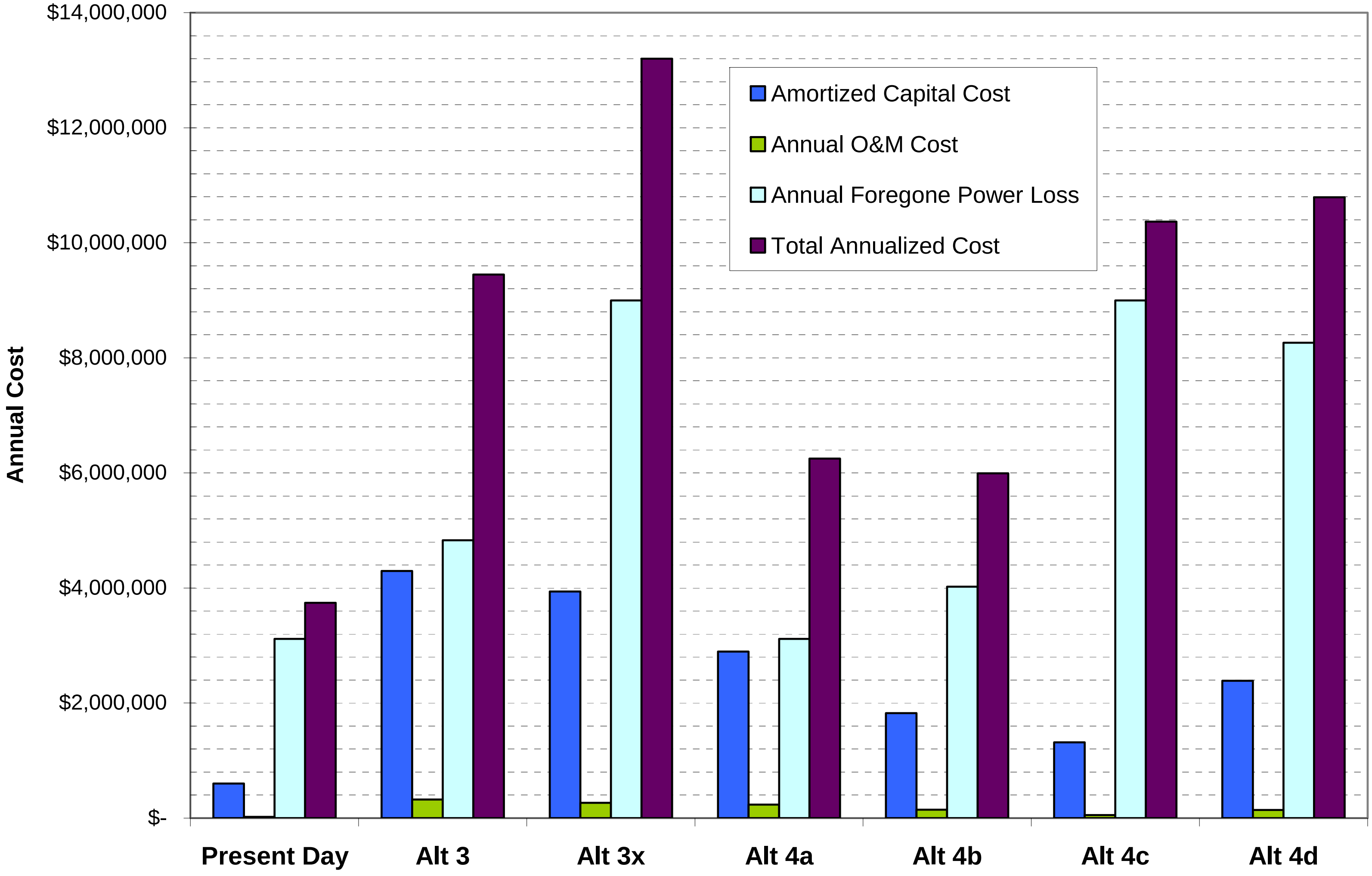


Figure 4-15 Comparison of Annualized Cost among Level 3 Alternatives



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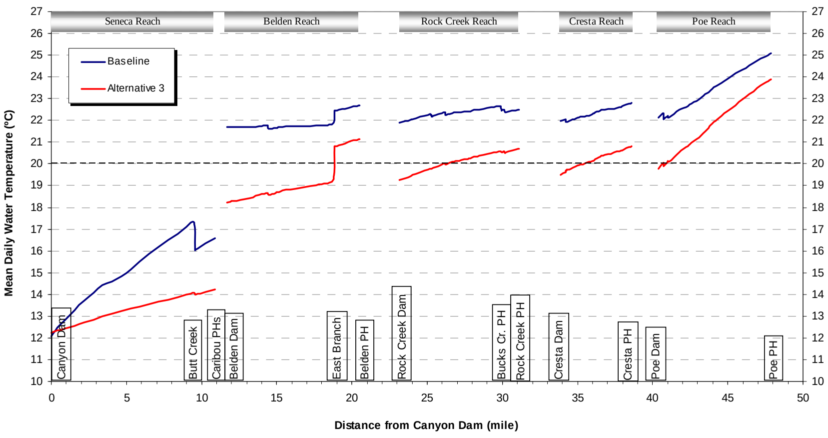
① INSTALL PRATTVILLE INTAKE THERMAL CURTAIN AND REMOVE SUBMERGED LEVEES

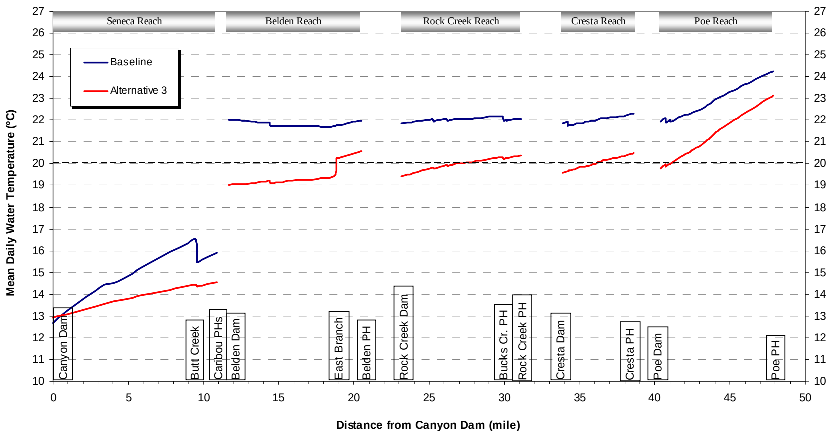
② MODIFY CANYON DAM LOW-LEVEL OUTLET TO INCREASE CANYON DAM RELEASE TO 250 CFS

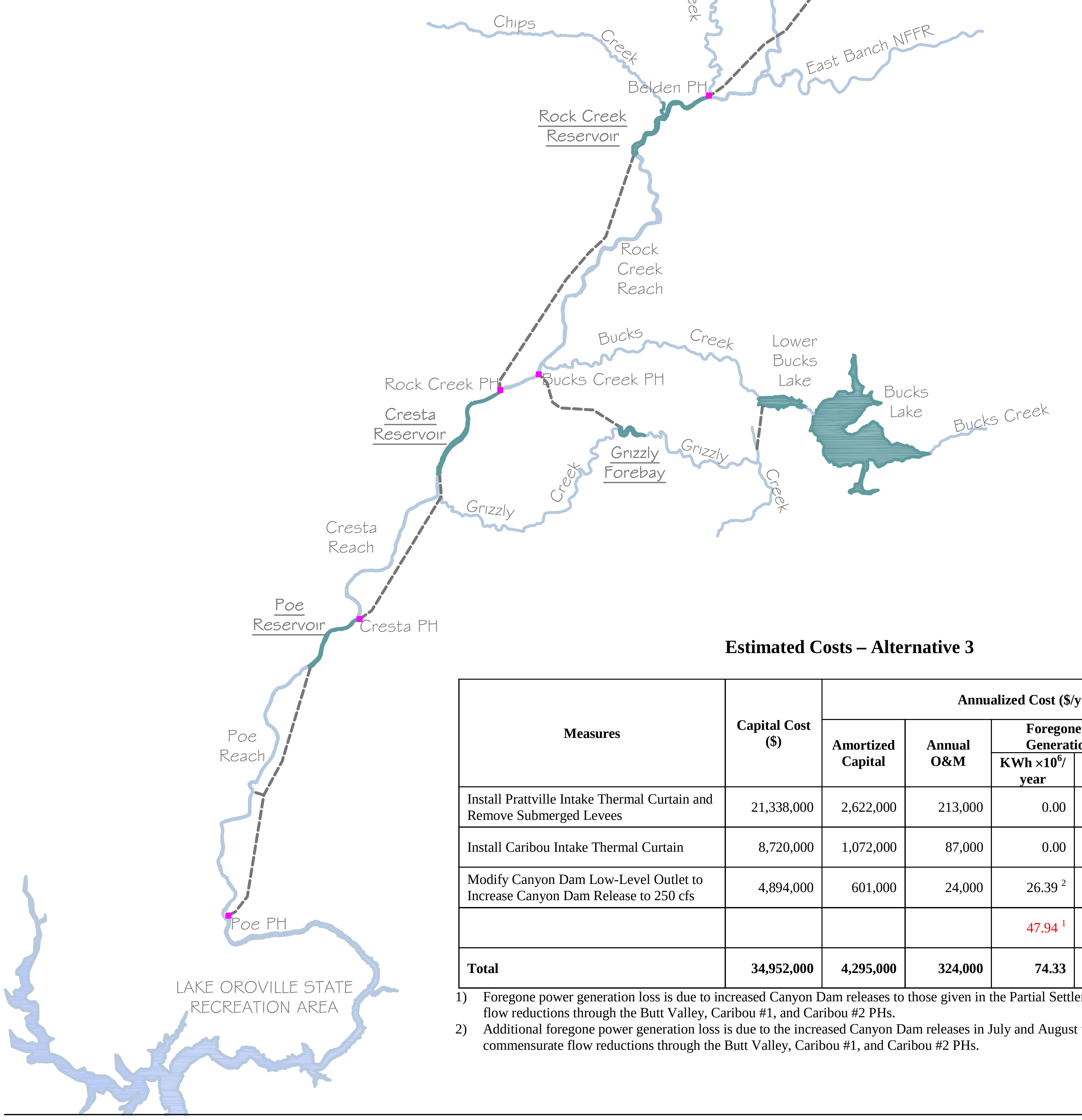
③ INSTALL CARIBOU INTAKE THERMAL CURTAIN

Mean Daily Temperature Profile along NFFR
July, 25% Exceedance
Comparison between Baseline and Alternative 3



Mean Daily Temperature Profile along NFFR
August, 25% Exceedance
Comparison between Baseline and Alternative 3





Estimated Costs – Alternative 3

Measures	Capital Cost ($)	Annualized Cost ($/year)				
		Amortized Capital	Annual O&M	Foregone Power Generation Loss		Total ($/year)
				KWh $\times 10^6$/ year	$/year	
Install Prattville Intake Thermal Curtain and Remove Submerged Levees	21,338,000	2,622,000	213,000	0.00	0	2,835,000
Install Caribou Intake Thermal Curtain	8,720,000	1,072,000	87,000	0.00	0	1,159,000
Modify Canyon Dam Low-Level Outlet to Increase Canyon Dam Release to 250 cfs	4,894,000	601,000	24,000	26.39 [2]	1,715,000	2,340,000
				47.94 [1]	3,116,000	3,116,000
Total	**34,952,000**	**4,295,000**	**324,000**	**74.33**	**4,831,000**	**9,450,000**

1) Foregone power generation loss is due to increased Canyon Dam releases to those given in the Partial Settlement and commensurate flow reductions through the Butt Valley, Caribou #1, and Caribou #2 PHs.
2) Additional foregone power generation loss is due to the increased Canyon Dam releases in July and August under the alternative and commensurate flow reductions through the Butt Valley, Caribou #1, and Caribou #2 PHs.

LEGEND
➡ COOL WATER INFUSION
— STREAM
- - POWERHOUSE CONDUIT
■ POWERHOUSE (PH)

NOTES:
1. SOURCE: USGS 7.5 MINUTE QUADRANGLE MAPS (PROJECTION: STATE PLANE NAD83 CALIFORNIA ZONE I IN FEET)
2. UNFFR: UPPER NORTH FORK FEATHER RIVER

SCALE (MILES)
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FIGURE 4-16

ALTERNATIVE 3

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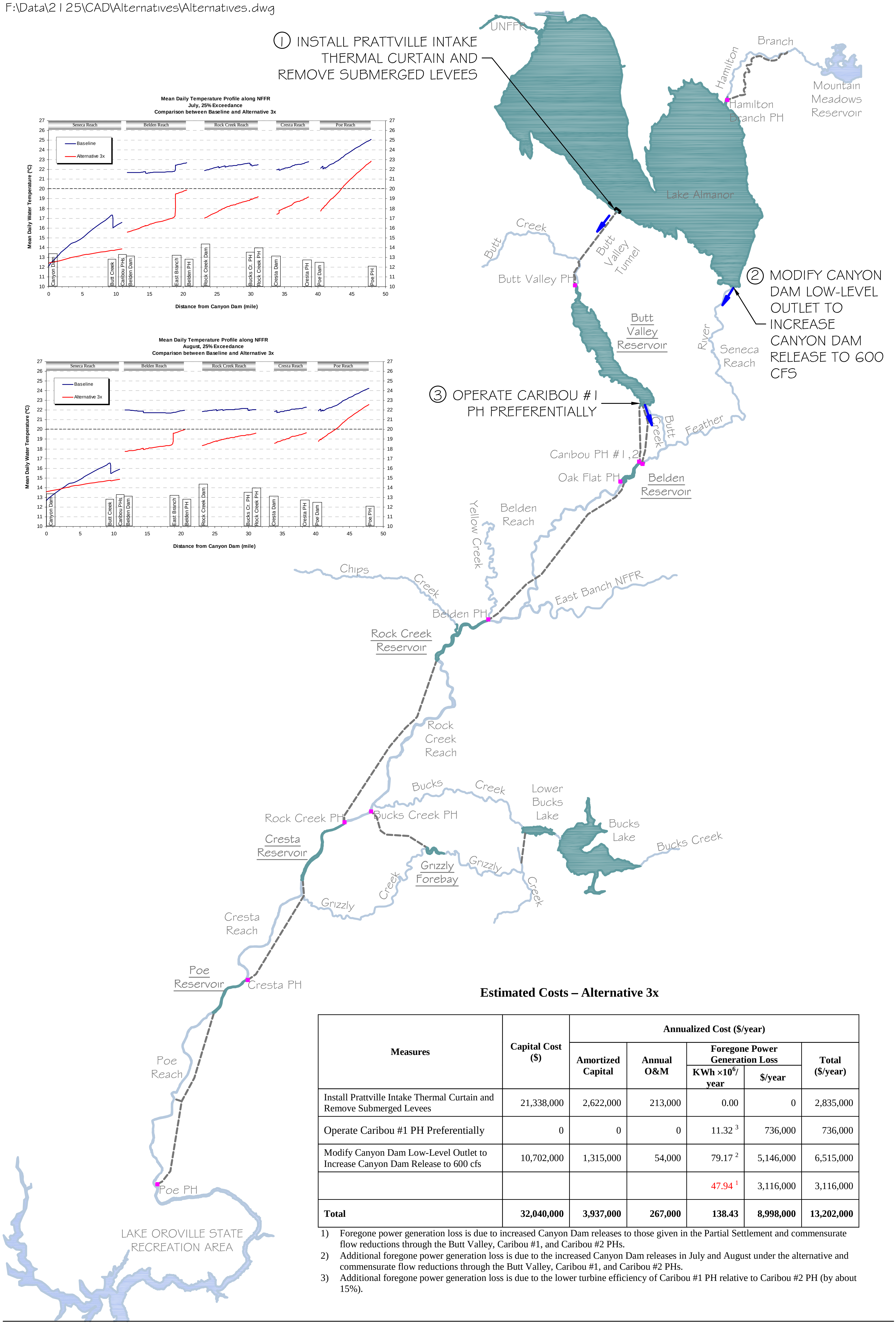

Estimated Costs – Alternative 3x

Measures	Capital Cost ($)	Annualized Cost ($/year)				
		Amortized Capital	Annual O&M	Foregone Power Generation Loss		Total ($/year)
				KWh ×10^6/ year	$/year	
Install Prattville Intake Thermal Curtain and Remove Submerged Levees	21,338,000	2,622,000	213,000	0.00	0	2,835,000
Operate Caribou #1 PH Preferentially	0	0	0	11.32 [3]	736,000	736,000
Modify Canyon Dam Low-Level Outlet to Increase Canyon Dam Release to 600 cfs	10,702,000	1,315,000	54,000	79.17 [2]	5,146,000	6,515,000
				47.94 [1]	3,116,000	3,116,000
Total	**32,040,000**	**3,937,000**	**267,000**	**138.43**	**8,998,000**	**13,202,000**

1) Foregone power generation loss is due to increased Canyon Dam releases to those given in the Partial Settlement and commensurate flow reductions through the Butt Valley, Caribou #1, and Caribou #2 PHs.
2) Additional foregone power generation loss is due to the increased Canyon Dam releases in July and August under the alternative and commensurate flow reductions through the Butt Valley, Caribou #1, and Caribou #2 PHs.
3) Additional foregone power generation loss is due to the lower turbine efficiency of Caribou #1 PH relative to Caribou #2 PH (by about 15%).

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FIGURE 4-17

ALTERNATIVE 3X

LEGEND

➡	COOL WATER INFUSION
━	STREAM
╍	POWERHOUSE CONDUIT
■	POWERHOUSE (PH)

NOTES:

1. SOURCE: USGS 7.5 MINUTE QUADRANGLE MAPS (PROJECTION: STATE PLANE NAD83 CALIFORNIA ZONE I IN FEET)
2. UNFFR: UPPER NORTH FORK FEATHER RIVER

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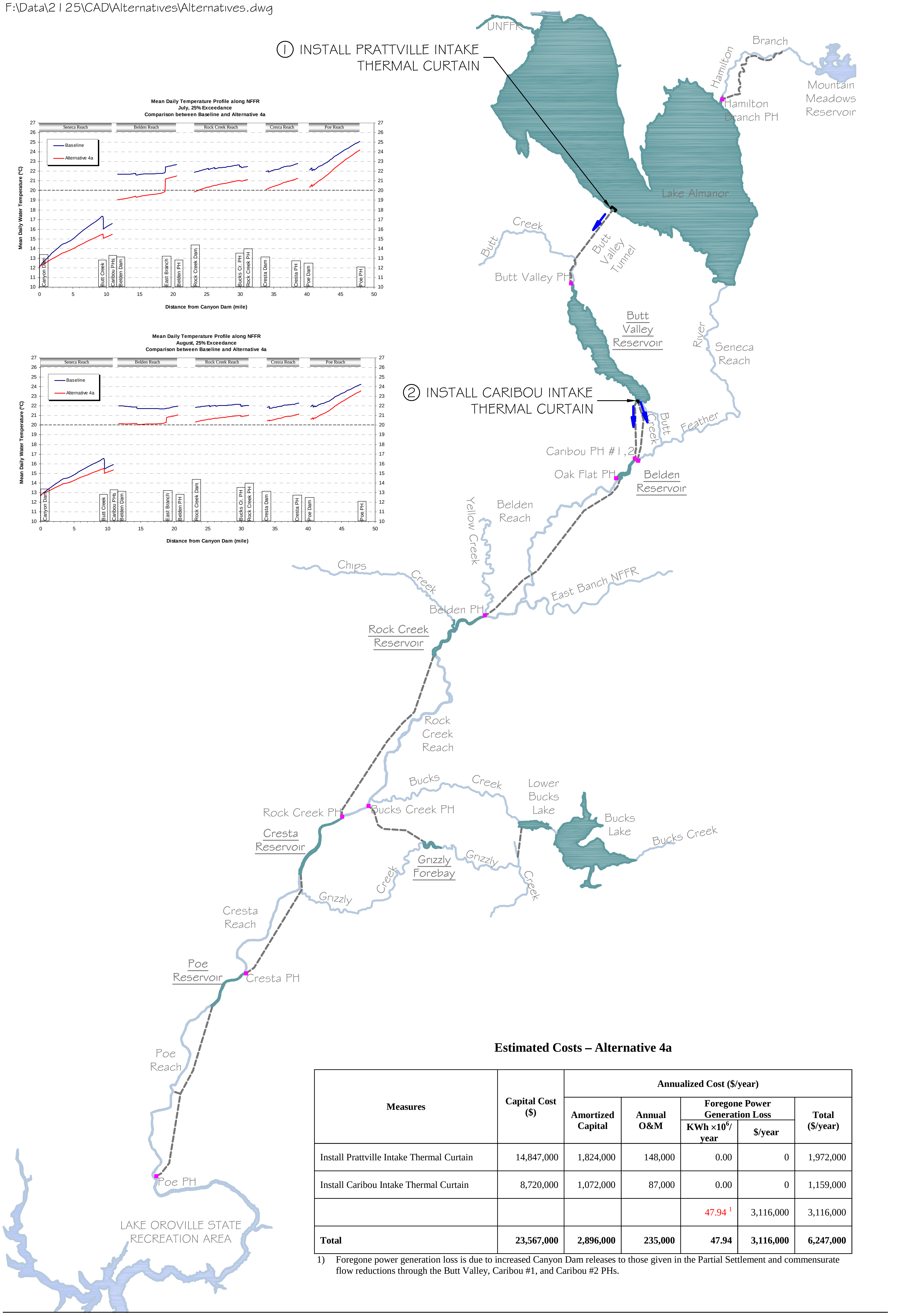

Estimated Costs – Alternative 4a

Measures	Capital Cost ($)	Annualized Cost ($/year)				
		Amortized Capital	Annual O&M	Foregone Power Generation Loss		Total ($/year)
				KWh ×10⁶/ year	$/year	
Install Prattville Intake Thermal Curtain	14,847,000	1,824,000	148,000	0.00	0	1,972,000
Install Caribou Intake Thermal Curtain	8,720,000	1,072,000	87,000	0.00	0	1,159,000
				47.94 [1]	3,116,000	3,116,000
Total	**23,567,000**	**2,896,000**	**235,000**	**47.94**	**3,116,000**	**6,247,000**

1) Foregone power generation loss is due to increased Canyon Dam releases to those given in the Partial Settlement and commensurate flow reductions through the Butt Valley, Caribou #1, and Caribou #2 PHs.

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FIGURE 4-18

ALTERNATIVE 4A

LEGEND

- ➡ COOL WATER INFUSION
- ― STREAM
- - - POWERHOUSE CONDUIT
- ■ POWERHOUSE (PH)

NOTES:

1. SOURCE: USGS 7.5 MINUTE QUADRANGLE MAPS (PROJECTION: STATE PLANE NAD83 CALIFORNIA ZONE 1 IN FEET)
2. UNFFR: UPPER NORTH FORK FEATHER RIVER

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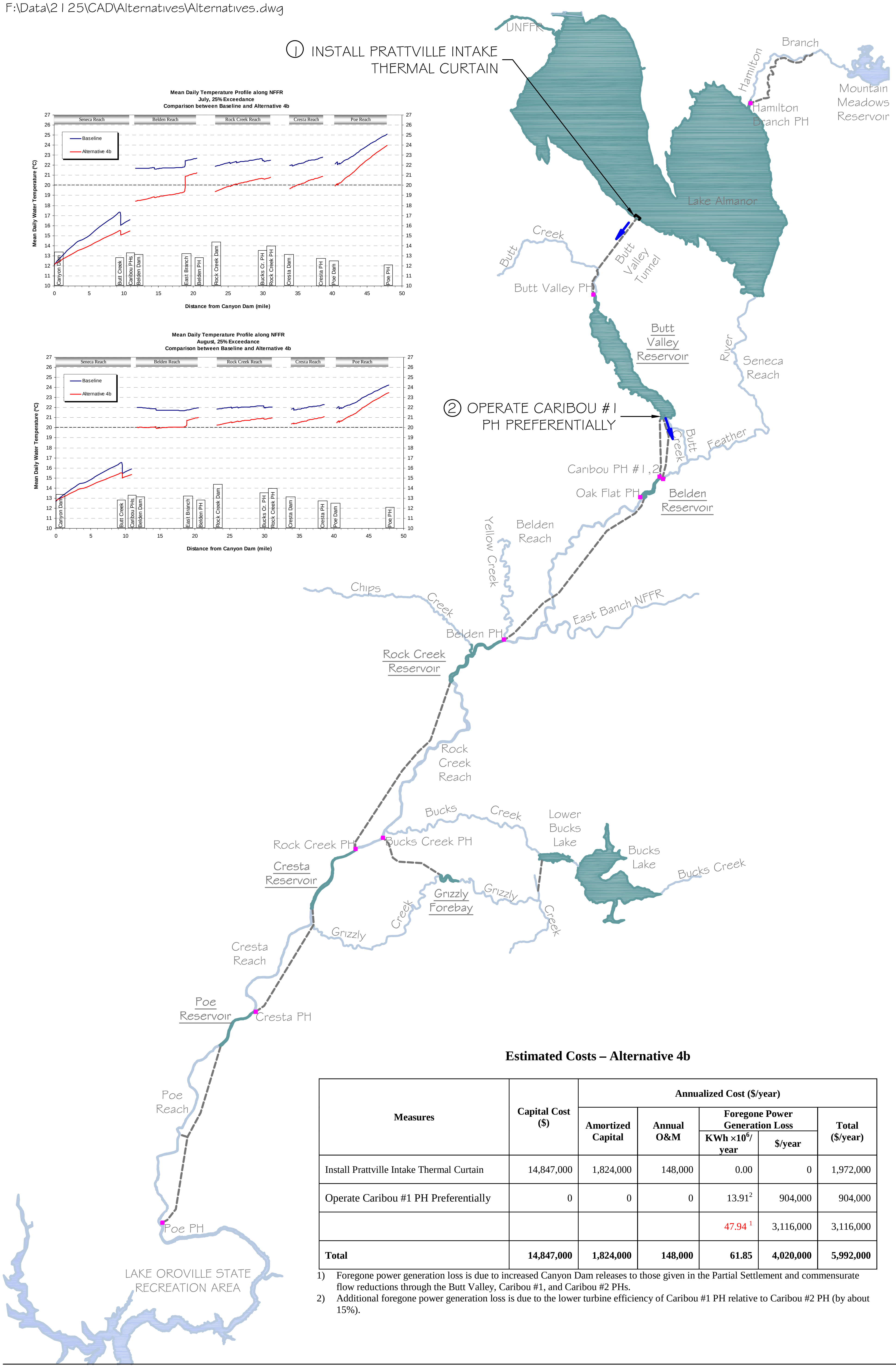

Estimated Costs – Alternative 4b

Measures	Capital Cost ($)	Annualized Cost ($/year)				
		Amortized Capital	Annual O&M	Foregone Power Generation Loss		Total ($/year)
				KWh ×10⁶/ year	$/year	
Install Prattville Intake Thermal Curtain	14,847,000	1,824,000	148,000	0.00	0	1,972,000
Operate Caribou #1 PH Preferentially	0	0	0	13.91[2]	904,000	904,000
				47.94 [1]	3,116,000	3,116,000
Total	**14,847,000**	**1,824,000**	**148,000**	**61.85**	**4,020,000**	**5,992,000**

1) Foregone power generation loss is due to increased Canyon Dam releases to those given in the Partial Settlement and commensurate flow reductions through the Butt Valley, Caribou #1, and Caribou #2 PHs.

2) Additional foregone power generation loss is due to the lower turbine efficiency of Caribou #1 PH relative to Caribou #2 PH (by about 15%).

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FIGURE 4-19

ALTERNATIVE 4B

LEGEND

➡ COOL WATER INFUSION
— STREAM
- - - POWERHOUSE CONDUIT
■ POWERHOUSE (PH)

NOTES:

1. SOURCE: USGS 7.5 MINUTE QUADRANGLE MAPS (PROJECTION: STATE PLANE NAD83 CALIFORNIA ZONE 1 IN FEET)
2. UNFFR: UPPER NORTH FORK FEATHER RIVER

SCALE (MILES)
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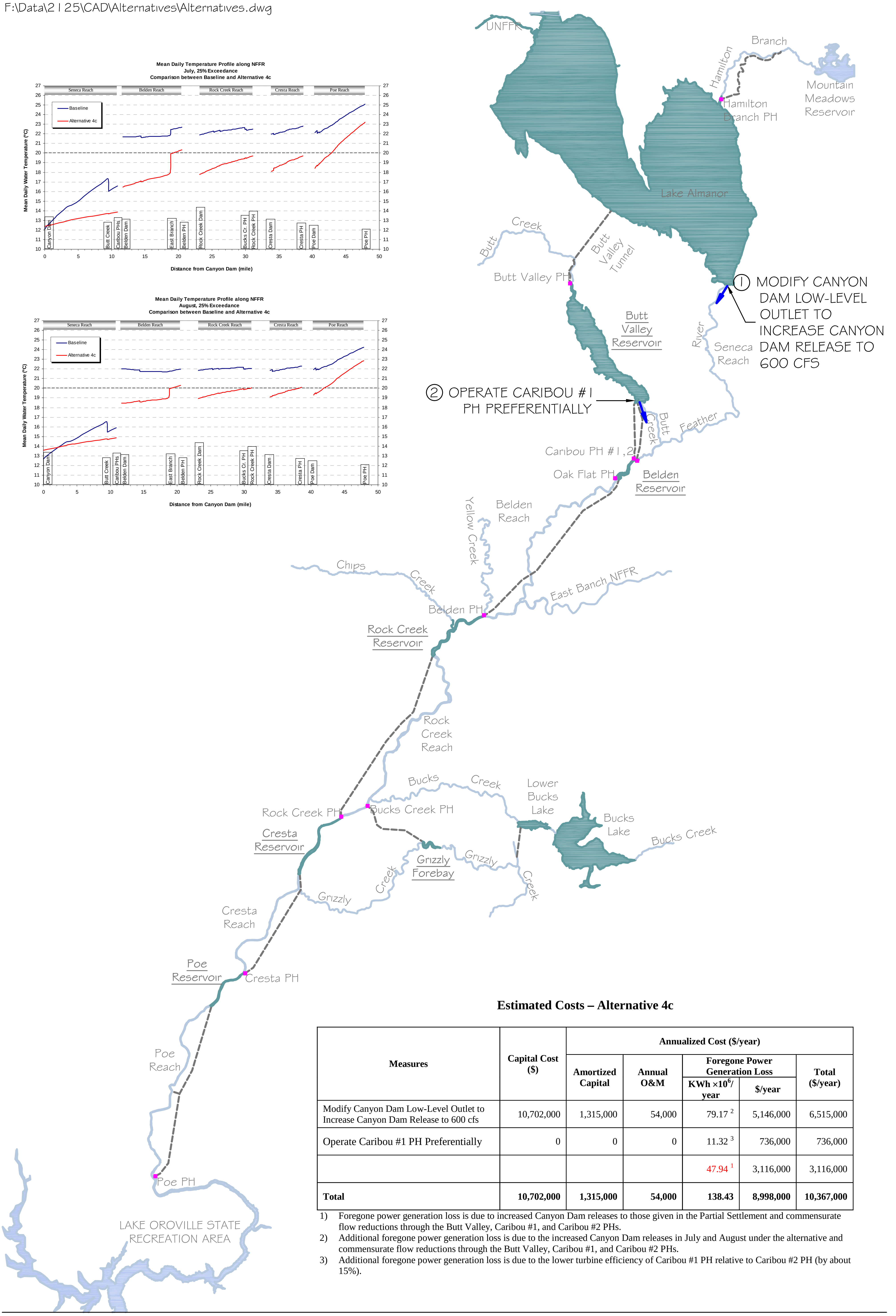

Mean Daily Temperature Profile along NFFR
July, 25% Exceedance
Comparison between Baseline and Alternative 4c

Mean Daily Temperature Profile along NFFR
August, 25% Exceedance
Comparison between Baseline and Alternative 4c

Estimated Costs – Alternative 4c

Measures	Capital Cost ($)	Annualized Cost ($/year)				
		Amortized Capital	Annual O&M	Foregone Power Generation Loss		Total ($/year)
				KWh ×10⁶/ year	$/year	
Modify Canyon Dam Low-Level Outlet to Increase Canyon Dam Release to 600 cfs	10,702,000	1,315,000	54,000	79.17 [2]	5,146,000	6,515,000
Operate Caribou #1 PH Preferentially	0	0	0	11.32 [3]	736,000	736,000
				47.94 [1]	3,116,000	3,116,000
Total	**10,702,000**	**1,315,000**	**54,000**	**138.43**	**8,998,000**	**10,367,000**

1) Foregone power generation loss is due to increased Canyon Dam releases to those given in the Partial Settlement and commensurate flow reductions through the Butt Valley, Caribou #1, and Caribou #2 PHs.
2) Additional foregone power generation loss is due to the increased Canyon Dam releases in July and August under the alternative and commensurate flow reductions through the Butt Valley, Caribou #1, and Caribou #2 PHs.
3) Additional foregone power generation loss is due to the lower turbine efficiency of Caribou #1 PH relative to Caribou #2 PH (by about 15%).

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FIGURE 4-20
ALTERNATIVE 4C

LEGEND

➡	COOL WATER INFUSION
━	STREAM
┅	POWERHOUSE CONDUIT
■	POWERHOUSE (PH)

NOTES:
1. SOURCE: USGS 7.5 MINUTE QUADRANGLE MAPS (PROJECTION: STATE PLANE NAD83 CALIFORNIA ZONE I IN FEET)
2. UNFFR: UPPER NORTH FORK FEATHER RIVER

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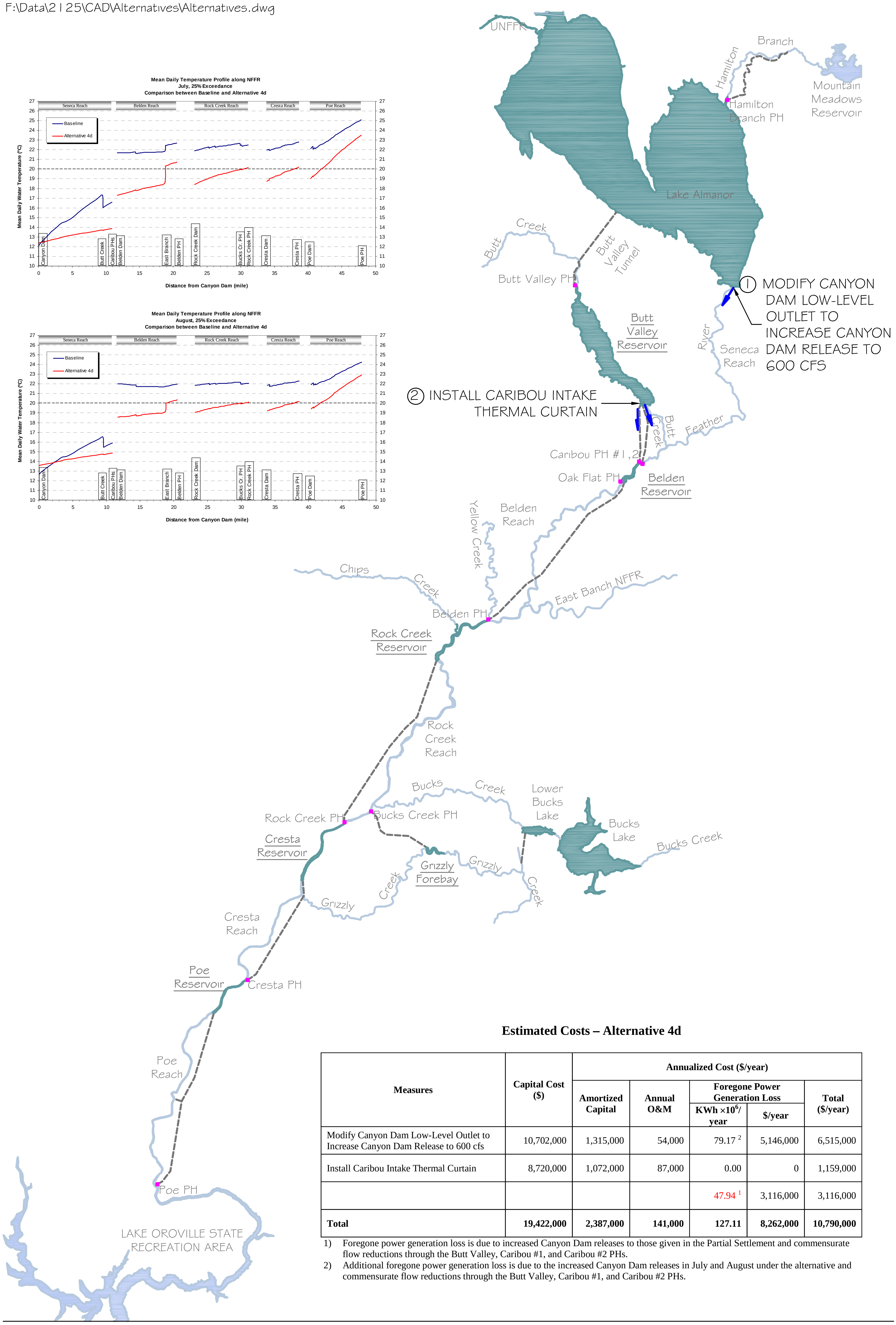

Mean Daily Temperature Profile along NFFR
July, 25% Exceedance
Comparison between Baseline and Alternative 4d

Mean Daily Temperature Profile along NFFR
August, 25% Exceedance
Comparison between Baseline and Alternative 4d

① MODIFY CANYON DAM LOW-LEVEL OUTLET TO INCREASE CANYON DAM RELEASE TO 600 CFS

② INSTALL CARIBOU INTAKE THERMAL CURTAIN

Estimated Costs – Alternative 4d

Measures	Capital Cost ($)	Annualized Cost ($/year)				
		Amortized Capital	Annual O&M	Foregone Power Generation Loss		Total ($/year)
				KWh ×10^6/ year	$/year	
Modify Canyon Dam Low-Level Outlet to Increase Canyon Dam Release to 600 cfs	10,702,000	1,315,000	54,000	79.17 [2]	5,146,000	6,515,000
Install Caribou Intake Thermal Curtain	8,720,000	1,072,000	87,000	0.00	0	1,159,000
				47.94 [1]	3,116,000	3,116,000
Total	**19,422,000**	**2,387,000**	**141,000**	**127.11**	**8,262,000**	**10,790,000**

1) Foregone power generation loss is due to increased Canyon Dam releases to those given in the Partial Settlement and commensurate flow reductions through the Butt Valley, Caribou #1, and Caribou #2 PHs.

2) Additional foregone power generation loss is due to the increased Canyon Dam releases in July and August under the alternative and commensurate flow reductions through the Butt Valley, Caribou #1, and Caribou #2 PHs.

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FIGURE 4-21

ALTERNATIVE 4D

LEGEND
→ COOL WATER INFUSION
— STREAM
- - - POWERHOUSE CONDUIT
■ POWERHOUSE (PH)
- - - NEW OR MODIFIED FACILITY

NOTES:
1. SOURCE: USGS 7.5 MINUTE QUADRANGLE MAPS (PROJECTION: STATE PLANE NAD83 CALIFORNIA ZONE 1 IN FEET)
2. UNFFR: UPPER NORTH FORK FEATHER RIVER

SCALE (MILES)
0 1.5 3
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REFERENCES

Bechtel Corporation and Thomas R. Payne and Associates, 2006. North Fork Feather River Instream Temperature Studies, 33 Years of Synthesized Reservoir Operations, Evaluation of Installation of Curtains and Modifications in Lake Almanor and Butt Valley Reservoir and High Instream Flow Releases from Canyon Dam.

Beck, M.B., 1987. Water Quality Modeling: A Review of the Analysis of Uncertainty. Water Resources Research, Vol. 23, No.8, pp.1393-1442.

Black and Veatch, 2004a. Prattville Intake Modifications, Phase 3, Feasibility Study.

Black and Veatch, 2004b. Prattville Intake Modifications, Phase 3, Close Out Status.

California Regional Water Quality Control Board, Central Valley Region, 2004. Water Quality Control Plan for the Central Valley Region.

FERC, 2001. FERC License No. 1962.

FERC, 2005. Final Environmental Impact Statement, Upper North Fork Feather River Project, California.

IIHR, the University of Iowa, 2004. Lake Almanor Cold-Water Feasibility Study: Hydraulic Model.

Northwest Hydraulic Consultant (NHC), 2006. Canyon Dam Low Level Outlet Hydraulic Model Study.

PG&E, 2002. Upper North Fork Feather River Project, FERC Project No. 2105, Application for New License.

PG&E, 2003. Water Temperature Monitoring of 2002, Rock Creek – Cresta Project, FERC Project No. 1962.

PG&E, 2004. Results of 2003 Water Temperature Monitoring and Special Caribou Powerhouse Test, FERC License Condition No. 4C and License Condition No. 5, Rock Creek-Cresta Project, FERC Project No. 1962.

PG&E, 2005. Water Temperature Monitoring of 2004, Rock Creek – Cresta Project, FERC Project No. 1962.

Reckhow, K.H. and S.C., Chapra, 1983. The Need for Simple Approaches for the Estimation of Lake Model Prediction Uncertainty, in *Uncertainty and Forecasting of Water Quality*, edited by M.B. Beck and G. van Straten, pp. 293-303, Springer Verlag, New York, 1983.

Stetson, 2007. Level 1 and 2 Report – Development and Screening of Potentially Effective and Feasible Alternatives to Achieve the Basin Plan Objective for Water Temperature and Protect Cold Freshwater Habitat Beneficial Use along the North Fork Feather River.

Stetson and PG&E, 2007. 2006 North Fork Feather River Special Testing Data Report.

Woodward-Clyde Consultants, 1986. Rock Creek – Cresta Project Cold Water Feasibility Study, Volume 1. Prepared for Pacific Gas and Electric Company.

-----, 2000. Rock Creek - Cresta Relicensing Settlement Agreement.

-----, 2004. Upper North Fork Feather Project, Project 2105 Relicensing Settlement Agreement.

Appendix A

Review of PG&E's Existing MITEMP and CE-QUAL-W2 Models of Lake Almanor and Documentation of Stetson Improvements to the CE-QUAL-W2 Model

Prepared For

State Water Resources Control Board

August 2008

Prepared By

Stetson Engineers, Inc.

STETSON
ENGINEERS INC.

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 BACKGROUND AND PURPOSE

Pacific Gas and Electric Company (PG&E) has submitted an application to the Federal Energy Regulatory Commission (FERC) for relicensing of the Upper North Fork Feather River Project (UNFFR Project; FERC No. 2105). Prior to issuance of the new FERC license, Clean Water Act 401 water quality certification must be obtained from the State Water Resources Control Board. The State Water Resources Control Board's issuance of 401 certification is a discretionary action subject to compliance with CEQA. Because of project complexity, the level of controversy surrounding unresolved temperature issues on the UNFFR Project, and the likelihood of significant impacts, the State Water Resources Control Board as the CEQA lead agency, made the decision to prepare an EIR. A reliable Lake Almanor water quality model is one of the important supporting tools in the EIR analysis.

The facilities of the UNFFR Project include three dams that impound water from the NFFR and Butt Creek, five powerhouses (PH), and three stream bypass reaches. Figures 1a and 1b show the locations and relationships of dams, impounded reservoirs, and bypass reaches associated with the UNFFR Project. UNFFR Project reservoirs include Lake Almanor (1,142,251 acre-ft), Butt Valley Reservoir (49,897 acre-ft), and Belden Forebay (2,477 acre-ft). The temperatures of the outflows from Lake Almanor and Butt Valley Reservoir dominate the thermal regime in the NFFR system. Over the years, PG&E has investigated opportunities to minimize adverse water temperature effects (i.e., warming) on the NFFR through operational changes or physical modifications to existing facilities.

PG&E has developed reservoir temperature models using MITEMP for Lake Almanor and Butt Valley Reservoir and stream temperature models using SNTEMP for the NFFR reaches to analyze and predict water temperature longitudinal profiles along the NFFR with different physical modifications, hydrologic operations, and under different meteorological conditions. PG&E has also developed a CE-QUAL-W2 model for Lake Almanor to simulate the impacts that withdrawal of cold water from near the lake bottom could have on the distribution of dissolved oxygen (DO) and water temperature and, thus, cold freshwater habitat in the lake.

This report reviews the existing Lake Almanor MITEMP and CE-QUAL-W2 models and evaluates their adequacy to support Level 3 analysis of UNFFR water temperature reduction alternatives[1], explains the need for modeling both water temperature and DO in

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[1] Stetson Engineers is assisting in the EIR analysis of the UNFFR Project. One of the CEQA analysis tasks is to formulate and evaluate water temperature reduction alternatives for the UNFFR Project. A systematic, three-phased approach to the development and screening of water temperature reduction alternatives has been developed. Stetson has completed the administrative draft Level 1 and 2 Report which documents the first two phases of the three-phased approach (Stetson, 2007). The water temperature reduction alternatives that passed Level 2 represent *the set of potentially effective and feasible* alternatives to achieving the

Lake Almanor and the reasoning for using both models in the Level 3 analysis, and documents Stetson's improvements to the Lake Almanor CE-QUAL-W2 model. Both the existing MITEMP model and the improved CE-QUAL-W2 model for Lake Almanor will be used for Level 3 analysis of UNFFR water temperature reduction alternatives. The water temperature reduction alternatives that pass Level 3 analysis and screening will represent *effective and feasible* water temperature reduction alternatives that are suitable for broader environmental analysis in the EIR.

1.2 LAKE ALMANOR

Lake Almanor is the primary storage reservoir on the NFFR. The lake was created in 1913 by the construction of an earth-fill dam (135 ft high and 1,400 ft wide), Canyon Dam. The lake has two main lobes or branches, the Chester Branch and the Hamilton Branch. At the normal maximum water surface elevation of 4,504 ft (USGS datum[2]), Lake Almanor has a storage capacity of 1,142,251 acre-ft and a surface area of 27,000 acres. Major sources of inflow feeding the lake are the NFFR at Chester (which accounts for approximately half the annual inflow), the Hamilton Branch of the NFFR (which provides 20 to 25% of the annual inflow), and a number of minor tributaries including Benner, Last Chance, and Bailey creeks. In addition, there are numerous submerged springs that feed into Lake Almanor. Major lake outlets include the Canyon Dam Outlet, which releases water to the NFFR downstream of Lake Almanor, and the Prattville Intake, which is the source of water for the Butt Valley PH and the principal source of inflow for the Butt Valley Reservoir. The average water residence time in Lake Almanor is approximately 291 days.

PG&E operates Lake Almanor to ensure that the lake level does not exceed the full-pool elevation of 4,504 feet in USGS Datum to avoid spill at Canyon Dam. Typically, outflows from Canyon Dam and the Prattville Intake are controlled in the spring to allow the lake to refill with snowmelt, though in dry years the lake may not completely fill. During the summer, the lake is operated for power generation and recreational opportunities. The Canyon Dam intake tower is designed to selectively draw from either the lower water column or higher in the lake strata, allowing some control over the temperature of flow releases. The Canyon Dam intake tower consists of two gate configurations, mid-level gates and low-level gates. The invert of the two mid-level gates at the Canyon Dam Outlet is located at elevation 4,477 ft (USGS datum) and the invert of the three low-level gates is located at elevation 4,432 ft (USGS datum). The Canyon Dam

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temperature target. These water temperature reduction alternatives were formulated using the results of existing modeling studies conducted primarily by PG&E with some enhancements by Stetson. The purpose of Level 3 analysis is to verify the effectiveness, sustainability, and long-term reliability of those water temperature reduction alternatives that passed Level 2. The water temperature reduction alternatives that passed Level 2 will be analyzed through detailed modeling. The detailed modeling will use newly developed and improved water quality models to modify or refine the alternatives where necessary and to screen the alternatives to arrive at a *set of effective and feasible* water temperature reduction alternatives that are suitable for broader environmental analysis in the EIR.

[2] USGS datum = PG&E datum + 10.2 ft

outlet structure has a maximum capacity of 2,100 cfs, but is generally operated to release only the required minimum instream flows to the Seneca bypass reach (Seneca Reach) of the NFFR[3]. Although current minimum flow releases are established at 35 cfs in accordance with License Article 26 of FERC Project No. 2105, the Partial Settlement provides for a revised and variable flow release schedule that will be evaluated in the EIR.

Releases from the Prattville Intake to Butt Valley Reservoir make up the greatest portion of water released from Lake Almanor; generally up to 1,800 cfs, but as great as 2,200 cfs when power generation reaches its peak, mostly in the summer months. The invert of Prattville Intake is located at elevation 4,420 feet (USGS datum) on the bottom of a narrow steep-sided trough[4] that connects the relatively shallow cove location of the intake with deeper areas of the lake. Access to the deeper areas of Lake Almanor is restricted by the shallow approach channel, which has a base elevation of 4,432 feet (USGS datum), and the submerged levees on both sides of the channel. Consequently, the water withdrawn by the Prattville Intake is primarily from the warmer layers in the lake due to the restriction of the approach channel and the submerged levees.

Numerous groundwater springs occur in the Lake Almanor area. The largest among these is Big Springs located in a cove to the east of the Hamilton Branch. Seepage flows emerge from underground all year round, both above and below the water line. Historically, seepage flows from Big Springs were conveyed to Hamilton Branch channel which led to Canyon Dam where it joined the NFFR. In 1924, a channel was excavated to intercept water from Big Springs and convey it to the Prattville Intake prior to raising Canyon Dam. All of these channels are now under water, and are believed to help convey cold water from the Hamilton Branch to the Prattville Intake.

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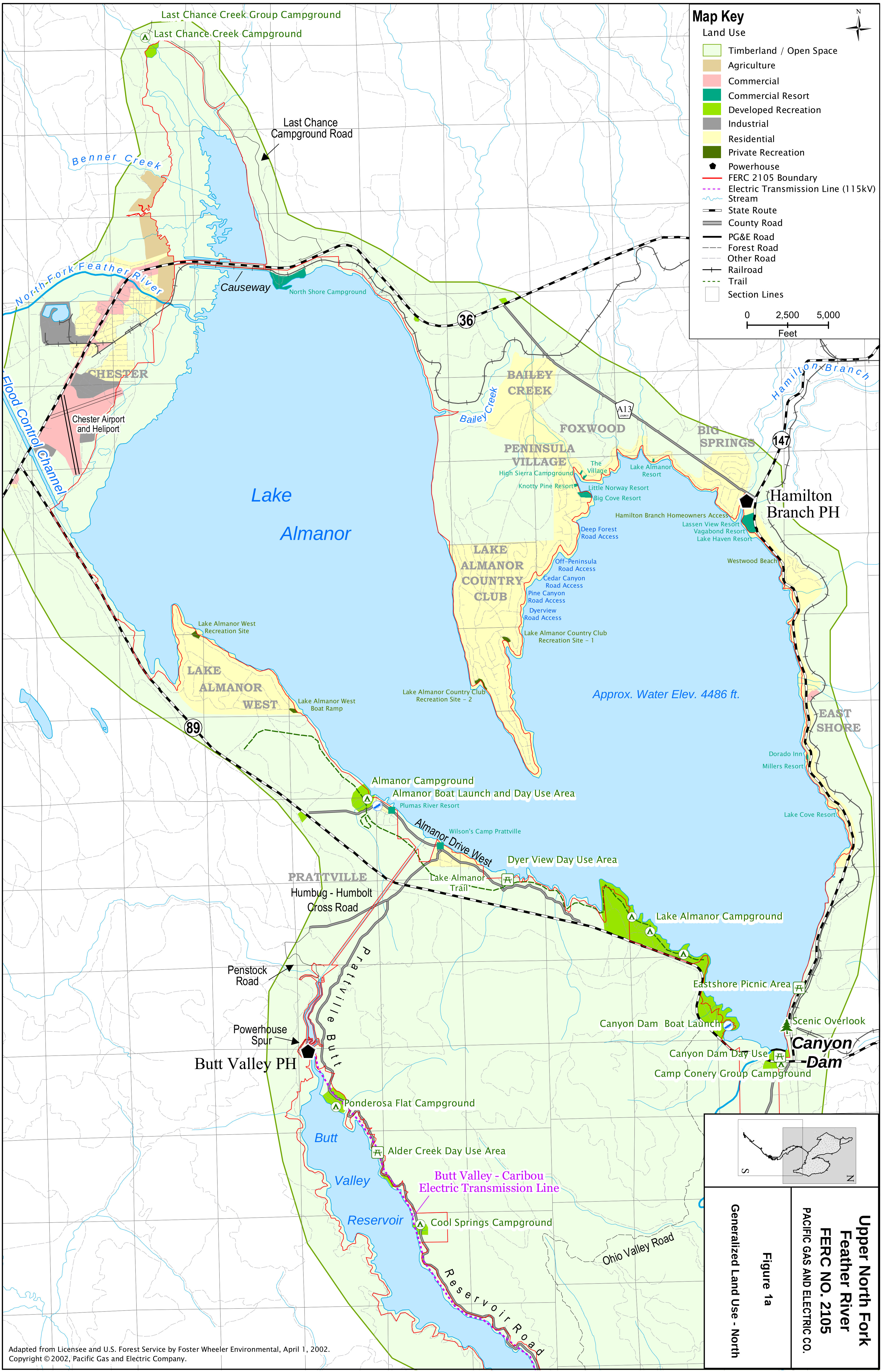
[3] The Canyon Dam intake tower has three low-level gates – Gate #1, Gate #3, and Gate #5 – all located at elevation 4,432 ft, about 72 ft below the maximum lake level elevation of 4,504 ft USGS datum. These three low level gates are damaged or are in poor condition due to corrosion and long-term hydrostatic loading on the gates and gate-stems. PG&E inspections revealed the poor condition of the gate-stems, gate connections, and bolts. In August-October 2005 PG&E did repair work on Gate #5 and rehabilitated the gate and gate-stem connection. Gate #5 is the only low level gate that is currently operable, but its operation is limited and it can reliably and safely release up to only about 73 cfs. Higher releases of water need to be released from the mid-level gates, but the water temperature of releases from the mid-level gates during the summer is warm.

[4] The steep-sided channel was originally dug from the Hamilton Branch to the Prattville Intake in the 1920's. The channel has an average depth of about 13 ft below the lakebed and is on average about 90 ft wide (IIHR, 2004). The channel was dug to intercept flows from the Big Springs area located near the Hamilton Branch PH and convey them to the old Prattville intake as part of the original hydropower development at Lake Almanor. The material excavated from this channel was piled along both sides of the excavated channel, giving rise to a set of levees on both sides of the channel. These submerged levees are about 6 - 8 ft high and restrict the flow of cold water to the Prattville Intake. Removing the submerged levees by dredging would enhance cold water movement to the intake and, thus, reduce withdrawal water temperature.



Adapted from Licensee and U.S. Forest Service by Foster Wheeler Environmental, April 1, 2002.

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Upper North Fork Feather River
FERC NO. 2105
PACIFIC GAS AND ELECTRIC CO.

Figure 1a

Generalized Land Use - North

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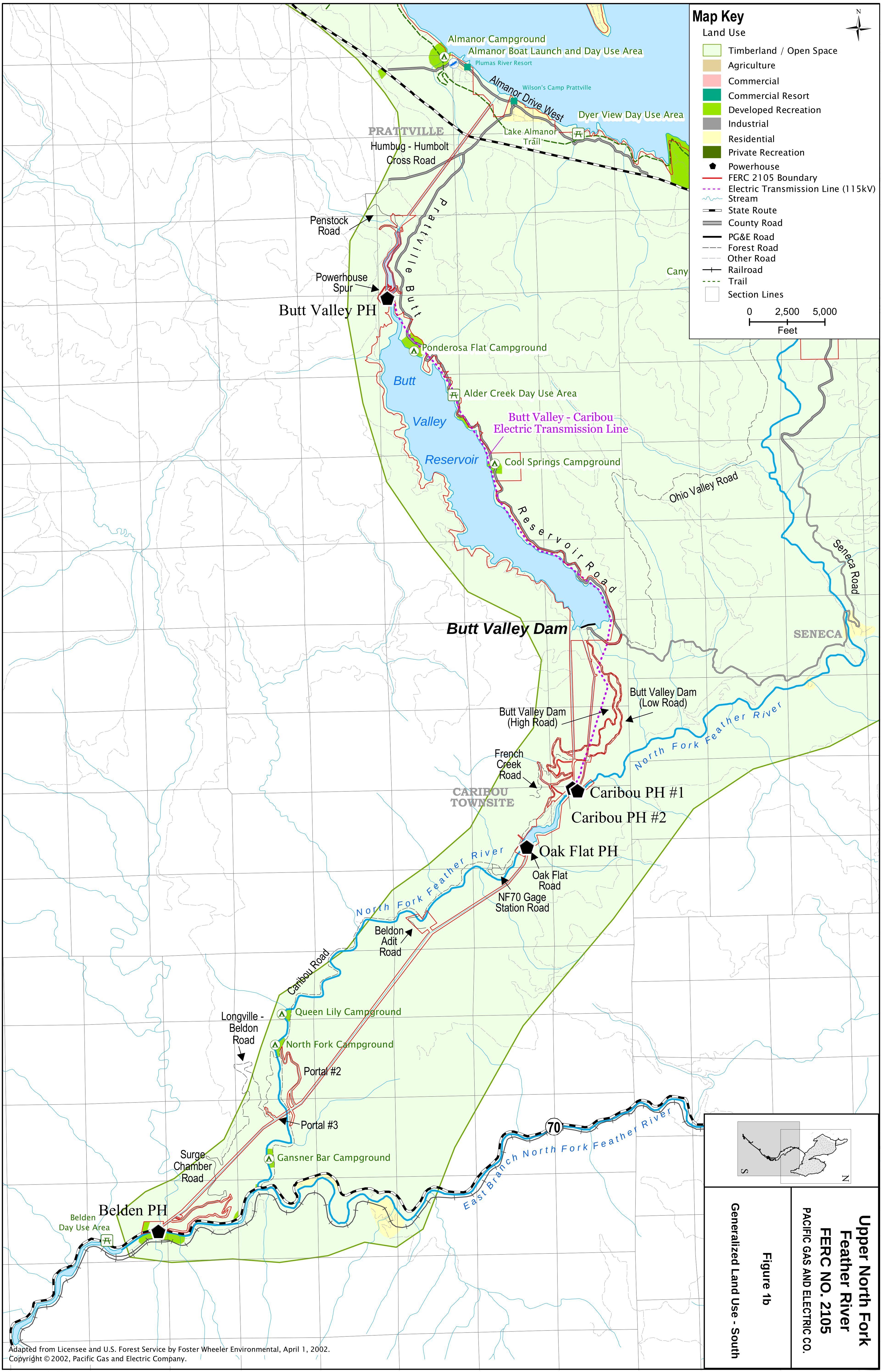

Upper North Fork Feather River
FERC NO. 2105
PACIFIC GAS AND ELECTRIC CO.

Figure 1b
Generalized Land Use - South

Adapted from Licensee and U.S. Forest Service by Foster Wheeler Environmental, April 1, 2002.

p:\projects_2001\unffr\land_use

1.3 THE NEED FOR MODELING BOTH WATER TEMPERATURE AND DISSOLVED OXYGEN IN LAKE ALMANOR

The water temperature reduction measures at Lake Almanor to be analyzed in Level 3 include hypolimnion cold water withdrawal from Lake Almanor through use of a thermal curtain that would be installed near the Prattville Intake and/or through release from the low-level outlet at Canyon Dam. Although normally under existing conditions the hypolimnion cold water in the lake has low dissolved oxygen (DO) in the summertime and is not suitable for cold freshwater habitat because of low DO, too much cold water withdrawal from Lake Almanor under alternatives to be analyzed in Level 3 could affect the lake's thermal structure and DO distribution and, thus, adversely impact the cold freshwater habitat beneficial use of the lake. A water quality model is needed to simulate both water temperature and DO distributions in the lake under Level 3 alternatives. The simulated water temperature and DO distributions would in turn be used to evaluate the impacts of the water temperature reduction measures on the cold freshwater habitat in the lake.

During summertime, DO concentrations at the hypolimnion of Lake Almanor are reduced and may approach zero with time until late fall when de-stratification begins. Fish are unable to survive in water with near-zero DO. For much of the year, Lake Almanor is stratified. Warm water stays in the mixed surface water (i.e., epilimnion) and does not mix much with the deeper water (i.e., hypolimnion). DO in the hypolimnion is reduced due to the oxygen consumption in the breakdown of organic materials and the reduced DO is not replenished by reaeration from the lake surface. Cold freshwater habitat in the lake is generally vertically confined to the lake thermocline[5] which has sufficiently low water temperature and sufficiently high DO. Lake Almanor thermocline is normally about 30-40 feet below the lake surface, and under a normal water year condition it is between el. 4,450 ft – 4,470 ft (USGS datum) in July and August. The Canyon Dam low-level outlet is located at elevation 4,432 ft (USGS datum), which is well below the thermocline. It is expected that, unless the water release from the Canyon Dam low-level outlet is sufficiently high or there exists an reaeration mechanism in the outfall structure (such as under the present configuration), the low-level outlet would withdraw primarily the cold hypolimnion water from the lake that is not suitable for cold freshwater habitat because of low DO in the source hypolimnion water. However, higher water release from the Canyon Dam low-level outlet would increase the potential of entraining thermocline water that consequently could reduce the cold water volume suitable for cold freshwater habitat beneficial use in the lake. A water quality model would be needed to simulate and

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[5] The thermocline is the transition layer between the warm surface epilimnion water and the cold bottom hypolimnion water. In the thermocline, the temperature decreases rapidly from the well-mixed warm surface water temperature to the much colder deep water temperature. The thermocline water is generally suitable for cold freshwater habitat because it is where both the temperature and DO can meet the requirements by cold freshwater habitat. Above the thermocline (i.e., epilimnion), water is generally not suitable for cold freshwater habitat because of the warm water temperature. Below the thermocline (i.e., hypolimnion), water is generally not suitable for cold freshwater habitat either because of low dissolved oxygen.

balance the potential competing effects of the increased Canyon Dam low-level outlet release measure on both water temperature and DO distributions in the lake. The increased Canyon Dam low-level outlet release measure of the maximum 600 cfs could be evaluated first. If this initial evaluation was to show that its impact on the lake's cold freshwater habitat would be insignificant, there would be no need to evaluate other release measures with a lower release rate.

Under existing conditions the water withdrawn by the Prattville Intake is primarily from the warmer surface layers. However, construction of a thermal curtain near the intake would induce withdrawal from the cold hypolimnion layer, which would reduce the temperature of water discharged from the lake to Butt Valley PH and Reservoir. As mentioned earlier, releases from the Prattville Intake to Butt Valley make up the greatest portion of water released from Lake Almanor; generally up to 1,800 cfs, but as great as 2,200 cfs when power generation reaches its peak, mostly in the summer months. This high release of cold hypolimnion water via the thermal curtain near the Prattville Intake, compounded by the lowering of lake surface in late summer, would likely cause thermocline water to be entrained into the withdrawal, which may reduce the cold water volume available for cold freshwater habitat beneficial use in the lake. A water quality model would be needed to simulate the potential effects of the thermal curtain on both water temperature and DO distributions in the lake.

1.4 THE REASONING FOR USING BOTH THE MITEMP AND CE-QUAL-W2 MODELS OF LAKE ALMANOR

The existing Lake Almanor MITEMP model was developed for PG&E by Woodward Clyde Consultants (WCC, 1986) and improved by Bechtel (Bechtel, 2002) for the purpose of simulating Lake Almanor water temperature profiles and discharge water temperatures at Butt Valley PH and Canyon Dam. The existing Lake Almanor CE-QUAL-W2 model was developed by Jones & Stokes (Jones & Stokes, 2004) for the purpose of simulating the impacts of cold water withdrawal on the distribution of temperature and DO concentrations and thereby evaluating suitable cold freshwater habitat in the lake. Both the MITEMP and CE-QUAL-W2 models of Lake Almanor will be used in the Level 3 analysis of UNFFR water temperature reduction alternatives for these purposes. The need for the Lake Almanor CE-QUAL-W2 model arises from the fact that MITEMP simulates reservoir water temperature only; MITEMP does not have the capability to simulate DO because it does not have water quality components. On the other hand, although the Lake Almanor CE-QUAL-W2 model has the capability to simulate both water temperature and DO, the MITEMP model will continually be used to simulate Lake Almanor water temperature profiles and discharge water temperatures at the Butt Valley PH and Canyon Dam for the following two main reasons:

- The water temperature reduction measures at the Prattville Intake to be analyzed in Level 3 include a thermal curtain under the conditions of with and without removing the submerged levees near the intake. The bathymetry of Lake Almanor in the Prattville Intake area is complicated and the hydraulics at the intake area is very much three-dimensional. Although the Lake Almanor CE-QUAL-W2 model was calibrated/validated to the existing conditions of 2000 and 2001, calibration of the Lake Almanor CE-QUAL-W2 model to the thermal curtain conditions of with and without the submerged levees near the intake by Jones & Stokes was limited. The reliability of the Lake Almanor CE-QUAL-W2 model in simulating the hydraulic effects of with and without removing the submerged levees near the intake under the thermal curtain condition has not been well established. Significant efforts would be needed to calibrate the Lake Almanor CE-QUAL-W2 model to the thermal curtain conditions of with and without the submerged levees near the intake (Refer to Sections 3.1 and 3.2 for more detailed review about the Lake Almanor CE-QUAL-W2 model).

- MITEMP is a one-dimensional (vertical) mathematical water temperature model. A basic assumption of the MITEMP program is that the temperature gradient is predominantly in the vertical direction and the variation in the horizontal and lateral directions is negligible. Because of its large size and significant retention time (291 days), Lake Almanor has a thermal structure that is strongly influenced by surface heat transfer but relatively unresponsive to daily flows. Temperature measurements in multiple years at various locations throughout Lake Almanor showed that the lake exhibits a significant temperature gradient in the vertical direction but little variation in the horizontal direction during the summer months. Both observations of water temperature profiles in Lake Almanor and the theoretical analysis of MITEMP applicability indicate that the one-dimensional MITEMP program is applicable for Lake Almanor (Refer to Sections 2.1 and 2.2 for more detailed review about the Lake Almanor MITEMP model). Further, considerable efforts were taken by Bechtel to calibrate the Lake Almanor MITEMP model under the thermal curtain conditions with and without the submerged levees near the intake based on the physical model results conducted at the University of Iowa (Bechtel, 2004). To calibrate the model, Bechtel modified the MITEMP source code to reflect the hydraulic effects of with and without removing the submerged levees near the intake under the thermal curtain condition. It is Stetson’s opinion that, compared to the Lake Almanor CE-QUAL-W2 model, the Lake Almanor MITEMP model appears more credible for simulating the incremental benefit in discharge water temperature reduction for different alternatives, a crucial parameter in the Level 3 analysis of water temperature reduction alternatives.

For the above-described reasons, it was judged that both the Lake Almanor MITEMP and CE-QUAL-W2 models will be used in the Level 3 analysis of UNFFR water temperature reduction alternatives. The Lake Almanor MITEMP model will be used for simulating Lake Almanor water temperature profiles and discharge water temperatures at the Butt Valley PH and Canyon Dam. The Lake Almanor CE-QUAL-W2 model will be used for assessing the impacts of cold water withdrawal on the distribution of temperature and DO concentrations, and thereby evaluating suitable cold freshwater habitat in the lake.

2.0 REVIEW OF THE EXISTING MITEMP MODEL OF LAKE ALMANOR

2.1 MITEMP BACKGROUND

MITEMP is a generic one-dimensional (vertical) mathematical water temperature model for natural deep lakes and cooling ponds and was originally developed by Massachusetts Institute of Technology (MIT) in the 1970's. This model divides the waterbody into a series of horizontal layers and assumes uniform spatial distribution of temperature within each layer (Figure 2). Thermal and kinetic energy are computed on a layer-by-layer basis for any required length of time. Physical processes considered in MITEMP include surface heat transfer, internal heat absorption, the entrance mixing of inflows, withdrawal dynamics, turbulent diffusion, overturning and mixing. The outputs of a MITEMP model include outflow water temperatures and water temperatures at each horizontal layer over time. The inputs to a MITEMP model consist of the following:

- Reservoir geometry (represented by the elevation - surface area - storage curves);
- Initial vertical water temperature profile;
- Inflows and inflow water temperatures;
- Outflows, outlet elevations, and specified outlet withdrawal scheme;
- Meteorology data, including air temperature, solar radiation, wind speed, relative humidity, and cloud cover;
- Model parameters, including light extinction coefficient, entrance mixing ratio, vertical diffusivity, etc. Model parameters are site-specific and may need to be adjusted during model calibration to achieve a match between model simulated and observed data.

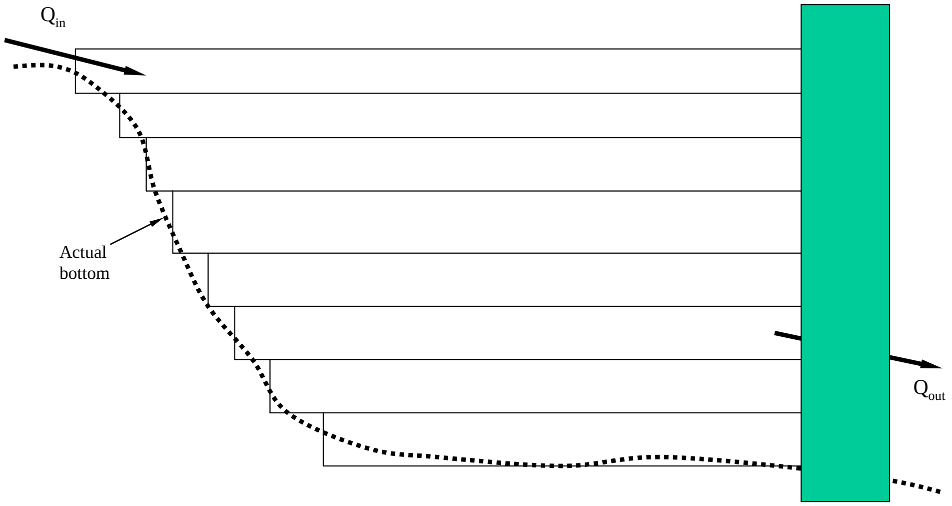

Figure 2 Typical One-Dimensional (Vertical) Grid for MITEMP

Central to MITEMP are several key assumptions, mostly related to using a one-dimensional model to describe the thermal structure in the reservoir:

1) The temperature gradient is predominantly in the vertical direction. Hence there is little variation in the horizontal (both longitudinal and lateral) direction.
2) The vertical motion due to inflow, outflow, wind, or Coriolis force is negligible.
3) Inflows are allowed to initially mix with the receiving water. The initial mixing is manually specified by the user with an entrance mixing coefficient. Once diluted, inflows are inserted at an elevation where water spreads horizontally without causing thermal instability. The initial mix is designed to capture some of the near-field, three-dimensional effect.
4) Although inflow and outflow occur locally, effects are "communicated" instantaneously to the entire computational "layer" at which these inflows and outflows take place.
5) The withdrawal scheme is based upon a prescribed flow distribution. The validity of this assumption should be tested using the principles of stratified flows and field observations.

The MITEMP application models of Lake Almanor and Butt Valley Reservoir were first developed by Woodward Clyde Consultants (WCC) in 1985-1986 as part of a cold water feasibility study for the Rock Creek – Cresta Project (WCC, 1986). During the model development, WCC modified the original program source code by adding wind mixing processes and named the modified program "MITEMP3". Daily time step and layer depth of one foot were used in the Lake Almanor and Butt Valley MITEMP models. The WCC calibrated the model using the field data for the period from June 3 to July 20, 1985 and validated the model for the period from July 9 to August 12, 1985.

In 2000 PG&E contracted with Bechtel Corporation to perform a peer review of the MITEMP3 models in connection with PG&E's relicensing work for the Rock Creek – Cresta Project and the UNFFR Project. Bechtel further modified the source code of MITEMP3 program by adding seasonal variability of light extinction coefficients, withdrawal capability under thermal curtain conditions, hydraulic effects of the bottom levee surrounding the Prattville Intake, and a modified withdrawal algorithm for the Prattville Intake based on the physical model test results. The modified MITEMP3 program by Bechtel was calibrated/validated using the flow and temperature data collected in 2000 and 2001 (Bechtel, 2002) for the existing conditions. Calibration/validation statistical evaluation results for the modified MITEMP3 models for the 2000 and 2001 data are summarized in Table 1. Bechtel also calibrated the MITEMP model to the physical model test results for the Prattville Intake thermal curtain conditions of with and without removing the submerged levees surrounding the intake[6]

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[6] The following describes Bechtel's MITEMP model calibration procedures to the physical model test results. Temperature profiles from the physical model studies were used as input to MITEMP. The outflow temperatures from MITEMP were then compared with the outflow temperatures obtained from the physical model studies (Curtain #4). Parameters in the expressions for calculating the outflow temperature with the

(Bechtel, 2004). Figures 3a and 3b are representative calibration results of the MITEMP model for two selected runs by Bechtel for the thermal curtain condition with levees under different lake conditions, and Figures 4a and 4b are representative calibration results of the MITEMP model for two selected runs by Bechtel for the thermal curtain condition without levees under different lake conditions.

Table 1 Calibration/Validation Statistical Evaluation Results of MITEMP Models of Lake Almanor and Butt Valley Reservoir for the Existing Conditions

(Source: Bechtel's MITEMP Calibration/Validation Report, 2002)

	Calibration/Validation Station and Time Period	Mean error (°C)	Maximum error (°C)
Lake Almanor	4/6-9/30, 2000		
	Butt Valley PH Discharge Temperatures	0.08	1.4
	Canyon Dam Outflow Temperatures	-0.16	0.7
	4/24-8/7, 2001		
	Butt Valley PH Discharge Temperatures	0.04	1.1
	Canyon Dam Outflow Temperatures	-0.66	1.3
Butt Valley Reservoir	4/6-9/30, 2000		
	Caribou PH #1 Discharge Temperatures	-0.18	2.8
	Caribou PH #2 Discharge Temperatures	0.01	1.4
	4/1-8/21, 2001		
	Caribou PH #1 Discharge Temperatures	0.89	4.6
	Caribou PH #2 Discharge Temperatures	-0.20	1.0

Notes:

1) 2000 was a "normal" year and 2001 was a "critical dry" year.
2) Error was defined as the difference between model-simulated and observed daily discharge water temperatures.
3) The statistical evaluation result of the Caribou #2 PH tailrace temperatures was obtained after discarding a significant amount of measurement data that were subject to "instrument error".

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curtain in place in the MITEMP model were adjusted so that the results from MITEMP agreed with the results of the physical model study predictions for the outflow temperatures from the Prattville Intake.

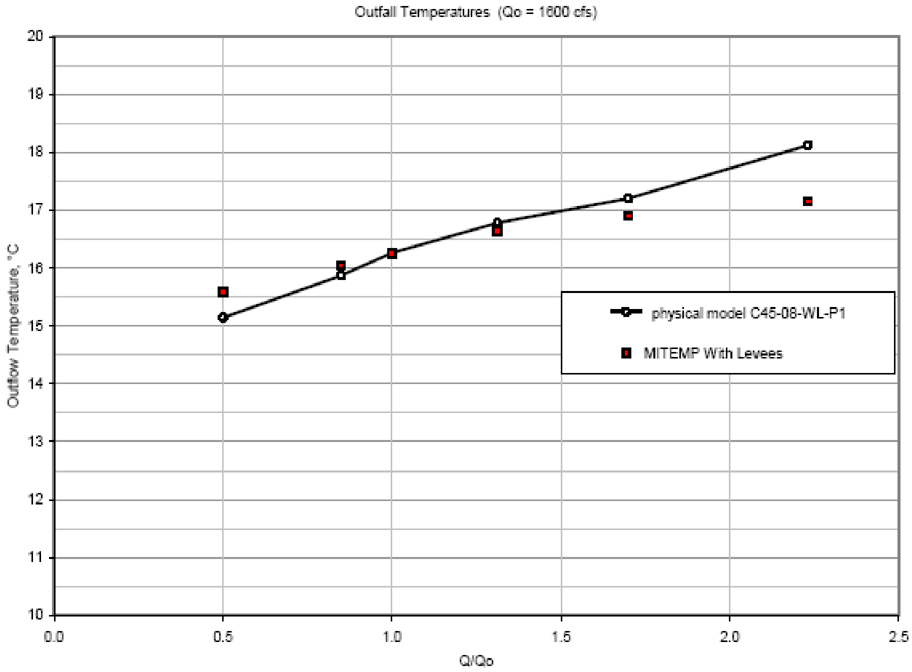

Figure 3a. Calibration of MITEMP for Prattville Intake Release with Curtain and Levees for August Temperature Profile, Iowa Test No. C45-08-WL-P1 (Source: Bechtel, 2004)

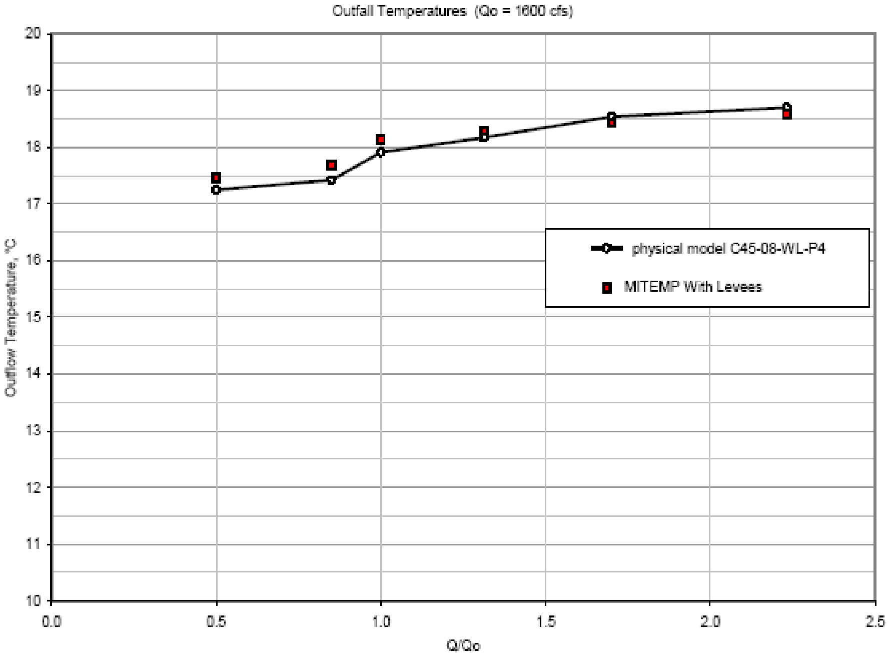

Figure 3b. Calibration of MITEMP for Prattville Intake Release with Curtain and Levees for August Temperature Profile, Iowa Test No. C45-08-WL-P4 (Source: Bechtel, 2004)

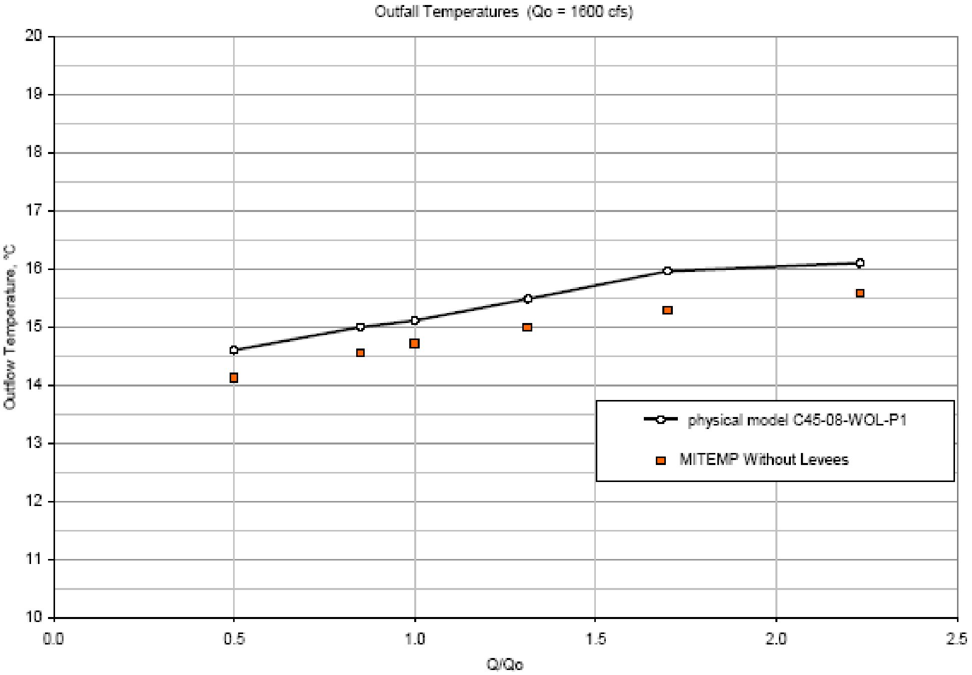

Figure 4a. Calibration of MITEMP for Prattville Intake Release with Curtain and Without Levees for August Temperature Profile, Iowa Test No. C45-08-WOL-P1 (Source: Bechtel, 2004)

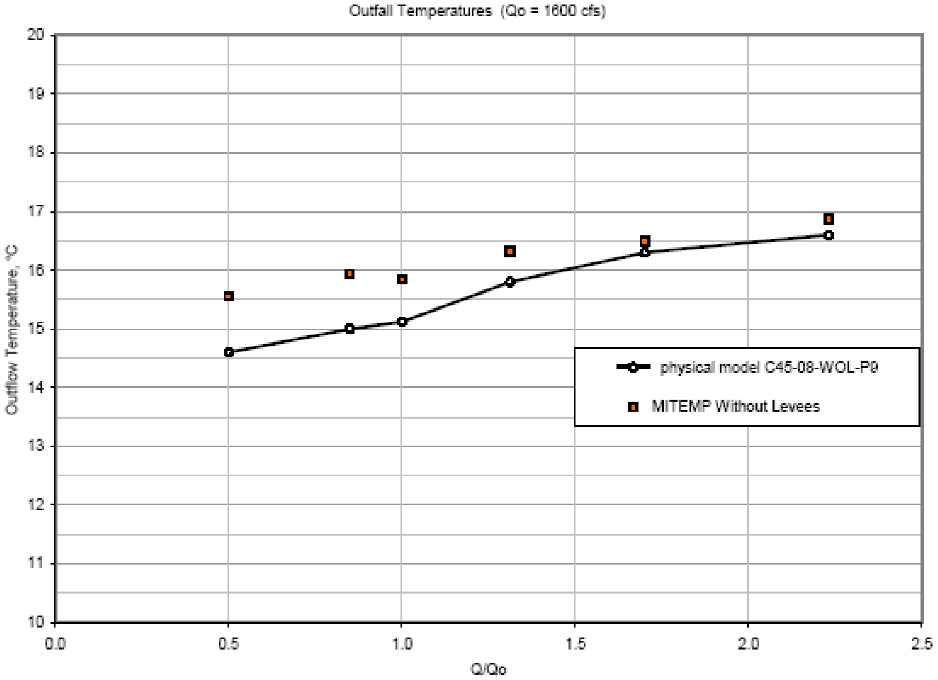

Figure 4b. Calibration of MITEMP for Prattville Intake Release with Curtain and Without Levees for August Temperature Profile, Iowa Test No. C45-08-WOL-P9 (Source: Bechtel, 2004)

2.2 MITEMP MODEL APPLICABILITY TO LAKE ALMANOR

MITEMP is a one-dimensional (vertical) mathematical water temperature model. A basic assumption of the MITEMP program is that the temperature gradient is predominantly in the vertical direction and the variation in the horizontal and lateral directions is negligible. According to the MITEMP documentation (MIT, 1978), the MITEMP program is generally applicable to well stratified deep lakes or reservoirs which satisfy the following empirical criterion:

$$F_D = 320 \frac{L \cdot Q}{H \cdot V} < \frac{1}{\pi} \approx 0.32$$

where:

F_D: Densimetric Froude number;
Q: Flow rate through a reservoir (m^3/s)
L: Reservoir length (m);
H: Reservoir mean depth (m);
V: Reservoir volume (m^3).

The MITEMP program is more applicable to deep lakes or reservoirs with smaller values of Densimetric Froude number F_D than those with larger values. The estimated F_D values for Lake Almanor and Butt Valley Reservoir are shown in Table 2. The estimated F_D value for Lake Almanor is less than 0.01, which is well below the empirical threshold for MITEMP applicability. The estimated F_D value for Butt Valley Reservoir is up to 0.27, which is close to the empirical threshold for MITEMP applicability. This might be the reason that the calibration results for Butt Valley Reservoir were not as good as the results for Lake Almanor (see Table 1).

Table 2 Estimated F_D values for Lake Almanor and Butt Valley Reservoir

Lake Almanor	L	6.5 miles	10,460 m
	Q	0 - 2,100 cfs	0 - 59.47 m^3/s
	V	1,142,000 acre-ft	1.409×10^9 m^3
	A	27,000 acres	1.093×10^8 m^2
	H	42.3 ft	12.9 m
	F_D		**0 – 0.01**
Butt Valley Reservoir	L	5.0 miles	8,045 m
	Q	0 - 2,200 cfs	0 – 62.30 m^3/s
	V	49,897 acre-ft	6.155×10^7 m^3
	A	1,600 acres	6.475×10^6 m^2
	H	31.2 ft	9.5 m
	F_D		**0 – 0.27**

Because of its large size, Lake Almanor has a thermal structure that is strongly influenced by surface heat transfer but relatively unresponsive to daily flows. The temperature measurements at various locations throughout Lake Almanor showed that the lake exhibits a significant temperature gradient in the vertical direction but little variation in the horizontal direction during the summer months. Both observations and theoretical analysis indicate that the one-dimensional MITEMP program is applicable to Lake Almanor.

2.3 LAKE ALMANOR MITEMP WITHDRAWAL ALGORITHM AND TESTING

The withdrawal algorithm is the computational process for simulating the hydraulics of water withdrawal near the intake (i.e., withdrawal zone). The withdrawal algorithm is important to accurately simulate outflow temperature because the hydraulics in the withdrawal zone is the main determinant of outflow temperature. In general the withdrawal zone is affected by outflow discharge rate, intake structure and elevation, intake geometry, approach channel configuration, near intake bathymetry, and intake upstream density gradient. The withdrawal algorithm in the Bechtel-modified MITEMP model was developed based on the physical model test results for the outflow range of 800 cfs – 2,400 cfs at the Prattville Intake. It appears the withdrawal algorithm was not tested for lower flow conditions. In addition, the Lake Almanor MITEMP model has arbitrarily set a minimum threshold outflow of 700 cfs which was prescribed in the model code for discharges at the Prattville Intake. More specifically, the model will automatically use 700 cfs to compute the withdrawal water temperature at the Prattville Intake, even if discharges are less than 700 cfs. The 700 cfs threshold was chosen because any flow less than this level was considered a short-term transient operation and such events rarely occurred in the past. This prescription may limit the applicability of the model to analyze certain water temperature reduction measures; for example, the measure that calls for increased Canyon Dam releases (to up to 600 cfs) and commensurately reduced outflows from the Prattville Intake. It is anticipated that, under this measure, there would be some times that discharges at the Butt Valley PH would be lower than 700 cfs. Using the prescribed minimum flow of 700 cfs would overestimate the temperature at the Butt Valley PH tailrace when its discharge was lower than 700 cfs.

At the request of Stetson in April 2006, Bechtel modified and recompiled the MITEMP model code to remove the setting of the 700 cfs minimum threshold flow. Figures 5a and 5b show the model testing results of Butt Valley PH discharge water temperatures and Canyon Dam release water temperatures in 2000 using the two MITEMP models: one is the existing MITEMP that has the setting of the 700 cfs minimum threshold outflow and the other is the modified MITEMP that does not have the setting of the 700 cfs minimum threshold outflow. As shown in Figure 5a, the modified MITEMP generated lower discharge water temperatures of Butt Valley PH for discharge rates below 700 cfs. The two models generated the same discharge water temperatures of Butt Valley PH for discharge rates above 700 cfs. For the low flow period in August 2000[7], it appears that the modified MITEMP better reflects the pattern of discharge water temperatures with discharge rates, compared to the existing MITEMP. Figure 5b shows that the existing MITEMP and modified MITEMP generated the same results for the Canyon Dam release water temperatures, indicating the existing MITEMP did not have the 700 cfs minimum threshold outflow setting on the Canyon Dam outlet.

In order to better correlate the relationship between the discharge rate and water temperature under different Lake Almanor elevations (and the associated dissolved oxygen level) of the Butt Valley PH operation, PG&E conducted a special test on August 1-5, 2006. This special test (i.e., Special Test 5 - Caribou Special Test with Reduced Butt Valley PH Flows) is one of the six separate special tests that were carried out by PG&E during summer 2006 (Stetson and PG&E, 2007) at the request of the State Water Resources Control Board. Special Test 5 was also intended to help evaluate whether the cold water released from the Butt Valley PH (through a reduction in discharge rate) would plunge and travel below the water surface the 5-mile distance through Butt Valley Reservoir and become available for withdrawal at the Caribou #1 Intake. Figure 6 shows Butt Valley PH daily discharges and discharge temperatures during Special Test 5. During this special test, the Butt Valley PH discharge was reduced from about 1,800 cfs to about 500 cfs, and measured water temperatures decreased from about 16.5°C to 12.5°C-13.0°C [8]. PG&E also conducted an additional test at Butt Valley PH on August 26, 2006, using a discharge rate midway between the typical 1,600 cfs operating condition and the 500 cfs test; at a discharge rate of about 890 cfs, the mean daily water temperature discharged at Butt Valley PH was about 16.2°C. Figure 7 shows the model testing results of Butt Valley PH discharge water temperatures during the special test using the two MITEMP models. As shown in the figure, compared to the existing MITEMP, the modified MITEMP generated closer results to the observed discharge water temperatures at the Butt Valley PH for discharge rates below 700 cfs during the special test period of August 1-5, 2006. The two MITEMP models generated the same simulated discharge water temperatures at the Butt Valley PH for discharge rates above 700 cfs. The reason that both models over-estimated the discharge water temperatures at the Butt Valley PH for the entire period may be related to the withdrawal scheme assumption used in the MITEMP models that the Prattville Intake uniformly withdrew water between elevation 4436 ft (USGS datum) and the water surface.

If a thermal curtain is installed at the front of the Prattville Intake to induce hypolimnion cold water withdrawal, the outflow water temperatures at the intake would not be sensitive to the withdrawal rate because all water would come from the lake bottom. The MITEMP withdrawal algorithm would not limit the applicability of the Lake Almanor

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[7] Although low flow period existed in May 2000, it is more important to examine the model's accuracy in simulating discharge water temperatures in the summertime because there were no temperature issues in other seasons.

[8] Note that 2006 was a very wet year. Lake Almanor had an unusually high water level at elevation about 4,501 ft (3 ft below the normal maximum water level of 4,504 ft in USGS datum) during Special Test 5.

MITEMP model to simulate the outflow water temperatures at Prattville Intake for the thermal curtain condition.

Based on the above discussions and testing, it was judged that the modified MITEMP (without the 700 cfs minimum threshold flow) will be used in Lake Alamnor water temperature simulations for alternatives that do not need physical modifications at the Prattville Intake. For alternatives that do need physical modifications at the Prattville Intake, such as installing a thermal curtain in front of the intake, the corresponding MITEMP executables[9] of Lake Almanor that were used by Bechtel in the 33-years simulations (Bechtel and TRPA, 2006) will be used in the Level 3 analysis of UNFFR water temperature reduction alternatives.

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[9] There were several MITEMP executables provided by Bechtel. Each MITEMP executable was designed for a specific physical modification at the Prattville Intake. The modified MITEMP executable without the 700 cfs minimum threshold flow was only applicable to the existing intake condition.

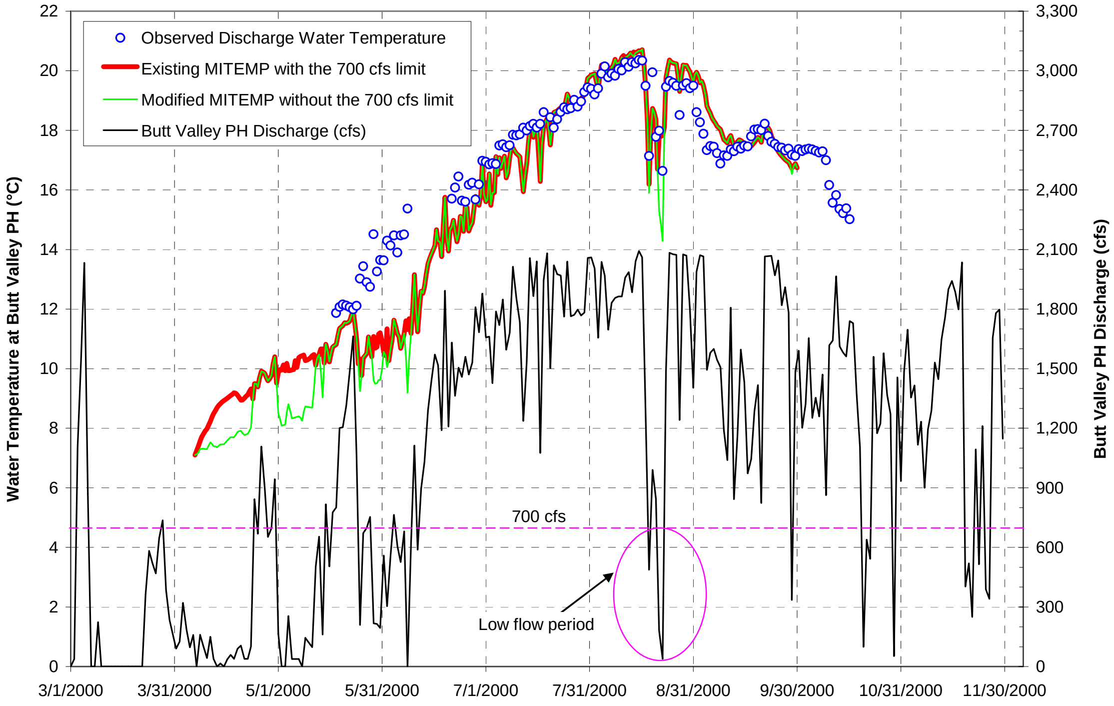
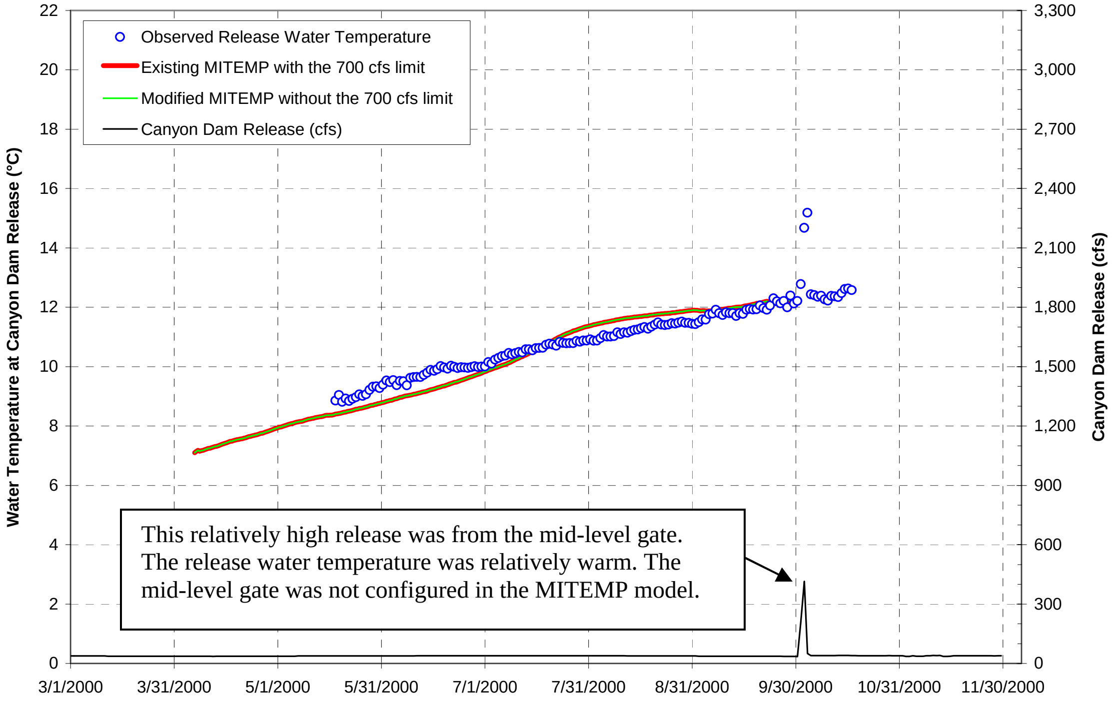


Figure 5a Observed and MITEMP-Simulated Discharge Water Temperatures at Butt Valley PH, 2000



This relatively high release was from the mid-level gate. The release water temperature was relatively warm. The mid-level gate was not configured in the MITEMP model.

Figure 5b Observed and MITEMP-Simulated Release Water Temperatures at Canyon Dam, 2000

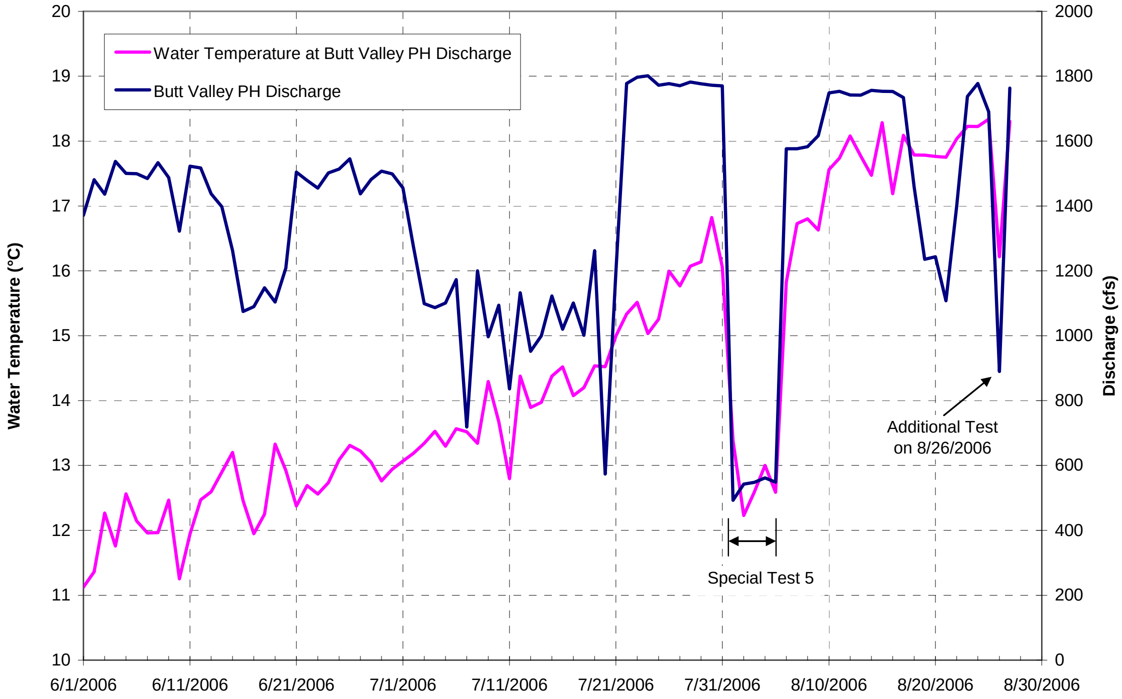


Figure 6 Observed Butt Valley PH Mean Daily Discharges and Discharge Water Temperatures during Summer 2006 Special Test

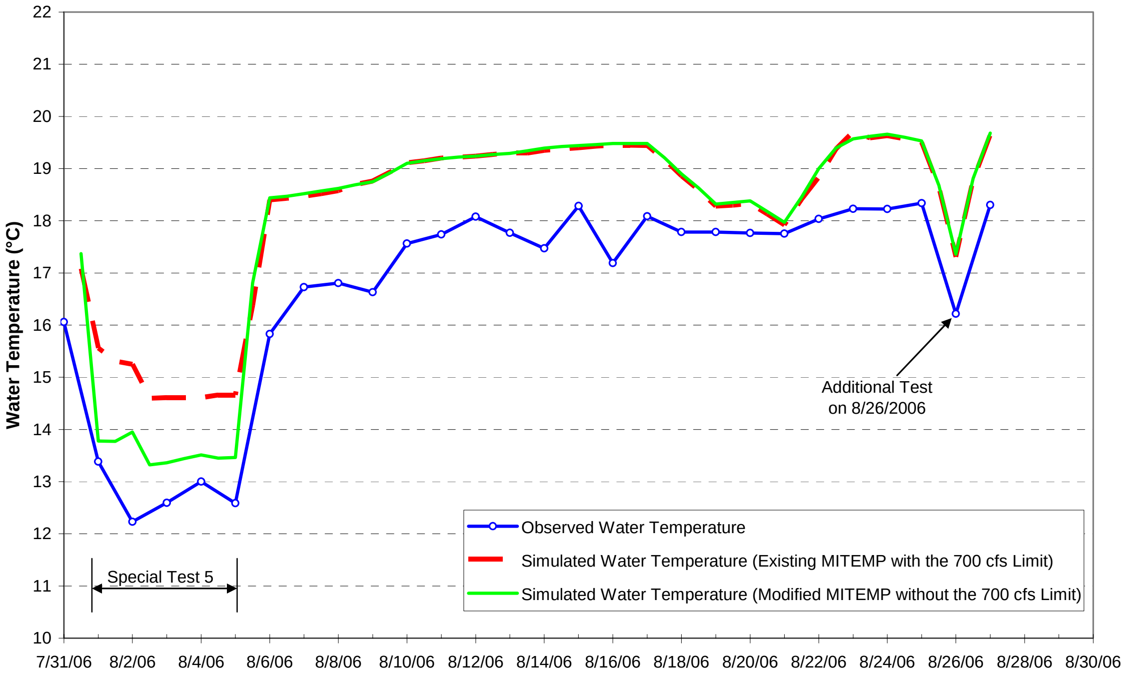


Figure 7 Observed and MITEMP-Simulated Discharge Water Temperatures at Butt Valley PH during 2006 Special Test

3.0 REVIEW OF THE EXISTING CE-QUAL-W2 MODEL OF LAKE ALMANOR AND STETSON IMPROVEMENTS TO THE MODEL

3.1 CE-QUAL-W2 BACKGROUND

CE-QUAL-W2 is a generic two-dimensional (longitudinal and vertical), laterally-averaged hydrodynamic and water quality model supported by the US Army Corps of Engineers, Waterways Experiment Station. The model divides a waterbody into multiple segments in the longitudinal direction and multiple layers in the vertical direction (see Figure 8). The model assumes uniform hydrodynamics and concentrations of water quality constituents in the lateral direction within the same segment and same layer. Because the model assumes lateral homogeneity, it is best suited for relatively long and narrow waterbodies exhibiting longitudinal and vertical water quality gradients and little lateral gradients. The model has been applied to rivers, lakes, reservoirs, and estuaries. The model can simulate selective withdrawal based on hydraulic principles: no user-specified flow distribution or withdrawal scheme is needed to simulate selective withdrawal (Refer to the Appendix for the CE-QUAL-W2 withdrawal algorithm which was directly extracted from the User Manual (Cole and Wells, 2002)). It can also simulate thermal curtain effects on cold water selective withdrawal. These capabilities are needed for Lake Almanor water quality modeling to assess the impacts of UNFFR water temperature reduction alternatives on cold freshwater habitat within the lake.

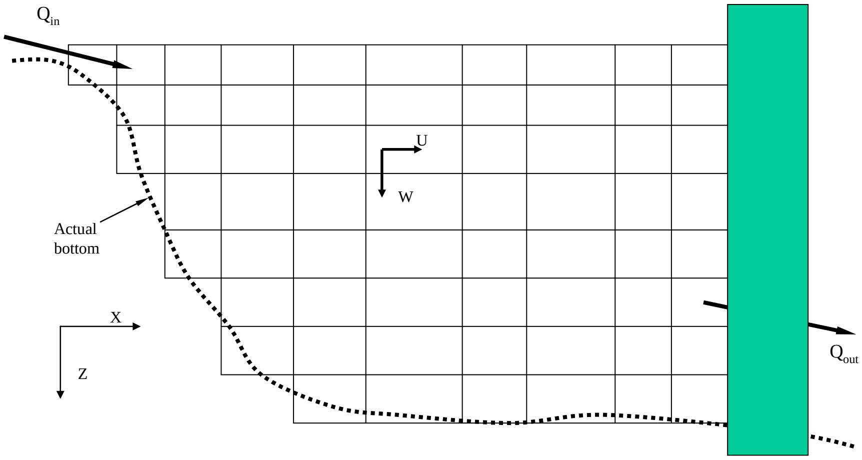


Figure 8 Typical Two-Dimensional (Longitudinal and Vertical) Grid for CE-QUAL-W2

As a hydrodynamic and water quality model, CE-QUAL-W2 can simulate both water temperature and DO and other water quality constituents. The outputs of a CE-QUAL-W2 model include outflow water temperatures and outflow concentrations of water quality constituents over time, water temperatures and concentrations of water quality constituents at each grid cell over time, and horizontal and vertical flow velocities at each grid cell over time.

The following data are required for representing the model domain and applying the CE-QUAL-W2 model for a reservoir:

- Bathymetry data and computational grid to represent the physical characteristics of the reservoir.
- Boundary conditions, including inflow rates, inflow water temperatures and water quality conditions at points where inflows enter the reservoir, and outflow rates at the downstream boundaries.
- Initial conditions, including reservoir water temperature, water elevation, and concentrations of water quality constituents at the beginning of the time period for which the model is applied.
- Meteorology data, including air temperature, dew point temperature, wind speed and direction, and cloud cover. The model uses short wave solar radiation if they are provided; otherwise, the model calculates solar radiation based on latitude, longitude, date, and cloud cover values.
- Model parameters, which are coefficients in the equations of the mathematical model that relate hydrodynamics, water temperature and water quality. Model parameters are site-specific and may need to be adjusted during model calibration to achieve a match between model simulated and observed data.
- Calibration/verification data, which are observed data used to test the performance of the model by comparing these data to model-simulated output data.

The CE-QUAL-W2 application model of Lake Almanor was originally developed by Jones and Stokes in 2004 for the purpose of predicting changes to lake dissolved oxygen (DO) concentrations and temperature distributions resulting from the selective cold water withdrawal from Lake Almanor. The lake was modeled using segments of varying length (i.e., 1.1 – 2.8 miles) to represent the longitudinal pieces of the lake. Each segment was divided into multiple layers: each layer was 3.3 feet deep (or 1 meter). The lake was divided into two branches. Branch 1, which consisted of eight active segments, covered the western portion of the lake that is fed by the NFFR at Chester and terminates at Canyon Dam. Branch 2, which consisted of three active segments, covered the eastern portion of the lake that is fed by Hamilton Branch (Figure 9).

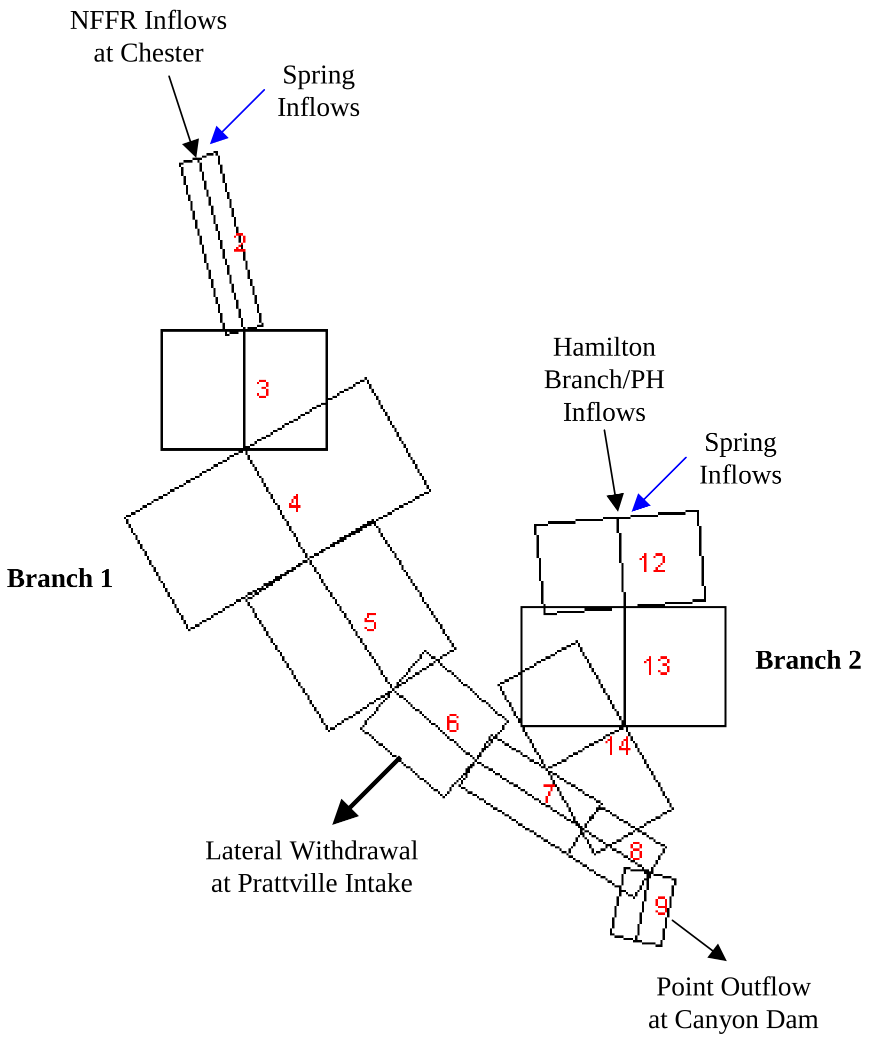


Figure 9 Lake Almanor CE-QUAL-W2 Model Configuration

The CE-QUAL-W2 model performance was evaluated by Jones & Stokes by comparing simulated results to available water quality and temperature measurements in March – November of 2000 and 2001. The average of the absolute values of the differences between the simulated and measured Butt Valley PH discharge water temperatures in time-series were 0.5ºC for 2000 and 0.3ºC for 2001, with the maximum deviation being 1.9ºC for 2000 and 1.2ºC for 2001. For the Canyon Dam releases, the averages of the absolute values of the differences between the simulated and measured temperatures in time-series were 0.4ºC for 2000 and 0.7ºC for 2001, with the maximum deviations being 1.2ºC for 2000 and 1.8ºC for 2001.

For year 2000, the overall average difference between simulated and observed vertical profiles near Canyon Dam was -0.4ºC for temperature and -0.5mg/L for DO concentration for 2000. The overall average of the absolute value of the differences was 0.6°C for temperature and 0.8 mg/l for DO concentration. For year 2001, the overall average difference between simulated and observed vertical profiles near Canyon Dam was -0.2ºC for temperature and -0.7mg/L for DO concentration. The overall average of the absolute value of the differences was 0.7°C for temperature and 1.1 mg/l for DO concentration.

Although the Lake Almanor CE-QUAL-W2 model was calibrated/validated to the existing conditions of 2000 and 2001, calibration of the Lake Almanor CE-QUAL-W2 model to the thermal curtain conditions of with and without the submerged levees near the intake by Jones & Stokes was limited. The reliability of the Lake Almanor CE-QUAL-W2 model in simulating the hydraulic effects of with and without removing the submerged levees near the intake under the thermal curtain condition has not been well established. Significant efforts would be needed to calibrate the Lake Almanor CE-QUAL-W2 model to the thermal curtain conditions of with and without the submerged levees near the intake.

3.2 POTENTIAL PROBLEMS OR LIMITATIONS IN THE CE-QUAL-W2 MODEL

1) Inconsistent Hydrology Input Data between the Existing CE-QUAL-W2 and MITEMP Models of Lake Almanor

Measured inflows at Chester, Hamilton Branch, and Hamilton Branch PH, measured outflows at Canyon Dam and the Prattville Butt Valley PH, and calibrated spring inflows were used in the CE-QUAL-W2 model as flow inputs. Precipitation was also included in the CE-QUAL-W2 model. Precipitation was not included in the MITEMP model. Figures 10a and 10b show different inflow inputs between the CE-QUAL-W2 and MITEMP models of Lake Almanor for the same calibration year 2000. Figures 11a and 11b show different inflow inputs between the CE-QUAL-W2 and MITEMP models of Lake Almanor for the same validation year 2001. There were no flow gage data available from PG&E Station NF1 (the North Fork of the Feather River above Lake Almanor) for January 1, 2000 – May 17, 2000. The difference in inflow inputs for the CE-QUAL-W2 and MITEMP models (Figure 10a) resulted from different methods used to estimate flows for this period. The estimated spring flows for the CE-QUAL-W2 model (Figures 10b and 11b) were calibrated directly from the model as the daily values needed to attain a water balance for the lake. However, it seems unreasonable that the daily variations and magnitude of spring flows during the summer would be much higher than other seasons. Spring flows during the summer should be relatively stable. It is Stetson's opinion that the CE-QUAL-W2 model and the MITEMP model need to use reasonable assumptions and consistent input data because water balance is an important factor affecting reservoir temperature modeling results.

Figure 10a Model Input Comparison of NFFR Inflows at Chester, 2000 Calibration

**(CE-QUAL-W2 calibration period: 3/1/2000 - 11/30/2000;
MITEMP calibration period: 4/6/2000 - 9/30/2000)**

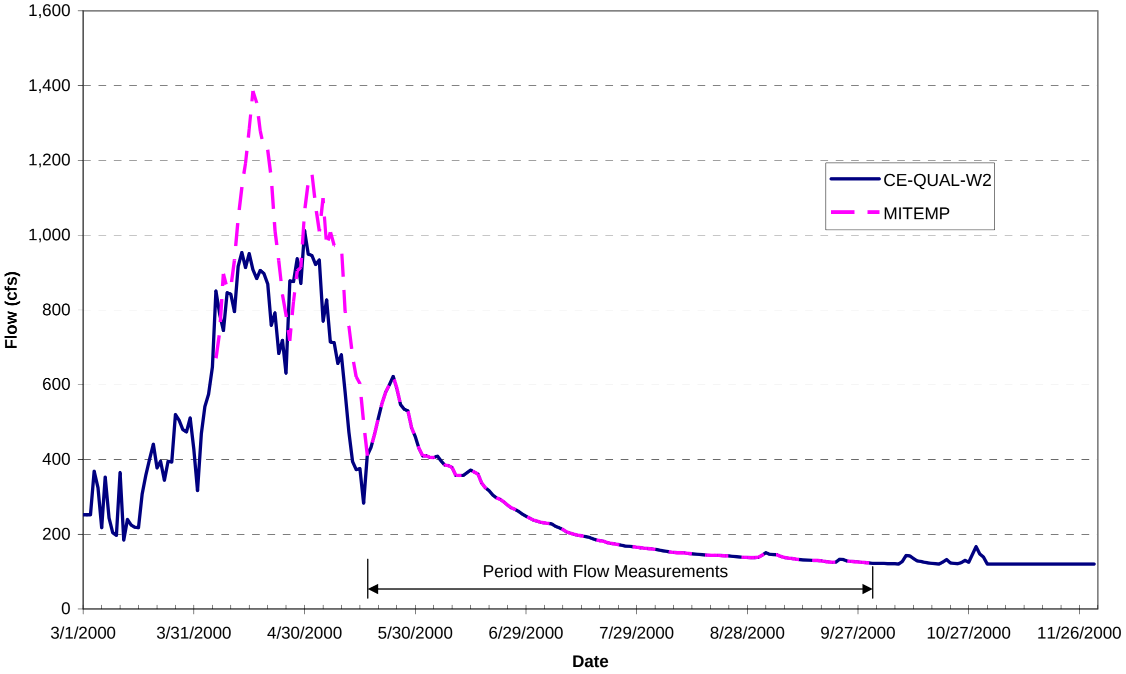


Figure 10b Model Input Comparison of Spring Inflows, 2000 Calibration

**(CE-QUAL-W2 calibration period: 3/1/2000 - 11/30/2000;
MITEMP calibration period: 4/6/2000 - 9/30/2000)**

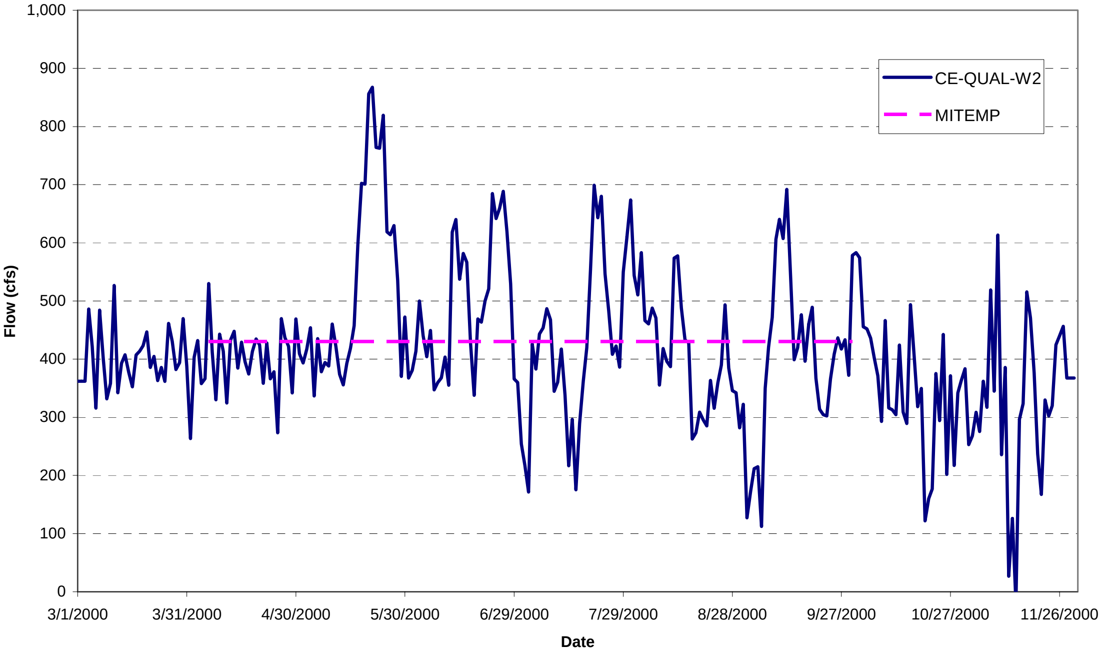


Figure 11a Model Input Comparison of NFFR Inflows at Chester, 2001 Validation

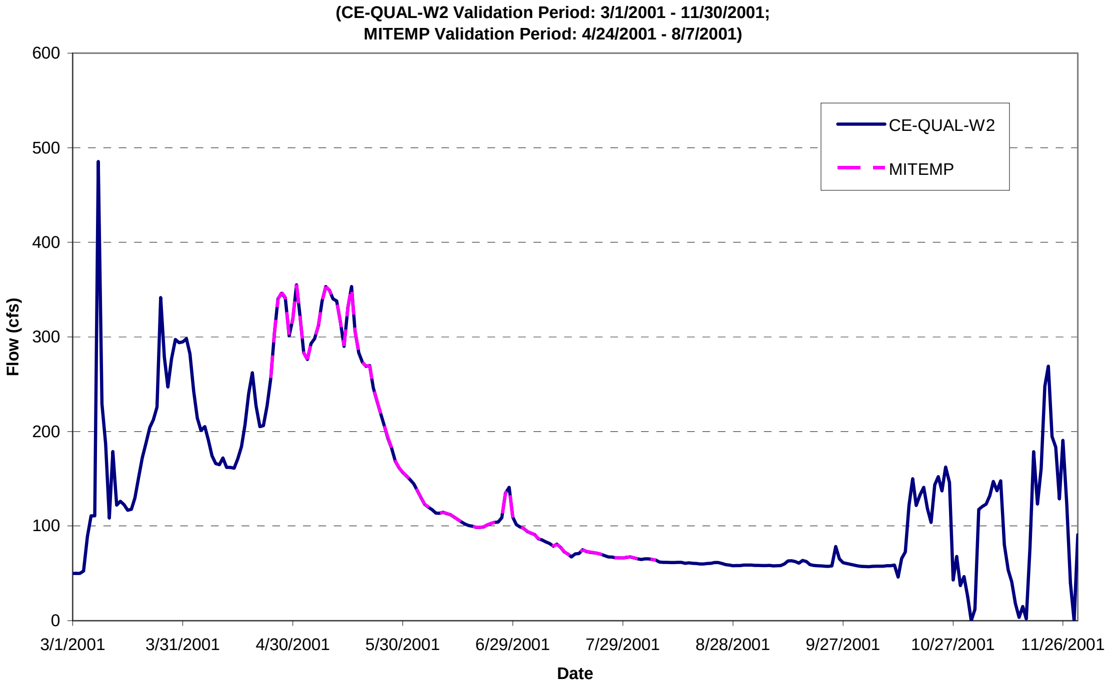
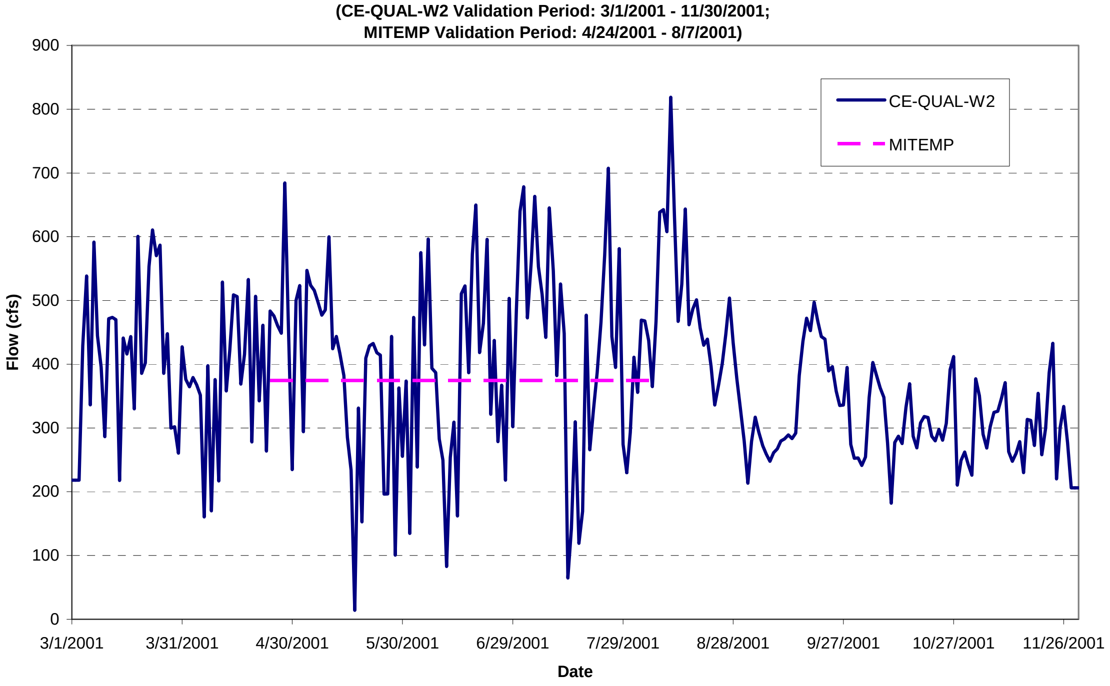


Figure 11b Model Input Comparison of Spring Inflows, 2001 Validation



2) Unreasonable High Effective Centerline Elevation of Prattville Intake in the Existing CE-QUAL-W2 Model

The CE-QUAL-W2 model represents the point withdrawal with centerline elevation of the intake and withdrawal zone limits. The effective centerline elevation of the Prattville Intake has a large effect on the Butt Valley PH discharge water temperatures. Although the actual invert elevation of the Prattville Intake structure is located at el. 4,420 ft in USGS datum, the withdrawal zone is controlled by the main approach channel, that has an elevation of 4,432 ft, and the submerged levees in front of the intake. The existing CE-QUAL-W2 model had a calibrated effective centerline elevation of 4,467 ft (USGS datum) and a withdrawal zone between elevation 4,446 ft (or the bottom of model layer 19) to the surface. The effective centerline elevation and the withdrawal limit were derived through trial and error to achieve a good match with the measured Butt Valley PH discharge temperatures. However, the calibrated effective centerline elevation of the Prattville Intake by Jones and Stokes appeared to be too high. Figure 12 shows the calibrated discharge water temperatures at the Butt Valley PH. The calibration results did not capture the discharge water temperatures when the discharge rates were relatively low. The effective centerline elevation in the existing CE-QUAL-W2 model, which was set at el. 4,467 ft (USGS datum), is generally close to or within the epilimnion of Lake Almanor during the summer stratification period. Lake Almanor epilimnion has a relatively uniform warm water temperature. So the existing CE-QUAL-W2 model generated warm discharge water temperatures at the Butt Valley PH regardless of the discharge rate. In other words, the existing CE-QUAL-W2 model did not capture the true relationship between the discharge rate and water temperature (and the associated dissolved oxygen level) of the Butt Valley PH discharge.

As discussed earlier, in order to better correlate the relationship between the discharge rate and water temperature under different Lake Almanor elevations (and the associated dissolved oxygen level) of the Butt Valley PH operation, PG&E conducted a special test on August 1-5, 2006. This special test (i.e., Special Test 5 - Caribou Special Test with Reduced Butt Valley PH Flows) is one of the six separate special tests that were carried out by PG&E during summer 2006 (Stetson and PG&E, 2007) at the request of the State Water Resources Control Board. Special Test 5 was also intended to help evaluate whether the cold water released from the Butt Valley PH (through a reduction in discharge rate) would plunge and travel the 5-mile distance through Butt Valley Reservoir and become available for withdrawal at the Caribou #1 Intake. Figure 13 shows Butt Valley PH daily discharges and discharge temperatures during Special Test 5. During this special test, the Butt Valley PH discharge was reduced from about 1,800 cfs to about 500 cfs, and measured water temperatures decreased from about 16.5°C to 12.5°C-13.0°C [10]. PG&E also conducted an additional test at Butt Valley PH on August 26, 2006, using a discharge midway between the typical 1,600 cfs operating condition and the 500 cfs test. At a discharge rate of about 890 cfs, the mean daily water temperature discharged at Butt Valley PH was about 16.2°C. Figure 14 shows Lake Almanor water temperature profiles measured near the Prattville Intake during Special

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[10] Note that 2006 was a very wet year. Lake Almanor had an unusually high water level at elevation about 4,501 ft (3 ft below the normal maximum water level) during Special Test 5.

Test 5. According to the measured water temperature profiles and the measured discharge water temperatures of about 12.5°C-13.0°C during Special Test 5, the effective centerline elevation of the Prattville Intake appeared to be at about 4,456 ft – 4,460 ft (USGS datum). Setting the effective centerline elevation at 4,467 ft (USGS datum) in the existing CE-QUAL-W2 model resulted in a simulated withdrawal of warm water. This is demonstrated in Figure 15, which shows that the simulated discharge water temperatures at the Butt Valley PH by the existing CE-QUAL-W2 model were consistently warm and significantly higher than the observed discharge water temperatures.

3.3 STETSON IMPROVEMENTS TO THE CE-QUAL-W2 MODEL

Before making any adjustments to the model parameters of the existing CE-QUAL-W2 model, the inconsistent hydrology input data in the existing CE-QUAL-W2 model that were discussed earlier were first replaced with the hydrology input data used in the existing MITEMP model. The primary reason for using the hydrology input data used in the existing MITEMP model, instead of the existing CE-QUAL-W2 model, was that, the constant spring flows used in the MITEMP model were more reasonable than the daily variable spring flows used in the existing CE-QUAL-W2 model. Figures 16 and 17 show the simulated water surface elevations for years 2000 and 2001 respectively. The results indicate that the simulated water surface elevations by the improved model can satisfactorily match the observed water surface elevations.

After ensuring the water balance of the lake was reasonably simulated, the following model parameters of the existing CE-QUAL-W2 model were adjusted to achieve satisfactory agreement between simulated and observed data for water temperature and dissolved oxygen.

Effective centerline elevation of the Prattville Intake – The effective centerline elevation of the Prattville Intake was adjusted to el. 4,456 ft (USGS datum) and the withdrawal zone was adjusted to between elevation 4,449 ft (or the bottom of model layer 18) to the surface. These adjustments were initially based on the 2006 water temperature profile measurements near the Prattville Intake (see Figure 14) and then fine-tuned through trial and error to achieve a satisfactory match with the measured Butt Valley PH discharge water temperatures. Table 3 is the measured water velocity profile at the Prattville Intake during the 2006 special test. The blue highlighted area, which has a water depth between 35 ft to 51 ft, is the core of water velocities when the Prattville Intake withdrawal rate was reduced to about 500 cfs. Lake Almanor water surface elevation during the 2006 special test was about 4,500 ft (USGS datum). So the centerline elevation of the core area of velocities was at about 4,456 ft. The velocity data also verified the adjusted effective centerline elevation of the Prattville Intake in the improved CE-QUAL-W2 model.

Table 3 Measured Water Velocity Profile at Prattville Intake during the 2006 Special Test

	Argonaut Data Prattville Intake (Mid-Channel) Averages		
Depth (ft)	Water Temperature (°F)	Water Velocity (fps)	Flow Direction (degree)
0			
14	72.6	0.15	148
27	72.2	0.13	161
30	68.3	0.10	59
35	64.9	0.23	206
38	61.0	0.48	197
39	56.1	0.56	193
41	53.0	0.73	191
42	52.4	0.77	189
44	51.3	0.69	194
45	50.5	0.74	196
46	49.9	0.78	197
48	49.6	0.73	208
49	49.3	0.88	201
51	48.9	0.67	201
52	bottom		

Light extinction coefficient — The extinction coefficient for light (by algae, suspended sediment, and water) controls the depth of light penetration in the water column and has a large effect on the thermal structure of the lake. The light extinction coefficient in the existing CE-QUAL-W2 model used daily variable values which were computed using a minimum value of 0.25 m^{-1} (for pure water) plus any additional contributions by the concentrations of algae and suspended sediment computed by the model. Using daily variable extinction coefficients is not preferred because it requires the model accurately simulate the concentrations of algae and suspended sediment. The existing CE-QUAL-W2 model did not demonstrate its accuracy in simulating the concentrations of algae and suspended sediment. For simplicity the light extinction coefficient in the Stetson improved model was adjusted to a constant 0.35 m^{-1}. This constant value was close to the average light extinction coefficient estimated from the measured secchi depth in the summertime as shown in Table 4.

Table 4 Estimated Light Extinction Coefficients from Measured Secchi Depth by California Department of Water Resources in 2000 and 2001

Measurement Date	Location	Secchi Depth (m)	Estimated Light Extinction Coefficient (m^{-1})
6/8/2000	Near Canyon Dam	4.8	0.35
7/21/2000	Near Canyon Dam	8.4	0.23
9/7/2000	Near Canyon Dam	6.9	0.27
6/8/2000	Central Hamilton Branch	5.0	0.34
7/21/2000	Central Hamilton Branch	8.2	0.24
9/7/2000	Central Hamilton Branch	6.9	0.27
7/21/2000	Central Chester Branch	7.2	0.26
9/7/2000	Central Chester Branch	4.4	0.38
6/7/2001	Near Canyon Dam	7.4	0.26
7/19/2001	Near Canyon Dam	6.0	0.30
9/6/2001	Near Canyon Dam	4.7	0.36
6/7/2001	Central Hamilton Branch	9.3	0.22
7/19/2001	Central Hamilton Branch	6.2	0.29
9/6/2001	Central Hamilton Branch	4.3	0.38
9/6/2001	Central Chester Branch	3.5	0.44

The light extinction coefficient, λ, was estimated from secchi depth D using the following equation as recommended in the CE-QUAL-W2 User Manual (Cole and Wells, 2002):

$$\lambda = 1.11 \cdot D^{-0.73}$$

Figures 18 to 22 show a comparison of simulated results between the existing and the improved CE-QUAL-W2 models for 2000. Figures 23 to 25 show a comparison of simulated results between the existing and the improved CE-QUAL-W2 models for 2001. Figure 26 shows a comparison of simulated results between the existing and the improved CE-QUAL-W2 models for the 2006 special test[11]. As shown in Figures 18 and 26, the simulated Butt Valley PH discharge water temperatures by the improved CE-QUAL-W2 model are apparently better than the existing CE-QUAL-W2 model.

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[11] Stetson developed Lake Almanor CE-QUAL-W2 input files covering the period of July 31, 2006 to August 27, 2006, with the observed water temperature profile on July 31 as the initial water temperature profile.

4.0 FINDINGS AND CONCLUSIONS

This report reviewed the adequacy of the existing Lake Almanor MITEMP and CE-QUAL-W2 models to support the Level 3 analysis of UNFFR water temperature reduction alternatives, explained the need for modeling both water temperature and dissolved oxygen (DO) in Lake Almanor and the reasoning for using both models in the Level 3 alternatives analysis, and documented Stetson's improvements to the Lake Almanor CE-QUAL-W2 model. The findings and conclusions are summarized as follows:

1) The water temperature reduction measures at Lake Almanor to be analyzed in Level 3 include hypolimnion cold water withdrawal from Lake Almanor through use of a thermal curtain that would be installed near the Prattville Intake and/or through release from the low-level outlet at Canyon Dam. Although normally under existing conditions the hypolimnion cold water in the lake has low dissolved oxygen (DO) in the summertime and is not suitable for cold freshwater habitat because of low DO, too much cold water withdrawal from Lake Almanor under alternatives to be analyzed in Level 3 could affect the lake's thermal structure and DO distribution and, thus, adversely impact the cold freshwater habitat beneficial use of the lake. A water quality model is needed to simulate both water temperature and DO distributions in the lake under Level 3 alternatives. The simulated water temperature and DO distributions would in turn be used to evaluate the impacts of the water temperature reduction measures on the cold freshwater habitat in the lake.

2) The existing Lake Almanor MITEMP model was developed for PG&E by Bechtel for the purpose of simulating Lake Almanor water temperature profiles and discharge water temperatures at Butt Valley PH and Canyon Dam. The existing Lake Almanor CE-QUAL-W2 model was developed by Jones & Stokes for the purpose of simulating the impacts of cold water withdrawal on the distribution of temperature and DO concentrations and thereby evaluating suitable cold freshwater habitat in the lake. It was judged that both the MITEMP and CE-QUAL-W2 models of Lake Almanor will be used in the Level 3 analysis of UNFFR water temperature reduction alternatives for these purposes. The need for the Lake Almanor CE-QUAL-W2 model arises from the fact that MITEMP simulates reservoir water temperature only; MITEMP does not have the capability to simulate DO because it does not have water quality components. On the other hand, although the Lake Almanor CE-QUAL-W2 model has the capability to simulate both water temperature and DO, the MITEMP model will be used to simulate Lake Almanor water temperature profiles and discharge water temperatures at Butt Valley PH and Canyon Dam for the following two main reasons:

   - The water temperature reduction measures at the Prattville Intake to be analyzed in Level 3 include a thermal curtain under the conditions of with and without removing the submerged levees near the intake. The bathymetry of Lake Almanor in the Prattville Intake area is complicated and the hydraulics at the intake area is very much three-dimensional. Although the Lake Almanor CE-QUAL-W2 model was calibrated/validated to the existing conditions of 2000 and 2001, calibration of the Lake Almanor CE-QUAL-W2 model to the thermal curtain conditions of with and without the submerged levees near the intake by Jones & Stokes was limited. The reliability of the Lake Almanor CE-QUAL-W2 model in simulating the hydraulic effects of with and without removing the submerged levees near the intake under the thermal curtain condition has not been well established. Significant efforts would be needed to calibrate the Lake Almanor CE-QUAL-W2 model to the thermal curtain conditions of with and without the submerged levees near the intake.

- MITEMP is a one-dimensional (vertical) mathematical water temperature model. A basic assumption of the MITEMP program is that the temperature gradient is predominantly in the vertical direction and the variation in the horizontal and lateral directions is negligible. Because of its large size, Lake Almanor has a thermal structure that is strongly influenced by surface heat transfer but relatively unresponsive to daily flows. Temperature measurements at various locations throughout Lake Almanor showed that the lake exhibits a significant temperature gradient in the vertical direction but little variation in the horizontal direction during the summer months. Both observations of water temperature profiles in Lake Almanor and the theoretical analysis of MITEMP applicability indicate that the one-dimensional MITEMP program is applicable for Lake Almanor. Further, considerable efforts were taken by Bechtel to calibrate the Lake Almanor MITEMP model under the thermal curtain conditions with and without the submerged levees near the intake based on the physical model results conducted at the University of Iowa. To calibrate the model, Bechtel modified the MITEMP source code to reflect the hydraulic effects of with and without removing the submerged levees near the intake under the thermal curtain condition. It is Stetson’s opinion that, compared to the Lake Almanor CE-QUAL-W2 model, the Lake Almanor MITEMP model appears more credible for simulating the incremental benefit in discharge water temperature reduction for different alternatives, a crucial parameter in the Level 3 analysis of UNFFR water temperature reduction alternatives.

3) There were several MITEMP executables provided by Bechtel. Each MITEMP executable was designed for a specific physical modification at the Prattville Intake. The withdrawal algorithm in the MITEMP executables was developed based on the physical model test results for the outflow range of 800 cfs – 2,400 cfs at the Prattville Intake. It appears that the withdrawal algorithm was not tested for lower flow conditions. In addition, the Lake Almanor MITEMP model has arbitrarily set a minimum threshold outflow of 700 cfs which was prescribed in the model code for discharges at the Prattville Intake. More specifically, the model will automatically use 700 cfs to compute the withdrawal water temperature at the Prattville Intake, even if discharges are less than 700 cfs. The 700 cfs threshold was chosen because any flow less than this level was considered a short-term transient operation and such events rarely occurred in the past. This prescription may limit the applicability of the model to analyze certain water temperature reduction measures; for example, the measure that calls for increased Canyon Dam releases (to up to 600 cfs) and commensurately reduced outflows from the Prattville Intake. It is anticipated that, under this measure,

there would be some times that discharges at the Butt Valley PH would be lower than 700 cfs. Using the prescribed minimum flow of 700 cfs would overestimate the temperature at the Butt Valley PH tailrace when its discharge was lower than 700 cfs.

At the request of Stetson in April 2006, Bechtel modified and recompiled the MITEMP model code to remove the setting of the 700 cfs minimum threshold flow. The modified MITEMP executable without the 700 cfs minimum threshold flow was only applicable to the existing intake condition. Model testing using the 2000 data and the 2006 special test data indicated that the modified MITEMP executable without the 700 cfs minimum threshold flow appeared to better reflect the relationship between the discharge rate and water temperature of the Butt Valley PH discharge.

If a thermal curtain is installed at the front of the Prattville Intake to induce hypolimnion cold water withdrawal, the outflow water temperatures at the intake would not be sensitive to the withdrawal rate because all water would come from the lake bottom. The MITEMP withdrawal algorithm would not limit the applicability of the Lake Almanor MITEMP model to simulate the outflow water temperatures at Prattville Intake for the thermal curtain condition.

Therefore, it was judged that the modified MITEMP (without the 700 cfs minimum threshold flow) will be used in Lake Alamnor water temperature simulations for alternatives that do not need physical modifications at the Prattville Intake. For alternatives that do need physical modifications at the Prattville Intake, such as installing a thermal curtain in front of the intake, the corresponding MITEMP executables of Lake Almanor that were used by Bechtel in the 33-years simulations (Bechtel and TRPA, 2006) will be used in the Level 3 analysis of UNFFR water temperature reduction alternatives.

4) Potential problems or limitations were identified in the existing CE-QUAL-W2 model of Lake Almanor, including a) inconsistent hydrology input data between the existing CE-QUAL-W2 and MITEMP models of Lake Almanor and, b) unreasonable high effective centerline elevation of Prattville Intake (4,467 ft in USGS datum) in the existing CE-QUAL-W2 model, which resulted in a unrealistic relationship between Butt Valley PH discharge rate and discharge water temperature (and associated dissolved oxygen level). Stetson improved the CE-QUAL-W2 model accordingly. The improved CE-QUAL-W2 model has consistent hydrology input data with the existing MITEMP model and provides a better relationship between the discharge rate and water temperature of the Butt Valley PH discharge. The improved CE-QUAL-W2 model has an effective centerline elevation of Prattville Intake at 4,456 ft in USGS datum. This effective centerline elevation is close to the observed condition during the 2006 special test. The improved CE-QUAL-W2 model will be used in the Level 3 alternatives analysis to simulate the impacts that withdrawal of cold water from near the lake bottom could have on the distribution of dissolved oxygen (DO) and water temperature and, thus, cold freshwater habitat in the lake.

REFERENCES

Bechtel Corporation, 2002. MITEMP3 Model Calibration and Validation in 2000-2001, Lake Almanor and Butt Valley Reservoir, CA. Prepared for Pacific Gas and Electric Company.

Bechtel Corporation, 2004. Revised MITEMP Model Code and Calibration with Physical Model Results from the IIHR Lake Almanor Cold-Water Feasibility Study.

Bechtel Corporation and Thomas R. Payne and Associates, 2006. North Fork Feather River Instream Temperature Studies, 33 Years of Synthesized Reservoir Operations, Evaluation of Installation of Curtains and Modifications in Lake Almanor and Butt Valley Reservoir and High Instream Flow Releases from Canyon Dam.

Cole, T.M., and S. A. Wells, 2002. "CE-QUAL-W2: A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 3.1," Instruction Report EL-2002-1, US Army Engineering and Research Development Center, Vicksburg, MS.

Jones & Stokes, 2004. Simulation of Temperature and Dissolved Oxygen in Lake Almanor, California Using the CE-QUAL-W2 Water Quality Model

Stetson Engineers Inc., 2007. Level 1 and 2 Report/ Development and Screening of Potentially Effective and Feasible Alternatives to Achieve the Basin Plan Objective for Water Temperature and Protect Cold Freshwater Habitat Beneficial Use along the North Fork Feather River.

Woodward-Clyde Consultants, 1986. Rock Creek – Cresta Project Cold Water Feasibility Study, Volume 1. Prepared for Pacific Gas and Electric Company.

Figure 12 Existing CE-QUAL-W2 Model-Simulated Discharge Water Temperatures at Butt Valley PH, 2000

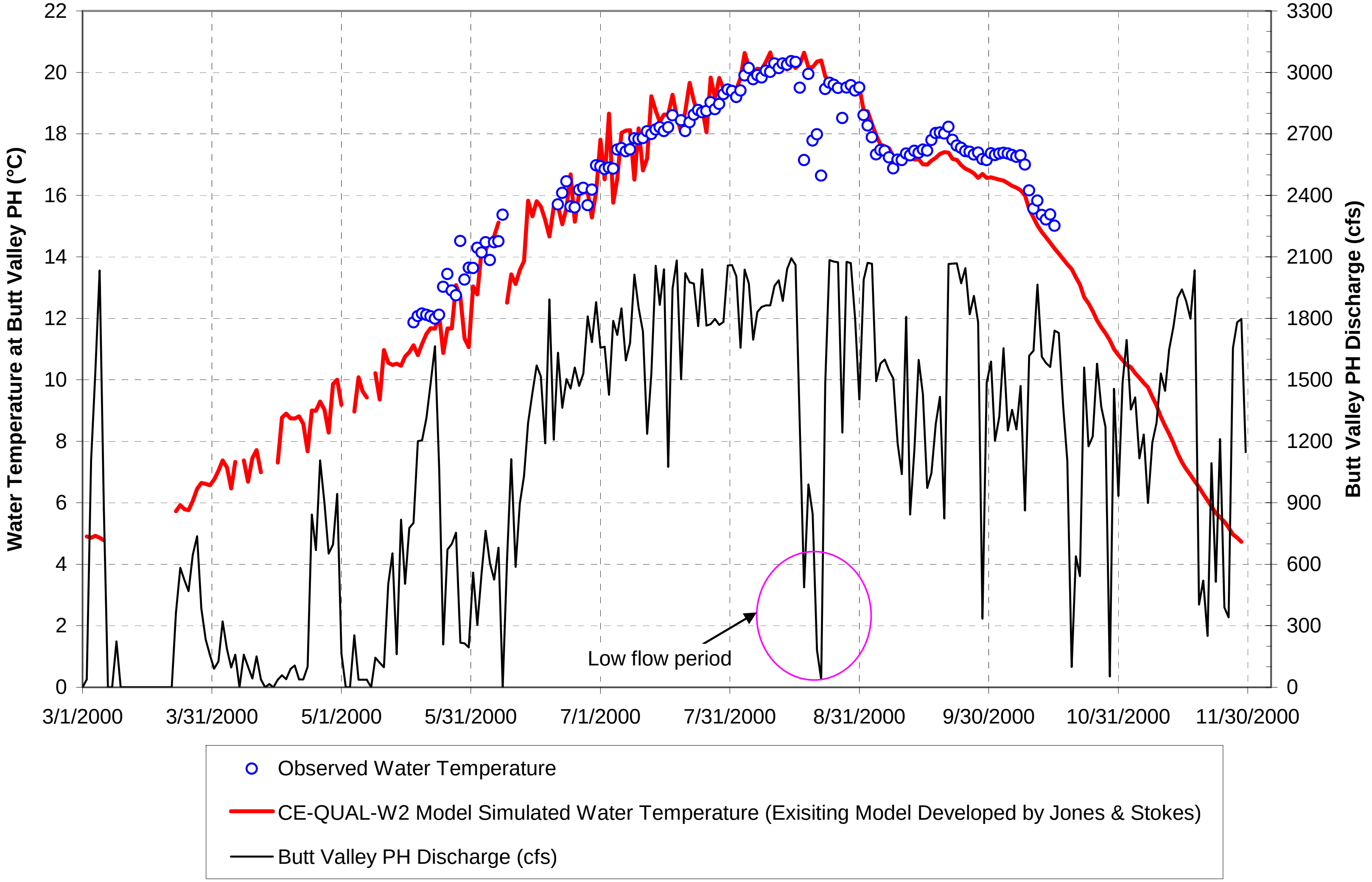


Figure 13 Observed Butt Valley PH Mean Daily Discharges and Discharge Water Temperatures during Summer 2006 Special Test

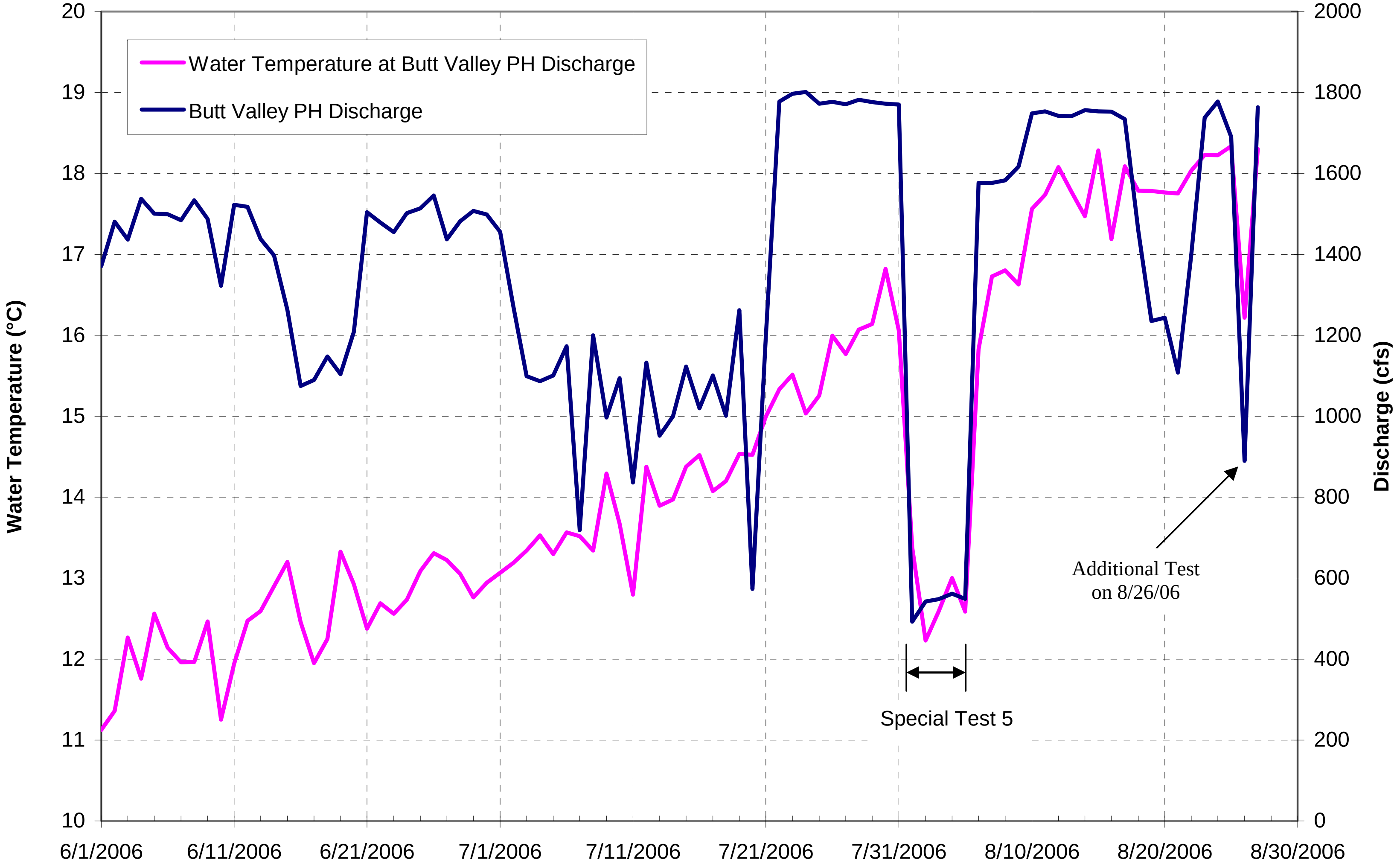


Figure 14 Lake Almanor Water Temperature Profiles near Prattville Intake (LA2) during Summer 2006 Special Test

(Butt Valley PH discharges were about 500 cfs during the special test)

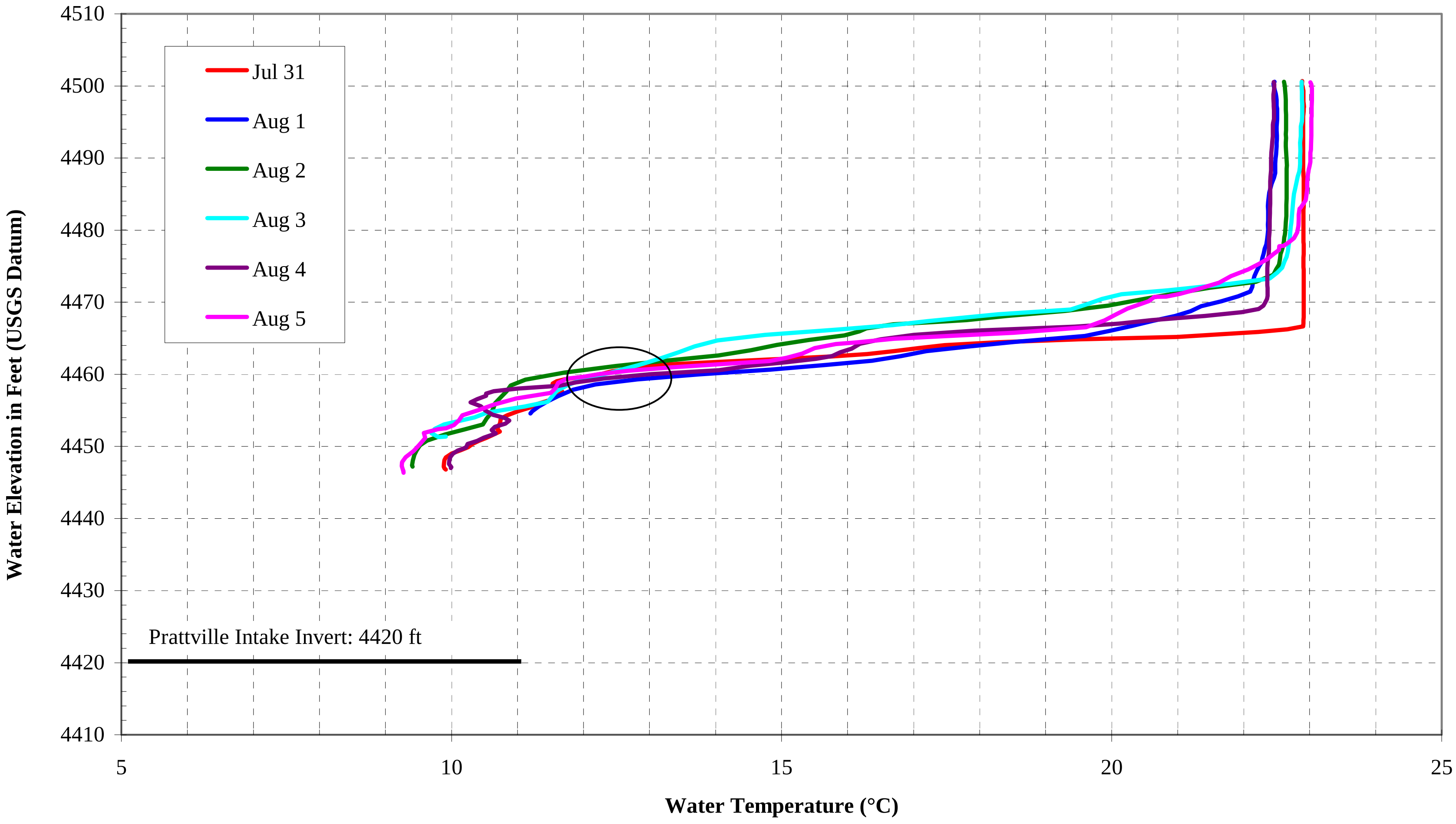


Figure 15 Existing CE-QUAL-W2 Model-Simulated Discharge Water Temperatures at Butt Valley PH, 2006 Special Test

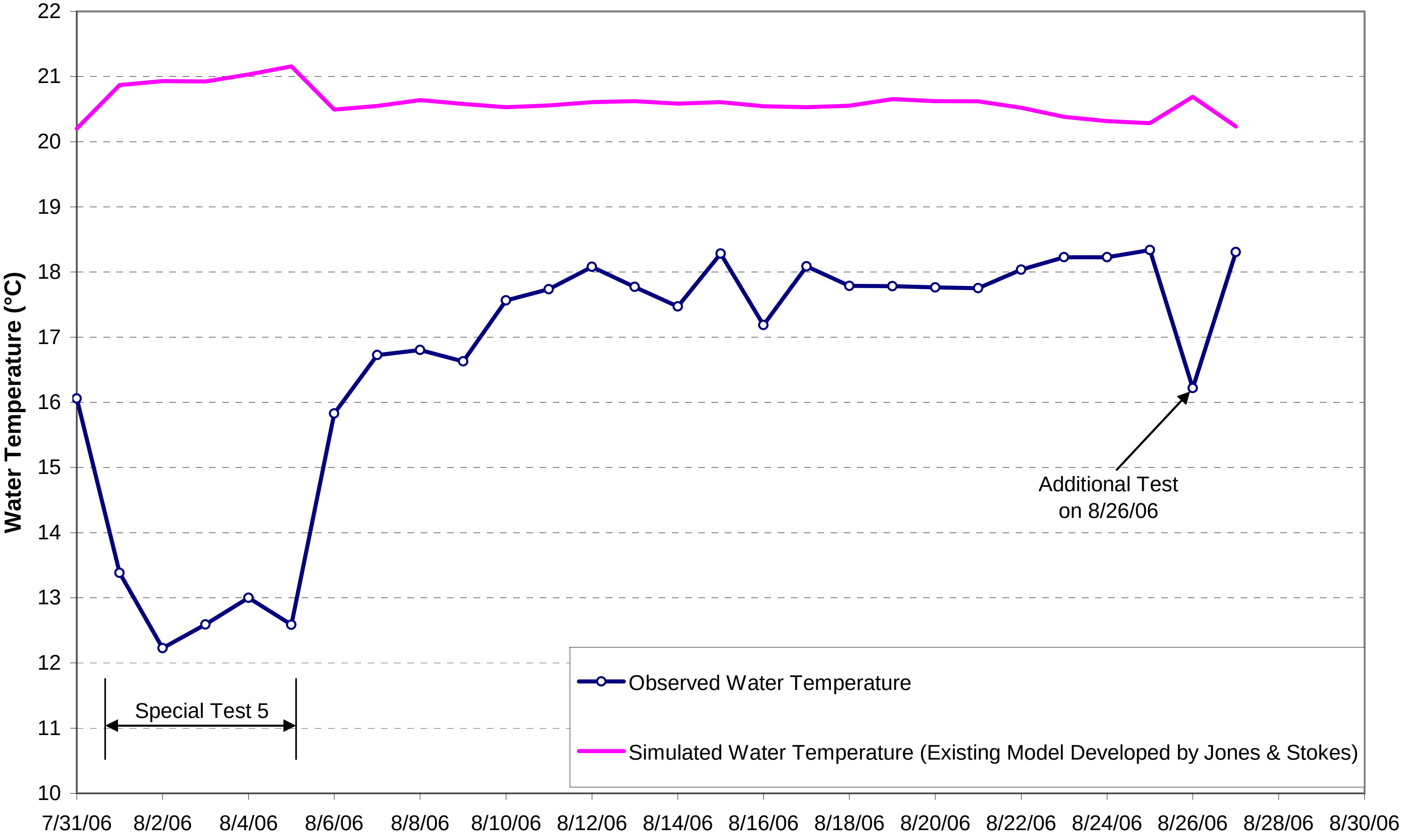


Figure 16 Simulated Water Surface Elevation of 2000 Using the Improved CE-QUAL-W2 Model

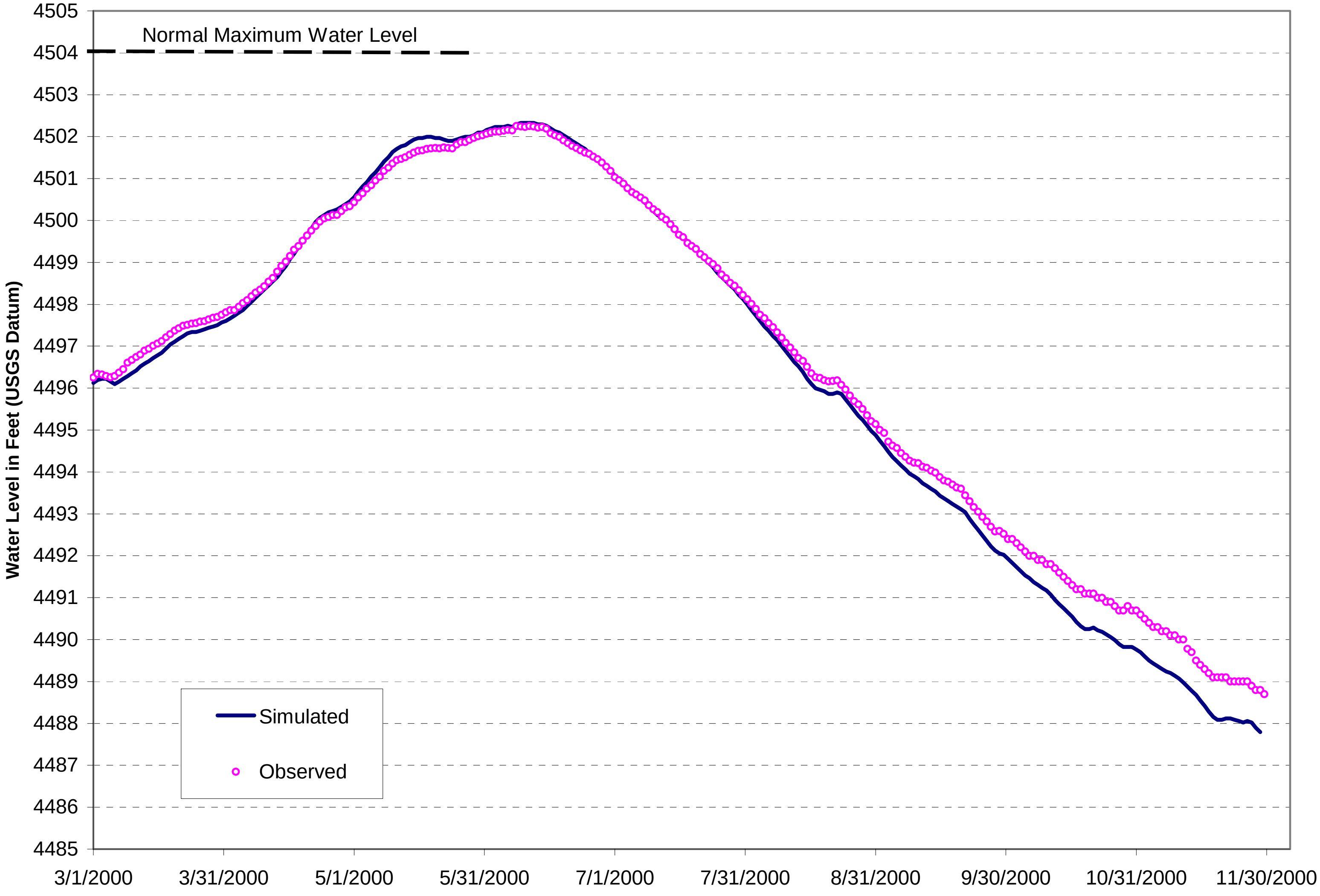


Figure 17 Simulated Water Surface Elevations of 2001 Using the Improved CE-QUAL-W2 Model

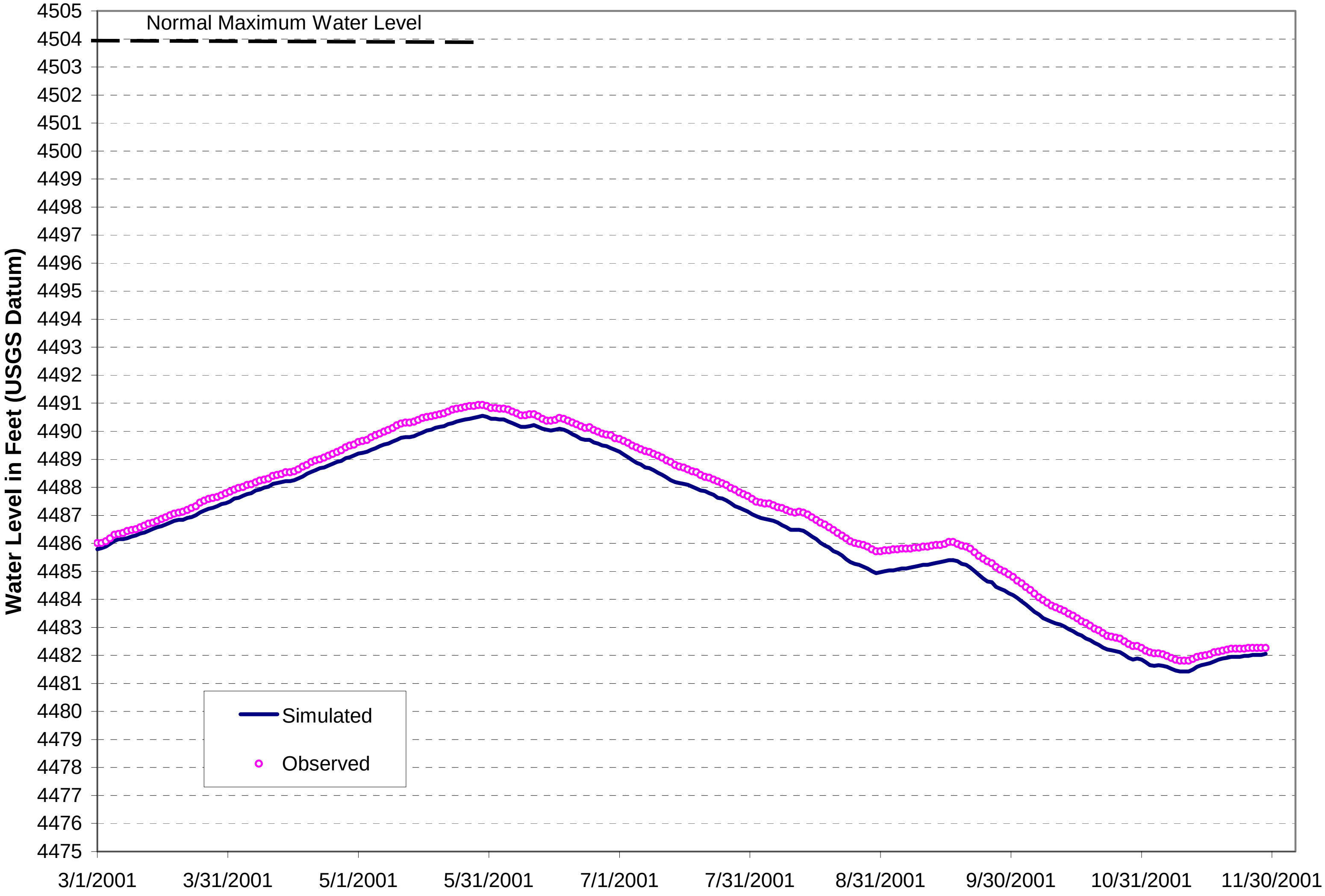


Figure 18 Comparison of Simulated Discharge Water Temperatures at Butt Valley PH, 2000 between the Existing and Improved CE-QUAL-W2 Models

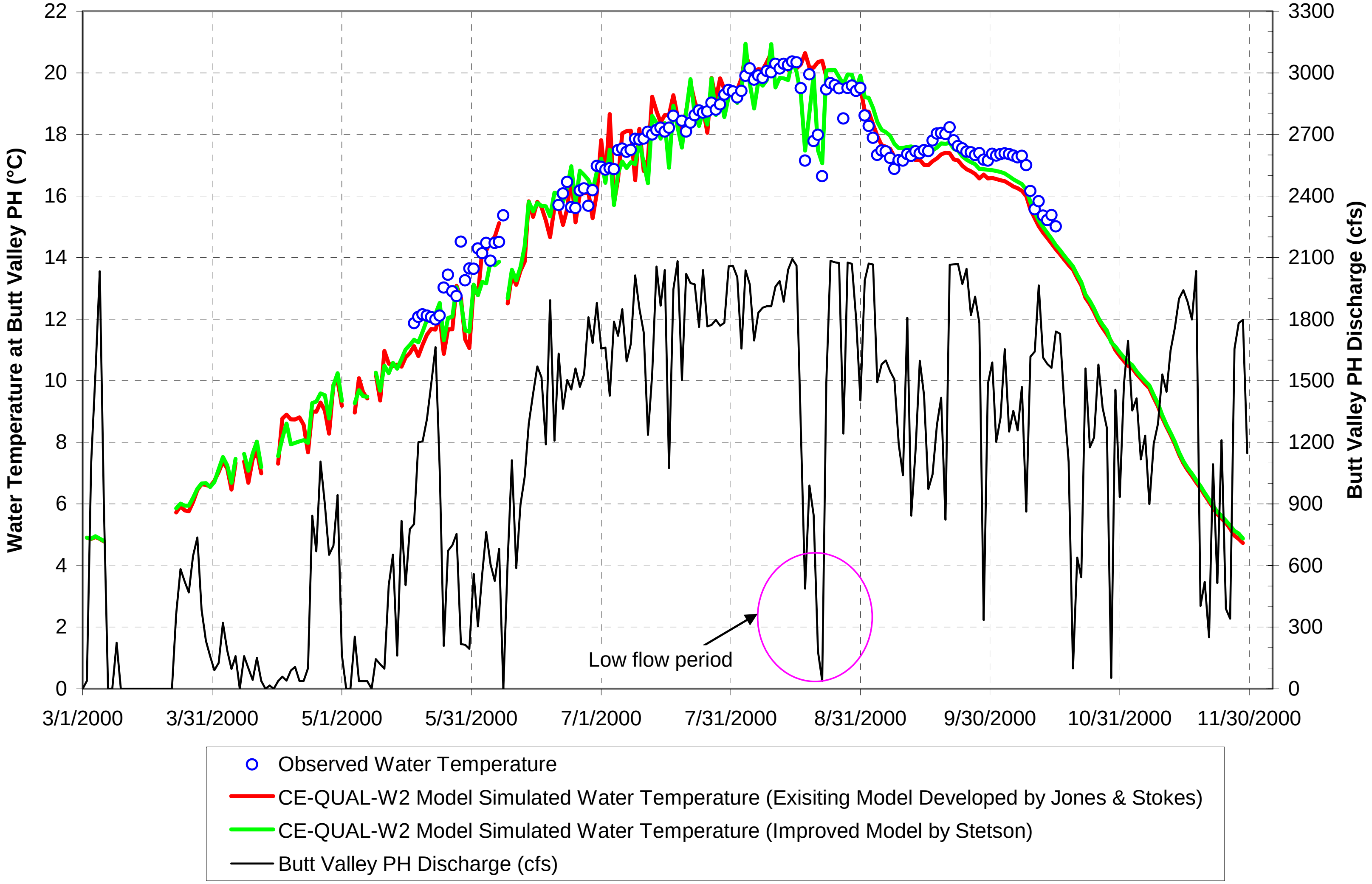
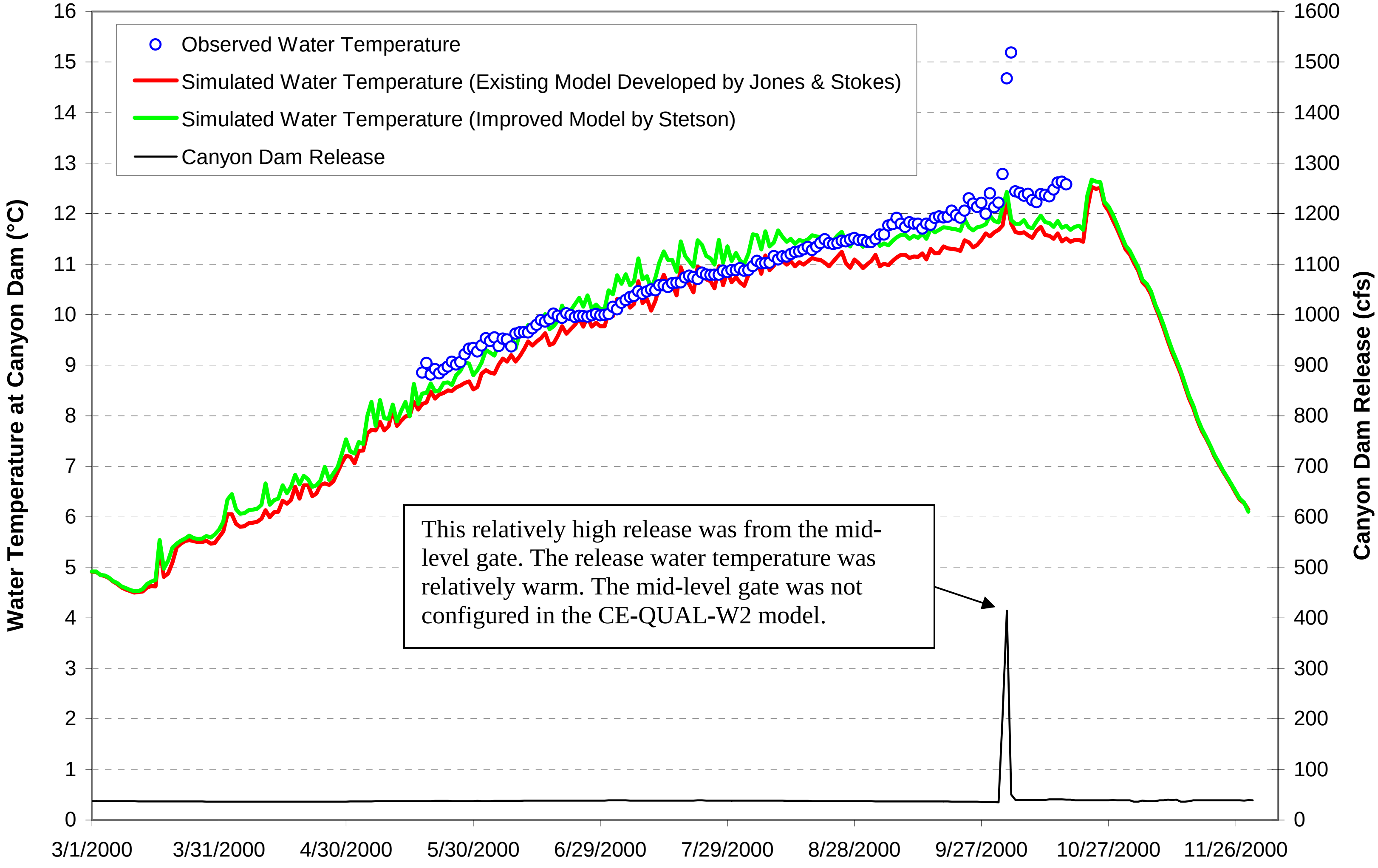


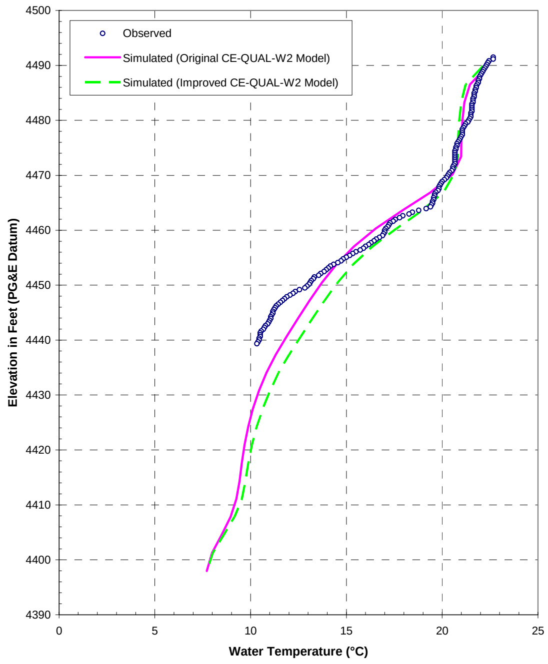
Figure 19 Comparison of Simulated Release Water Temperatures at Canyon Dam, 2000 between the Existing and Improved CE-QUAL-W2 Models



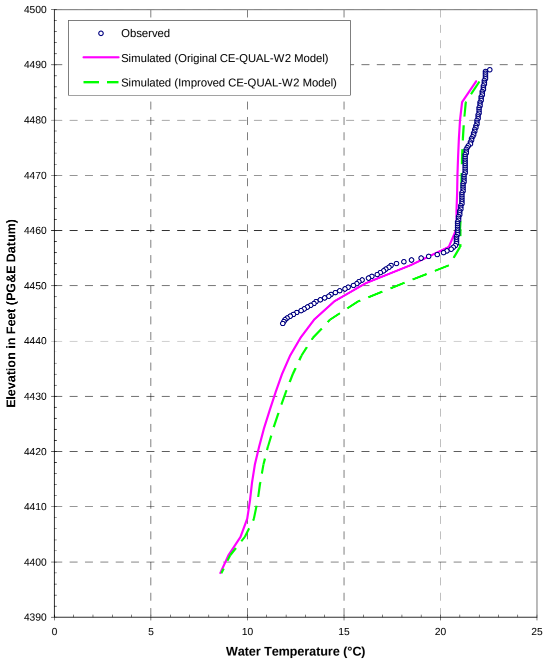
This relatively high release was from the mid-level gate. The release water temperature was relatively warm. The mid-level gate was not configured in the CE-QUAL-W2 model.

Figure 20 Comparison of Simulated Temperature Profiles near Canyon Dam, 2000 between the Existing and Improved CE-QUAL-W2 Models

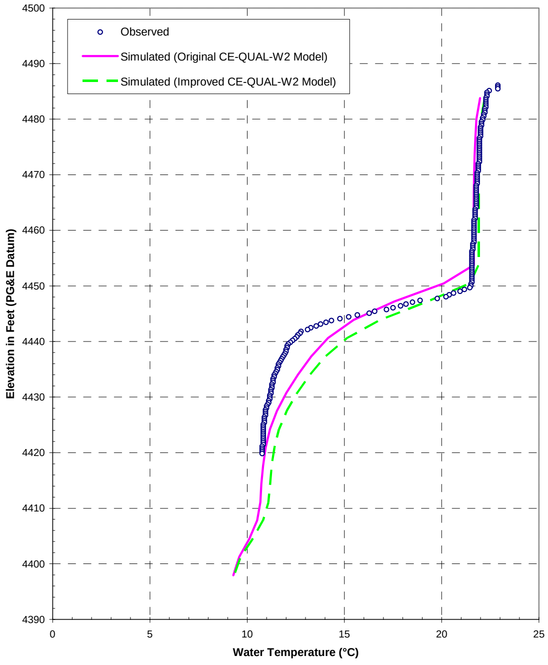
Observed and Simulated Water Temperature Profiles near Canyon Dam (LA-1)
June 22, 2000



Observed and Simulated Water Temperature Profiles near Canyon Dam (LA-1)
July 20, 2000



Observed and Simulated Water Temperature Profiles near Canyon Dam (LA-1)
August 17, 2000



Observed and Simulated Water Temperature Profiles near Canyon Dam (LA-1)
September 28, 2000

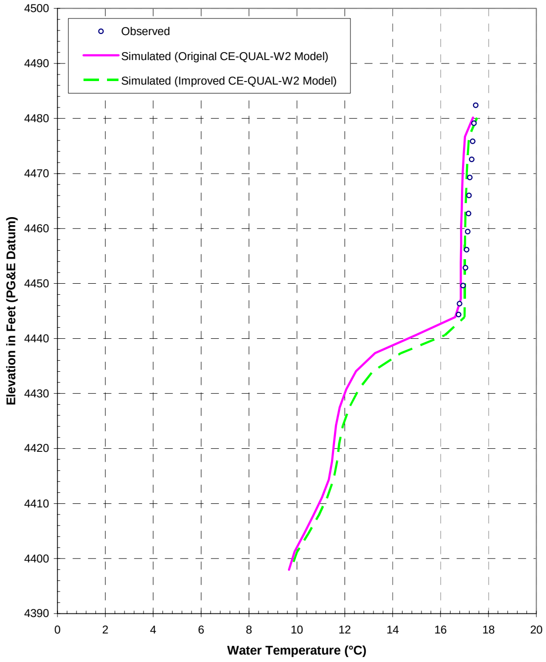
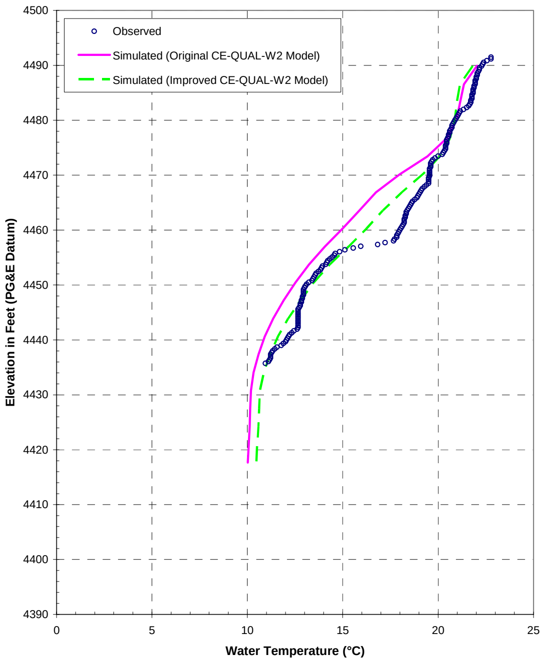
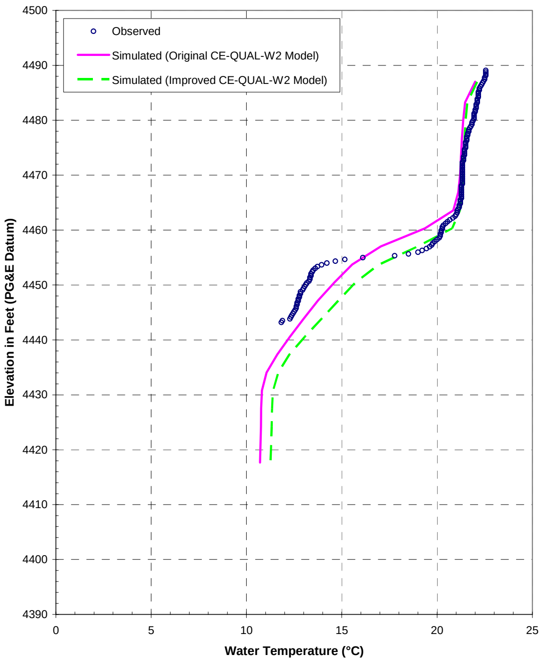
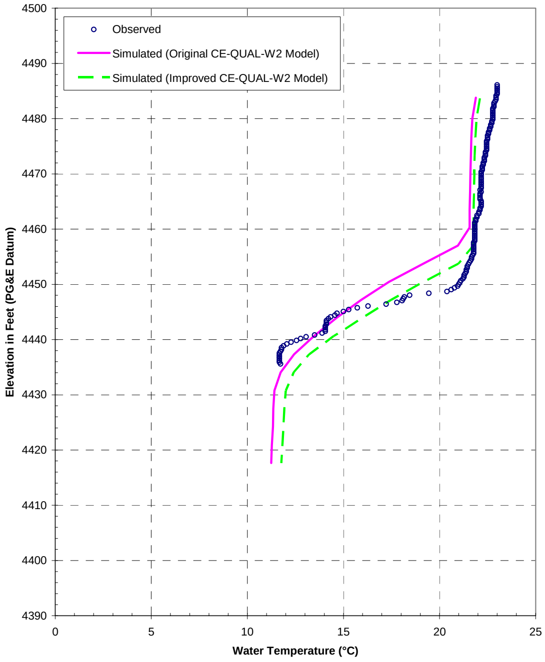


Figure 21 Comparison of Simulated Temperature Profiles near Prattville Intake, 2000 between the Existing and Improved CE-QUAL-W2 Models


Observed and Simulated Water Temperature Profiles near Prattville Intake (LA-2)
June 22, 2000


Observed and Simulated Water Temperature Profiles near Prattville Intake (LA-2)
July 20, 2000


Observed and Simulated Water Temperature Profiles near Prattville Intake (LA-2)
August 17, 2000

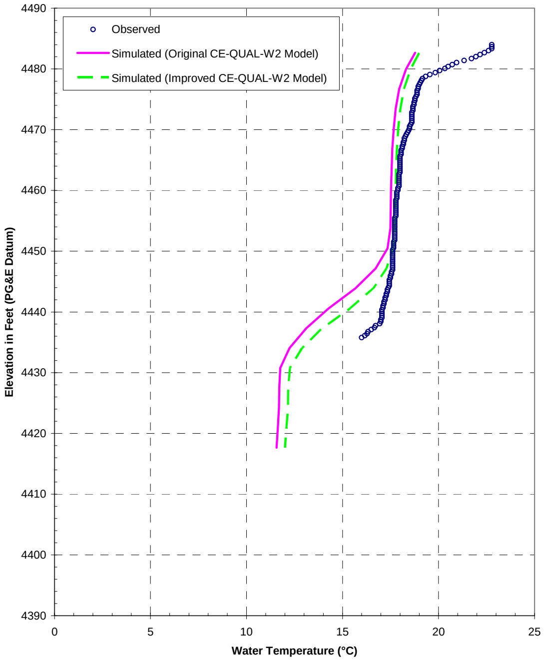

Observed and Simulated Water Temperature Profiles near Prattville Intake (LA-2)
September 9, 2000

Figure 22 Comparison of Simulated DO Profiles near Canyon Dam, 2000 between the Existing and Improved CE-QUAL-W2 Models

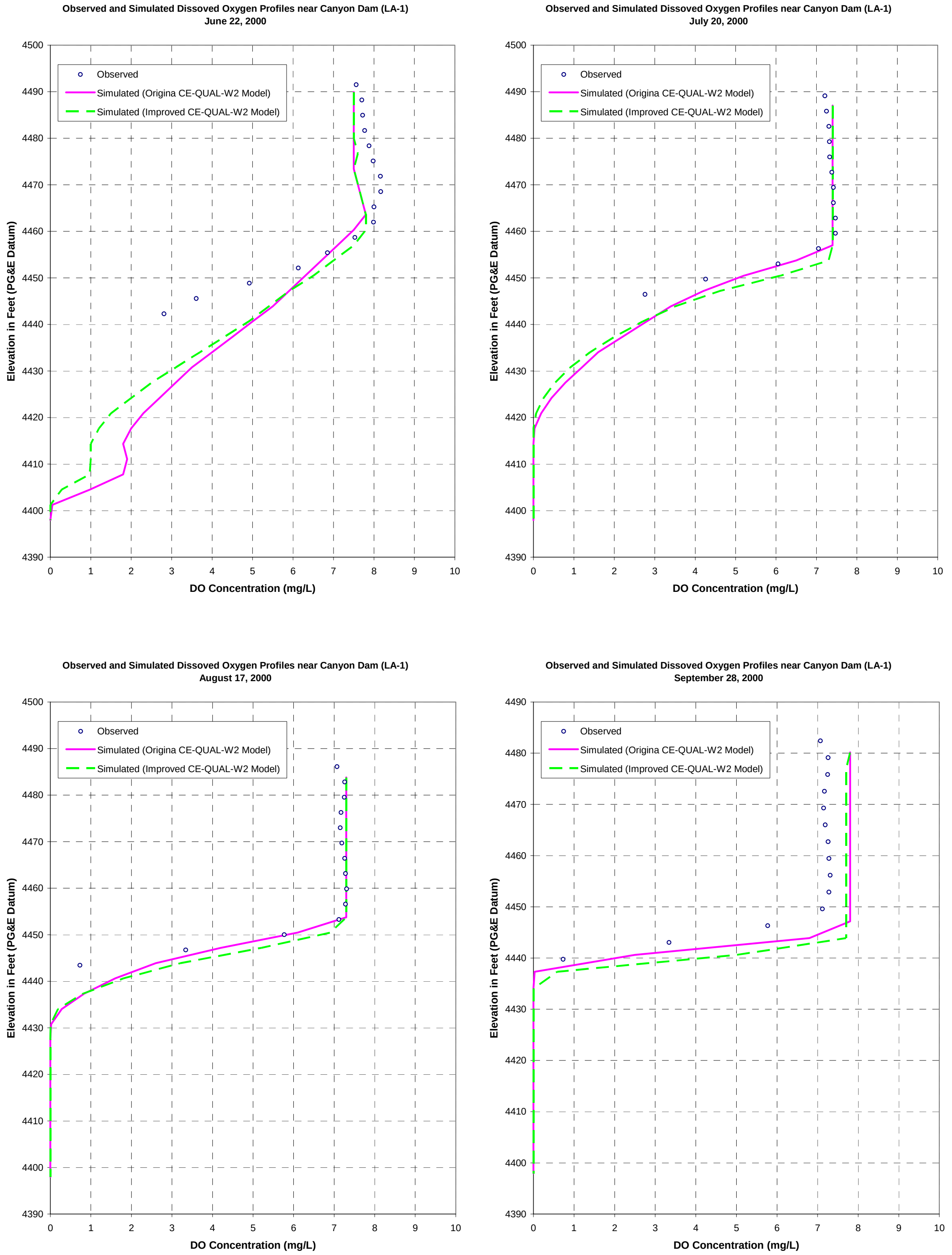


Figure 23 Comparison of Simulated Discharge Water Temperatures at Butt Valley PH, 2001 between the Existing and Improved CE-QUAL-W2 Models

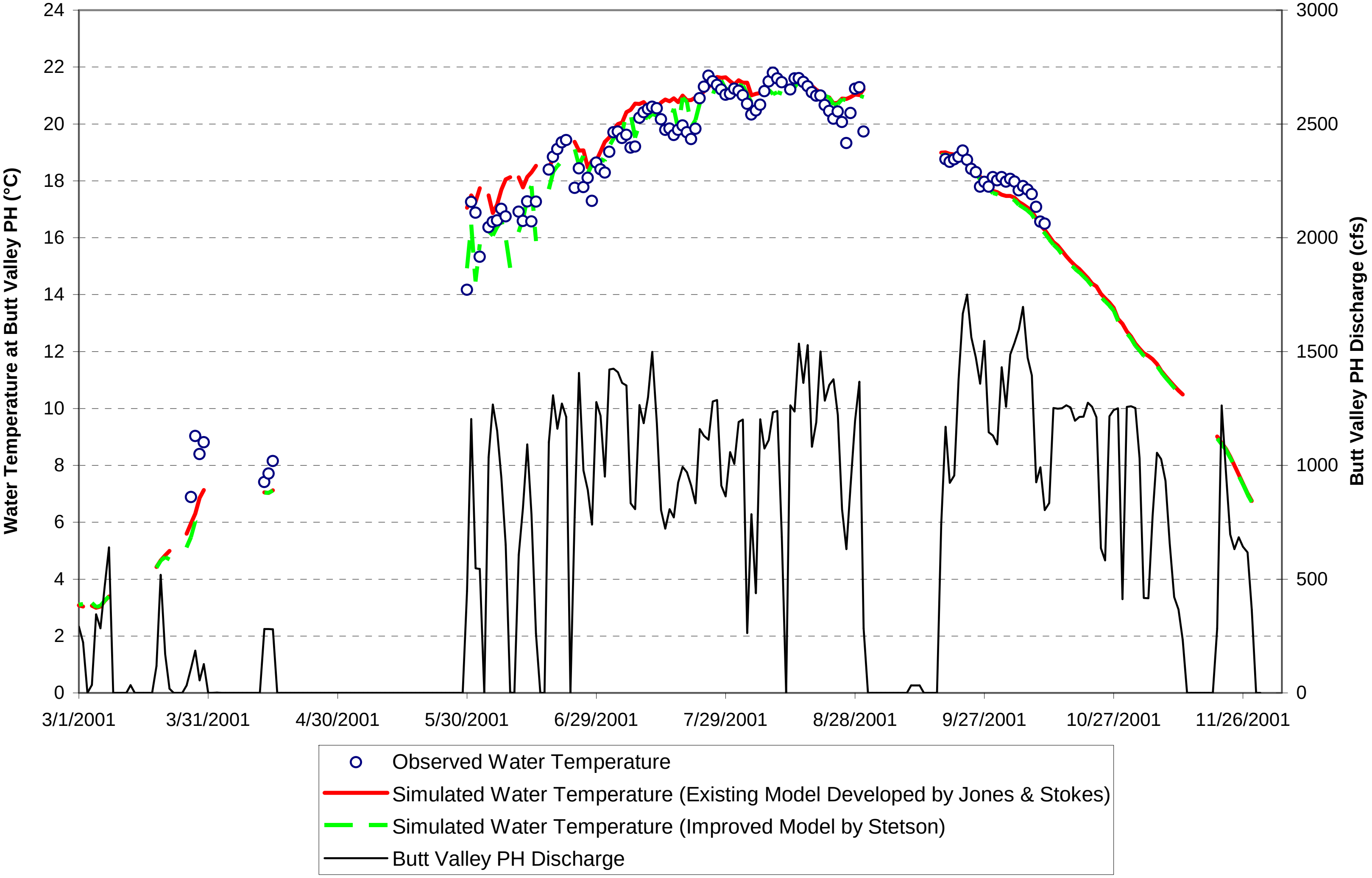
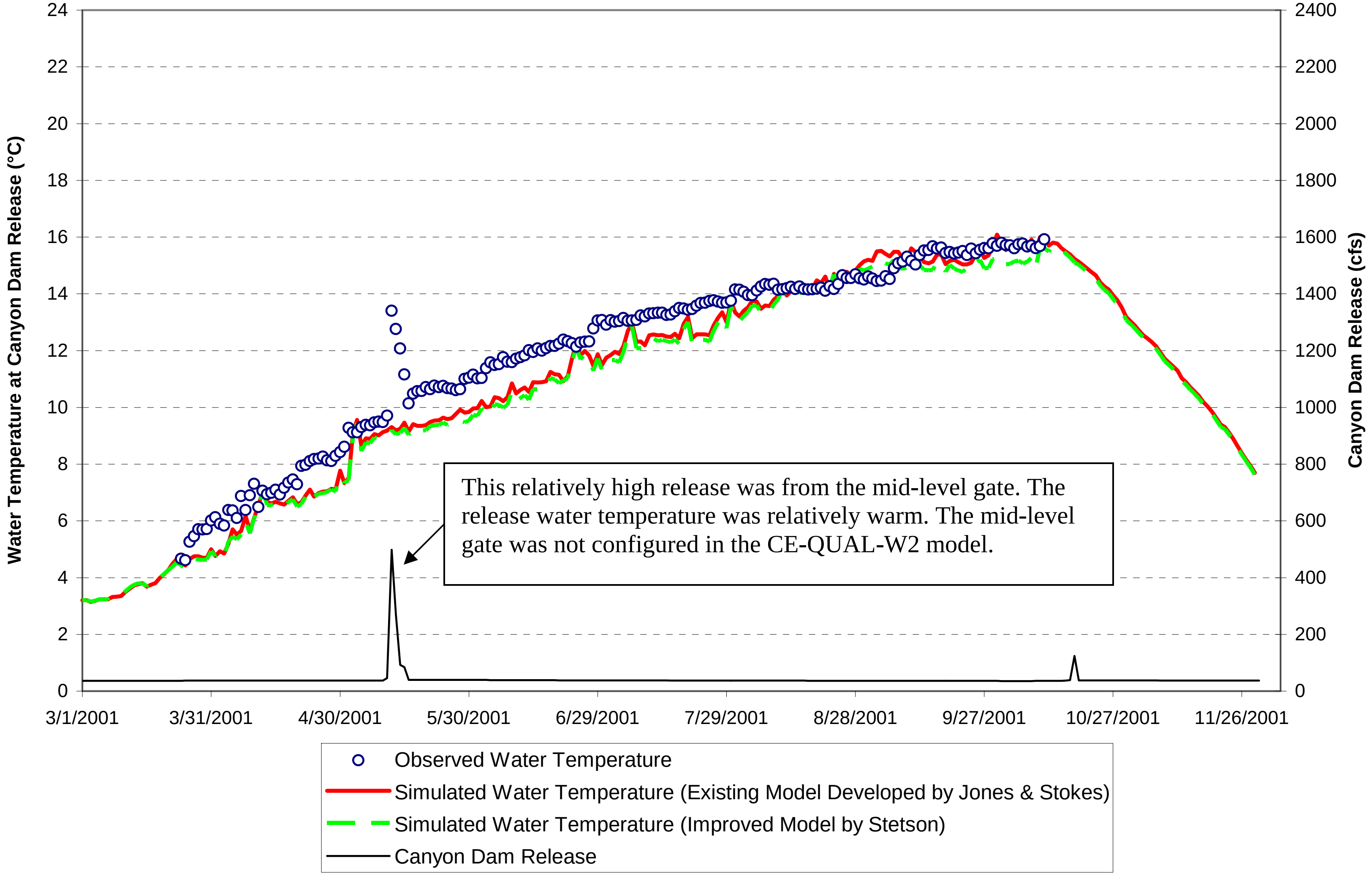


Figure 24 Comparison of Simulated Release Water Temperatures at Canyon Dam, 2001 between the Existing and Improved CE-QUAL-W2 Models



This relatively high release was from the mid-level gate. The release water temperature was relatively warm. The mid-level gate was not configured in the CE-QUAL-W2 model.

Figure 25 Comparison of Simulated Temperature Profiles near Canyon Dam, 2001 between the Existing and Improved CE-QUAL-W2 Models

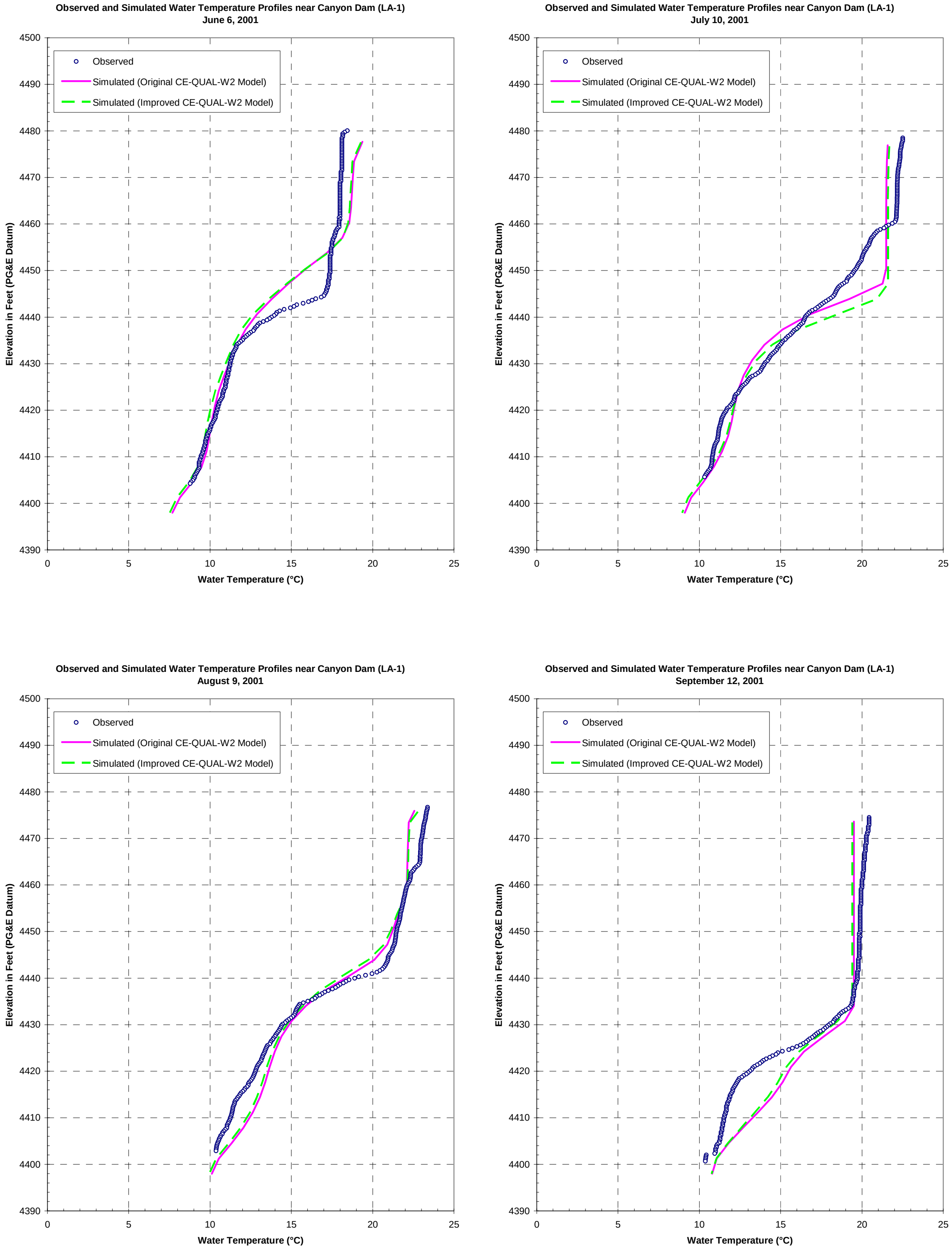
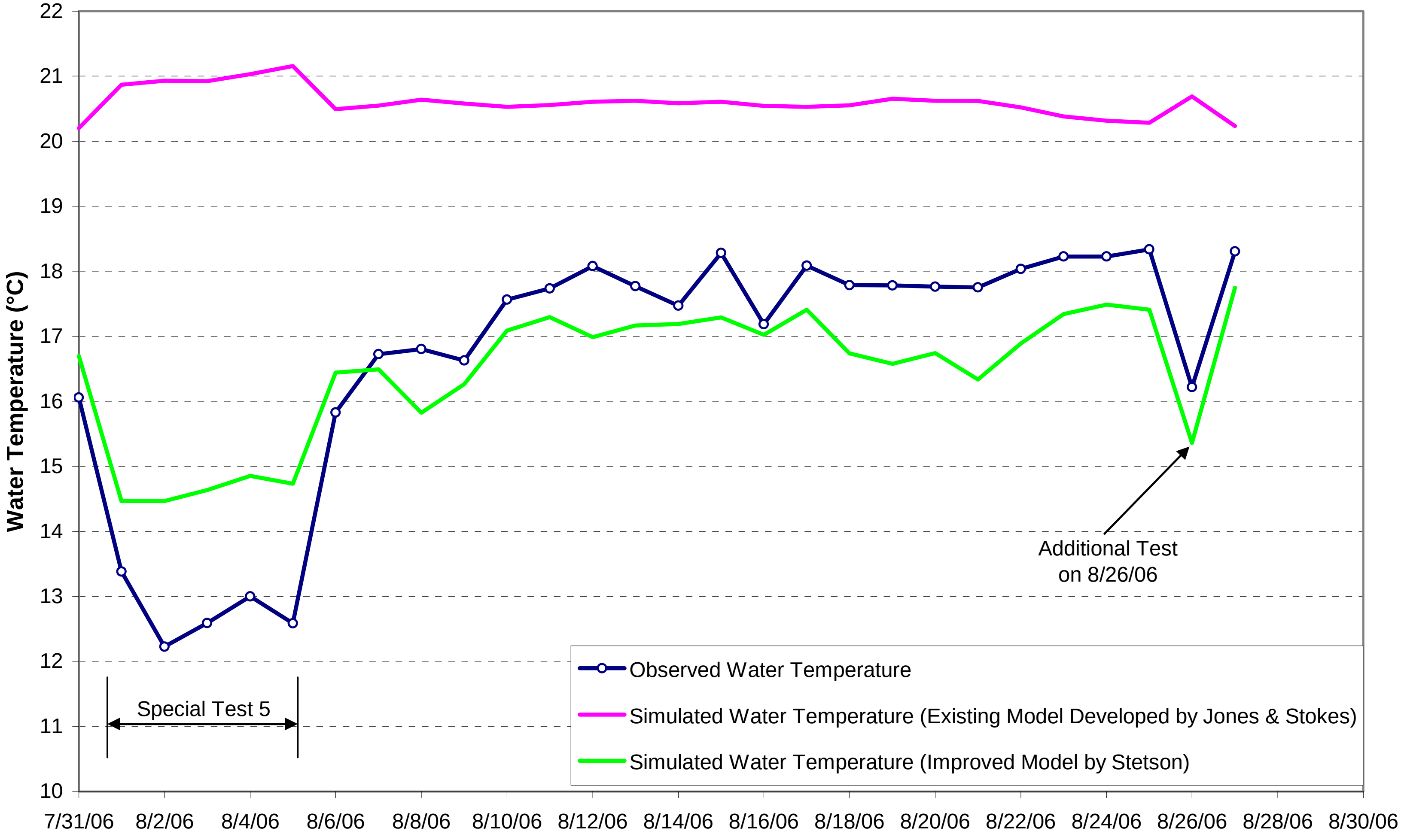


Figure 26 Comparison of Simulated Discharge Water Temperatures at Butt Valley PH during the 2006 Special Test between the Existing and Improved CE-QUAL-W2 Models



APPENDIX:

CE-QUAL-W2 Withdrawal Algorithm

(Directly extracted from CE-QUAL-W2 User Manual)

Selective Withdrawal

The latest verson includes selective withdrawal for all outflows where layer locations and outflows at each layer are calculated based on the total outflow **[QOUT]**, structure type **[SINKC]**, elevation **[ESTR]**, and computed upstream density gradients. The selective withdrawal computation uses these values to compute vertical withdrawal zone limits and outflows. It also sums the outflows for multiple structures.

Outflow distribution is calculated in the subroutine SELECTIVE_WITHDRAWAL. This routine first calculates limits of withdrawal based on either a user specified point or line sink approximation for outlet geometry **[SINKC]**. The empirical expression for point sink withdrawal limits is:

$$d = (c_{bi} Q/N)^{0.3333} \tag{A-238}$$

and for a line sink:

$$d = (c_{bi} 2\, q/N)^{0.5} \tag{A-239}$$

where:

d = withdrawal zone half height, m
Q = total outflow, $m^3\ s^{-1}$
N = internal buoyancy frequency, Hz
q = outflow per unit width, $m^2\ s^{-1}$
c_{bi} = boundary interference coefficient

The width is the outlet width. The point sink approximation assumes approach flow is radial both longitudinally and vertically while the line sink approximation assumes flow approaches the outlet radially in the vertical. The boundary interference coefficient is two near a physical boundary and one elsewhere.

Velocities are determined using a quadratic shape function:

$$V_k = 1 - \left[\frac{(\rho_k - \rho_o)}{(\rho_l - \rho_o)} \right]^2 \tag{A-240}$$

where:

V_k = normalized velocity in layer k
ρ_k = density in layer k, $kg\ m^{-3}$
ρ_o = density in the outlet layer, $kg\ m^{-3}$
ρ_l = density of the withdrawal limit layer, $kg\ m^{-3}$

The shape function generates a maximum velocity at the outlet level with velocities approaching zero at withdrawal limits. During non-stratified periods, outflow from top to bottom is uniform. Uniform flows also result from large outflows during periods of mild stratification. As stratification develops, withdrawal limits decrease and outflow is weighted towards the outlet elevation.

Withdrawal limits can be varied by specifying a line sink and changing the effective width. Small outlet widths result in nearly uniform outflows, while large widths limit outflows to the outlet layer.

Appendix B

Development of a CE-QUAL-W2 Model for Simulation of Water Temperature and Dissolved Oxygen in Butt Valley Reservoir, CA

Prepared For

State Water Resources Control Board

September 2008

Prepared By

Stetson Engineers, Inc.

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 BACKGROUND AND PURPOSE

Pacific Gas and Electric Company (PG&E) has submitted an application to the Federal Energy Regulatory Commission (FERC) for relicensing of the Upper North Fork Feather River Project (UNFFR Project; FERC No. 2105). Prior to issuance of the new FERC license, Clean Water Act 401 water quality certification must be obtained from the State Water Resources Control Board. The State Water Resources Control Board's issuance of 401 certification is a discretionary action subject to compliance with CEQA. Because of project complexity, the level of controversy surrounding unresolved temperature issues on the UNFFR Project, and the likelihood of significant impacts, the State Water Resources Control Board as the CEQA lead agency, made the decision to prepare an EIR. A reliable Butt Valley Reservoir water temperature model is one of the important supporting tools in the EIR analysis.

The facilities of the UNFFR Project include three dams that impound water from the NFFR and Butt Creek, five powerhouses (PH), and three stream bypass reaches. Figures 1a and 1b show the locations and relationships of dams, impounded reservoirs, and bypass reaches associated with the UNFFR Project. UNFFR Project reservoirs include Lake Almanor (1,142,251 acre-ft), Butt Valley Reservoir (49,897 acre-ft), and Belden Forebay (2,477 acre-ft). The temperatures of the outflows from Lake Almanor and Butt Valley Reservoir dominate the thermal regime in the NFFR system. Over the years, PG&E has investigated opportunities to minimize adverse water temperature effects (i.e., warming) on the NFFR through operational changes or physical modifications to existing facilities.

PG&E has developed reservoir temperature models using MITEMP for Lake Almanor and Butt Valley Reservoir and stream temperature models using SNTEMP for the NFFR reaches to analyze and predict water temperature longitudinal profiles along the NFFR with different physical modifications, hydrologic operations, and under different meteorological conditions. PG&E has also developed a CE-QUAL-W2 model for Lake Almanor to simulate the impacts that withdrawal of cold water from near the lake bottom could have on the distribution of dissolved oxygen (DO) and water temperature and, thus, cold freshwater habitat in the lake.

This report reviews the existing Butt Valley Reservoir MITEMP model and evaluates its adequacy to support Level 3 analysis of UNFFR water temperature reduction alternatives[1], explains the need for development of a new CE-QUAL-W2 model for Butt

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[1] Stetson Engineers is assisting in the EIR analysis of the UNFFR Project. One of the CEQA analysis tasks is to formulate and evaluate water temperature reduction alternatives for the UNFFR Project. A systematic, three-phased approach to the development and screening of water temperature reduction alternatives has been developed. Stetson has completed the administrative draft Level 1 and 2 Report which documents the first two phases of the three-phased approach (Stetson, 2007). The water temperature reduction alternatives that passed Level 2 represent *the set of potentially effective and feasible* alternatives to achieving the

Valley Reservoir for modeling both water temperature and DO, and documents the new CE-QUAL-W2 model development, calibration, and verification. The new CE-QUAL-W2 model was calibrated to the observed data collected in 2006 (wet year) and verified using the observed data collected in 2000 (normal year). The calibrated and verified CE-QUAL-W2 model for Butt Valley Reservoir will be used for Level 3 analysis of UNFFR water temperature reduction alternatives. The water temperature reduction alternatives that pass Level 3 analysis and screening will represent *effective and feasible* water temperature reduction alternatives that are suitable for broader environmental analysis in the EIR.

1.2 BUTT VALLEY RESERVOIR

Butt Valley Reservoir serves as the afterbay to Butt Valley PH and the forebay for the Caribou #1 and #2 PHs. At the normal maximum water surface elevation of 4,142 ft (USGS datum)[2], the reservoir has a historical storage capacity of 49,897 acre-ft and a surface area of 1,600 acres based on survey data when the reservoir was created in 1924. Probably due to sedimentation, the reservoir has a current storage capacity of approximately 46,000 acre-ft at the normal maximum water surface elevation based on the 1996 bathymetric survey data. The reservoir receives the majority of its inflows from Butt Valley PH and some contribution from Butt Creek above the reservoir. In a typical year, the natural stream flow in Butt Creek peaks at about 350 cfs in the spring but decreases to a base flow of about 50-60 cfs in the summer. The water surface elevation of Butt Valley Reservoir fluctuates by about 10 to 15 ft below the normal maximum water surface elevation on an annual basis.

Water in Butt Valley Reservoir is released to the two Caribou PHs through two separate intake structures. The Caribou #1 Intake is located at an invert elevation of 4,077 ft in Butt Valley Reservoir and releases up to 1,100 cfs to the Caribou #1 PH. The actual Caribou #1 Intake structure is located in a small depression zone. The Caribou #2 Intake is located in a shallow cove area with an invert elevation of 4,103 ft, and normally releases up to 1,460 cfs to the Caribou #2 PH. Both Caribou #1 and #2 PHs discharge to Belden Reservoir located in the NFFR.

Because discharges from Butt Valley Reservoir are a direct source to the NFFR, accurately simulating water temperature distributions and outflow water temperatures from Butt Valley Reservoir is crucial to evaluating the effectiveness, sustainability, and reliability of different water temperature reduction alternatives.

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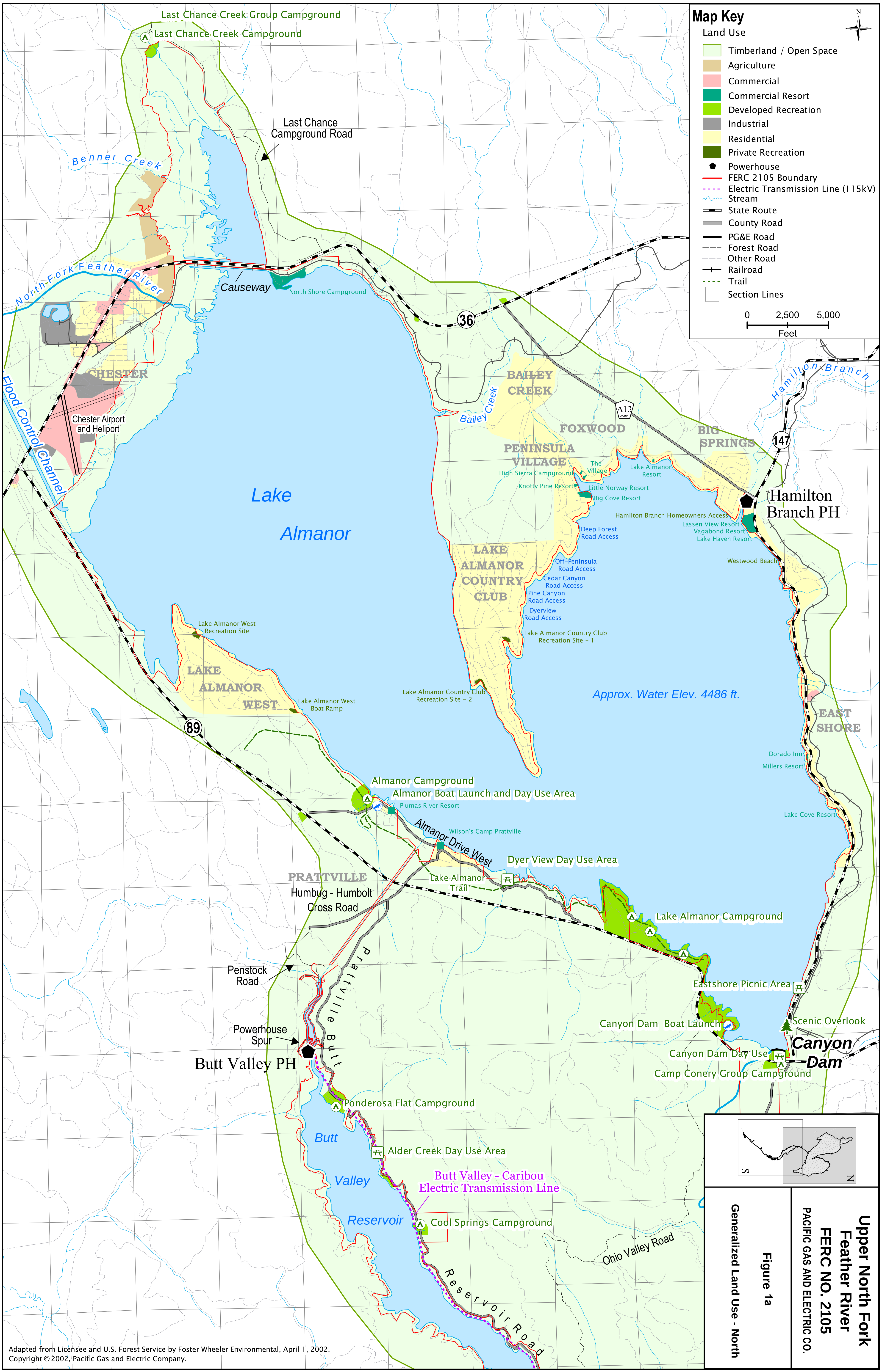
temperature target. These water temperature reduction alternatives were formulated using the results of existing modeling studies conducted primarily by PG&E with some enhancements by Stetson. The purpose of Level 3 analysis is to verify the effectiveness, sustainability, and long-term reliability of those water temperature reduction alternatives that passed Level 2. The water temperature reduction alternatives that passed Level 2 will be analyzed through detailed modeling. The detailed modeling will use newly developed and improved water quality models to modify or refine the alternatives where necessary and to screen the alternatives to arrive at a *set of effective and feasible* water temperature reduction alternatives that are suitable for broader environmental analysis in the EIR.

[2] USGS datum is used in this report for all elevations. USGS datum = PG&E datum + 10.2 ft



Upper North Fork Feather River
FERC NO. 2105
PACIFIC GAS AND ELECTRIC CO.

Figure 1a

Generalized Land Use - North

Adapted from Licensee and U.S. Forest Service by Foster Wheeler Environmental, April 1, 2002.

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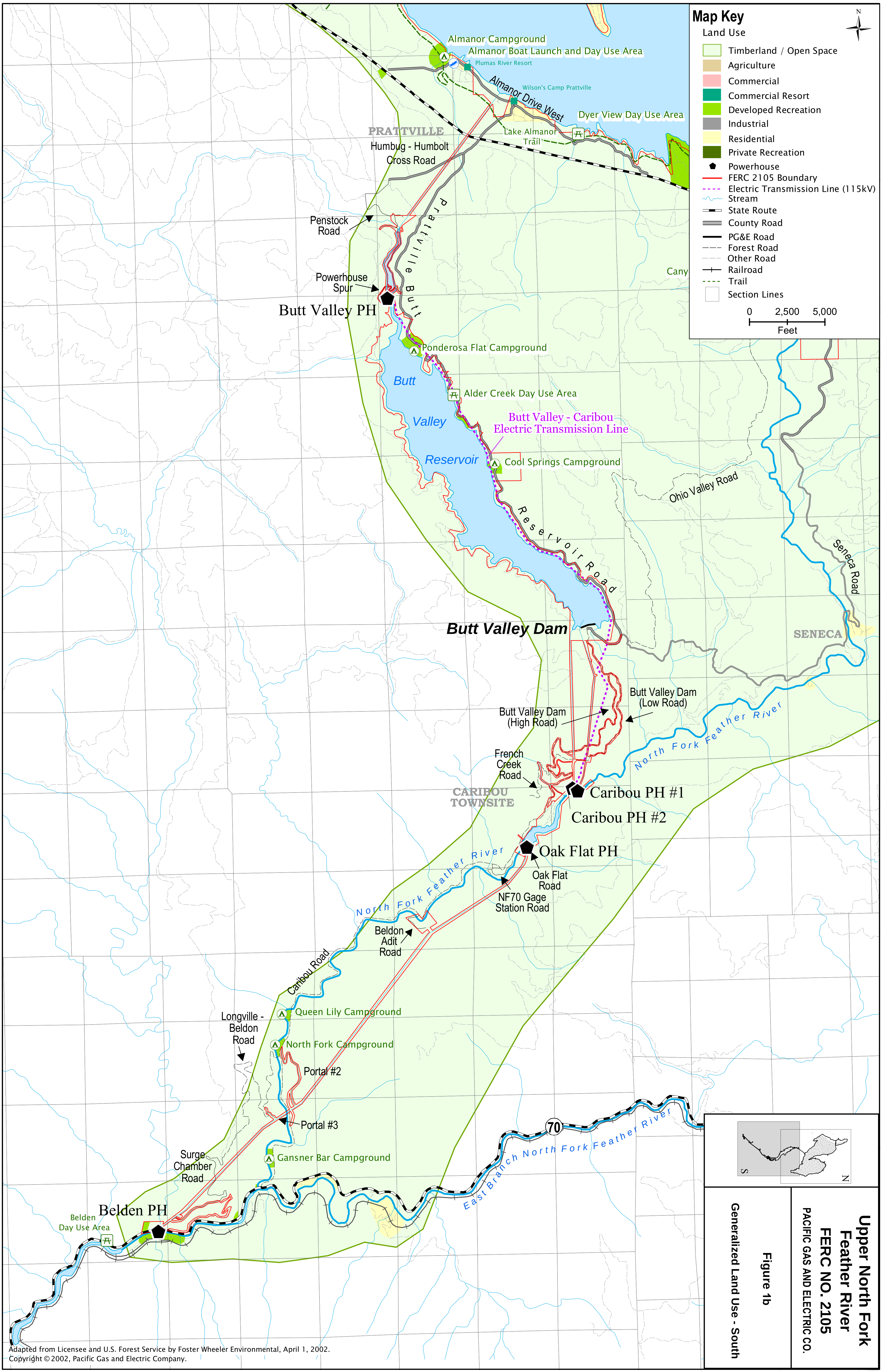

Upper North Fork Feather River
FERC NO. 2105
PACIFIC GAS AND ELECTRIC CO.

Figure 1b

Generalized Land Use - South

Adapted from Licensee and U.S. Forest Service by Foster Wheeler Environmental, April 1, 2002.

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1.3 REVIEW OF THE EXISTING BUTT VALLEY RESERVOIR MITEMP MODEL

1.3.1 MITEMP Background

MITEMP is a generic one-dimensional (vertical) mathematical water temperature model for natural deep lakes and cooling ponds and was originally developed by Massachusetts Institute of Technology (MIT) in the 1970's. This model divides the waterbody into a series of horizontal layers and assumes uniform spatial distribution of temperature within each layer (Figure 2). The outputs of a MITEMP model include outflow water temperatures and water temperatures at each horizontal layer over time.

The MITEMP application models of Lake Almanor and Butt Valley Reservoir were first developed by Woodward Clyde Consultants (WCC) in 1985-1986 as part of a cold water feasibility study for the Rock Creek – Cresta Project (WCC, 1986). During the model development, WCC modified the original program source code by adding wind mixing processes and named the modified program "MITEMP3". Daily time step and layer depth of 1 foot were used in the Lake Almanor and Butt Valley MITEMP models. WCC calibrated/validated the model using data collected in summer 1985.

In 2000 PG&E contracted with Bechtel Corporation to perform a peer review of the MITEMP3 models in connection with PG&E's relicensing work for the Rock Creek – Cresta Project and the UNFFR Project. Bechtel further modified the source code of MITEMP3 program by adding seasonal variability of light extinction coefficients, withdrawal capability under thermal curtain conditions, hydraulic effects of the bottom levee surrounding Prattville Intake, and a modified withdrawal algorithm for Prattville Intake based on the physical model test results. The modified MITEMP3 program by Bechtel was calibrated/validated using the flow and temperature data collected in 2000 and 2001 (Bechtel, 2002). Calibration/validation statistical evaluation results for the MITEMP models are summarized in Table 1. The statistical evaluation result of the Caribou #2 PH tailrace temperatures was obtained after discarding a significant amount of measurement data that were subject to "instrument error".

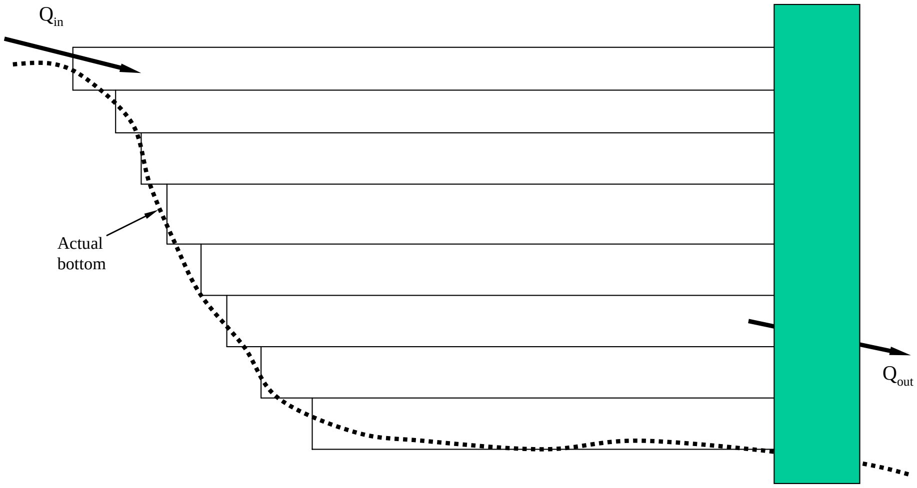

Figure 2 Typical One-Dimensional (Vertical) Grid for MITEMP

Table 1 Calibration/Validation Statistical Evaluation Results of MITEMP Models of Lake Almanor and Butt Valley Reservoir

(Source: Bechtel's MITEMP Calibration/Validation Report, 2002)

	Calibration/Validation Station and Time Period	Mean error (°C)	Maximum error (°C)
Lake Almanor	4/6 - 9/30, 2000		
	Butt Valley PH Discharge Temperatures	0.08	1.4
	Canyon Dam Outflow Temperatures	-0.16	0.7
	4/24 - 8/7, 2001		
	Butt Valley PH Discharge Temperatures	0.04	1.1
	Canyon Dam Outflow Temperatures	-0.66	1.3
Butt Valley Reservoir	4/6 - 9/30, 2000		
	Caribou PH #1 Discharge Temperatures	-0.18	2.8
	Caribou PH #2 Discharge Temperatures	0.01	1.4
	4/1 - 8/21, 2001		
	Caribou PH #1 Discharge Temperatures	0.89	4.6
	Caribou PH #2 Discharge Temperatures	-0.20	1.0

Notes:
1) 2000 was a "normal" year and 2001 was a "critical dry" year.
2) Error was defined as the difference between model-simulated and observed daily discharge water temperatures.

1.3.2 Potential Limitations of the Butt Valley Reservoir MITEMP Model

1) MITEMP Model Applicability

MITEMP is a one-dimensional (vertical) mathematical water temperature model. A basic assumption of the MITEMP program is that the temperature gradient is predominantly in the vertical direction and the variation in the horizontal and lateral directions is negligible. According to the MITEMP documentation (MIT, 1978), the MITEMP program is generally applicable to well stratified deep lakes or reservoirs which satisfy the following empirical criterion:

$$F_D = 320\frac{L \cdot Q}{H \cdot V} < \frac{1}{\pi} \approx 0.32$$

where:

F_D:	Densimetric Froude number;
Q:	Flow rate through a reservoir (m^3/s)
L:	Reservoir length (m);
H:	Reservoir mean depth (m);
V:	Reservoir volume (m^3).

The MITEMP program is more applicable to deep lakes or reservoirs with smaller values of Densimetric Froude number F_D than those with larger values. The estimated F_D values for Lake Almanor and Butt Valley Reservoir are shown in Table 2. The estimated F_D value for Lake Almanor is less than 0.01, which is well below the empirical threshold for MITEMP applicability. The estimated F_D value for Butt Valley Reservoir is up to 0.27, which is close to the empirical threshold for MITEMP applicability. This might be the reason that the calibration results for Butt Valley Reservoir were not as good as the results for Lake Almanor (see Table 1).

Table 2 Estimated F_D values for Lake Almanor and Butt Valley Reservoir

Lake Almanor	L	6.5 miles	10,460 m
	Q	0 - 2,100 cfs	0 - 59.47 m^3/s
	V	1,142,000 acre-ft	1.409×10^9 m^3
	A	27,000 acres	1.093×10^8 m^2
	H	42.3 ft	12.9 m
	F_D		**0 – 0.01**
Butt Valley Reservoir	L	5.0 miles	8,045 m
	Q	0 - 2,200 cfs	0 – 62.30 m^3/s
	V	49,897 acre-ft	6.155×10^7 m^3
	A	1,600 acres	6.475×10^6 m^2
	H	31.2 ft	9.5 m
	F_D		**0 – 0.27**

Under existing conditions, Lake Almanor exhibits a significant temperature gradient in the vertical direction but little variation in the horizontal direction during the summer months. Both observations and theoretical analysis indicate that the one-dimensional MITEMP program is applicable to Lake Almanor.

Under existing conditions, Butt Valley Reservoir also exhibits a significant temperature gradient in the vertical direction during the summer months, but not as significant as Lake Almanor. Butt Valley Reservoir also exhibits 1 - 3°C warming in the horizontal direction during the summer months as reflected in the temperature difference between Caribou #2 intake and the Butt Valley PH discharge. (It is noted that existing temperatures between the Butt Valley PH discharge and the Caribou #1 intake are similar). Both observations and theoretical analysis indicate that the MITEMP program is questionable for Butt Valley Reservoir under existing conditions.

If outflow temperatures from the Butt Valley PH are reduced by 4-5°C through modification of the Prattville Intake or other means, the inflow temperature in Butt Valley Reservoir will be close to the water temperature in the metalimnion of the reservoir. Interflow would be the dominant inflow-plume routing mode. Both solar radiation and wind mixing could significantly affect spatial variations of (in both vertical and horizontal directions) water temperature under this interflow condition. The horizontal temperature gradient would be more pronounced under this condition, compared with the existing condition. MITEMP's basic assumption of negligible horizontal temperature variation would not be justified in this case and, thus, the applicability of MITEMP to analyzing temperature reduction measures at Butt Valley Reservoir would be questionable[3].

2) MITEMP Withdrawal Algorithm Limitations

The withdrawal algorithm is the computational process for simulating the hydraulics of water withdrawal near the intake (i.e., withdrawal zone). The withdrawal algorithm is important to accurately simulate outflow temperature because the hydraulics in the withdrawal zone is the main determinant of outflow temperature. In general the withdrawal zone is affected by outflow discharge rate, intake structure and elevation, intake geometry, approach channel configuration, near intake bathymetry, and intake upstream density gradient. The withdrawal algorithm in the Bechtel-modified MITEMP model was developed based on the physical model test results for the outflow range of 800 cfs – 2,400 cfs at the Prattville Intake. It appears the withdrawal algorithm was not tested for lower flow conditions. In addition, the Butt Valley Reservoir MITEMP model has arbitrarily set a minimum threshold outflow of 700 cfs which was prescribed in the model code for discharges at the Caribou #1 and #2 PHs. More specifically, the model will automatically use 700 cfs to compute the withdrawal water temperatures at the Caribou #1 and #2 Intakes, even if discharges are less than 700 cfs. The 700 cfs threshold was chosen because any flow less than this level was considered a short-term transient operation and such events rarely occurred in the past. This prescription limits the applicability of the model to analyze certain water temperature reduction measures; for example, the measure that calls for increased Canyon Dam releases (to up to 600 cfs) and commensurately reduced outflows from Prattville Intake. It is anticipated that, under this measure, there would be many times that discharges at Caribou #1 PH and/or Caribou #2 PHs would be lower than 700 cfs due to reduced inflows from the Butt Valley PH to Butt Valley Reservoir. Using the prescribed minimum flow of 700 cfs would overestimate the temperature at the Caribou #1 tailrace when its discharge was lower than 700 cfs.

Furthermore, the existing MITEMP model of Butt Valley Reservoir is limited by the optimal withdrawal schemes available to the user. Two are available; (1) uniform withdrawal scheme or (2) Gaussian distribution withdrawal scheme. In reality, the withdrawal scheme may be either, depending on the flow rate. Caribou #1 and #2 PHs are powerhouses with peaking operations. Discharges from these two PHs have significant fluctuations. Pre-prescribing a single withdrawal scheme for the two PHs, particularly the Caribou #1 PH, without regard to flow rate, would not accurately predict the changes in discharge water temperatures with discharge rates, and thus, would limit the model's reliability. The model needs to be programmed to choose a variable withdrawal scheme between selective and uniform withdrawal scheme based upon the prevailing temperature and flow conditions.

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[3] MITEMP accounted for overall warming within the reservoir. However, it did not provide warming details and hydrodynamic transport along the reservoir.

1.4 THE NEED FOR MODELING BOTH WATER TEMPERATURE AND DISSOLVED OXYGEN IN BUTT VALLEY RESERVOIR

One of the water temperature reduction measures to be analyzed in Level 3 includes the cold water withdrawal from Lake Almanor via a thermal curtain near the Prattville Intake that causes metalimnion and/or hypolimnion colder water withdrawal. The hypolimnion cold water may have low dissolved oxygen (DO). This cold water would plunge into Butt Valley Reservoir (as demonstrated in the 2006 special test) and could adversely impact the cold freshwater habitat beneficial use of Butt Valley Reservoir. A water quality model would be needed to simulate DO distributions in the reservoir if hypolimnion cold water (with low DO) is withdrawn through the Prattville Intake of Lake Almanor. The simulated water temperature and DO distributions in the reservoir would be used to evaluate the impacts of the water temperature reduction measure on the cold freshwater habitat in the reservoir.

The existing MITEMP model developed by PG&E for Butt Valley Reservoir simulates reservoir water temperature only. MITEMP does not have capability to simulate DO because it does not have water quality components. In addition, as discussed earlier, the MITEMP model may not even be a suitable and reliable application to Butt Valley Reservoir due to its limitations under low flow conditions. Accurately simulating water temperature distributions of Butt Valley Reservoir is very important because discharges from this reservoir are a direct source to the NFFR. A more suitable and reliable model for Butt Valley Reservoir, having the capability to simulate both water temperature and DO, is needed for Level 3 analysis of UNFFR water temperature reduction alternatives.

1.5 SUITABILITY OF CE-QUAL-W2 MODEL FOR BUTT VALLEY RESERVOIR

CE-QUAL-W2 is a generic two-dimensional (longitudinal and vertical), laterally-averaged hydrodynamic and water quality model supported by the US Army Corps of Engineers, Waterways Experiment Station. The model divides a waterbody into multiple segments in the longitudinal direction and multiple layers in the vertical direction (see Figure 3). The model assumes uniform hydrodynamics and concentrations of water quality constituents in the lateral direction within the same segment and same layer. Because the model assumes lateral homogeneity, it is best suited for relatively long and narrow waterbodies exhibiting longitudinal and vertical water quality gradients and little lateral gradients. The model has been applied to rivers, lakes, reservoirs, and estuaries. The model can simulate selective withdrawal based on hydraulic principles: no user-specified flow distribution (or withdrawal scheme as in MITEMP) is needed to simulate selective withdrawal (Refer to Appendix II for the CE-QUAL-W2 withdrawal algorithm which was directly extracted from the User Manual (Cole and Wells, 2002)). It can also simulate thermal curtain effects on cold water selective withdrawal. These capabilities are important for Butt Valley Reservoir modeling of UNFFR water temperature reduction alternatives.

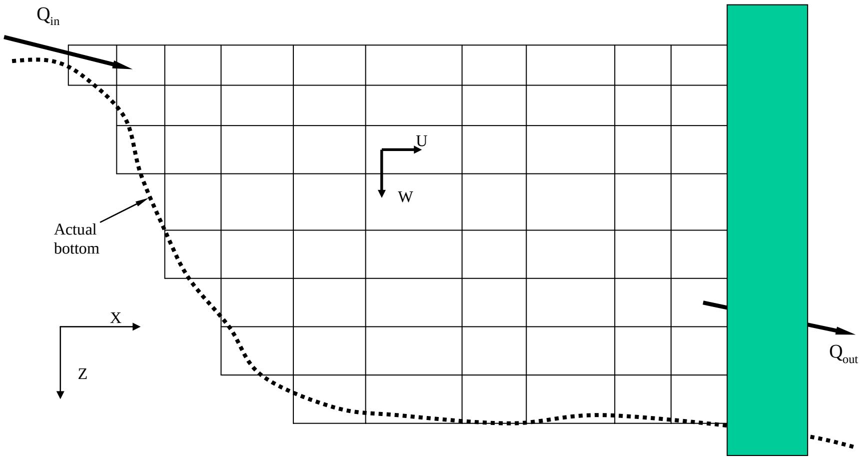

Figure 3 Typical Two-Dimensional (Longitudinal and Vertical) Grid for CE-QUAL-W2

The shape of Butt Valley Reservoir is relatively long and narrow, making CE-QUAL-W2 well-suited for this reservoir. Since CE-QUAL-W2 is a two dimensional (longitudinal and vertical) hydrodynamic and water quality model, it can simulate vertical temperature variations as well as longitudinal temperature variations in the reservoir. No pre-assumptions are needed about whether temperature variations in Butt Valley Reservoir are one-dimensional or two-dimensional under existing conditions or with reduced temperatures in the discharge from Butt Valley PH. As a hydrodynamic and water quality model, CE-QUAL-W2 can simulate both water temperature and DO and other water quality constituents. The outputs of a CE-QUAL-W2 model include outflow water temperatures and outflow concentrations of water quality constituents over time, water temperatures and concentrations of water quality constituents at each grid cell over time, and horizontal and vertical flow velocities at each grid cell over time.

2.0 MODEL DEVELOPMENT AND DATA

2.1 BASIC DATA REQUIREMENTS

The following data are required for representing the model domain and applying the CE-QUAL-W2 model for Butt Valley Reservoir:

- Bathymetry data and computational grid to represent the physical characteristics of the reservoir.

- Boundary conditions, including inflow rates, inflow water temperatures and water quality conditions at points where inflows enter the reservoir, and outflow rates at the downstream boundaries.

  To simulate DO dynamics, the following water quality constituents were included in the CE-QUAL-W2 model:
    - Water temperature
    - DO
    - Algae
    - Sediment oxygen demand (SOD)
    - Inorganic suspended solids (ISS)
    - Phosphates (PO_4)
    - Ammonia (NH_4)
    - Nitrate (NO_3)
    - Dissolved and particulate organic matter
    - Total iron (Fe)

  All above constituents directly or indirectly affect DO dynamics. Algae and sediment oxygen demand directly affect DO dynamics. Algae photosynthesis produces oxygen and algae respiration consumes oxygen. SOD is the sum of all biological and chemical processes in sediment that utilize (take up) oxygen. Phosphates, ammonia and nitrate are nutrients that affect algae dynamics and thus indirectly affect DO dynamics. ISS can affect orthophosphate concentrations through adsorption and settling, it can also affect depth of light penetration which can affect water temperature and DO concentrations. The decomposition of organic material uses DO and creates nutrients. Total iron is included in this model primarily because of its effect on orthophosphate concentrations through adsorption and settling. Water temperature affects chemical and biological reaction rates.

- Initial conditions, including reservoir water temperature, water elevation, and concentrations of water quality constituents at the beginning of the time period for which the model is applied.

- Meteorology data, including air temperature, dew point temperature, wind speed and direction, and cloud cover. The model uses short wave solar radiation if they are provided; otherwise, the model calculates solar radiation based on latitude, longitude, date, and cloud cover values.

- Model parameters, which are coefficients in the equations of the mathematical model that relate hydrodynamics, water temperature and water quality. Model parameters are site-specific and may need to be adjusted during model calibration to achieve a match between model simulated and observed data.

- Calibration/verification data which are observed data used to test the performance of the model by comparing these data to model-simulated output data.

2.2 RESERVOIR BATHYMETRY AND COMPUTATIONAL GRID

The CE-QUAL-W2 model was set-up for Butt Valley Reservoir covering the entire reservoir from the discharge point of Butt Valley PH to Butt Valley Dam. Butt Creek above the reservoir was represented in the model as a point tributary inflow. The model represents the reservoir in the form of a grid of cells consisting of longitudinal segments and vertical layers. The geometry of the computational grid is determined by the boundaries of the longitudinal segments, the depth interval of the vertical layers, and average lateral cross sectional width (shoreline to shoreline). The model divides the reservoir into 18 active segments of varying length from 560 ft to 3,800 ft (i.e., 171 m to 1,158 m) to represent the longitudinal pieces of the reservoir. Each segment is divided into multiple layers extending downward to the reservoir bottom; each layer is 2 feet deep (i.e., 0.61 m). Figure 4 shows the segment spacing and Figure 5 shows the computational grid. Relatively short spacing is used for the segments in the upstream portion of the reservoir to provide enhanced resolution for better simulating the cold water plunging process observed in the summer 2006 special test[4].

The 1996 bathymetric survey data provided by PG&E was used to generate the computational grid. The transect cross section measurements for the upstream portion of the reservoir (Figures 4 and 6) during the summer 2006 special test were used to supplement the 1996 bathymetric survey data. The source 1996 bathymetric survey data was in the format of X, Y, and Z coordinates and the elevation was up to 4,136 ft in USGS datum. Stetson digitized the 4,142 ft contour line from the USGS quad maps using AutoCAD and added this contour line to the 1996 bathymetric survey data. 4,142 ft is the normal maximum water surface elevation of Butt Valley Reservoir.

The contoured bathymetric map of the reservoir based on the 1996 bathymetric survey data is shown in Figure 4. The bathymetric survey data were first utilized to generate segment and depth polygons for setting up input grid geometry using *AutoCAD Land Development Desktop*. The input grid geometry for the upstream portion of the reservoir was then modified to reflect the transect measurements during the 2006 special test

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[4] Refer to 2006 North Fork Feather River Special Testing Data Report (Stetson and PG&E, 2007) for detailed information on the summer 2006 special test.

(Figures 4 and 6). The input grid geometry for the upstream portion of the reservoir is shown in Figure 7. During the 2006 special test, a submerged deep channel was identified along the west side of the reservoir entrance above the Boat Ramp, but measurements could not locate the course of a distinct channel downstream of the Boat Ramp[5]. The representative cross section of the deep channel at Transect X3 is shown in Figure 6, and the deep channel was represented in the CE-QUAL-W2 model grid in segments 5-8 as shown in Figure 7. Note that historic map (PG&E drawing number 402240 and 402241) revealed the old remnant channel existed in the pre-reservoir condition. This channel could not be completely mapped downstream of the Boat Ramp during the 2006 special field test. It is assumed that any deep channel downstream below Segment 9 ceases to exist in the current CE-QUAL-W2 model geometry[4].

Figure 8 shows the final elevation-storage curve developed for use by the CE-QUAL-W2 model. For purpose of comparison, the original elevation-storage curve at the time when the reservoir was created in 1924 is also shown in the figure. The 1996 surveyed reservoir storage is smaller than the original storage by about 8% at the normal maximum water surface elevation of 4,142 ft. This reduction in storage probably resulted from sedimentation during the last 84 years since the reservoir was created in 1924.

2.3 BOUNDARY CONDITIONS

The boundary conditions are represented by observed or known flows, water temperature and/or water quality data for external sources and sinks that are connected to the modeled reservoir. The following boundary conditions were used for the Butt Valley Reservoir CE-QUAL-W2 model:

- Inflow rate, inflow temperature, inflow DO concentration, and concentrations of the DO-related water quality constituents for the Butt Valley PH discharge;
- Inflow rate, inflow temperature, inflow DO concentration, and concentrations of the DO-related water quality constituents for Butt Creek flows above Butt Valley Reservoir;
- Outflows from the reservoir at the Caribou #1 PH discharge; and
- Outflows from the reservoir at the Caribou #2 PH discharge.

All flow data and corresponding water temperatures and water quality constituent concentrations were provided by PG&E. Based on data availability, hourly input data for the upstream and downstream boundary conditions were used for the model calibration year 2006, and daily input data for the upstream and downstream boundary conditions were used for the model verification year 2000. Figures 9 and 10 show the hourly inflow

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[5] The deep channel is surmised to be a remnant of the pre-reservoir Butt Creek channel. The topographical expression of the remnant channel could not be located downstream of the Boat Ramp, possibly due to filling in by sediment over the last 84 years.

rates and temperature time series data used as the upstream boundary conditions for the calibration year 2006. Outflows at the downstream boundaries (i.e., Caribou #1 and #2 PH discharges) for the calibration year are shown in Figures 11a and 12a. Although outflow temperatures at Caribou #1 and #2 PH are not input data, they are also shown in Figures 11b and 12b for the purpose of clearly identifying the questionable water temperature data at the Caribou #1 PH discharges during the period of early to mid July in 2006. Figures 13 and 14 show the daily inflow rates and temperature time series data used as the upstream boundary conditions for the verification year 2000. Outflows at the downstream boundaries (i.e., Caribou #1 and #2 PH discharges) for the verification year are shown in Figures 15 and 16.

PG&E collected synoptic monthly water quality data at the Butt Valley PH discharges and Butt Creek flows in 2000, but did not collect water quality data at these upstream boundaries in 2006 except for some DO data that were collected during the 2006 special test. The observed concentrations of most water quality constituents (including algae) in 2000 at the Butt Valley PH discharges and Butt Creek flows were either below the detection limit or relatively low. This suggests that the water quality conditions at the upstream boundaries would not significantly affect DO simulations in Butt Valley Reservoir as long as the DO concentrations at the upstream boundaries were reasonably set. For simplicity the observed upstream water quality conditions in 2000 plus the DO data collected during the 2006 special test were used for the upstream water quality conditions for the model calibration year 2006. For observations with values below the detection limit, values equal to one-half of the detection limit were used. As there were no available data for algae, algae concentrations (dry weight of biomass per volume of water) were obtained by multiplying measured chlorophyll-*a* concentrations by the default algal biomass to chlorophyll-*a* ratio of 145 as recommended by the CE-QUAL-W2 User Manual (Cole and Wells, 2002). Tables 3 and 4 show the Julian date and water quality data used as the upstream boundary conditions for the calibration year.

As for the model verification year 2000, the Butt Creek water quality conditions for the model verification year 2000 were assumed the same as the model calibration year 2006. The simulated time-series water quality concentrations at the Butt Valley PH discharges from the Stetson-improved Lake Almanor CE-QUAL-W2 calibration model for 2000 were used as the upstream boundary conditions. It is acknowledged that the actual DO concentrations at the Butt Valley PH discharge may differ from the CE-QUAL-W2 model-generated concentrations due to reaeration at the Butt Valley PH. However, reaeration under actual existing conditions is not expected to be significant because the Prattville Intake mainly withdraws epilimnion water which has high concentrations of DO. If a thermal curtain near the Prattville Intake is used to cause hypolimnion cold water withdrawal, reaeration under this condition may be more significant because the hypolimnion cold water may have low DO. The significance of reaeration will be investigated in the Level 3 analysis of water temperature reduction alternatives.

For the upstream boundary condition data for the natural inflows of Butt Creek, the model uses linear interpolation to fill in data for the boundary flow, temperature and water quality time series data. For the upstream boundary condition data for the regulated discharges of Butt Valley PH, the model uses step-function to fill in data for the boundary flow, temperature and water quality time series data. For the downstream boundary condition data for the regulated discharges of Caribou #1 and #2 PHs, the model uses step-function to fill in data for the boundary flow time series data.

Table 3 Water Quality Data (mg/L) Used at the Butt Valley PH Discharges for the Model Calibration Year 2006

Date	Julian Day	ISS	PO4	NH4	NO3	FE	LDOM	RDOM	LPOM	RPOM	ALGAE	DO
4/6/06	97	0.5	0.005	0.05	0.05	0.110	0.3	0.3	0.3	0.3	0.036	10.24
6/22/06	174	0.5	0.010	0.05	0.05	0.093	0.3	0.3	0.3	0.3	0.036	8.27
7/20/06	202	0.5	0.005	0.05	0.05	0.160	0.3	0.3	0.3	0.3	0.101	6.66
7/31/06	212	0.5	0.005	0.05	0.05	0.160	0.3	0.3	0.3	0.3	0.101	6.60
	212.999	0.5	0.005	0.05	0.05	0.160	0.3	0.3	0.3	0.3	0.101	6.60
8/1/06	213	0.5	0.005	0.05	0.05	0.160	0.3	0.3	0.3	0.3	0.101	8.70
8/2/06	214	0.5	0.005	0.05	0.05	0.160	0.3	0.3	0.3	0.3	0.101	8.30
8/3/06	215	0.5	0.005	0.05	0.05	0.160	0.3	0.3	0.3	0.3	0.101	8.40
8/4/06	216	0.5	0.005	0.05	0.05	0.160	0.3	0.3	0.3	0.3	0.101	8.20
8/5/06	217	0.5	0.005	0.05	0.05	0.160	0.3	0.3	0.3	0.3	0.101	8.90
	217.999	0.5	0.005	0.05	0.05	0.160	0.3	0.3	0.3	0.3	0.101	8.90
8/6/06	218	0.5	0.005	0.05	0.05	0.160	0.3	0.3	0.3	0.3	0.101	6.60
8/17/06	230	4.0	0.005	0.05	0.05	0.005	0.3	0.3	0.3	0.3	0.420	6.25
9/28/06	272	1.6	0.005	0.05	2.70	0.005	0.3	0.3	0.3	0.3	0.036	7.62
10/1/06	275	1.6	0.005	0.05	2.70	0.005	0.3	0.3	0.3	0.3	0.036	7.62

Note: The data for the days 4/6/06, 6/22/06, 7/20/06, 8/17/06, and 9/28/06 are from the observed data on the respective days in 2000. Organic matter data consisting of LDOM, RDOM, LPOM, and RPOM were estimated from the outputs of the Lake Almanor CE-QUAL-W2 model. The DO data for the period of 7/31-8/6/2006 are observed data derived from the 2006 special test.

LDOM: Labile dissolved organic matter; RDOM: Refractory dissolved organic matter;
LPOM: Labile particulate organic matter; RDOM: Refractory particulate organic matter.

Table 4 Water Quality Data (mg/L) Used at the Butt Creek Inflows for the Model Calibration Year 2006

Date	Julian Day	ISS	PO4	NH4	NO3	FE	ALGAE	DO
4/6/06	97	0.5	0.005	0.05	0.05	0.41	0	11.24
6/22/06	174	0.5	0.005	0.05	0.05	0	0.145	9.28
7/20/06	202	0.5	0.005	0.05	0.05	0.44	0.276	9.53
8/17/06	230	1.6	0.030	0.05	0.05	0.14	0.420	9.36
9/28/06	272	2.1	0.005	0.05	0.05	0	0	10.71
10/1/06	275	2.1	0.005	0.05	0.05	0	0	10.71

Note: The data are from the observed data on the respective days in 2000.

2.4 INITIAL CONDITIONS

Initial conditions are required for reservoir water level, water temperature, DO and all other modeled constituents. The initial conditions for hydrodynamic, water temperature and water quality simulations were derived from the same data sources used for model calibration and verification.

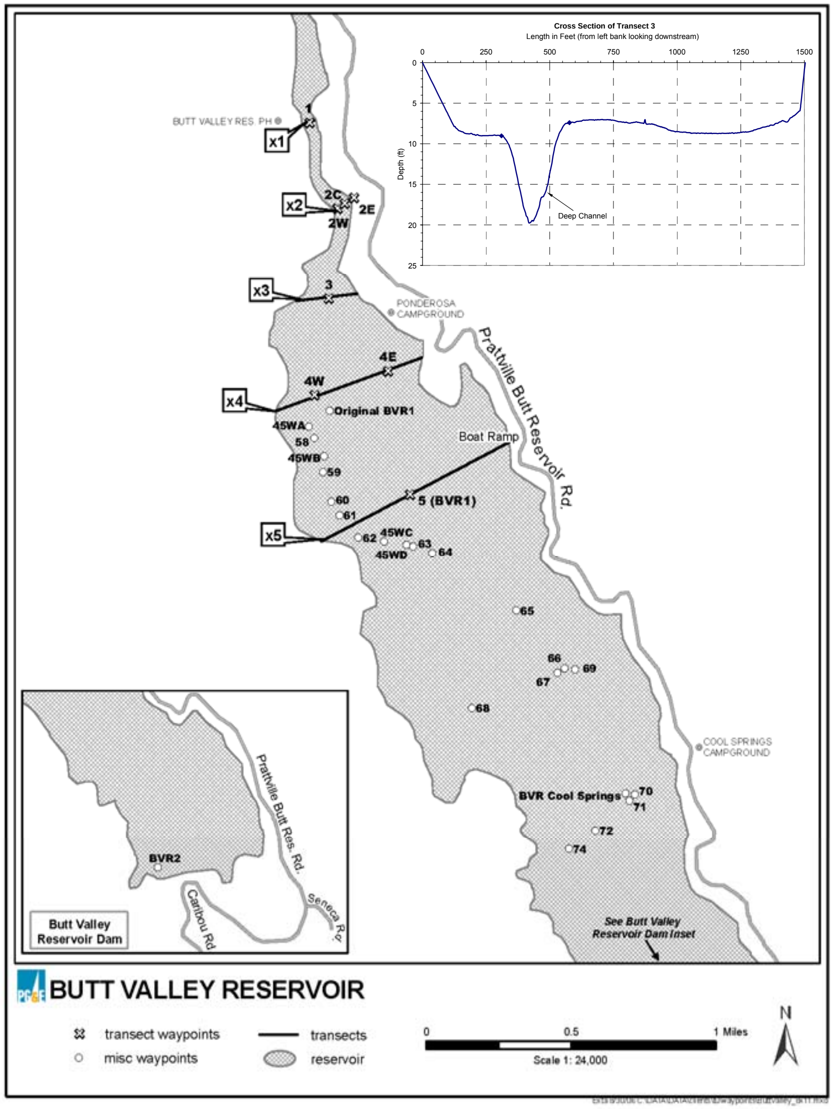
2.5 METEOROLOGY DATA

Hourly meteorology data at the Prattville Intake station for the model calibration year 2006 and the verification year 2000 were provided by PG&E. The data included hourly air temperature, wind speed and direction, relative humidity, and solar radiation. The CE-QUAL-W2 also requires input data for dew point temperature and cloud cover. The dew point temperature was computed from air temperature and relative humidity, and the cloud cover was estimated from observed solar radiation. There were some missing meteorology data for the model verification year 2000. Any missing data in air temperature, wind speed and direction, and relative humidity were directly filled in with data from the US Forest Service station at Chester, California obtained through the California Data Exchange Center (CDEC) of California Department of Water Resources. Solar radiation data collected at the Prattville Intake by PG&E for the model verification year 2000 were replaced with the solar radiation data collected at the California Irrigation Management Information System (CIMIS) station at McArthur, California (station 43). The CIMIS McArthur station is about 55 miles north of the Prattville Intake station. Examination and comparison of the solar radiation data collected by PG&E at the Prattville Intake station in 2000-2006 with the solar radiation data collected at the CIMIS McArthur station indicated that the solar radiation data collected at the Prattville Intake station for years 2000 – 2003 were generally lower than the solar radiation data collected at the McArthur station, which may not be correct since the solar radiation data collected at these two stations are similar for years 2004-2006. It would be expected that solar radiation would be similar for stations within the same general region. Using the solar radiation data collected at the CIMIS McArthur station for the model verification year 2000 is consistent with the solar radiation data used in the PG&E’s CE-QUAL-W2 model development for Lake Almanor. Using hourly meteorological data as the model inputs for model calibration and verification is consistent with the recommendation of the CE-QUAL-W2 User Manual (Cole and Wells, 2002).

2.6 MODEL PARAMETERS

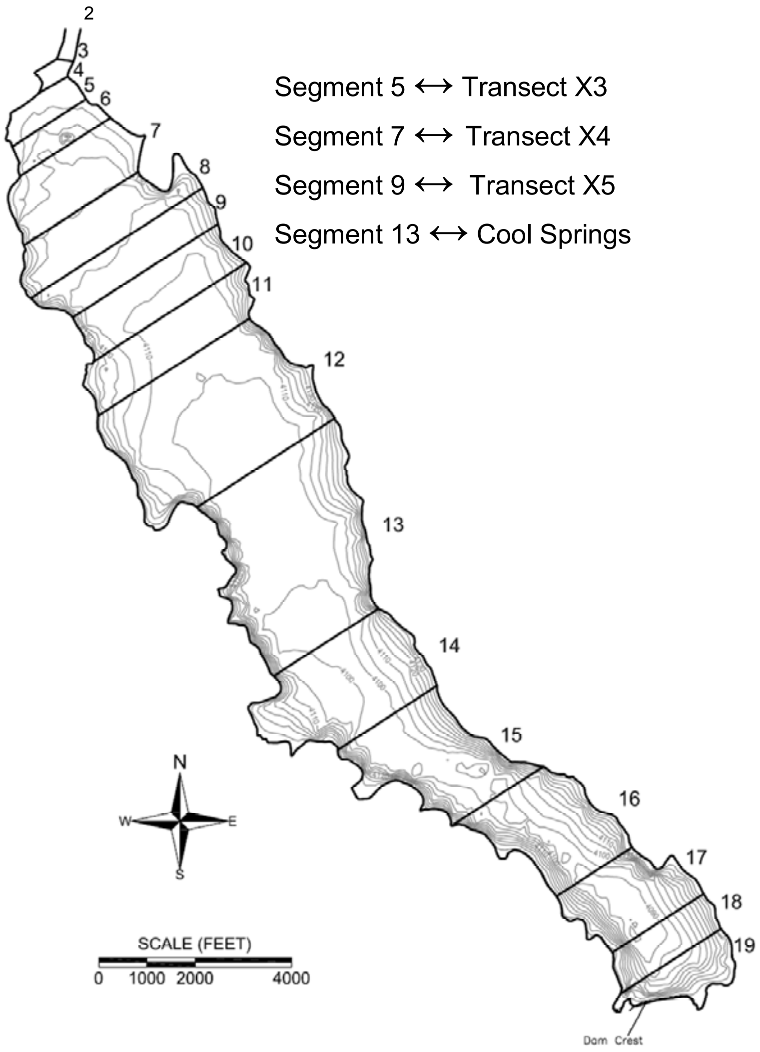
Model parameters, including hydraulic and kinetic coefficients, are site-specific and may need to be adjusted during calibration to achieve a satisfactory match between model predicted and observed data. The hydraulic parameters include mixing related factors, such as horizontal dispersion and vertical diffusion coefficients, Chezy coefficient or Manning’s n for reservoir bottom friction, and coefficients for wind stress. The CE-QUAL-W2 model allows a user to specify a wind sheltering coefficient which, when multiplied with the wind speed, reduces (if the coefficient is less than 1.0) or increases (if the coefficient is greater than 1.0) the effects of the wind to take into account differences in terrain from the meteorology station and the reservoir site. There are a lot of kinetic parameters in the CE-QAUL-W2 model that directly or indirectly affect water temperature, DO, and DO-related water quality constituents within the water column of the reservoir.

Figure 4 Butt Valley Reservoir CE-QUAL-W2 Model Segmentation



2006 Water Temperature Profile Monitoring Locations and Water Velocity Transects – Butt Valley Reservoir

Butt Valley Reservoir CE-QUAL-W2 Model Segmentation



Segment 5 ↔ Transect X3

Segment 7 ↔ Transect X4

Segment 9 ↔ Transect X5

Segment 13 ↔ Cool Springs

Figure 5 Computational Grid of Butt Valley Reservoir CE-QUAL-W2 Model

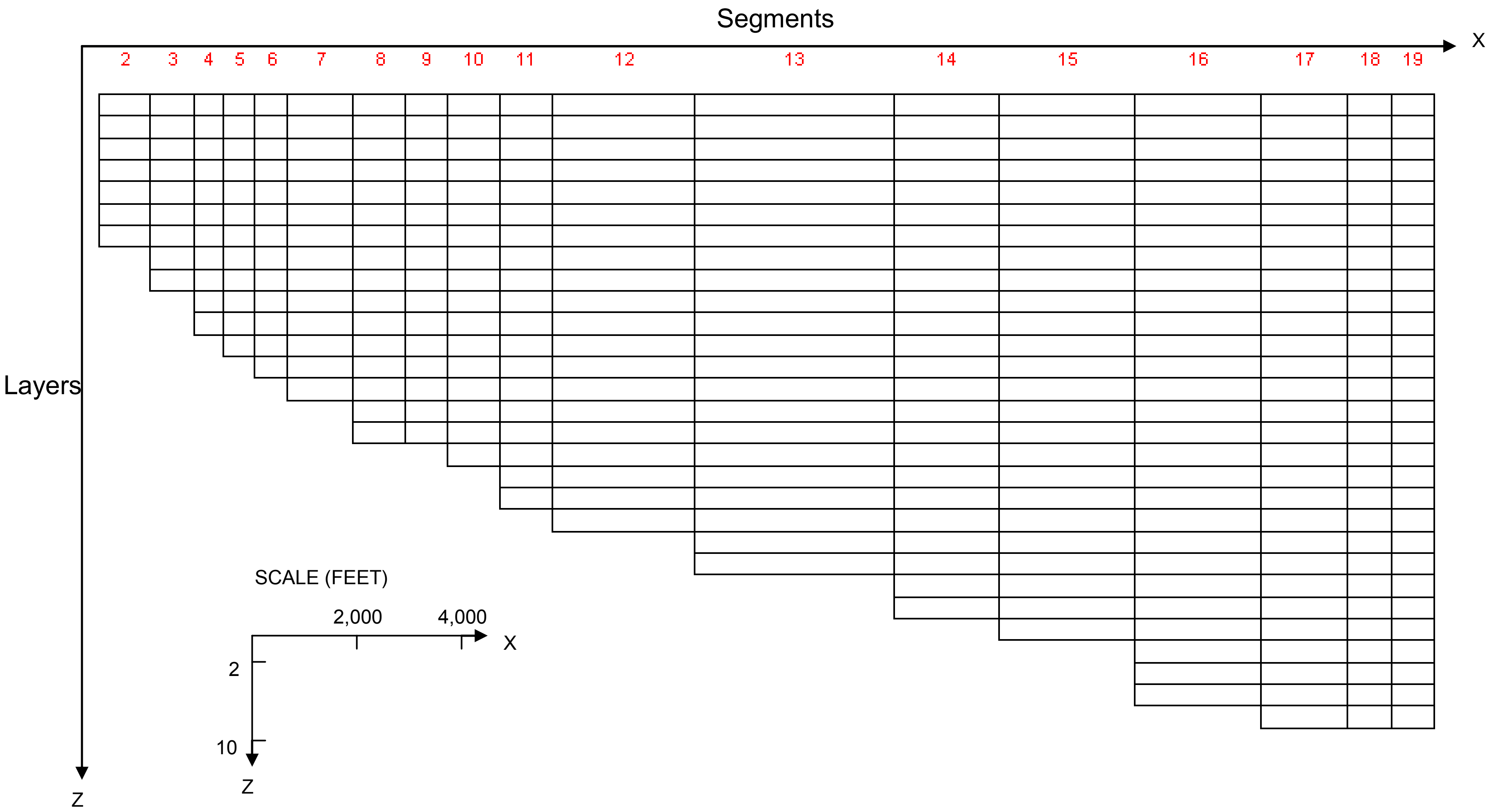
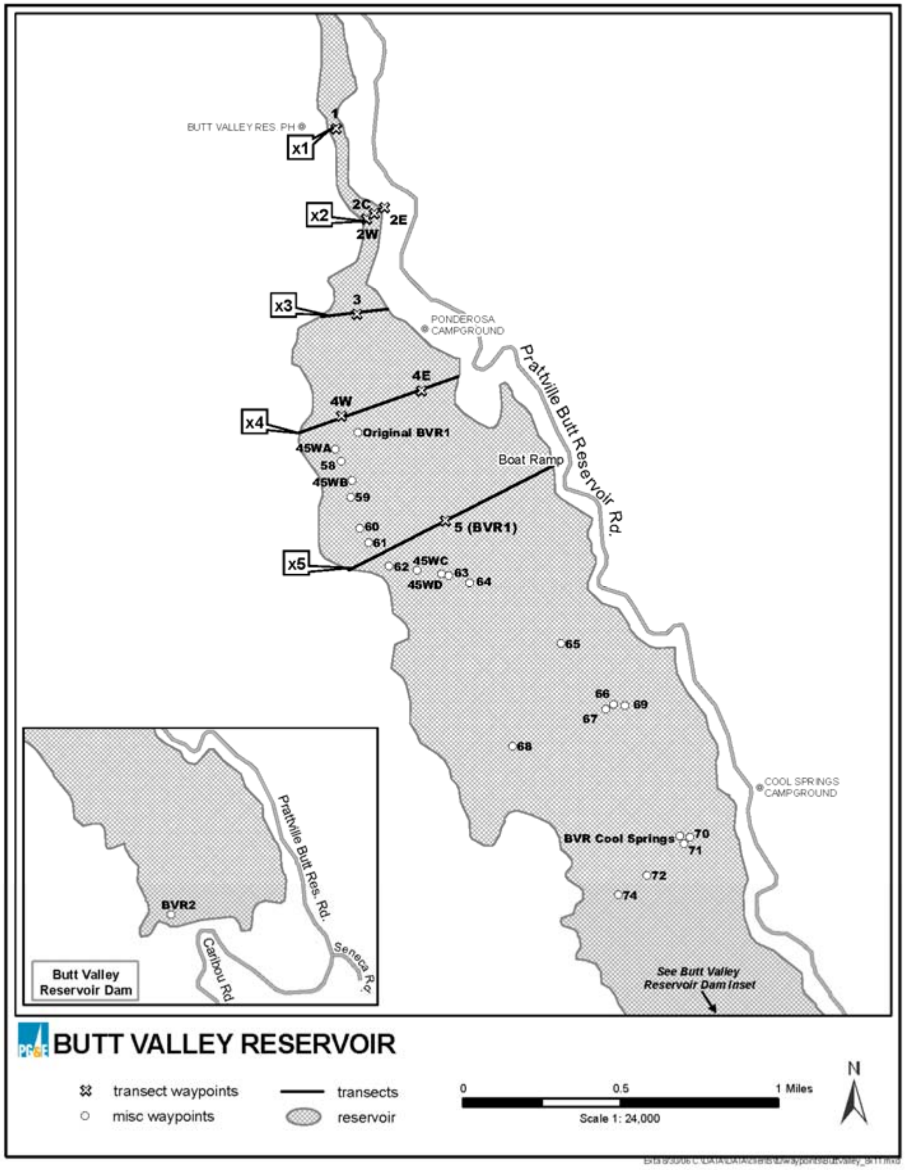
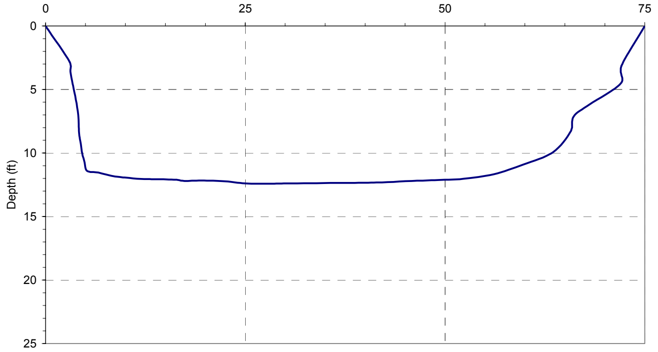


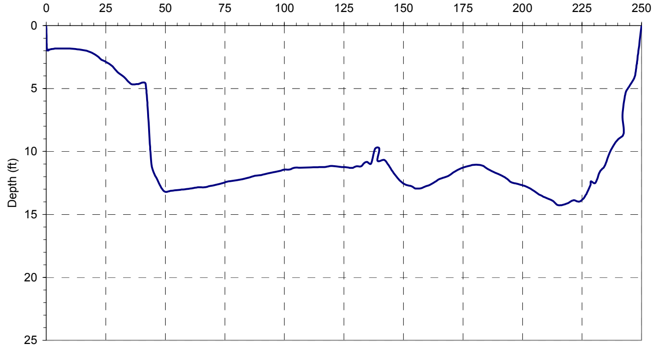
Figure 6 Transect Cross Sections



Cross Section of Transect 1
Length in Feet (from left bank looking down stream)



Cross Section of Transect 2
Length in Feet (from left bank looking downstream)



Cross Section of Transect 3
Length in Feet (from left bank looking downstream)

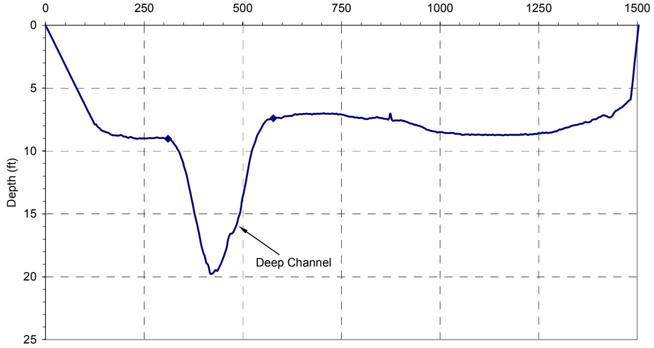


Figure 7 Butt Valley Reservoir Cross-Sections in the CE-QUAL-W2 Model for Segments 5 – 10 (Note the submerged deep channel represented in segments 5 – 8)

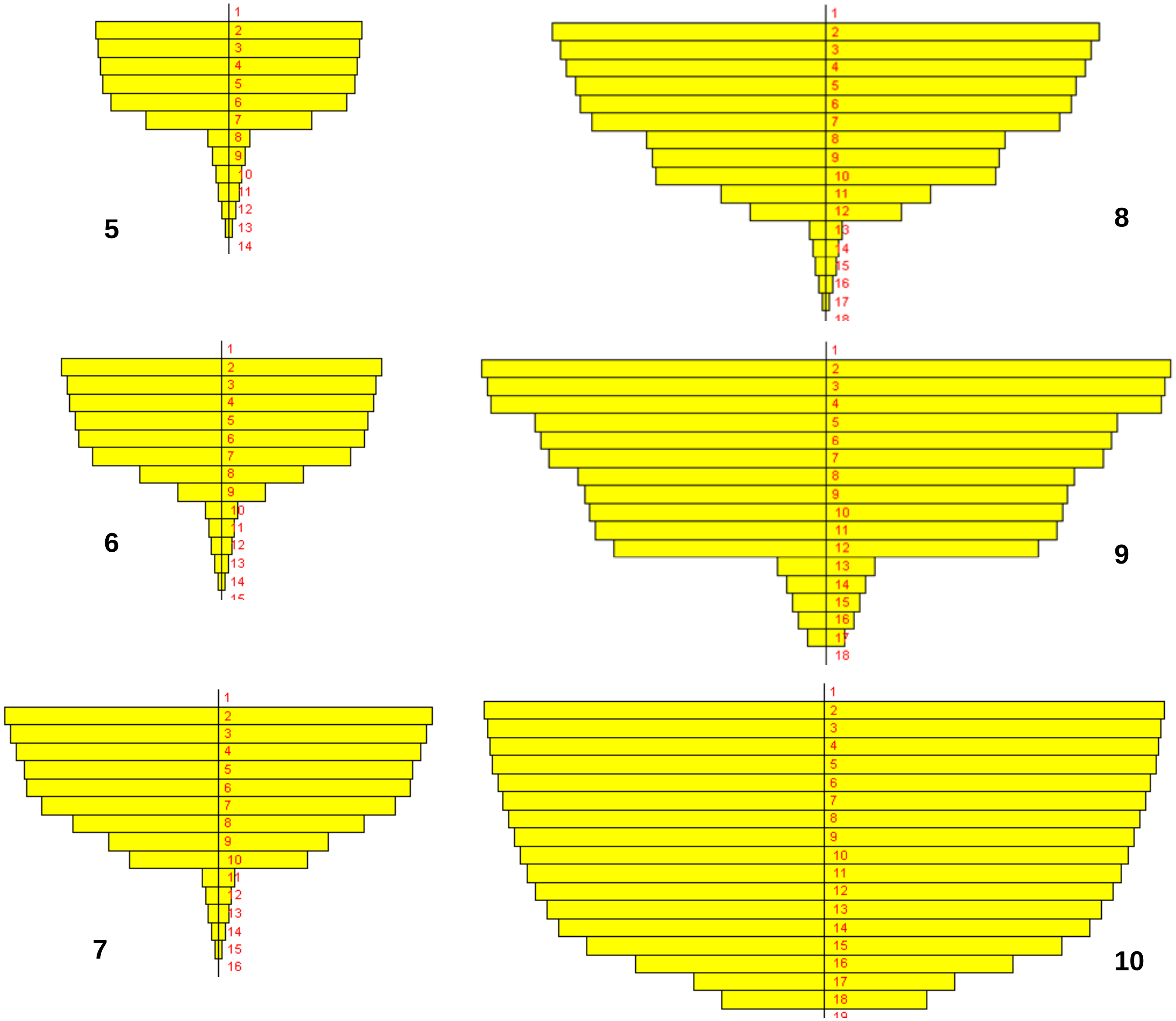


Figure 8 Butt Valley Reservoir Elevation – Storage Curve

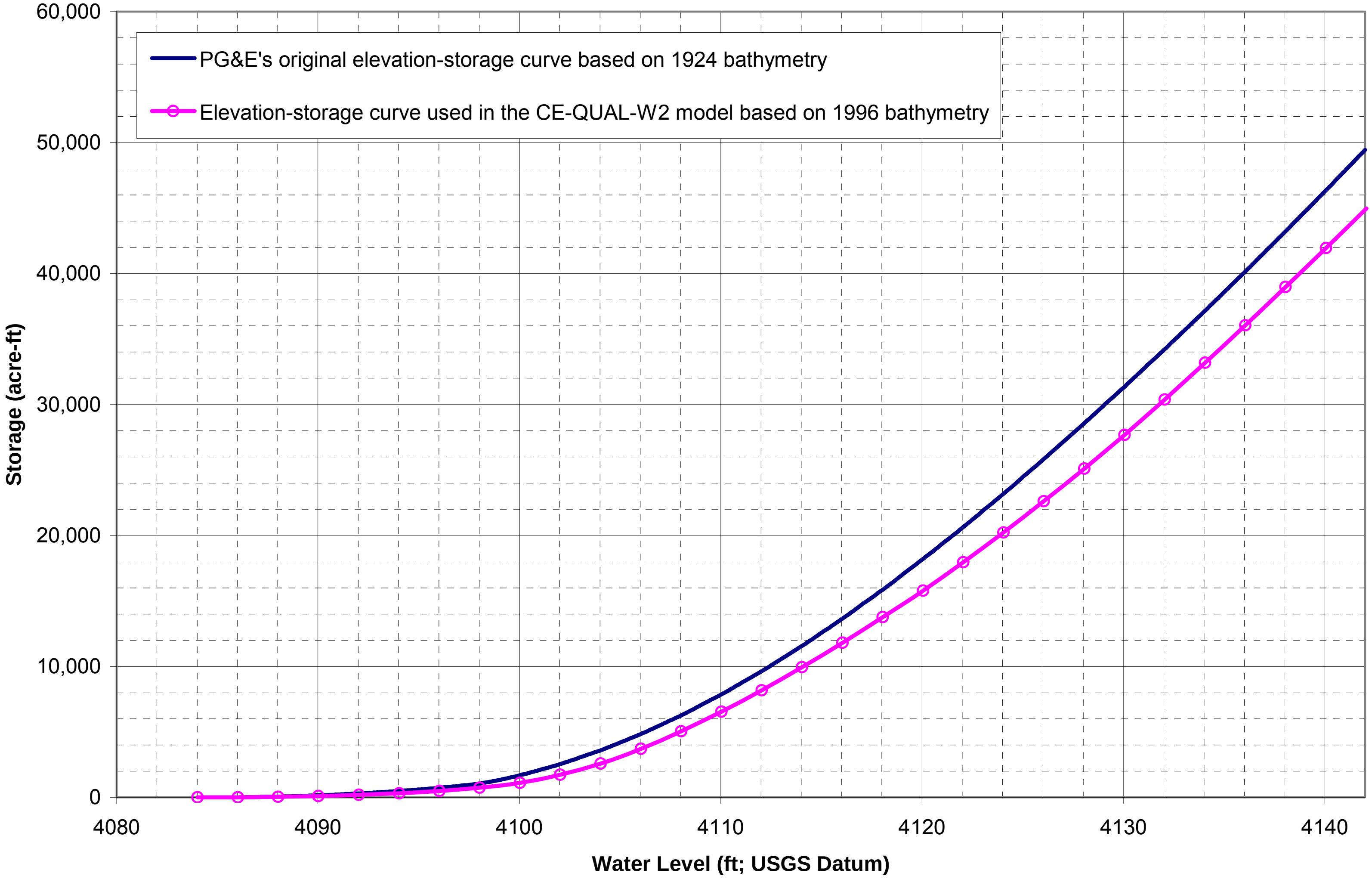


Figure 9a

Hourly Butt Valley PH Discharges in 2006
(The original flow data were reduced by 3.5% to achieve water balance)

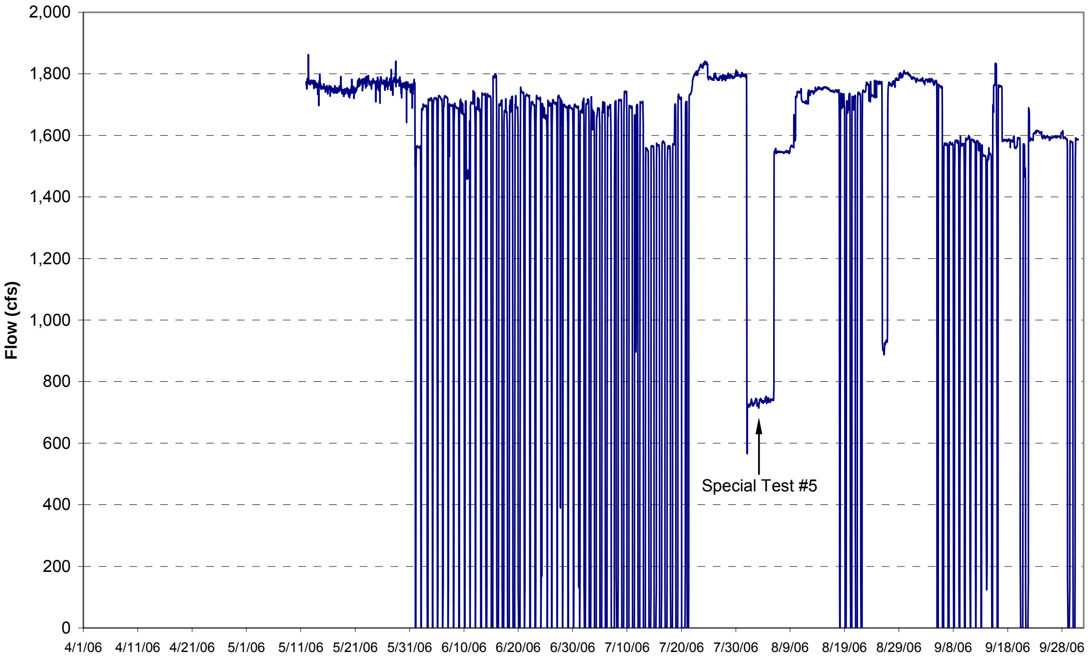


Figure 9b

Hourly Butt Valley PH Discharge Temperatures in 2006

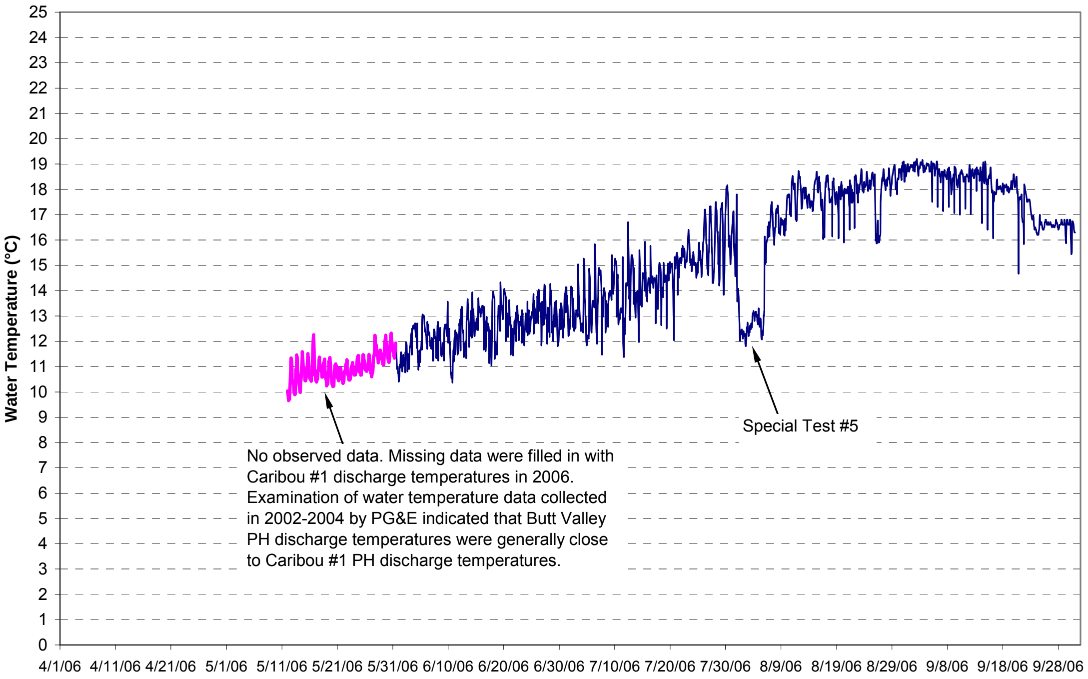


Figure 10a

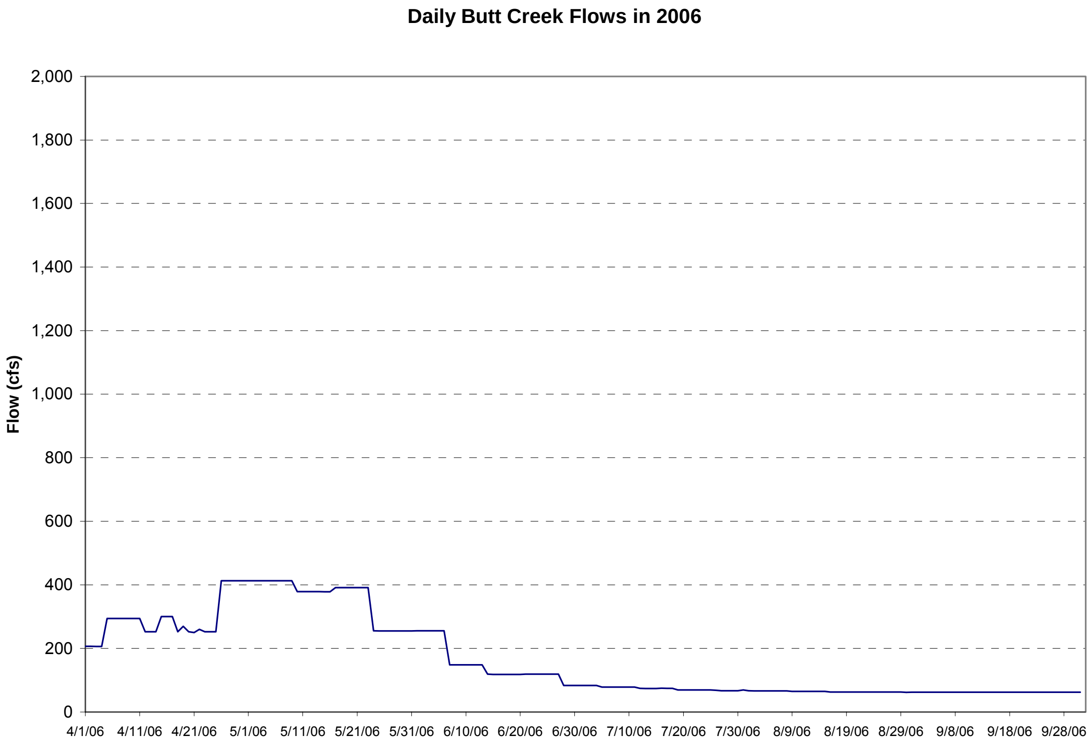


Figure 10b

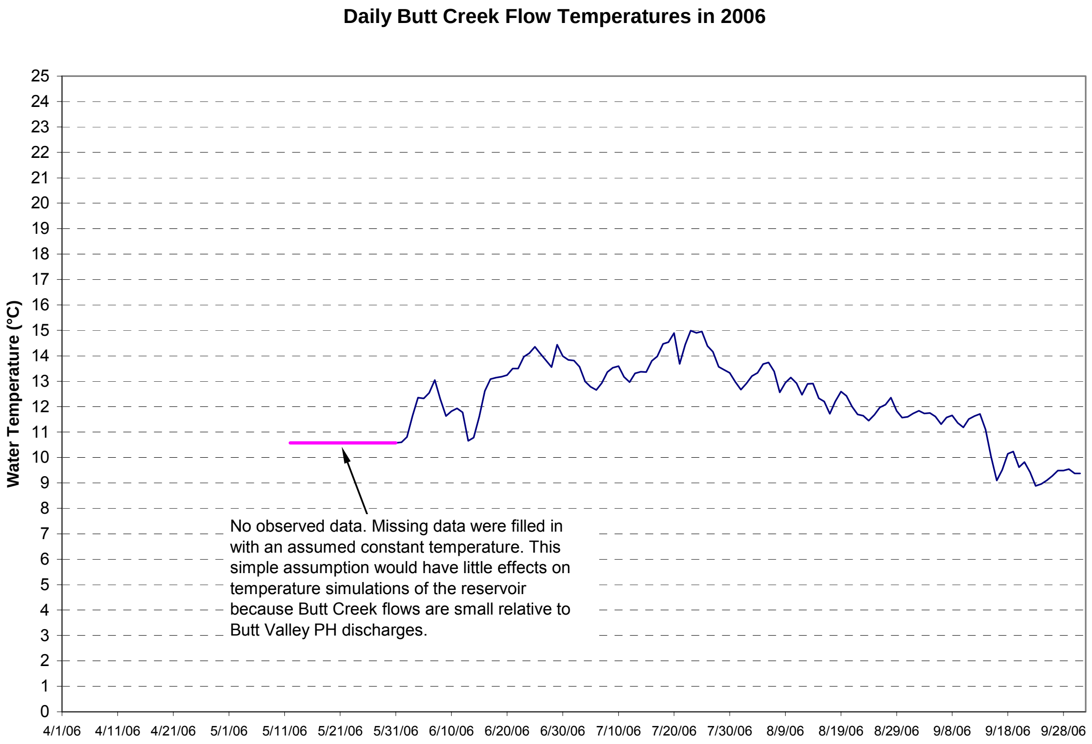


Figure 11a

Hourly Caribou #1 PH Discharges in 2006

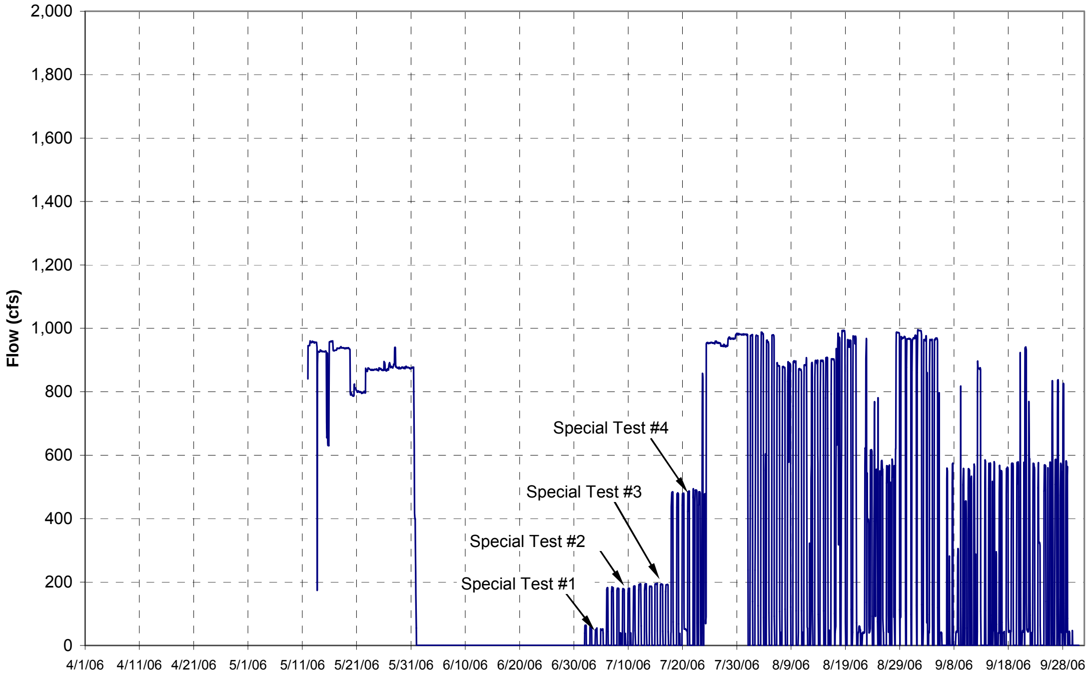


Figure 11b

Hourly Caribou #1 PH Discharge Temperatures in 2006

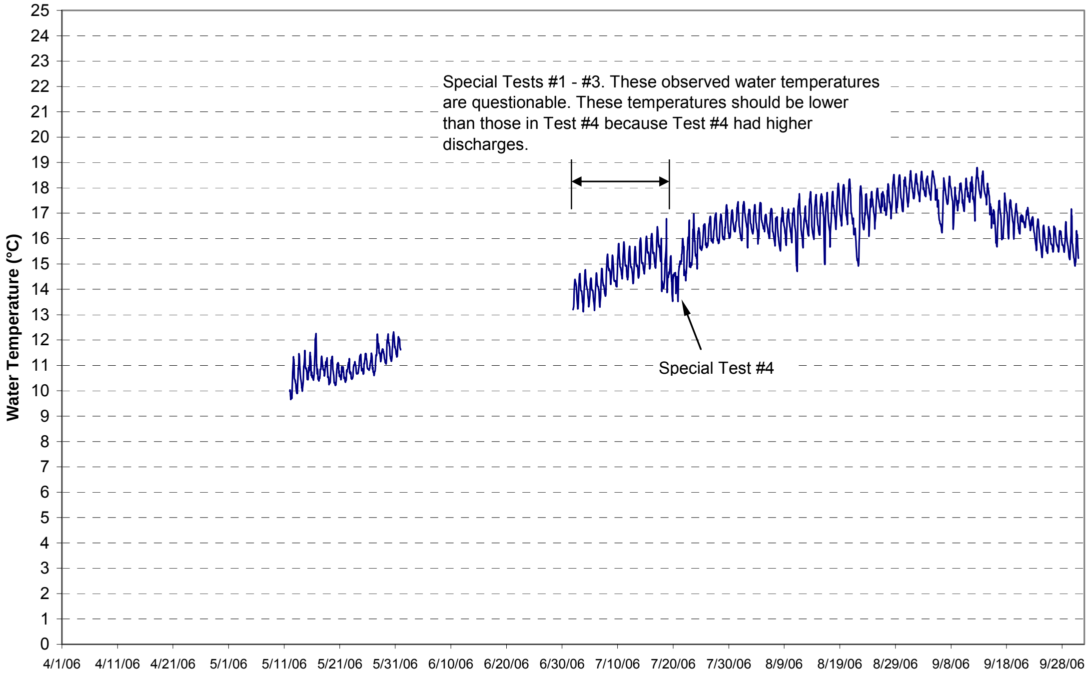


Figure 12a

Hourly Caribou #2 PH Discharges in 2006

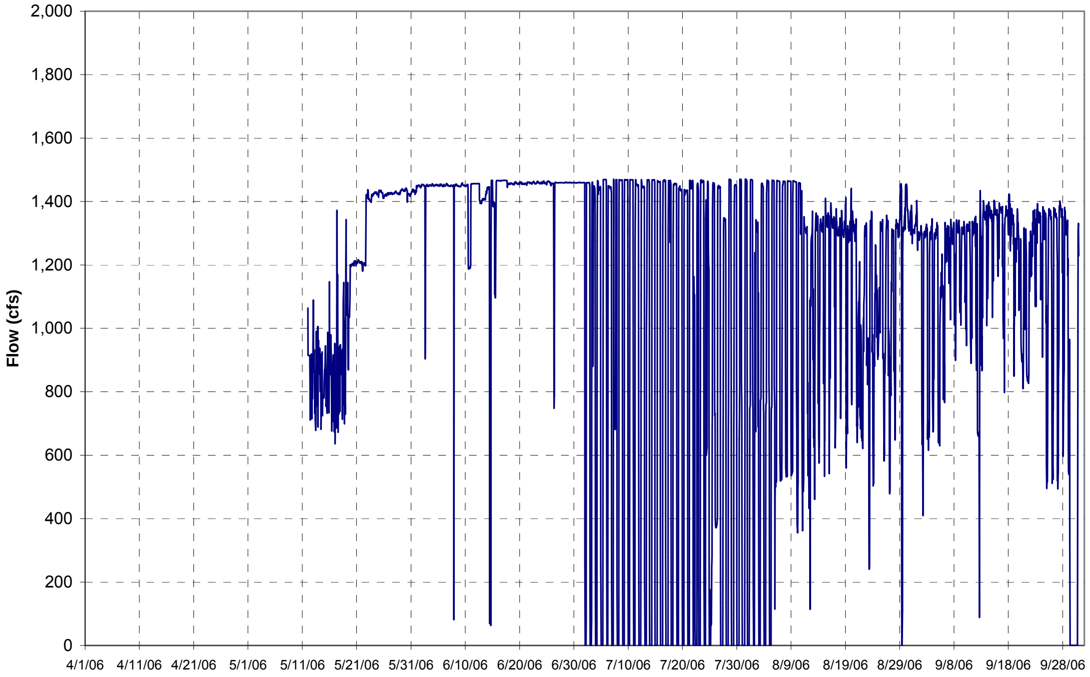


Figure 12b

Hourly Caribou #2 PH Discharge Temperatures in 2006

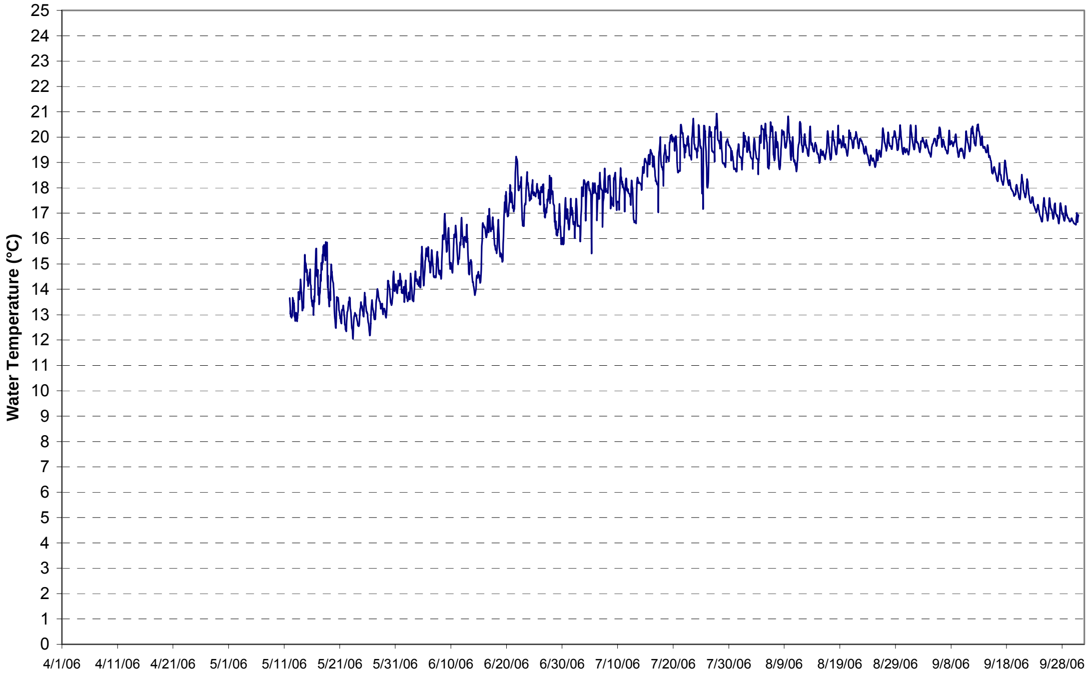


Figure 13a

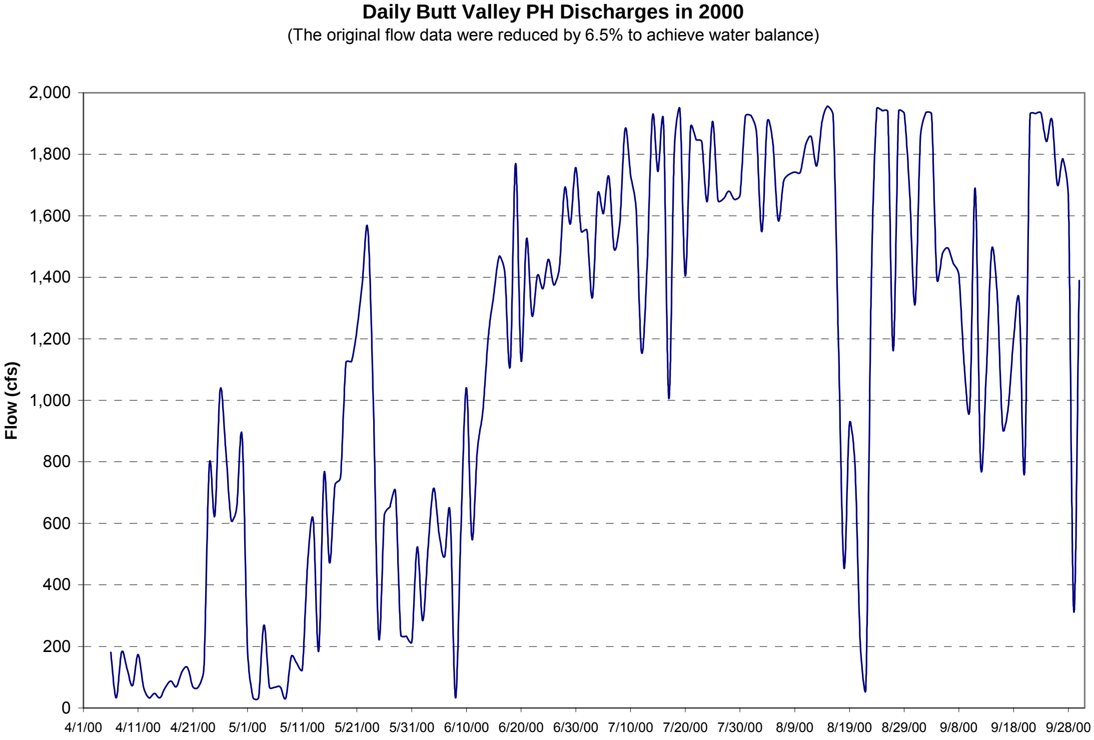
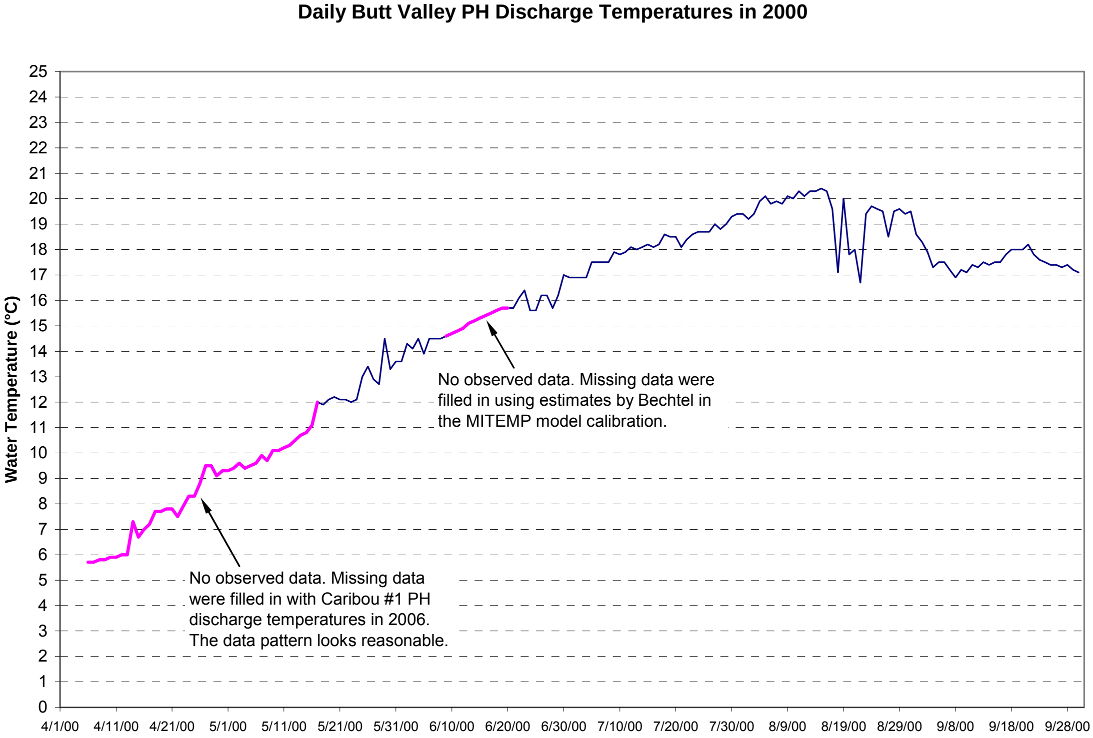


Figure 13b



No observed data. Missing data were filled in using estimates by Bechtel in the MITEMP model calibration.

No observed data. Missing data were filled in with Caribou #1 PH discharge temperatures in 2006. The data pattern looks reasonable.

Figure 14a

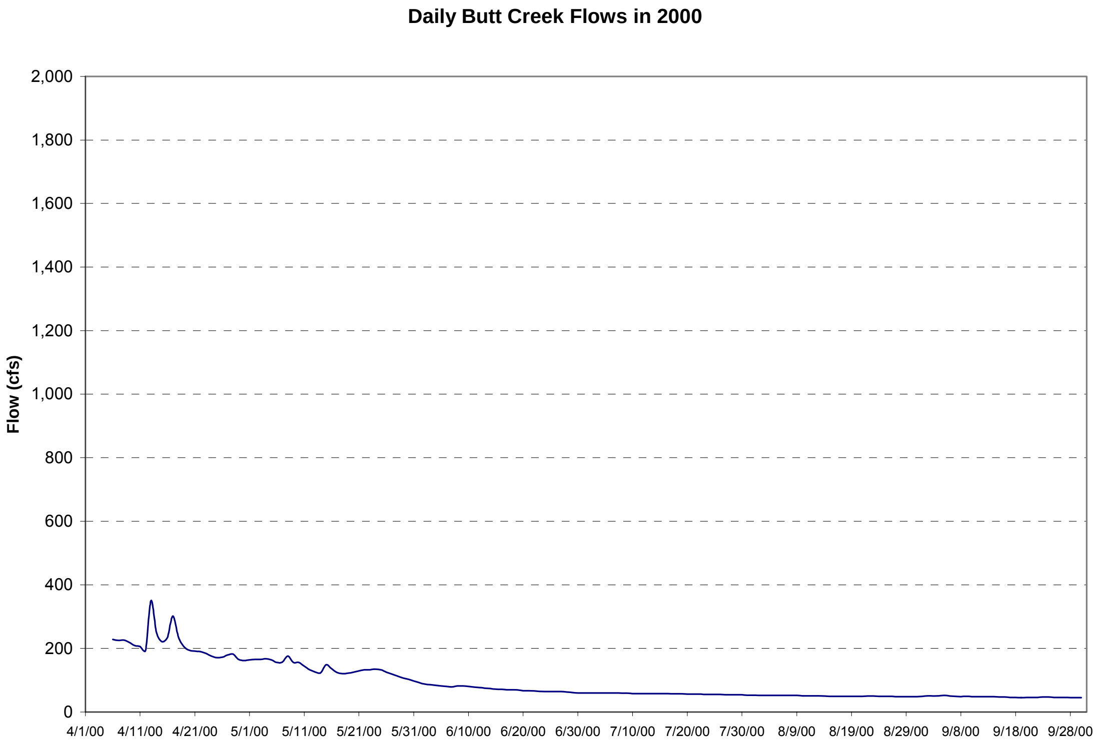


Figure 14b

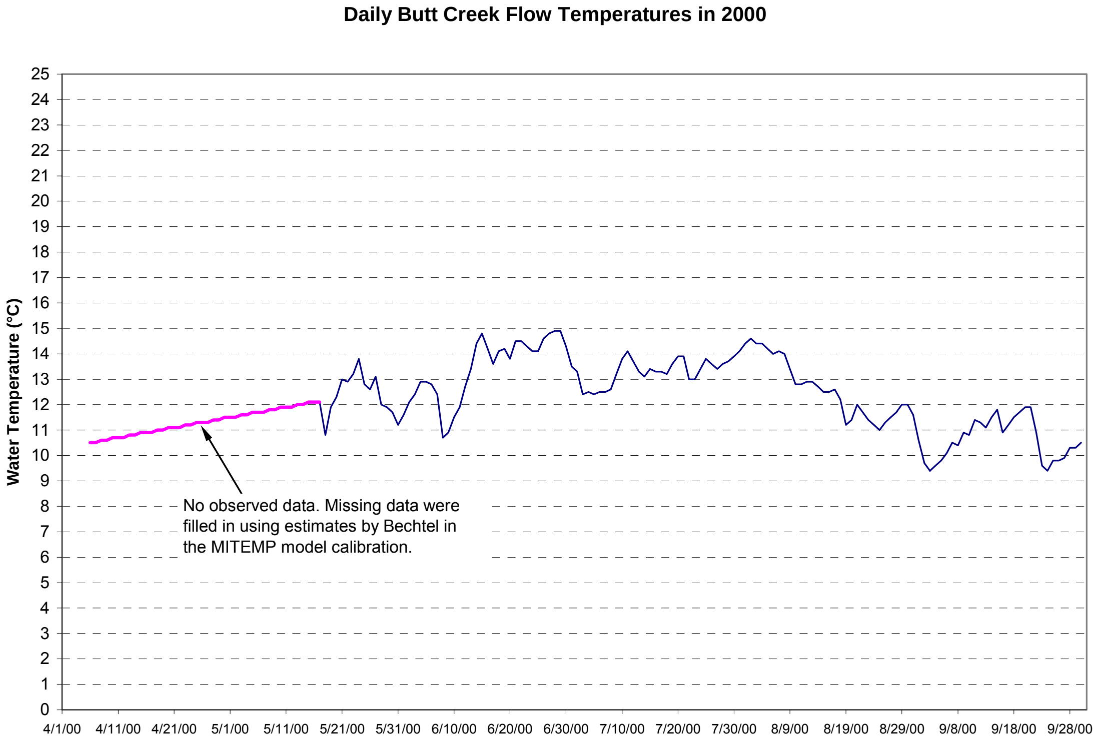


Figure 15

Daily Caribou #1 PH Discharges in 2000

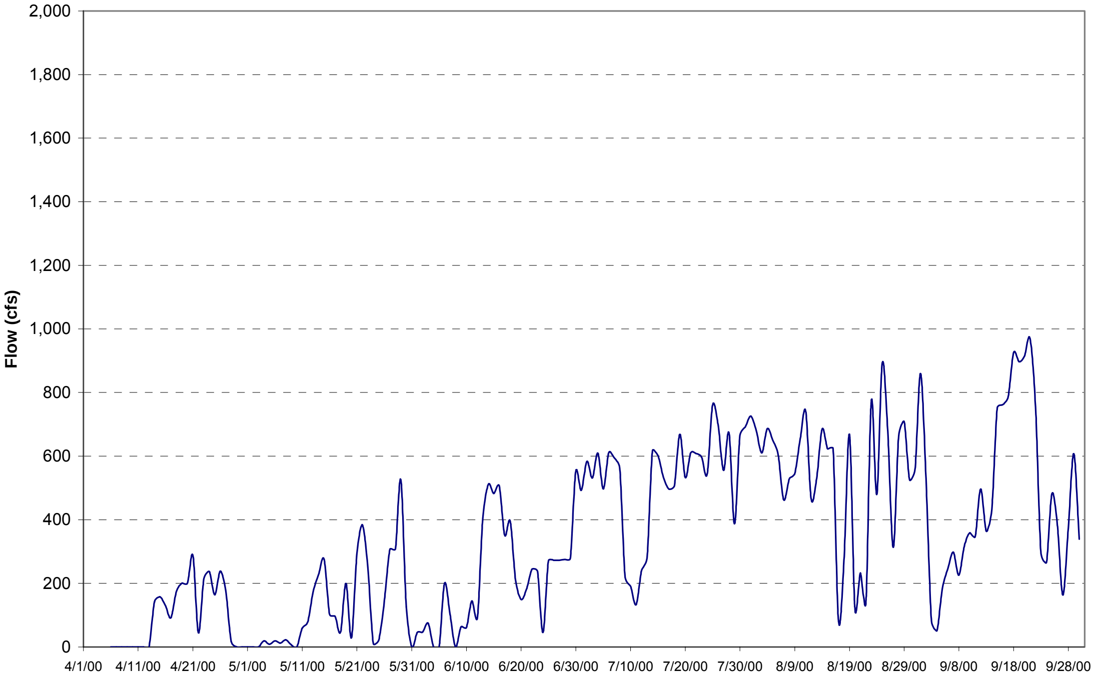
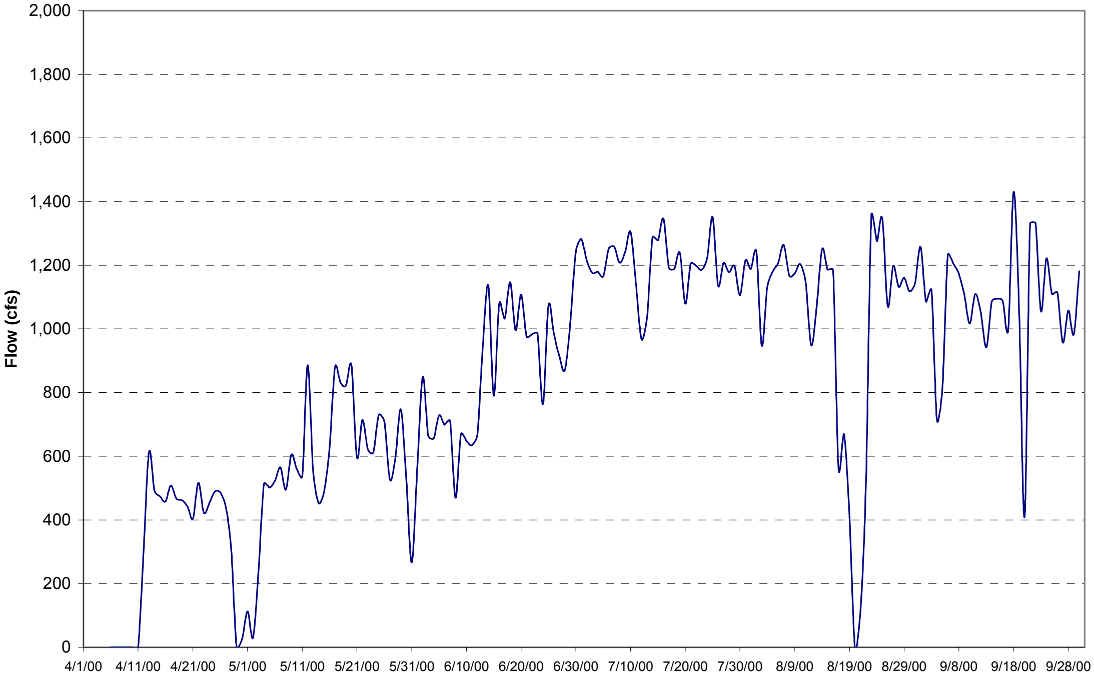


Figure 16

Daily Caribou #2 PH Discharges in 2000



3.0 MODEL CALIBRATION USING 2006 DATA (WET YEAR)

Model calibration is the process of adjusting the model parameters (within the well-established scientific ranges of the parameters) to best describe observed water temperature and water quality for a particular data set. Model calibration is an important step in model development. The data collected in 2006 (wet year), particularly the data collected during the summer 2006 special test, were used for model calibration. Based on data availability, the analysis period of May 12 to September 30, 2006 was selected for model calibration.

The water temperature and DO vertical profiles and water surface elevation measured on May 12, 2006 were used to initialize the calibration run. The initial water temperature distribution had about a 9°C temperature difference from surface (16°C) to bottom (7°C). The initial DO concentration distribution had about a 4 mg/L difference from surface (11.0 mg/L) to bottom (7.0 mg/L). PG&E did not collect water quality data for other constituents. The in-reservoir water quality data collected during the synoptic measurements in April and June 2000 (normal year) were averaged and used for the initial water quality conditions for the selected water quality constituents that were discussed in Section 2.1. As measured in April and June 2000, the observed concentrations of most water quality constituents in the reservoir were below the detection limit. For observations with values below the detection limit, a value equal to one-half of the detection limit was used. The initial concentration of algae was estimated from the measured chlorophyll-a concentrations in the reservoir in April and June 2006. Using the default value of the model, algae concentrations were assumed to 145 times the chlorophyll-*a* concentrations. Because concentrations of the DO-related water quality constituents in Butt Valley Reservoir were either below the detection limit or relatively low based on the 2000 measurements, the initial concentrations of these water quality constituents would not have a significant effect on DO simulations in the reservoir.

3.1 2006 SPECIAL TEST

The infusion of cold water from an appropriate source would likely be necessary to achieve the temperature objective target for protection of the cold freshwater habitat beneficial use along the NFFR. To assess the thermal response of the river to the infusion of cold water, at the request of the State Water Resources Control Board, PG&E carried out a special test in summer 2006 (Stetson and PG&E, 2007). The test consisted of modifying the operations of certain NFFR hydroelectric project facilities to infuse cold water into the river, coupled with monitoring of flow and temperature at strategic points along the river to measure the thermal response. The test results yielded important information that was used in the development of water temperature reduction measures and alternatives that may be considered as possible solutions to NFFR temperature concerns. The test also provided data to support development of new or enhancement of existing computer simulation models of water temperature for evaluating water temperature reduction measures.

The 2006 special test actually consisted of six separate special tests. All tests were conducted during summer 2006. Special Test 5 (i.e., Caribou Special Test with Reduced Butt Valley PH Flows) conducted in Butt Valley Reservoir on August 1-5, 2006 was based on the data information collected by PG&E during testing conducted on August 1-5, 1994, which suggested that reducing approach velocities at the Prattville Intake by decreasing the rate of Butt Valley PH discharge to below 800 cfs would, in effect, increase selective withdrawal water from the Lake Almanor hypolimnion and reduce the discharge water temperature[6]. The purpose of Special Test 5 was to better correlate the relationship between the discharge rate and water temperature (and the associated dissolved oxygen level) of the Butt Valley PH operation under different Lake Almanor elevations. Note that 2006 was a very wet year with lake level near its normal maximum water level during Special Test 5, whereas 1994 was a normal water year. This special test was also intended to help evaluate whether the cold water released from the Butt Valley PH (through a reduction in discharge rate) would plunge and travel the 5-miles through Butt Valley Reservoir to become available for withdrawal at the Caribou #1 Intake. This special test was designed to include collection of hydraulic and water quality data (water temperature, DO and velocity) to better characterize hydraulic conditions within the reservoir with changes in water delivery temperature.

Following are summaries of the major findings of Special Test 5.

- Special Test 5 verified that decreasing the rate of Butt Valley PH discharge to below 800 cfs when Lake Almanor elevation is high would selectively withdraw cold water from the Lake Almanor hypolimnion and lower discharge water temperatures to Butt Valley Reservoir. During this special test, the Butt Valley PH discharge was reduced from about 1,800 cfs to about 500 cfs, and measured water temperatures decreased from about 16.5°C to 12.5°C-13.0°C [7] (Figure 17).

- Special Test 5 demonstrated that the cold water from Butt Valley PH (through a reduction in discharge rate to about 500 cfs under high Lake Almanor condition) would plunge at a location near the Butt Valley Reservoir entrance. Figure 19 shows vertical water temperature profiles collected from the upper portion of Butt Valley Reservoir during Special Test 5 (see Figure 18 for Butt Valley Reservoir water temperature monitoring sites and transect cross-section locations). Water temperature profiles at transects X1 and X2 were generally uniform and cold. Water temperature profiles at transects X3 and X4 showed relatively strong stratification, implying that the cold water possibly plunged at a location upstream of transect X3 [8]. Field observation confirmed the plunging phenomenon and the

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[6] Source: Figure 7 <u>in</u> North Fork Feather River Study Data and Informational Report on Water Temperature Monitoring and Additional Reasonable Water Temperature Control Measures, PG&E, Amended September 2005.

[7] Note that 2006 was a very wet year. Lake Almanor had an unusually high water level at elevation about 4,501 ft (3 ft below the normal maximum water level of 4,504 ft in USGS datum) during Special Test 5.

[8] There were no field temperature profiles to demonstrate whether stratification already existed or not at Transect X3 prior to Special Test 5. However, the calibrated CE-QUAL-W2 model results showed that the

location actually occurred immediately upstream of transect X3 where the wind-induced surface turbulence showed an interfacial line with the colder plunging water. At this demarcation line, rapid temperature change was evident by in-situ instrument onboard the survey vessel.

- During Special Test 5, field efforts to trace the cold water plume in Butt Valley Reservoir were conducted. The intent was to capture and document the mixing process by measuring water temperature and DO profiles at various points along the pathway of the cold water plume[9]. A deep submerged channel was identified along the west side of the reservoir entrance above the Boat Ramp, but measurements could not locate the course of a distinct channel downstream of the Boat Ramp[10]. The representative cross section of the deep channel at Transect X3 is shown in Figure 6, and the deep channel was represented in the CE-QUAL-W2 model in segments 5-8 as shown in Figure 7.

- Water temperature stratification measurements in Butt Valley Reservoir indicated that the cold water that plunged moved primarily in the deep channel with little entrainment or mixing with warm surface water. However, mixing with warm surface water was relatively high starting at the Boat Ramp area, where the deep channel began to disappear, to Cool Springs.

- Water temperature time series data collected at different depths in Butt Valley Reservoir near the Caribou #1 Intake (BVR2) indicated that the Caribou #1 Intake mainly withdrew water at depth around 30 ft and the Caribou #2 Intake mainly withdrew water at depth around 5-10 ft (Figure 20).

Special Test 5 in Butt Valley Reservoir provided useful information on cold water selective withdrawal at Prattville Intake and cold water plunge and movement within Butt Valley Reservoir. The special test also provided crucial data for the CE-QUAL-W2 model development and calibration.

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temperature profile at Transect X3 on July 31, 2006 (prior to Special Test 5) was generally uniform (with temperature difference about 1.0°C between surface and bottom, indicating the strong stratification shown on Figure 19 was indeed caused by cold water plunge during the special test.

[9] The DO profiles near Prattville Intake during the special test showed a very unique distribution, with higher DO concentrations in the thermocline layer between epilimnion and hypolimnion waters. Immediately preceding Special Test 5 (July 31, 2006), the observed DO concentration at Butt Valley PH discharge was 6.6 mg/L. During Special Test 5 (August 1-5, 2006), the observed DO concentration at Butt Valley PH discharge ranged from 8.2 mg/L to 8.9 mg/L. The higher DO concentrations in the cold water withdrawn selectively through the Prattville Intake (about 12.5 – 13.0°C) and discharged from Butt Valley PH during Special Test 5 provided a unique signature to differentiate the test plume from the receiving cold water of the reservoir (which contained a relatively low DO level). The DO signature was used as an additional indicator to track the cold water movement in Butt Valley Reservoir.

[10] The deep channel is surmised to be a remnant of the pre-reservoir Butt Creek channel. The topographical expression of the remnant channel could not be located downstream of the Boat Ramp, possibly due to filling in by sediment over the last 84 years.

Figure 17 Observed Butt Valley PH Mean Daily Discharges and Discharge Water Temperatures during Summer 2006 Special Test

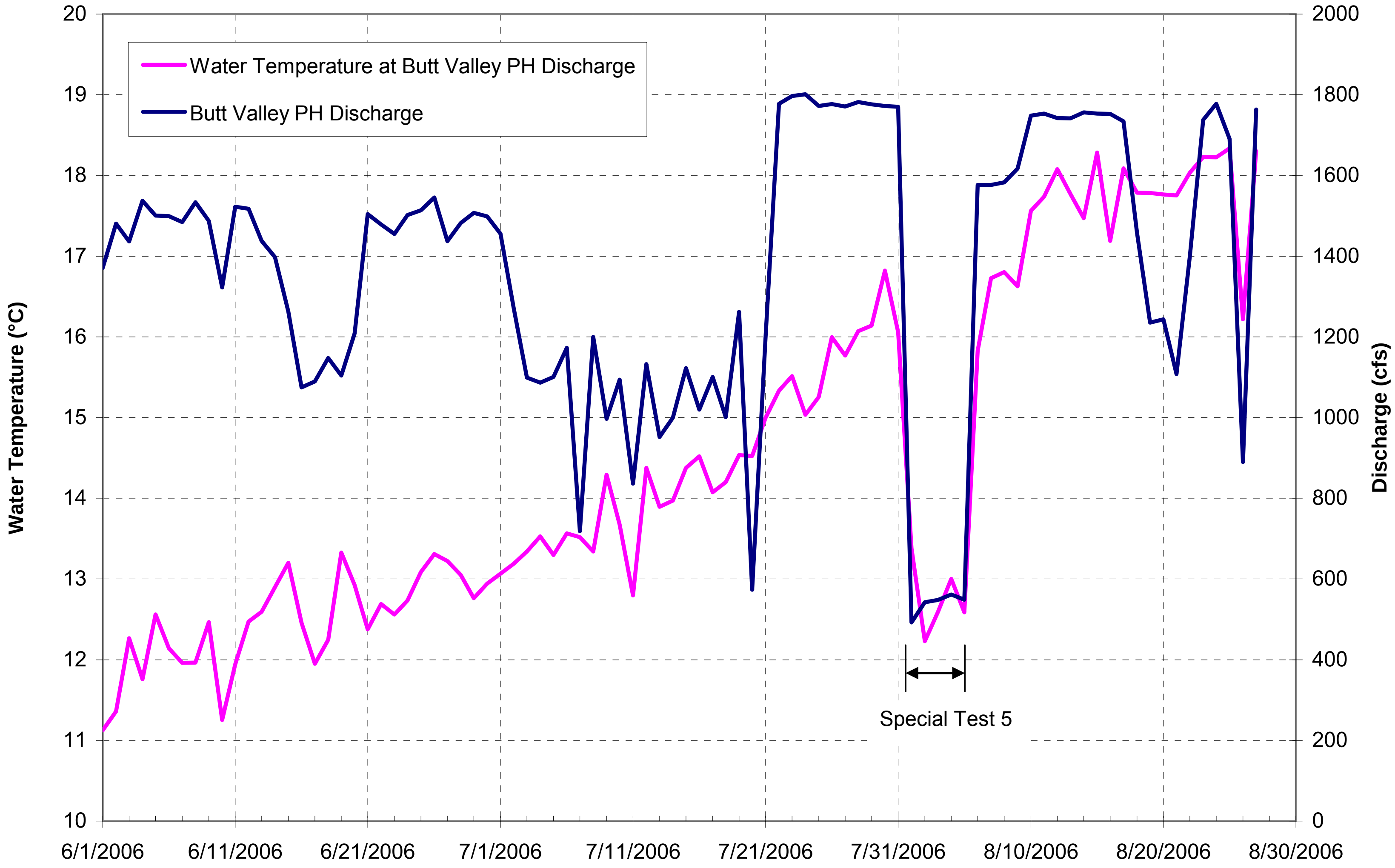


Figure 18 Butt Valley Reservoir Temperature Profile Monitoring Sites and Water Velocity Transects during Summer 2006 Special Test

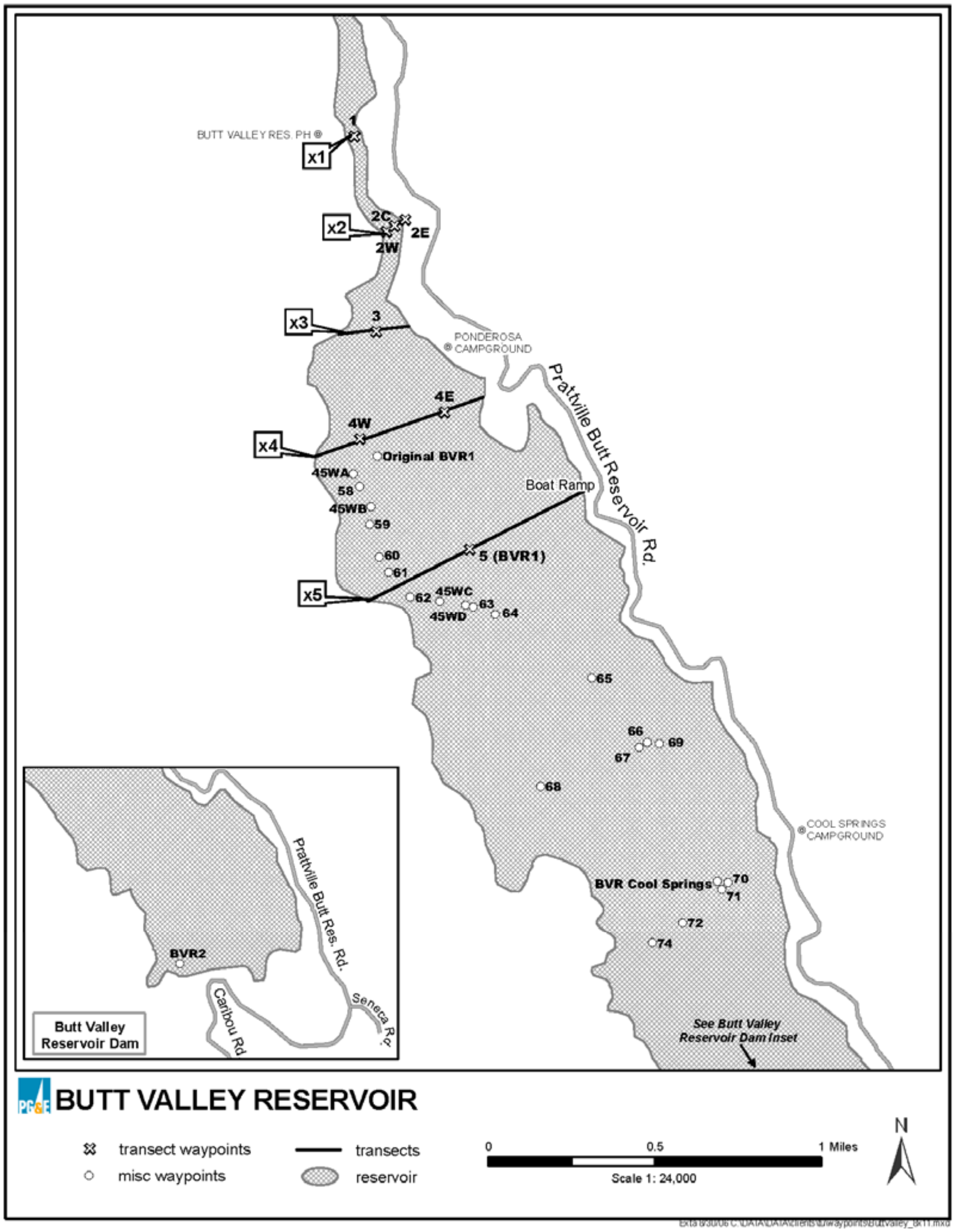


Figure 19 Observed Water Temperature Profiles along the Upper Portion of Butt Valley Reservoir
August 3, 2006
(Refer to Figure 18 for monitoring locations)

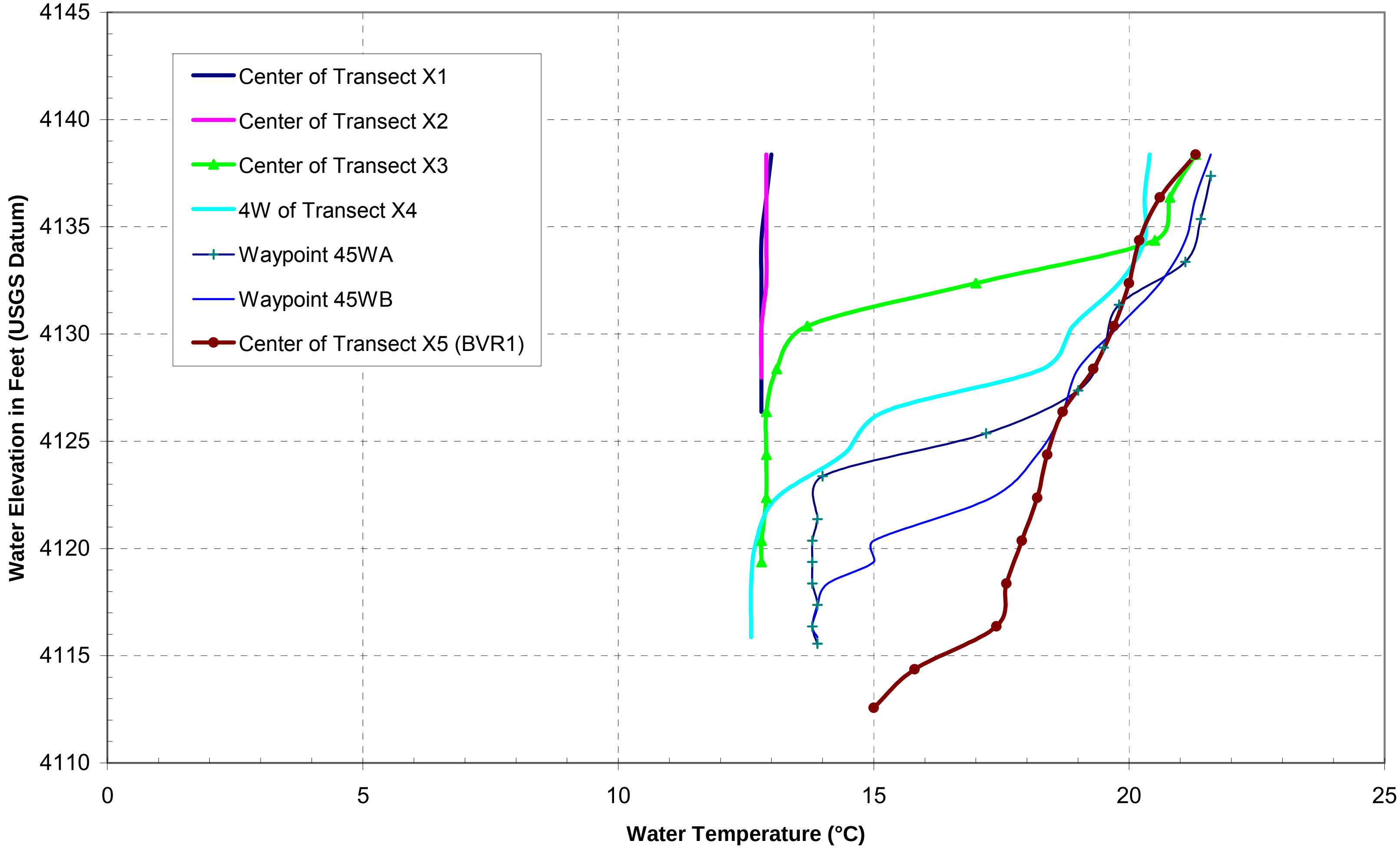
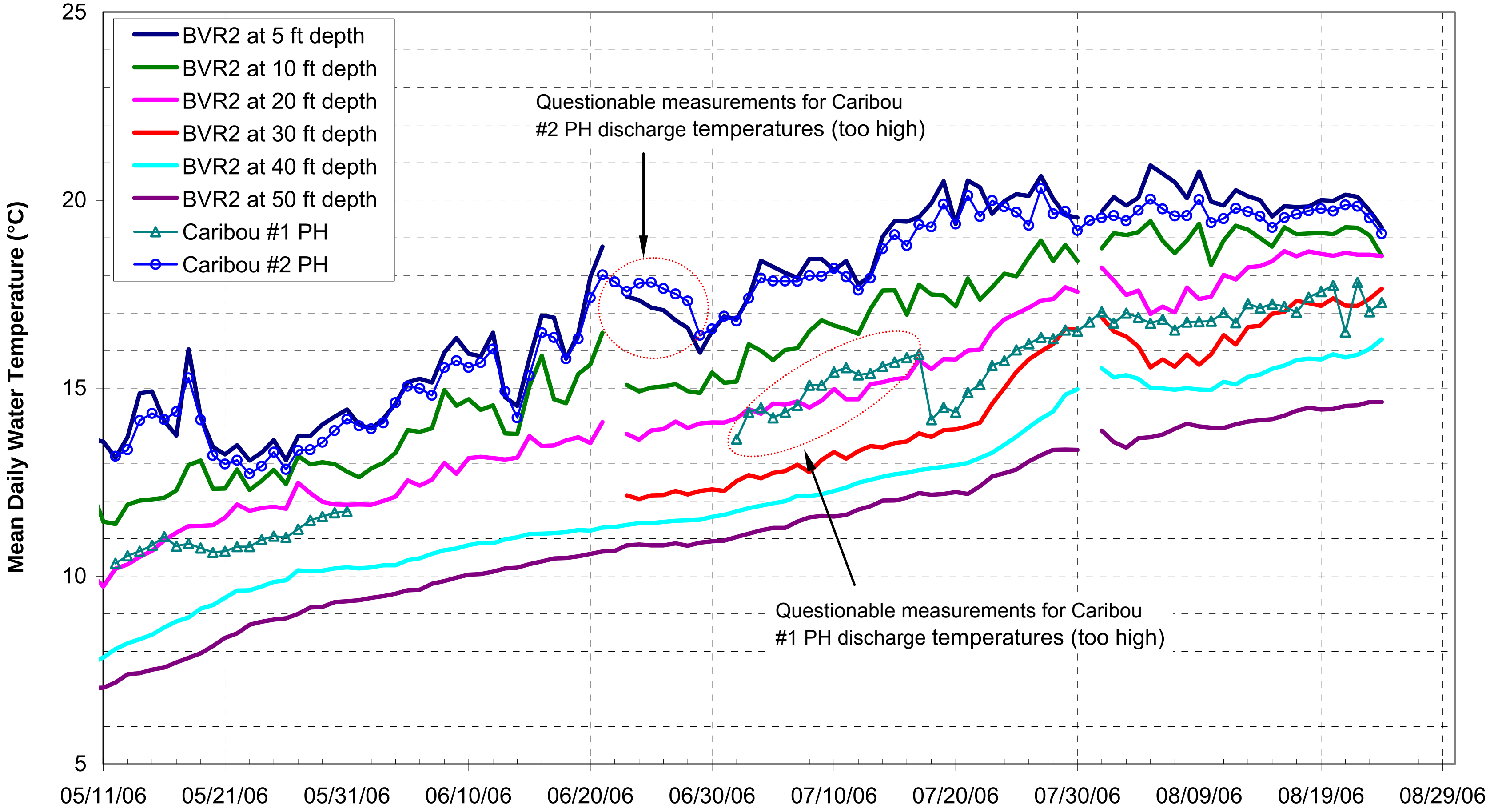


Figure 20 Observed Water Temperatures at Different Depths in Butt Valley Reservoir near Caribou #1 Intake (BVR2)



Questionable measurements for Caribou #2 PH discharge temperatures (too high)

Questionable measurements for Caribou #1 PH discharge temperatures (too high)

3.2 CALIBRATION APPROACH

Model calibration consisted of a systematic procedure of adjusting various process parameters that control hydrodynamics, vertical and horizontal mixing, surface and bottom heat exchanges, and water quality constituents within the water column. The calibration started by ensuring the water balance of the reservoir was reasonably simulated. After satisfactory water balance calibration was achieved, the hydrodynamics (in terms of water velocity) and water temperature and water quality were simulated using the default process parameter values from the CE-QUAL-W2 User Manual (Cole and Wells, 2002). The parameter values were then systematically adjusted (within reasonably defensible and/or literature ranges) to achieve the closest agreement between simulated and observed data for water velocity, water temperature and DO at different measurement locations.

A number of model parameters were systematically adjusted during model calibration. Some of these parameters had more of an effect on results than others. Parameter modification was only incorporated into the final simulation if it had a beneficial effect on model performance. A summary of the parameters that were adjusted and whether they affected model performance is provided below. Default values were otherwise specified as recommended in the CE-QUAL-W2 User Manual (Cole and Wells, 2002).

Manning's n — The Manning's n is a measure of bottom friction. The Manning's n has a fairly large effect on current velocity and the temperature in the bottom of the reservoir. Lower values increase water velocity and allow cold water to descend to greater depths more rapidly, helping to keep the water cold at the bottom of the reservoir. Increasing water velocity would increase interfacial mixing and thus increase the overall temperature in the hypolimnion. The final calibrated Manning's n was 0.04. Table 5 compares the simulated water velocity and measured velocity by PG&E at the upstream portion of the reservoir during the 2006 special test.

Table 5 Comparison between Observed and Simulated Water Velocities (fps)

	Transect X1	Transect X2	Transect X3	Deep Channel in Transect X3
Measured Mean Velocity	0.62	0.30	0.21	0.40
Simulated Mean Velocity	0.44	0.22	0.20	0.30

Note: Refer to Figure 6 or Figure 18 for Transect locations.

Light extinction coefficient — The extinction coefficient for light (by algae, ISS, and water) controls the depth of light penetration in the water column and has a large effect on the thermal structure of the reservoir. The final calibrated light extinction coefficient was 0.35 m^{-1}. This value is close to the light extinction coefficient estimated from the measured secchi depth during the 2006 special test as shown in the following table.

Table 6 Estimated Light Extinction Coefficient from Measured Secchi Depth

Measurement Date	Location	Secchi Depth (m)	Estimated Light Extinction Coefficient (m^{-1})
7/31/2006	BVR1	4.75	0.36
8/1/2006	BVR2	5.50	0.31
8/3/2006	BVR2	5.75	0.30
8/5/2006	BVR2	6.00	0.32

The light extinction coefficient, λ, was estimated from secchi depth D using the following equation as recommended in the CE-QUAL-W2 User Manual (Cole and Wells, 2002):

$$\lambda = 1.11 \cdot D^{-0.73}$$

Wind Sheltering Coefficient — The simulated reservoir temperatures and thermal structure are responsive to wind speed. Higher wind speeds cause mixing in the reservoir that can increase the depth of the thermocline and also cause an increase in hypolimnion temperature of the reservoir. The CE-QUAL-W2 model has a parameter called wind sheltering coefficient to adjust the measured wind speed to estimate the effective wind speed for shear stress (mixing) and evaporation. The wind sheltering coefficient is intended to adjust wind speed values that are measured at the meteorology station so that they match local wind speeds. Its physical basis is that surrounding terrain often shelters the waterbody so that observed winds taken from meteorological stations are not the effective winds reaching the waterbody. The measured wind speed at the Prattville Intake station was used in the model input and was not adjusted because the station is very close to Butt Valley Reservoir and, thus, the physical basis to adjust the measured wind speed at the Prattville Intake station can not be justified. A value of 1.0 for the wind sheltering coefficient was kept in the model calibration.

Effective centerline elevation of the Caribou #1 Intake — The CE-QUAL-W2 model represents the point withdrawal with centerline elevation of the intake and withdrawal zone limits. The effective centerline elevation of the Caribou #1 Intake has a large effect on the Caribou #1 PH discharge water temperatures and the thermal structure of the reservoir. Although the actual invert elevation of the Caribou #1 Intake structure is located at 4,077 ft (USGS datum), the withdrawal zone is controlled by the main approach channel that has an elevation of 4,095 ft (USGS datum) based on the 1996 bathymetric survey. The observed water temperature time series data collected at different depths in Butt Valley Reservoir near the Caribou #1 Intake (BVR2) indicated that the Caribou #1 Intake mainly withdrew water at depth around 30 ft (see Figure 20). The final calibrated effective centerline elevation of the Caribou #1 Intake was 4,100 ft, which was derived through trial and error to achieve a good match with the measured Caribou #1 PH discharge temperatures.

Effective centerline elevation of the Caribou #2 Intake — The effective centerline elevation of the Caribou #2 Intake has a large effect on the Caribou #2 PH discharge water temperatures and the thermal structure of the reservoir. The Caribou #2 Intake is located in a shallow cove area with an entrance elevation of 4,110 ft (USGS datum). Although the actual invert elevation of the Caribou #2 Intake structure is located at 4,103 feet, the withdrawal zone is controlled by the entrance of the shallow cove area. The observed water temperature time series data collected at different depths in Butt Valley Reservoir near the Caribou #2 Intake (BVR2) indicated that the Caribou #2 Intake mainly withdrew water at depth around 5-10 ft[11] (see Figure 20). The final calibrated effective centerline elevation of the Caribou #2 Intake was 4,125 ft with a withdrawal zone between elevation 4,118 ft to the surface, which was derived through trial and error to achieve a good match with the measured Caribou #2 PH discharge temperatures.

Sediment oxygen demand — the model user can specify the SOD and how it changes as a function of temperature. As mentioned earlier, the observed concentrations of most water quality constituents (including algae) in 2000 at the Butt Valley PH discharges and Butt Creek flows, as well as within the reservoir, were either below the detection limit or relatively low. This suggests that the water quality conditions at the upstream boundaries would not have significant effects on DO simulations in the reservoir as long as the DO concentrations at the upstream boundaries were reasonably set. This also suggests that SOD was an important sink that caused the relatively low DO observed in the hypolimnion of the reservoir. Model calibration through trial and error indeed showed that SOD has a large effect on hypolimnion DO concentrations in the reservoir. Changing SOD improved model estimates of DO concentrations. The final calibrated model had a SOD of 0.35 gram of oxygen per square meter per day ($gO_2/m^2/day$). Sediment oxygen demand typically ranges from 0.1 to 1.0 $gO_2/m^2/day$. In addition to the SOD adjustment, the upper temperature for SOD decay was also adjusted from the default 25°C to 20°C to achieve better calibration of DO in the hypolimnion[12].

3.3 CALIBRATION RESULTS TO THE OBSERVED WATER SURFACE ELEVATIONS

Butt Valley Reservoir has two inflows: Butt Valley PH discharge and Butt Creek flow above the reservoir. Water in Butt Valley Reservoir is discharged through the two intake structures of Caribou #1 and #2 PHs to the Belden Forebay in NFFR. The powerhouse flows were determined by PG&E using relationships between power load and turbine flows. Water budget analysis indicated that the inflows and outflows of Butt Valley Reservoir can not be well balanced due to the imperfect flow determinations. The mass imbalance could also be introduced because there are times that Butt Valley PH was on stand-by mode, i.e., cold spinning, when water enters through the powerhouse but without generating power. Butt Valley Reservoir storage volume is relatively small.

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[11] The corresponding water elevation at these depths was about 4,130 ft to 4,135 ft in USGS datum.

[12] For comparison purpose, the developed CE-QUAL-W2 for Lake Almanor by Jones and Stokes had a SOD of 1.0 $gO_2/m^2/day$, and the upper temperature for SOD decay was adjusted from the default 25°C to 15°C.

Water balance of a relatively small reservoir is sensitive to the accuracy of inflow and outflow determinations. A sensitivity analysis was conducted to determine the most probable bias in the flow determinations. A constant 3.5% reduction to the Butt Valley PH inflows was found to yield a good prediction for the Butt Valley Reservoir water levels for year 2006. Figure 21 shows the model calibration result to the observed water surface elevations in 2006. Although adjusting Caribou #1 and #2 PH discharges could also have yielded a satisfactory prediction for the Butt Valley Reservoir water levels, it was judged better not to adjust the Caribou #1 and #2 PH discharges because such an adjustment would have significantly affected Belden Forebay water balance, a small reservoir with a reported storage volume of 2,477 acre-ft. Adjusting Butt Valley PH discharges would not have significant effects on Lake Almanor water levels because the lake has a large storage volume.

3.4 CALIBRATION RESULTS TO THE OBSERVED DISCHARGE WATER TEMPERATURES

Figure 22 shows comparison between simulated and observed water temperatures at Caribou #1 and #2 PHs discharges. As shown in the figure, the simulated discharge water temperatures are consistent with the timing and trajectory of the measured water temperatures. The absolute mean difference between simulated and observed water temperatures of the Caribou #1 PH discharges for the calibration period was 0.43°C with standard deviation of 0.46°C, and the root mean square error was 0.51°C. The absolute mean difference between simulated and observed water temperatures of the Caribou #2 PH discharges for the calibration period was 0.39°C with standard deviation of 0.38°C, and the root mean square error was 0.49°C.

While the simulations capture the timing and pattern of measured temperature change over time, the simulated temperatures for Caribou #1 PH discharges for the period of July 2 to 17, 2006 appear to be underestimated by about 1.5°C to 2.0°C. This discrepancy mainly resulted from the unrealistically high temperature measurements at the Caribou #1 PH discharges during the period. Looking at Figures 11a and 11b, the Caribou #1 PH discharges during the period of July 2 to 17, 2006 (i.e, Special Tests #1 to #3) were lower than the discharges at the following Special Test #4, yet the observed discharge temperatures for the Special Tests #1 to #3 were higher. It was suspected that the Caribou #1 temperature sensor was covered by debris or was not completely submerged during the low discharge period of July 2 to 17, 2006, during which time the Caribou #1 PH discharges were about 50 cfs – 180 cfs.

PG&E conducted synoptic field measurements at NF4 (a monitoring station at NFFR above Caribou #1 PH), Caribou #1 PH tailrace, and Caribou #2 PH tailrace during the 2006 special test. Table 7 compares the datalogger measurements and synoptic measurements in water temperature. It shows that the datalogger temperature sensor in the Caribou #1 PH over-measured its discharge water temperature by 2.3°C to 2.7°C. This indicates that the actual water temperatures at the Caribou #1 PH discharges during the period of July 2 to 17, 2006 would be in close agreement with the simulated water temperatures.

Table 7 Comparison of Water Temperature Data Collected by Datalogger Measurements and Synoptic Field Measurements

Time	Datalogger Measurements			Synoptic Field Measurements			Difference		
	NF4	Caribou #1 PH Tailrace	Caribou #2 PH Tailrace	NF4	Caribou #1 PH Tailrace	Caribou #2 PH Tailrace	NF4	Caribou #1 PH Tailrace	Caribou #2 PH Tailrace
7/5/06 at 12:00pm	12.0°C	14.0°C	17.9°C	12.7°C	N/A	17.7°C	0.7°C	-	-0.2°C
7/12/06 at 6:15am	11.1°C	15.4°C	17.7°C	11.0°C	13.1°C	N/A	-0.1°C	-2.3°C	-
7/17/06 at 6:20am	11.7°C	16.3°C	18.1°C	11.7°C	13.6°C	N/A	0.0°C	-2.7°C	-
7/21/06 at 7:30am	12.6°C	15.0°C	19.8°C	13.2°C	N/A	18.8°C	0.6°C	-	-1.0°C
7/22/06 at 8:00am	12.0°C	14.7°C	19.7°C	12.2°C	N/A	N/A	0.2°C	-	-

3.5 CALIBRATION RESULTS TO THE OBSERVED VERTICAL PROFILES OF WATER TEMPERATURE

Graphical presentations of simulated and observed vertical profiles of water temperature at different measurement locations are shown in Figures 23 through 27. The vertical temperature profiles for the Transects X3, X4 (4W), and X5 (BVR1) reflect the model’s capability to capture the cold water plunge and mixing process during the special test. The vertical temperature profiles for the measurement locations at Cool Springs and Caribou #1 Intake (BVR2) reflect the model’s capability to simulate the overall thermal structure of the reservoir. An overview of all of the graphical comparisons indicates that the model satisfactorily captures the observed cold water plunging and mixing process and the patterns of overall thermal structure.

3.6 CALIBRATION RESULTS TO THE OBSERVED VERTICAL PROFILES OF DO

Graphical presentations of simulated and observed vertical profiles of DO at different measurement locations are shown in Figures 28 through 30. Higher concentrations of the vertical DO profiles at the lower layers of the Transects X3 and X4 (4W) indicate that the model satisfactorily captures the cold water plunge process (see Figures 28 and 29)[13]. The introduced cold water discharges from the Prattville Intake through reduced withdrawal

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[13] There were no field DO profiles at the Transects X3 and X4 prior to Special Test 5. However, the calibrated CE-QUAL-W2 model results showed that the DO profiles at the Transects X3 and X4 on July 31, 2006 (prior to Special Test 5) was generally uniform at about 6.7 mg/L, indicating that the higher DO concentrations (about 8.0 – 9.0 mg/L) at the lower layers of the Transects X3 and X4 shown on Figures 28 and 29 were indeed caused by cold water plunge (with higher DO) during the special test.

rates had higher concentrations of DO during the special test. The higher DO concentrations from the Butt Valley PH discharges during the special test provided a unique signature to differentiate the test plume from the ambient cold water of the reservoir (which contained a relatively low DO level). The DO signature was used as an additional indicator to track the cold water movement through Butt Valley Reservoir.

An overview of all of the graphical comparisons at the measurement location near the Caribou #1 Intake (BVR2) indicates that the model satisfactorily captures the observed patterns of overall DO distributions (Figure 30).

4.0 MODEL VERIFICATION USING 2000 DATA (NORMAL YEAR)

Model verification is the next step in model development following the calibration effort. The calibrated model is used to predict water temperature and water quality using an independent set of data. Ideally, the independent data set should have a different environmental condition from the calibration set for a more rigorous verification. The overall reliability of the model to predict future conditions increases in proportion to the amount of historical data that the model is able to describe successfully (Note: the data sets must come from a range of conditions, otherwise the model reliability will be limited). The data collected in 2000 were used for model verification. Year 2000 was classified as a normal year and provided a good contrast to the calibration data in 2006 which were obtained under a wet year condition. The analysis period of April 6 to September 30, 2000 was selected for model verification. This verification period comprises the same data as the PG&E's model calibration period for the Butt Valley Reservoir MITEMP water temperature model.

The water temperature and DO vertical profiles, water surface elevation, and water quality conditions measured on April 6, 2000 were used to initialize the verification run. The initial water temperature distribution had about 6°C temperature difference from surface (12°C) to bottom (6°C). The initial DO concentration distribution had about 2 mg/L difference from surface (10.0 mg/L) to bottom (8.0 mg/L).

4.1 VERIFICATION RESULTS TO THE OBSERVED WATER SURFACE ELEVATIONS

Similar to the calibration year of 2006, the measured inflows and outflows of Butt Valley Reservoir in 2000 could not be well balanced due to the imperfect flow determinations and the relatively small storage volume of Butt Valley Reservoir. A sensitivity analysis was conducted to determine the most probable bias in the flow determinations. A constant 6.5% reduction to the Butt Valley PH inflows was found to yield a satisfactory prediction for the Butt Valley Reservoir water levels for year 2000. The flow reduction is in close agreement with the 7% flow reduction that Bechtel applied in their MITEMP modeling effort (Bechtel, 2002), except that Bechtel adjusted the flows for Caribou PHs. Figure 31 shows the model verification result to the observed water surface elevations in 2000.

4.2 VERIFICATION RESULTS TO THE OBSERVED DISCHARGE WATER TEMPERATURES

Figure 32 shows a comparison between simulated and observed water temperatures at Caribou #1 and #2 PHs discharges. As shown in the figure, the simulated discharge water temperatures are consistent with the timing and trajectory of the measured water temperatures. The absolute mean difference between the simulated and observed water temperatures of the Caribou #1 PH discharges for the verification period was 0.45°C with standard deviation of 0.54°C, and the root mean square error was 0.55°C. The absolute mean difference between simulated and observed water temperatures of the Caribou #2 PH discharges for the verification period was 0.51°C with standard deviation of 0.69°C, and the root mean square error was 0.70°C.

While the simulations capture the timing and pattern of measured temperature change over time, the simulated temperatures for Caribou #2 PH discharges at the period of mid to late September 2000 appear to be significantly underestimated. Close inspection suggests that the measured water temperatures at the Caribou #2 PH discharges during the period were unrealistically high. Take September 28, 2000 for example, both measured and simulated vertical temperature profiles show a uniform temperature of about 17.0°C over the full depth (see Figure 34), which suggests that the entire reservoir had a temperature of about 17.0°C and, thus, the discharge water temperatures at the Caribou #1 and #2 PHs should be about 17.0°C. Yet the Caribou #2 temperature sensor gave a temperature of 19.5°C (see Figure 32). The same discrepancy was observed by Bechtel (Bechtel, 2002) when the same data were used during MITEMP model verification. The sensor location measuring Caribou #2 PH discharge water temperature was located in the main valve house from the penstock. It was determined earlier on that the data discrepancy was caused by a clogging of organic debris in the valve house. The data reliability at this station was much improved in recent years by a more frequent maintenance schedule. The simulated discharge temperatures at the Caribou #1 and #2 PHs are in close agreement with the observed water temperature in the reservoir.

4.3 VERIFICATION RESULTS TO THE OBSERVED VERTICAL PROFILES OF WATER TEMPERATURE

PG&E conducted synoptic measurements at three locations along the axis of Butt Valley Reservoir in 2000 (Figure 33). Graphical presentations of simulated and observed vertical water temperature profiles at the three measurement locations are shown in Figure 34. An overview of all of the graphical comparisons indicates that the model satisfactorily captures the observed patterns of overall thermal structure.

4.4 VERIFICATION RESULTS TO THE OBSERVED VERTICAL PROFILES OF DO

Graphical presentations of simulated and observed vertical profiles of DO at the measurement location near the Dam are shown in Figure 35. An overview of all of the graphical comparisons indicates that the model satisfactorily captures the observed patterns of overall DO distributions.

4.5 COMPARISON BETWEEN THE CE-QUAL-W2 AND EXISTING MITEMP MODELING RESULTS IN WATER TEMPERATURE

Figures 36, 37, and 38 show the existing Butt Valley Reservoir MITEMP model results of reservoir water surface elevations[14], Caribou #1 and #2 discharge water temperatures, and vertical profiles of water temperature for year 2000. Comparing the MITEMP model results to the CE-QUAL-W2 model results (see the corresponding Figures 31, 32, and 34), the CE-QUAL-W2 model-simulated discharge water temperatures at the Caribou #2 PH are apparently better than the MITEMP model results. In the MITEMP model, it was assumed that the Caribou #2 Intake uniformly withdraws water from elevation 4,110 ft to the surface. This assumption appears invalid based on the water temperature time series data collected at different depths in the reservoir near the Caribou #1 Intake during the 2006 special test (see Figure 20). Based on the observed time series data collected at different depths, the Caribou #2 Intake mainly withdrew water at depth around 5-10 ft[15] , or the Caribou #2 Intake mainly withdrew surface water. That explains why the MITEMP model underestimated the discharge water temperatures at the Caribou #2 PH. Figures 39 and 40 show the observed mean daily water temperatures of Butt Valley Reservoir in 2002 (dry year) and 2003 (normal year), respectively. These two figures show that the observed discharge water temperatures at the Caribou #2 PH were generally close to the observed surface water temperatures and about several degree Celsius higher than the Caribou #1 PH discharge temperatures from Spring to early August. But the MITEMP model results show that the difference between the Caribou #1 and #2 PH discharge temperatures over time from Spring to mid August is generally less than 1.5°C. This MITEMP-simulated pattern in water temperature difference between the two PHs discharges appears unrealistic. The CE-QUAL-W2-simulated pattern in water temperature difference between the two PHs discharges appears to be more close to the observed pattern in 2002 and 2003.

Because discharges from Butt Valley Reservoir are a direct source to the NFFR, accurately simulating water temperature distributions and outflow water temperatures from Butt Valley Reservoir is crucial to evaluating the effectiveness, sustainability, and reliability of different water temperature reduction alternatives. The newly developed CE-QUAL-W2 model of Butt Valley Reservoir not only is a better temperature prediction tool to support the Level 3 analysis of UNFFR water temperature reduction alternatives, but also it provides additional support to assess DO condition.

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[14] In the MITEMP model, Bechtel increased the Caribou #1 and #2 PH discharges by 7% to allow the simulated water surface elevations to satisfactorily match the observed water surface elevations. In the CE-QUAL-W2 model, Stetson decreased the Butt Valley PH discharges by 6.5% to yield a satisfactory prediction for the reservoir water levels. It was judged better not to adjust the Caribou #1 and #2 PH discharges because such an adjustment would have highly affected Belden Forebay water balance, a small reservoir with a reported storage volume of 2,477 acre-ft. Adjusting Butt Valley PH discharges would not have significantly affected Lake Almanor water levels because the lake has a large storage volume.

[15] The corresponding water elevation at these depths was about 4,130 ft to 4,135 ft in USGS datum.

5.0 FINDINGS AND CONCLUSIONS

This report reviewed the adequacy of the existing Butt Valley Reservoir MITEMP temperature model to support the Level 3 analysis of UNFFR water temperature reduction alternatives, explained the need for developing a CE-QUAL-W2 water quality model to simulate both water temperature and dissolved oxygen (DO) for the Level 3 alternative analysis, and documented the CE-QUAL-W2 model development, calibration, and verification. The findings and conclusions are summarized as follows:

1) Discharges from Butt Valley Reservoir are a direct source to the NFFR. Accurately simulating water temperature distributions and outflow water temperatures from Butt Valley Reservoir is crucial to evaluating the effectiveness, sustainability, and reliability of different water temperature reduction alternatives. Based on review of MITEMP's limitations and its modeling results, the newly developed CE-QUAL-W2 model of Butt Valley Reservoir provides a better prediction tool to support the Level 3 analysis of UNFFR water temperature reduction alternatives.

2) One of the water temperature reduction measures to be analyzed in Level 3 includes the cold water withdrawal from Lake Almanor via a thermal curtain near the Prattville Intake that causes hypolimnion cold water withdrawal. The hypolimnion cold water may have low DO. This cold water would plunge into Butt Valley Reservoir (as demonstrated in the 2006 special test) and could adversely impact cold freshwater habitat beneficial use of Butt Valley Reservoir. A water quality model would be needed to simulate DO distributions in the reservoir if hypolimnion cold water (with low DO) is withdrawn through the Prattville Intake of Lake Almanor. The simulated water temperature and DO distributions in the reservoir would be used to evaluate the impacts of the water temperature reduction measure on the cold freshwater habitat in the reservoir.

3) CE-QUAL-W2 is a generic two-dimensional (longitudinal and vertical), laterally-averaged hydrodynamic and water quality model supported by the US Army Corps of Engineers, Waterways Experiment Station. Because the model assumes lateral homogeneity, it is best suited for relatively long and narrow waterbodies exhibiting longitudinal and vertical water quality gradients and little lateral gradients. The shape of Butt Valley Reservoir is relatively long and narrow, making CE-QUAL-W2 well-suited for this reservoir. CE-QUAL-W2 can simulate selective withdrawal based on hydraulic principles: no user-specified flow distribution (or withdrawal scheme) is needed to simulate selective withdrawal. It can also simulate thermal curtain effects on cold water selective withdrawal. These capabilities are important for Butt Valley Reservoir water temperature and DO modeling. As a hydrodynamic and water quality model, CE-QUAL-W2 can simulate both water temperature and DO and other water quality constituents.

4) The Butt Valley Reservoir CE-QUAL-W2 model geometry was developed using the 1996 bathymetric survey data supplemented with the transect cross sectional

data for the upstream portion of the reservoir collected during the summer 2006 special test. The 1996 surveyed reservoir storage is about 46,000 acre-ft, which is smaller than the original storage (49,897 acre-ft) by about 8% at the normal maximum water surface elevation of 4,142 ft. This reduction in storage probably resulted from sedimentation over the 84 years since the reservoir was created in 1924.

5) The Butt Valley Reservoir CE-QUAL-W2 model was calibrated using the data collected in 2006 (wet year), particularly the data collected during the summer 2006 special test. The analysis period of May 12 to September 30, 2006 was selected for model calibration. The model's performance was evaluated based on the following parameters:

   - Caribou #1 and #2 PH discharge water temperatures: The model-simulated discharge water temperatures at the Caribou #1 and #2 PHs are consistent with the timing and trajectory of the measured discharge water temperatures. The absolute mean difference between simulated and observed water temperatures of the Caribou #1 PH discharges for the calibration period was 0.43°C with standard deviation of 0.46°C, and the root mean square error was 0.51°C. The absolute mean difference between simulated and observed water temperatures of the Caribou #2 PH discharges for the calibration period was 0.39°C with standard deviation of 0.38°C, and the root mean square error was 0.49°C.

   - Vertical profiles of water temperature and DO: The model satisfactorily captures the observed cold water plunging and mixing process observed during the 2006 special test and the patterns of overall thermal structure and DO distributions.

   - Water velocity: Using Manning's n of 0.04 for the reservoir bottom friction, the model-simulated water velocities for the Transects X1, X2, and X3 and for the deep channel satisfactorily match the observed velocities.

6) The Butt Valley Reservoir CE-QUAL-W2 model was verified using the data collected in 2000 (normal year). The analysis period of April 6 to September 30, 2000 was used for model verification. This analysis period is the same as the period used in calibrating the existing MITEMP model. The model's performance was evaluated based on the following parameters:

   - Caribou #1 and #2 PH discharge water temperatures: The model-simulated discharge water temperatures at the Caribou #1 and #2 PHs are consistent with the timing and trajectory of the measured discharge water temperatures. The absolute mean difference between the simulated and observed water temperatures of the Caribou #1 PH discharges for the verification period was 0.45°C with standard deviation of 0.54°C, and the root mean square error was 0.55°C. The absolute mean difference between simulated and observed water temperatures of the Caribou #2 PH discharges for the verification period was 0.51°C with standard deviation of 0.69°C, and the root mean square error was 0.70°C.

- <u>Vertical profiles of water temperature and DO</u>: The model satisfactorily captures the observed the patterns of overall thermal structure and DO distributions.

7) Water temperature time series data collected at different depths in Butt Valley Reservoir near the Caribou #1 Intake during the summer 2006 special test indicated that the Caribou #1 Intake mainly withdrew water at depth around 30 ft and the Caribou #2 Intake mainly withdrew water at depth around 5-10 ft. In the MITEMP model, it was assumed that the Caribou #2 Intake uniformly withdraws water from elevation 4,110 ft to the reservoir surface. This assumption appears invalid and it explains why the MITEMP model underestimated the Caribou #2 PH discharge water temperatures.

8) Water budget analysis indicated that the inflows and outflows of Butt Valley Reservoir could not be well balanced in both the model calibration and verification years due to the imperfect flow determinations (Powerhouse flows were determined by PG&E using relationships between power load and turbine flows). Butt Valley Reservoir storage volume is relatively small. Water balance of a relatively small reservoir is sensitive to the accuracy of inflow and outflow determinations. A sensitivity analysis was conducted to determine the most probable bias in the flow determinations. A constant 3.5% reduction to the Butt Valley PH inflows was found to yield a satisfactory prediction for the Butt Valley Reservoir water levels for the CE-QUAL-W2 model calibration year 2000, and a constant 6.5% reduction to the Butt Valley PH inflows was found to yield a satisfactory prediction for the Butt Valley Reservoir water levels for the model verification year 2000. In contrast, Bechtel increased the Caribou #1 and #2 PH discharges by 7% to allow the simulated water surface elevations to satisfactorily match the observed water surface elevations in the MITEMP model calibration. It was judged better not to adjust the Caribou #1 and #2 PH discharges because such an adjustment would have highly affected Belden Forebay water balance, a small reservoir with a reported storage volume of 2,477 acre-ft. Adjusting Butt Valley PH discharges would not have significantly affected Lake Almanor water levels because the lake has a large storage volume.

9) The observed concentrations of most water quality constituents (including algae) in 2000 at the Butt Valley PH discharges and Butt Creek flows, as well as within the reservoir, were either below the detection limit or relatively low. This suggests that sediment oxygen demand (SOD) was an important sink that caused the relatively low DO observed in the hypolimnion of the reservoir. Model calibration through trial and error indeed showed that SOD has a large effect on hypolimnion DO concentrations in the reservoir. Changing SOD improved model estimates of DO concentrations. The final calibrated model had a SOD of 0.35 gram of oxygen per square meter per day (gO_2/m^2/day). Sediment oxygen demand typically ranges from 0.1 to 1.0 gO_2/m^2/day.

REFERENCES

Bechtel Corporation, 2002. MITEMP3 Model Calibration and Validation in 2000-2001, Lake Almanor and Butt Valley Reservoir, CA. Prepared for Pacific Gas and Electric Company.

Cole, T.M., and S. A. Wells, 2002. "CE-QUAL-W2: A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 3.1," Instruction Report EL-2002-1, US Army Engineering and Research Development Center, Vicksburg, MS.

PG&E, 2005. North Fork Feather River Study Data and Informational Report on Water Temperature Monitoring and Additional Reasonable Water Temperature Control Measures.

Stetson Engineers Inc. and PG&E, 2007. 2006 North Fork Feather River Special Testing Data Report.

Stetson Engineers Inc., 2007. Level 1 and 2 Report/ Development and Screening of Potentially Effective and Feasible Alternatives to Achieve the Basin Plan Objective for Water Temperature and Protect Cold Freshwater Habitat Beneficial Use along the North Fork Feather River.

Woodward-Clyde Consultants, 1986. Rock Creek – Cresta Project Cold Water Feasibility Study, Volume 1. Prepared for Pacific Gas and Electric Company.

Figure 21 Model Calibration Results of Butt Valley Reservoir Water Surface Elevations, 2006

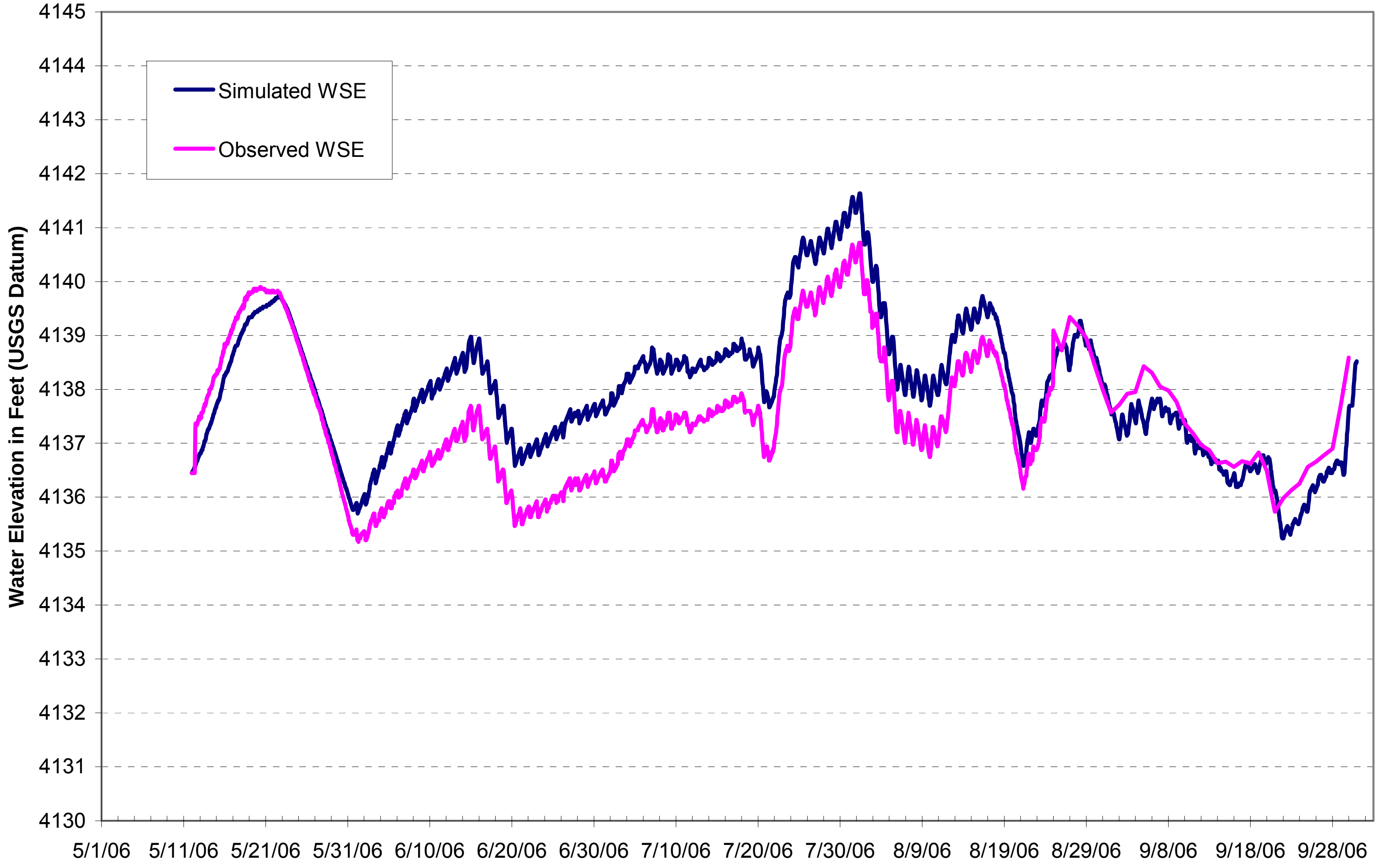
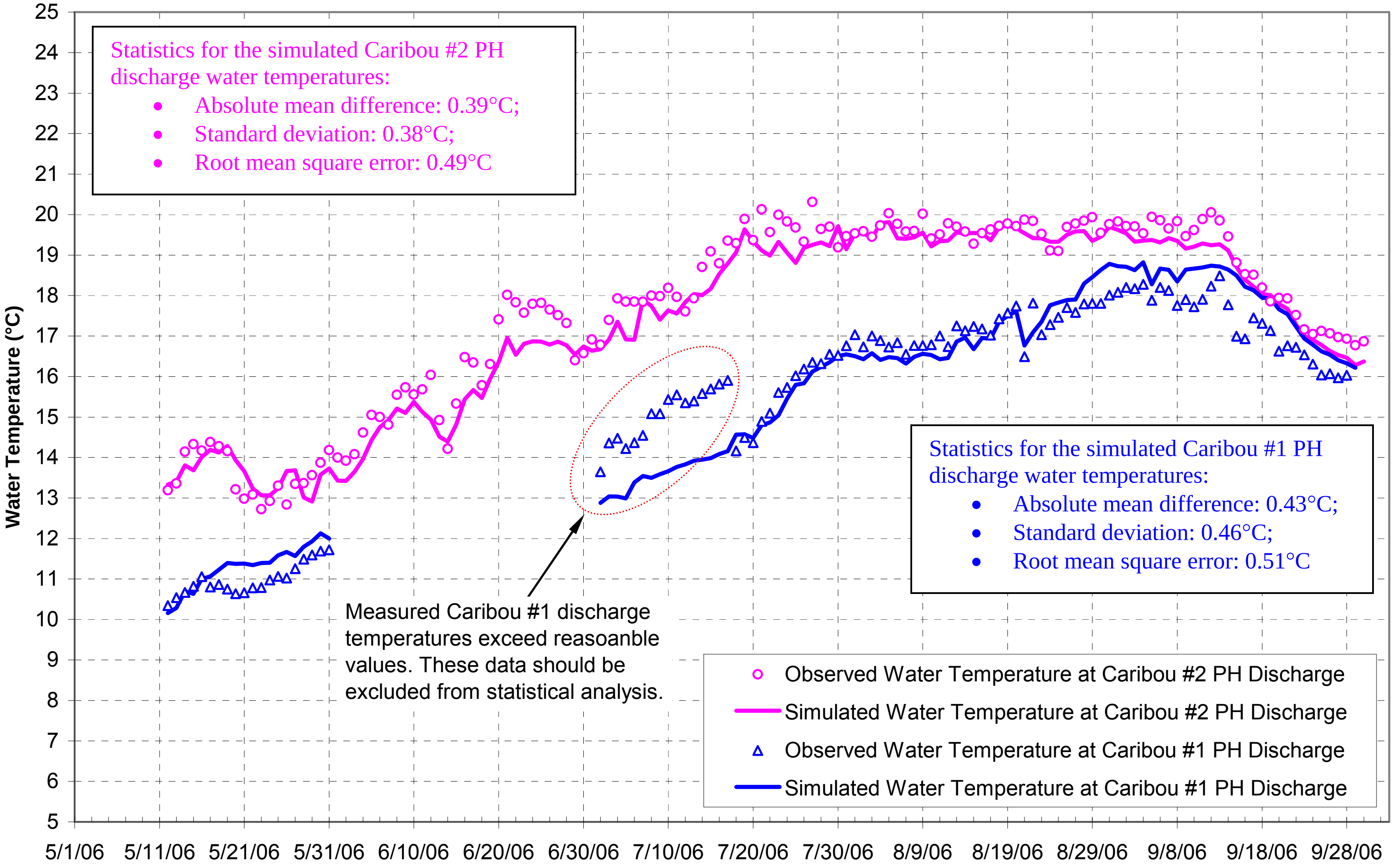


Figure 22 Model Calibration Results of Butt Valley Reservoir Mean Daily Outflow Temperatures, 2006



Statistics for the simulated Caribou #2 PH discharge water temperatures:

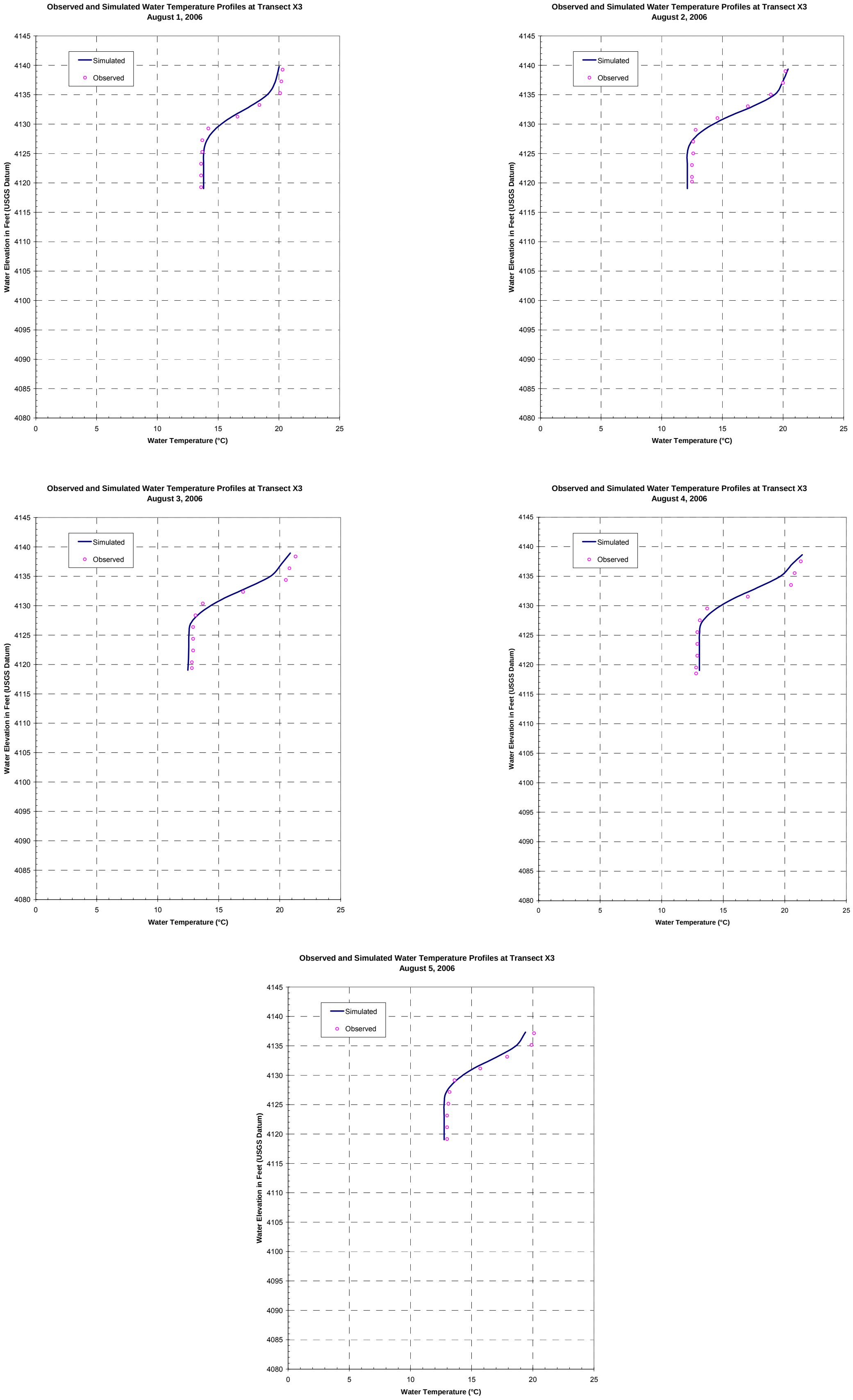
- Absolute mean difference: 0.39°C;
- Standard deviation: 0.38°C;
- Root mean square error: 0.49°C

Statistics for the simulated Caribou #1 PH discharge water temperatures:

- Absolute mean difference: 0.43°C;
- Standard deviation: 0.46°C;
- Root mean square error: 0.51°C

Measured Caribou #1 discharge temperatures exceed reasoanble values. These data should be excluded from statistical analysis.

Figure 23 Observed and Simulated Water Temperature Profiles at Transect X3, 2006



Observed and Simulated Water Temperature Profiles at Transect X3
August 1, 2006

Observed and Simulated Water Temperature Profiles at Transect X3
August 2, 2006

Observed and Simulated Water Temperature Profiles at Transect X3
August 3, 2006

Observed and Simulated Water Temperature Profiles at Transect X3
August 4, 2006

Observed and Simulated Water Temperature Profiles at Transect X3
August 5, 2006

Figure 24 Observed and Simulated Temperature Profiles at Transect X4 (4W), 2006

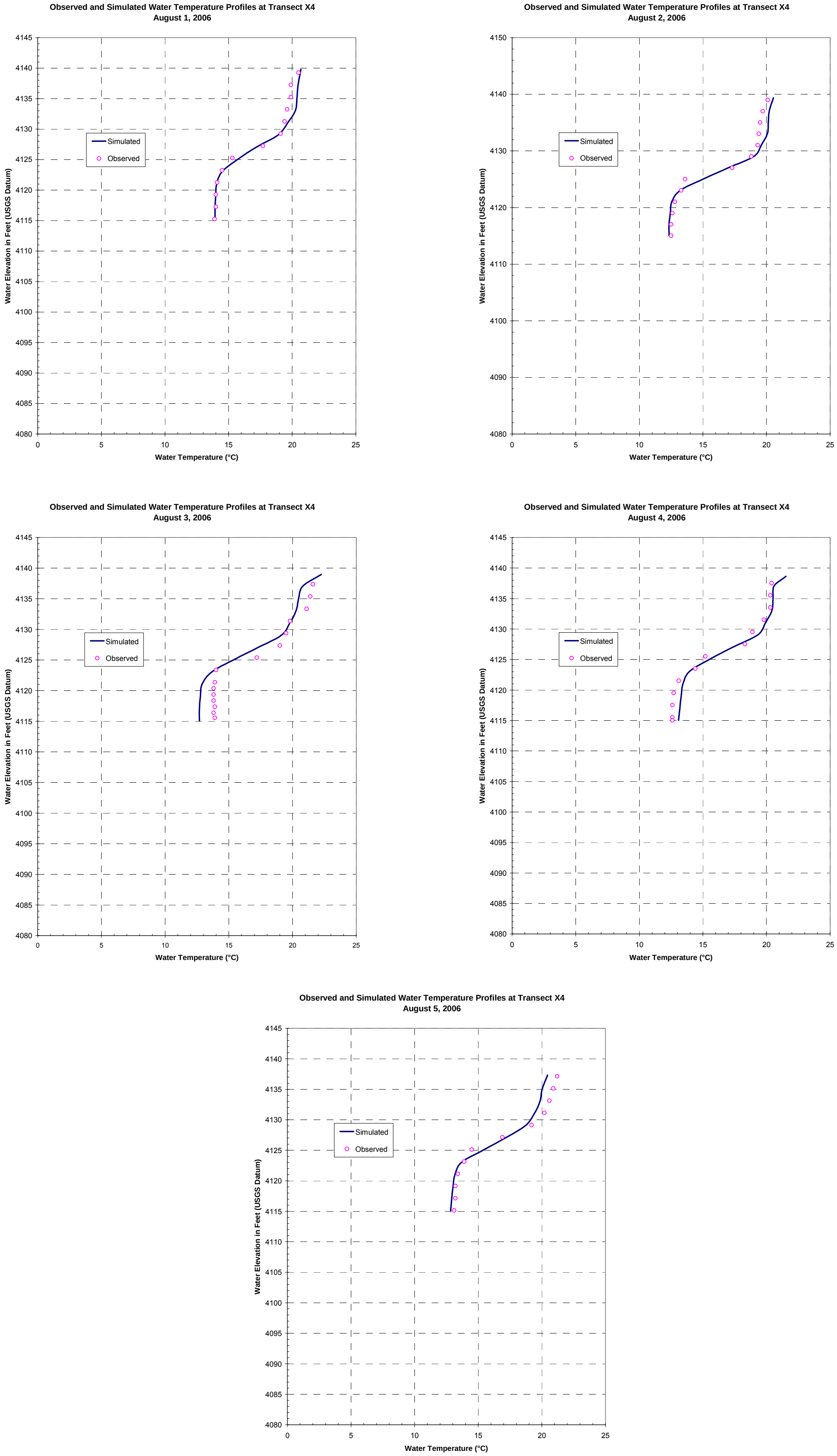


Figure 25 Observed and Simulated Water Temperature Profiles at BVR1, 2006

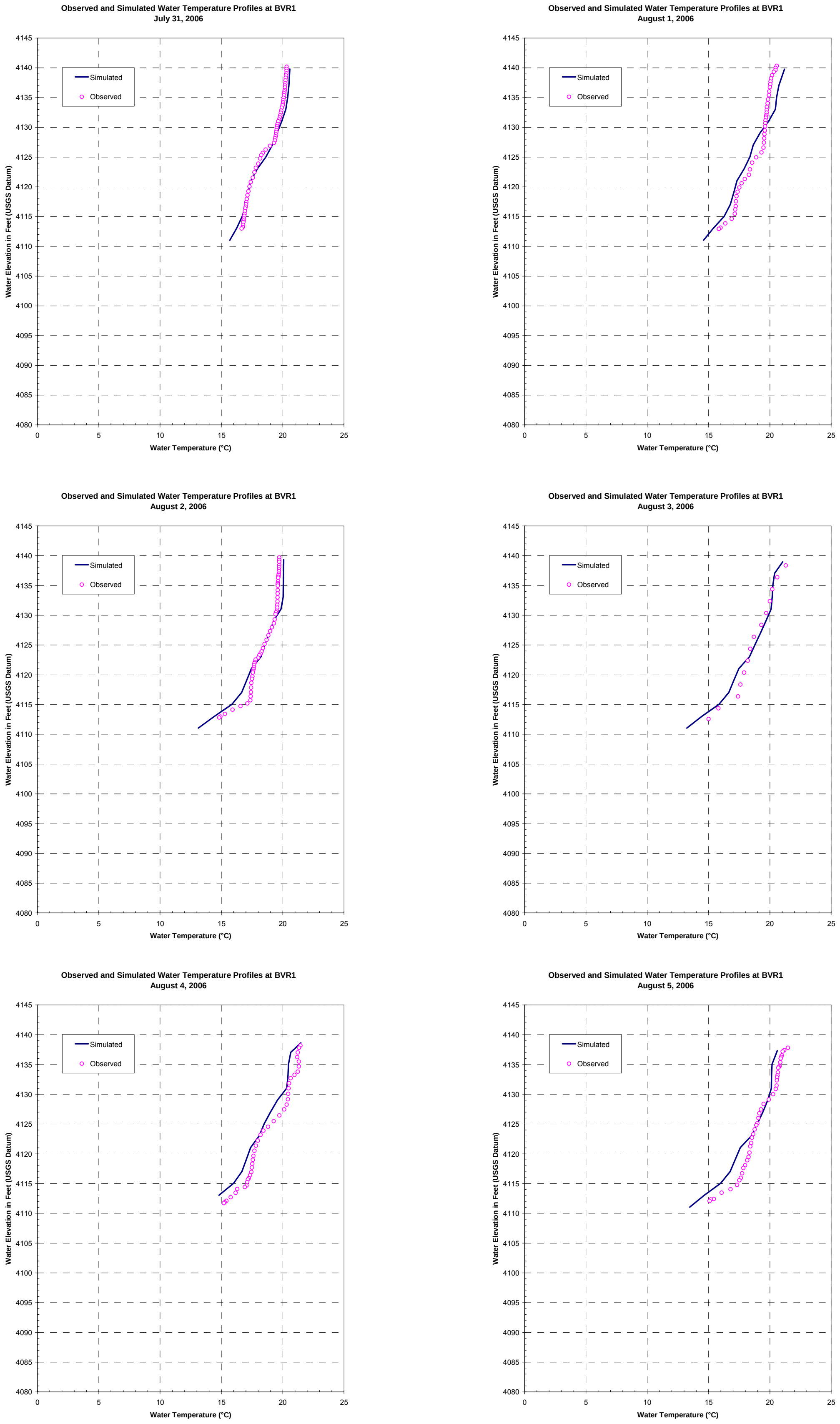
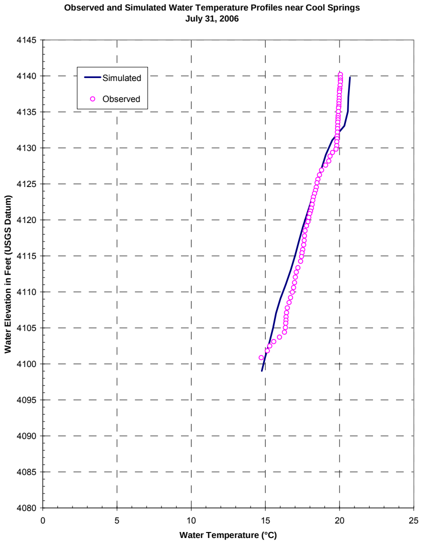
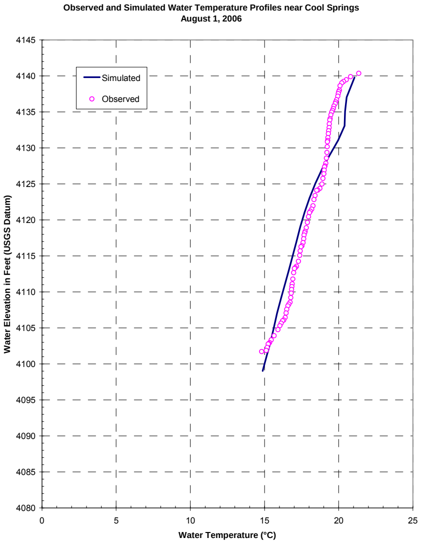
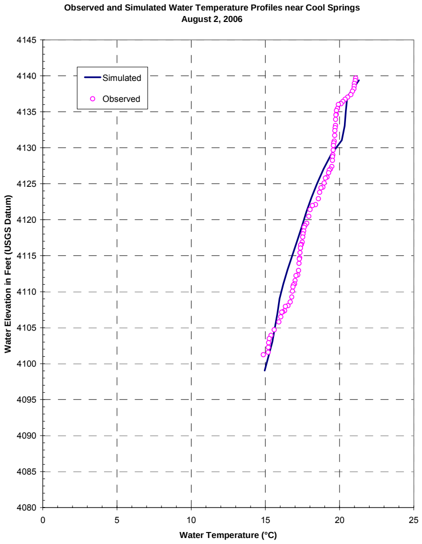
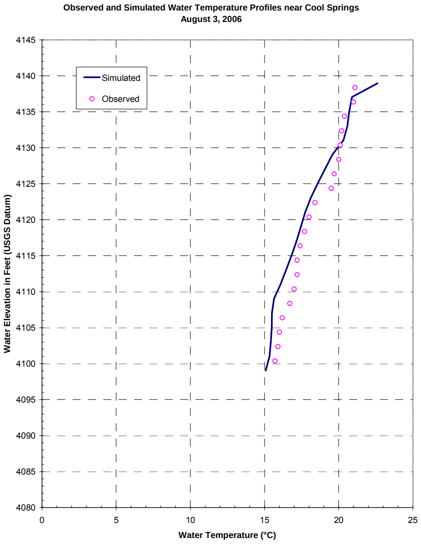


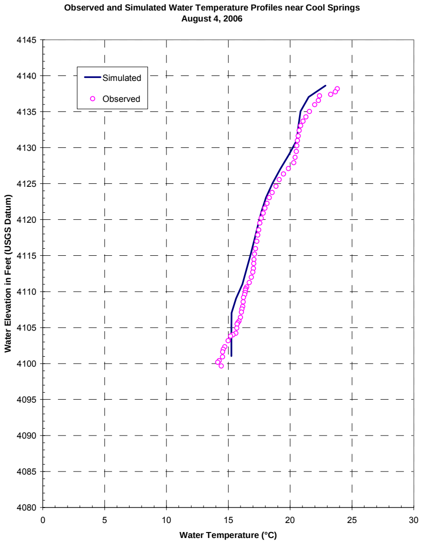
Figure 26 Observed and Simulated Water Temperature Profiles at Cool Springs, 2006











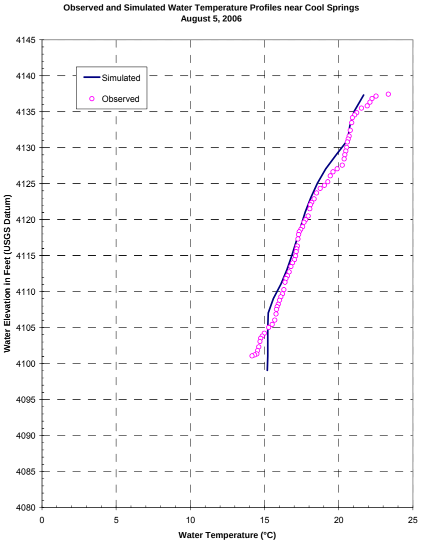
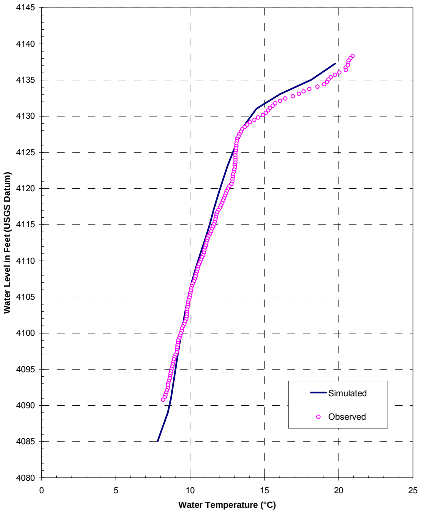
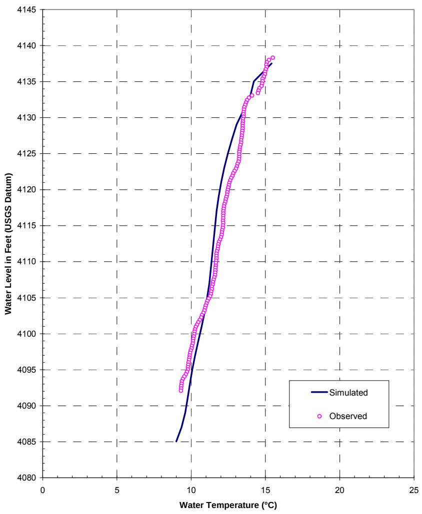
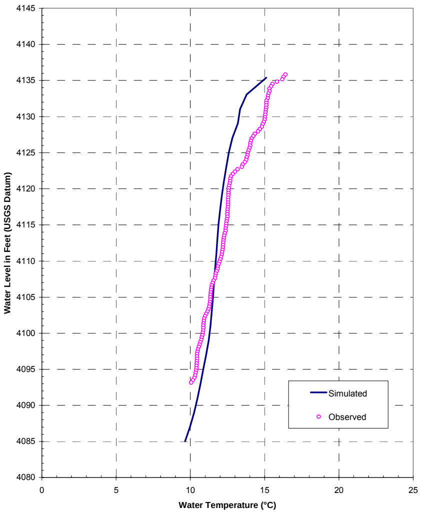
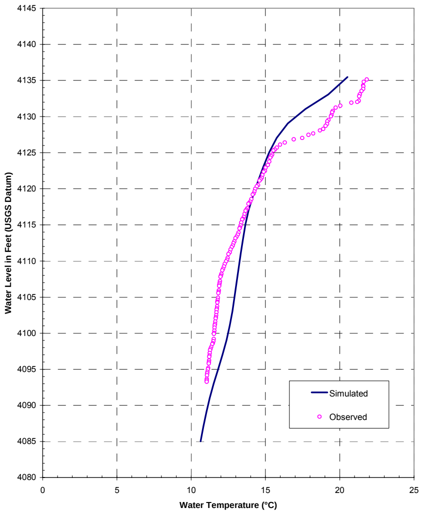


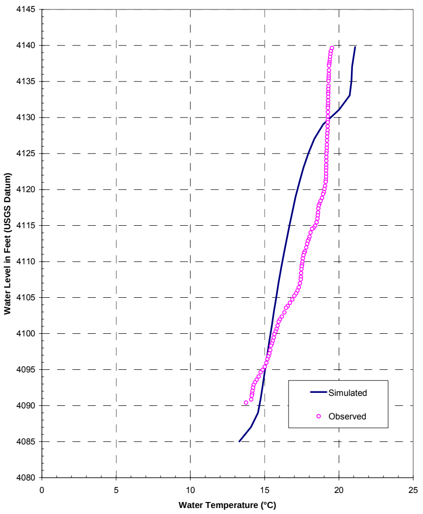
Figure 27 Observed and Simulated Water Temperature Profiles near Dam, 2006


Observed and Simulated Water Temperature Profiles at BVR2
May 16, 2006


Observed and Simulated Water Temperature Profiles at BVR2
May 24, 2006


Observed and Simulated Water Temperature Profiles at BVR2
May 29, 2006


Observed and Simulated Water Temperature Profiles at BVR2
June 22, 2006


Observed and Simulated Water Temperature Profiles at BVR2
July 31, 2006

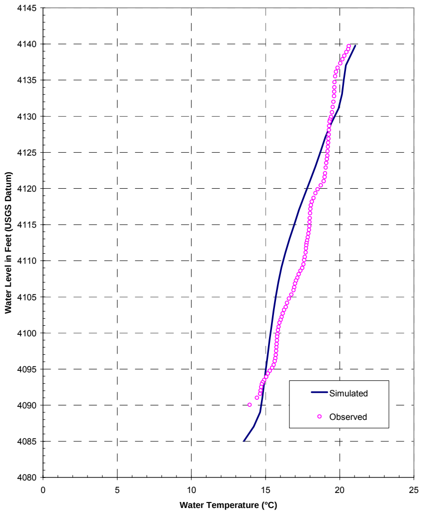

Observed and Simulated Water Temperature Profiles at BVR2
August 1, 2006

Figure 27 Observed and Simulated Water Temperature Profiles near Dam, 2006

(Continued)

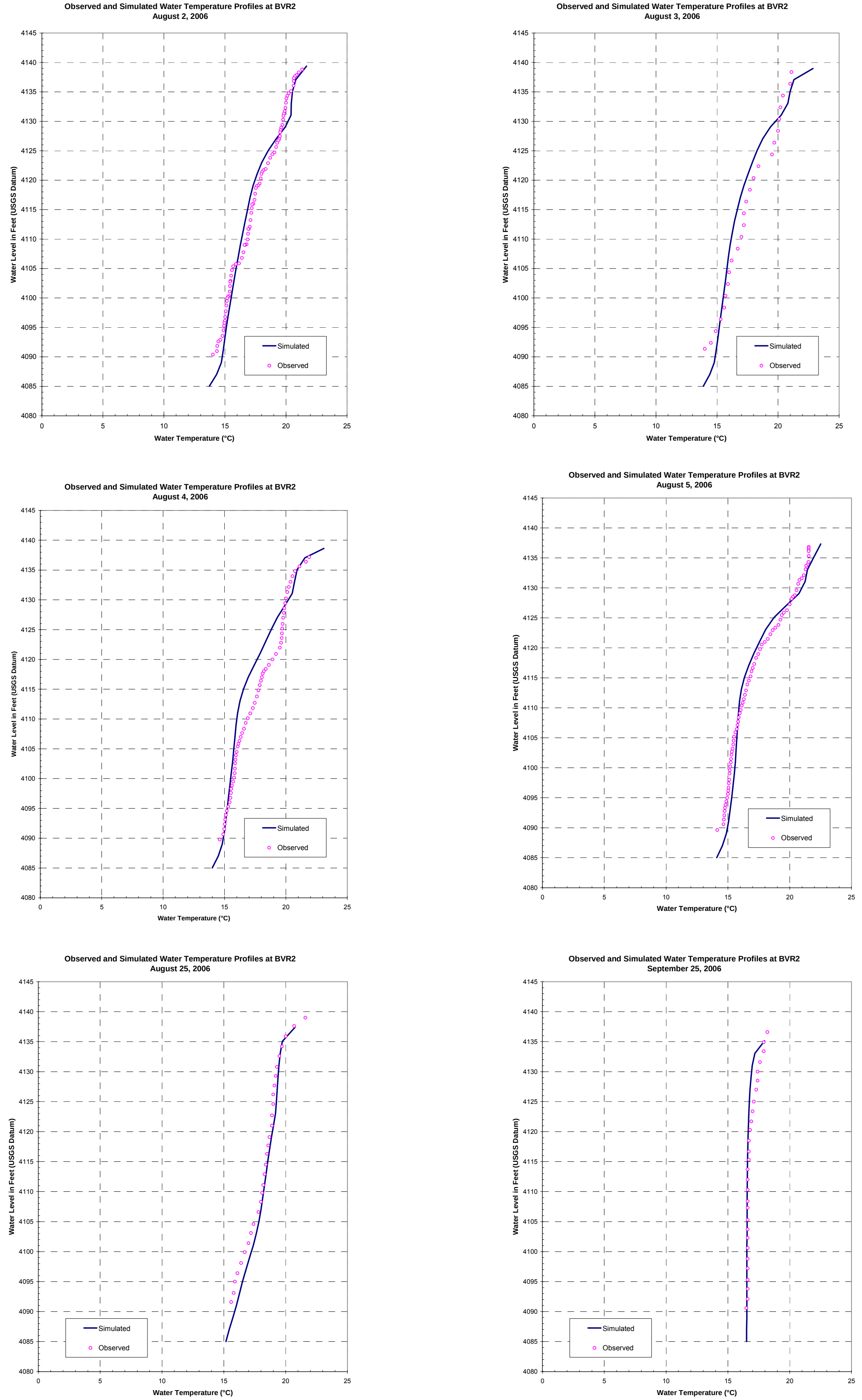
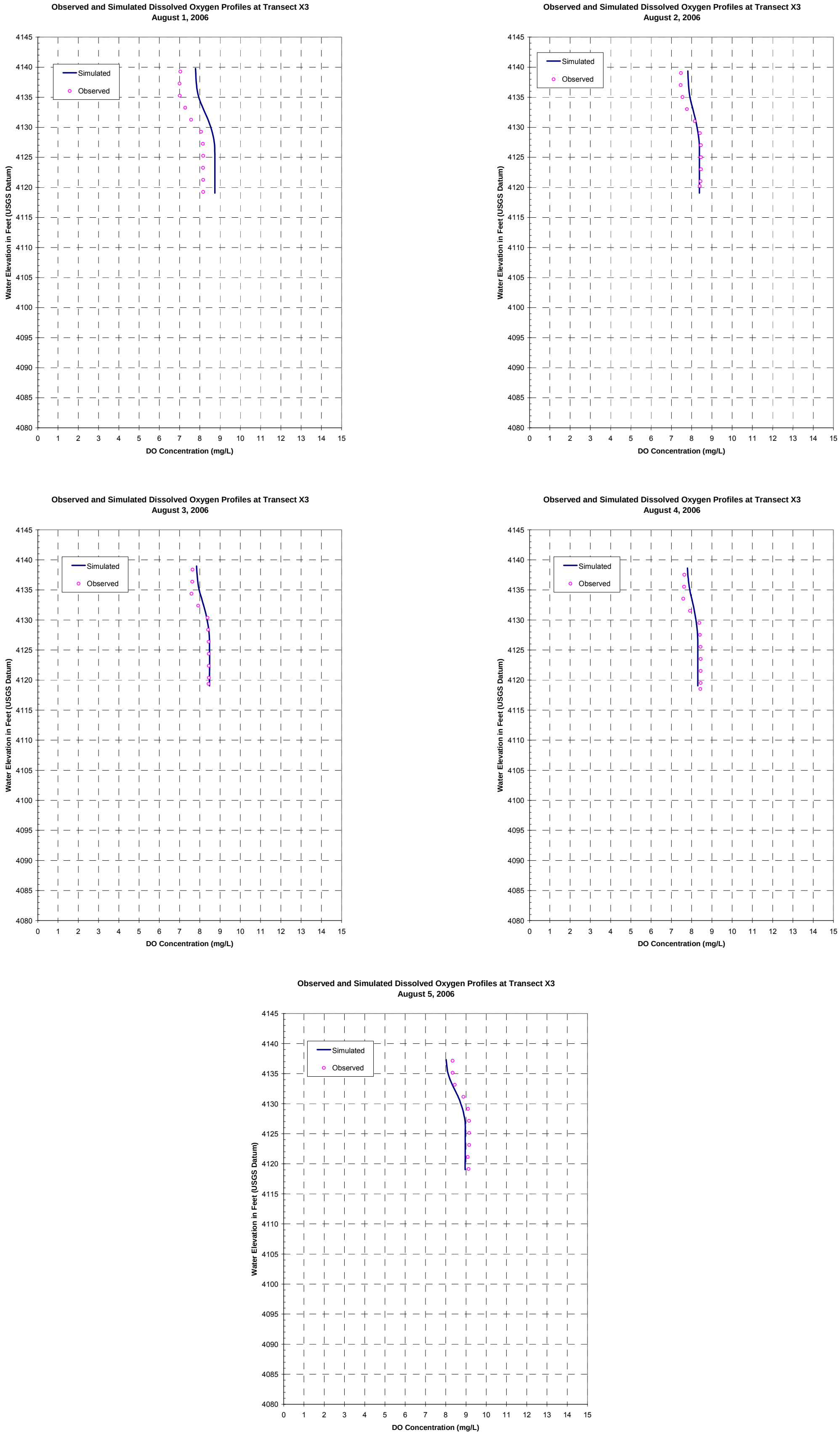


Figure 28 Observed and Simulated DO Profiles at Transect X3, 2006



Observed and Simulated Dissolved Oxygen Profiles at Transect X3
August 1, 2006

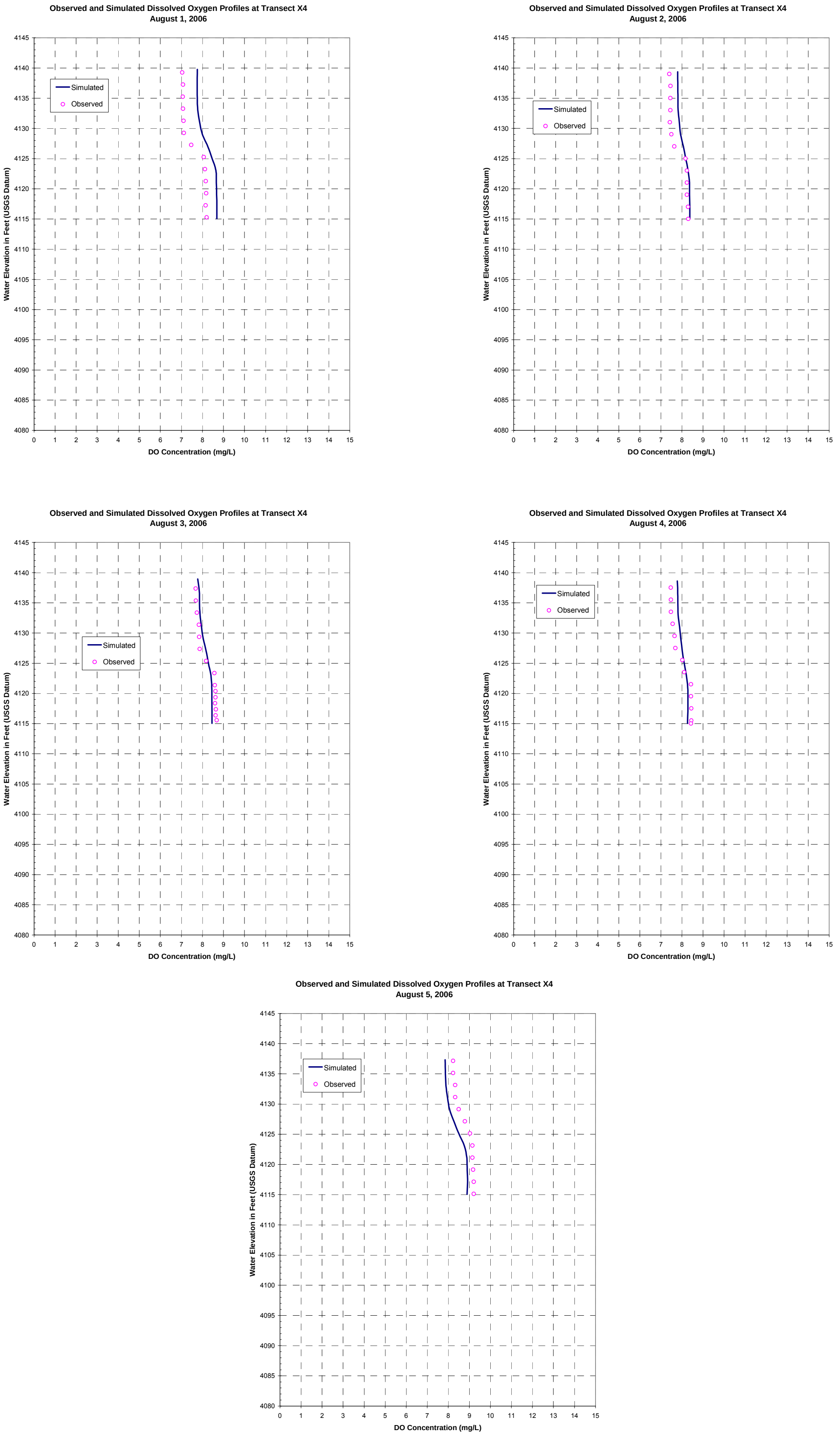
Observed and Simulated Dissolved Oxygen Profiles at Transect X3
August 2, 2006

Observed and Simulated Dissolved Oxygen Profiles at Transect X3
August 3, 2006

Observed and Simulated Dissolved Oxygen Profiles at Transect X3
August 4, 2006

Observed and Simulated Dissolved Oxygen Profiles at Transect X3
August 5, 2006

Figure 29 Observed and Simulated DO Profiles at Transect X4 (4W), 2006



Observed and Simulated Dissolved Oxygen Profiles at Transect X4
August 1, 2006

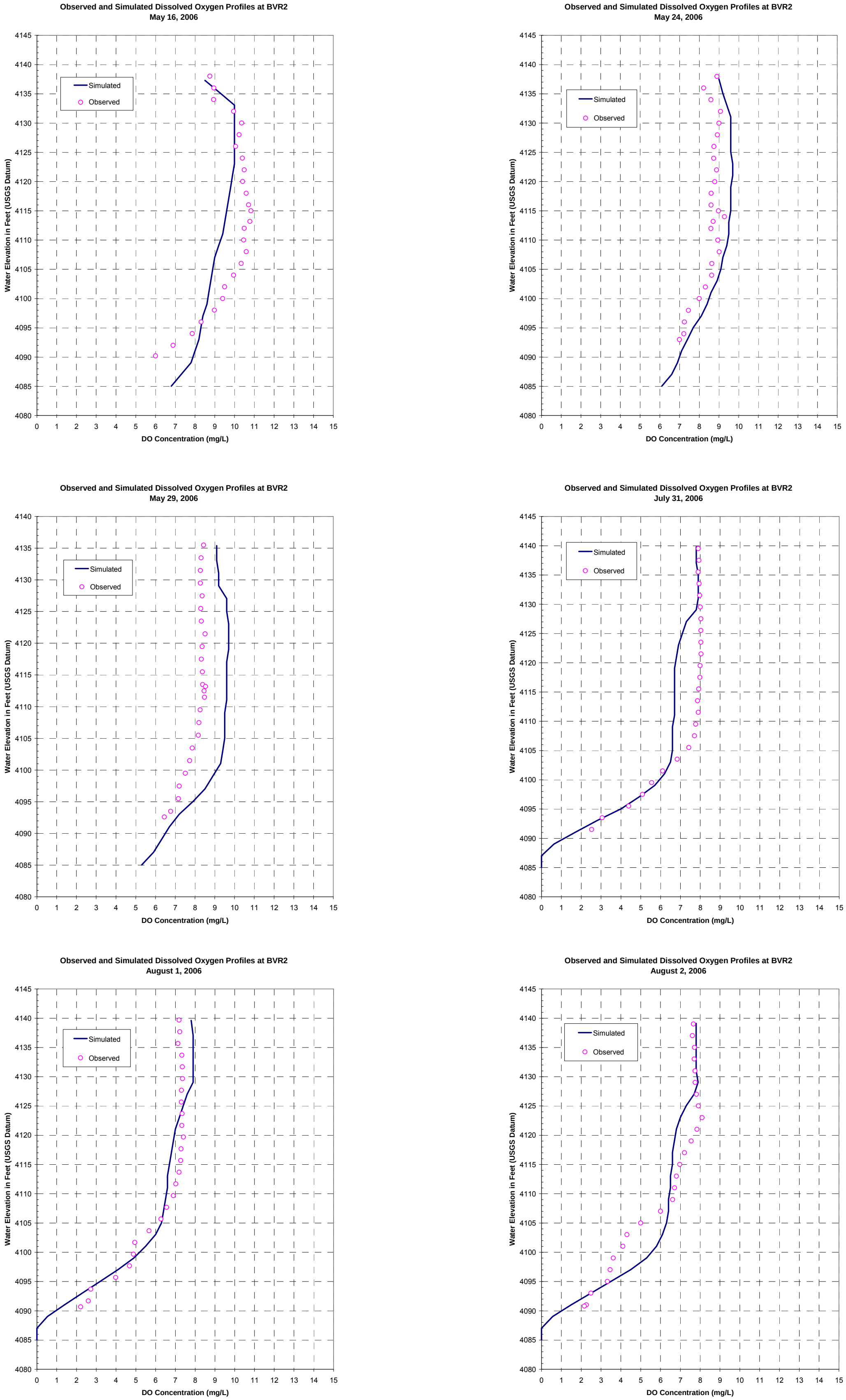
Observed and Simulated Dissolved Oxygen Profiles at Transect X4
August 2, 2006

Observed and Simulated Dissolved Oxygen Profiles at Transect X4
August 3, 2006

Observed and Simulated Dissolved Oxygen Profiles at Transect X4
August 4, 2006

Observed and Simulated Dissolved Oxygen Profiles at Transect X4
August 5, 2006

Figure 30 Observed and Simulated DO Profiles near Dam, 2006



Observed and Simulated Dissolved Oxygen Profiles at BVR2
May 16, 2006

Observed and Simulated Dissolved Oxygen Profiles at BVR2
May 24, 2006

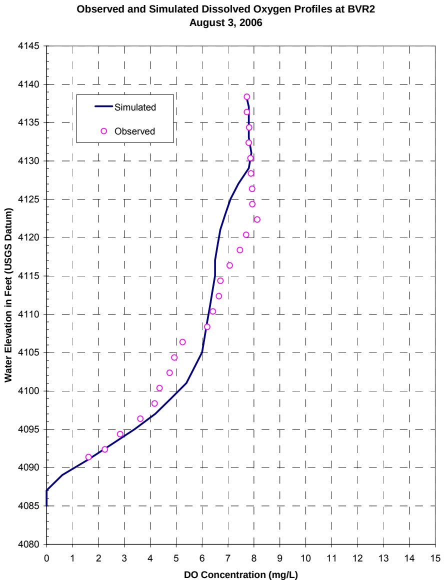
Observed and Simulated Dissolved Oxygen Profiles at BVR2
May 29, 2006

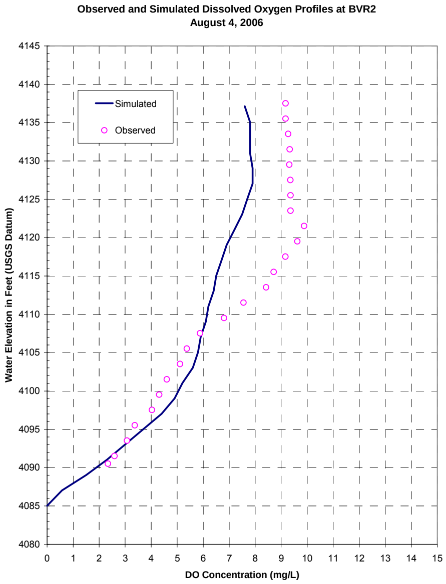
Observed and Simulated Dissolved Oxygen Profiles at BVR2
July 31, 2006

Observed and Simulated Dissolved Oxygen Profiles at BVR2
August 1, 2006

Observed and Simulated Dissolved Oxygen Profiles at BVR2
August 2, 2006

Figure 30 Observed and Simulated DO Profiles near Dam, 2006
(Continued)





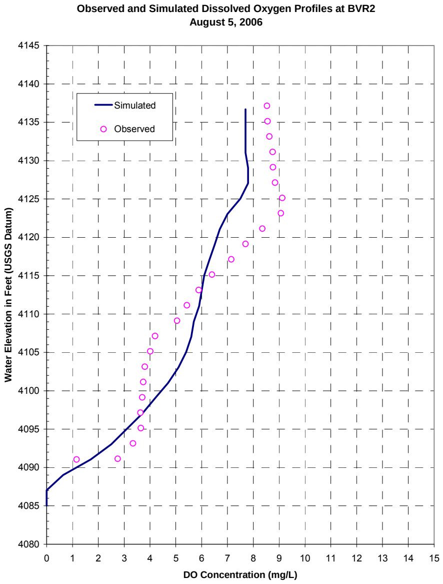


Figure 31 Model Verification Results of Butt Valley Reservoir Water Surface Elevations, 2000

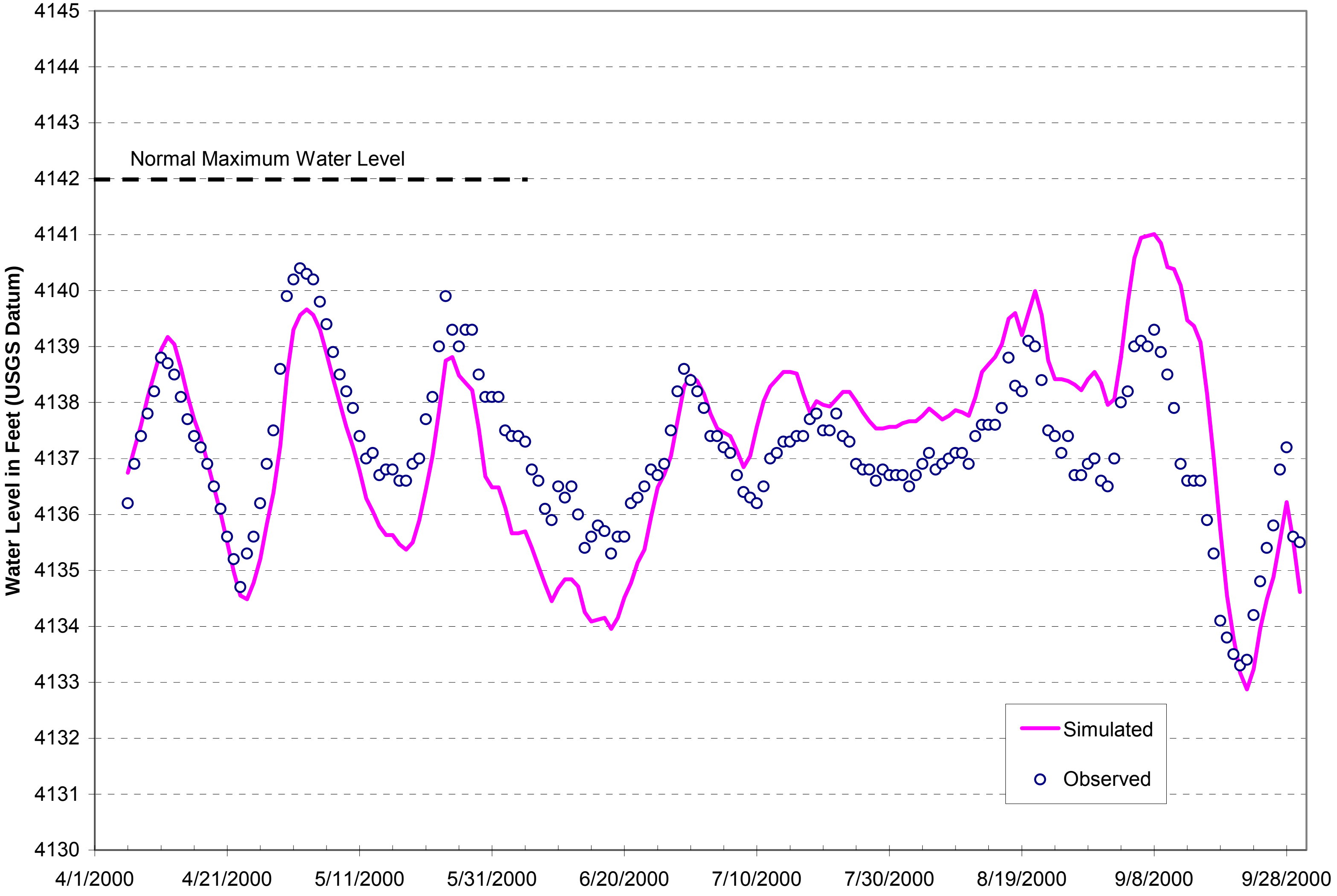
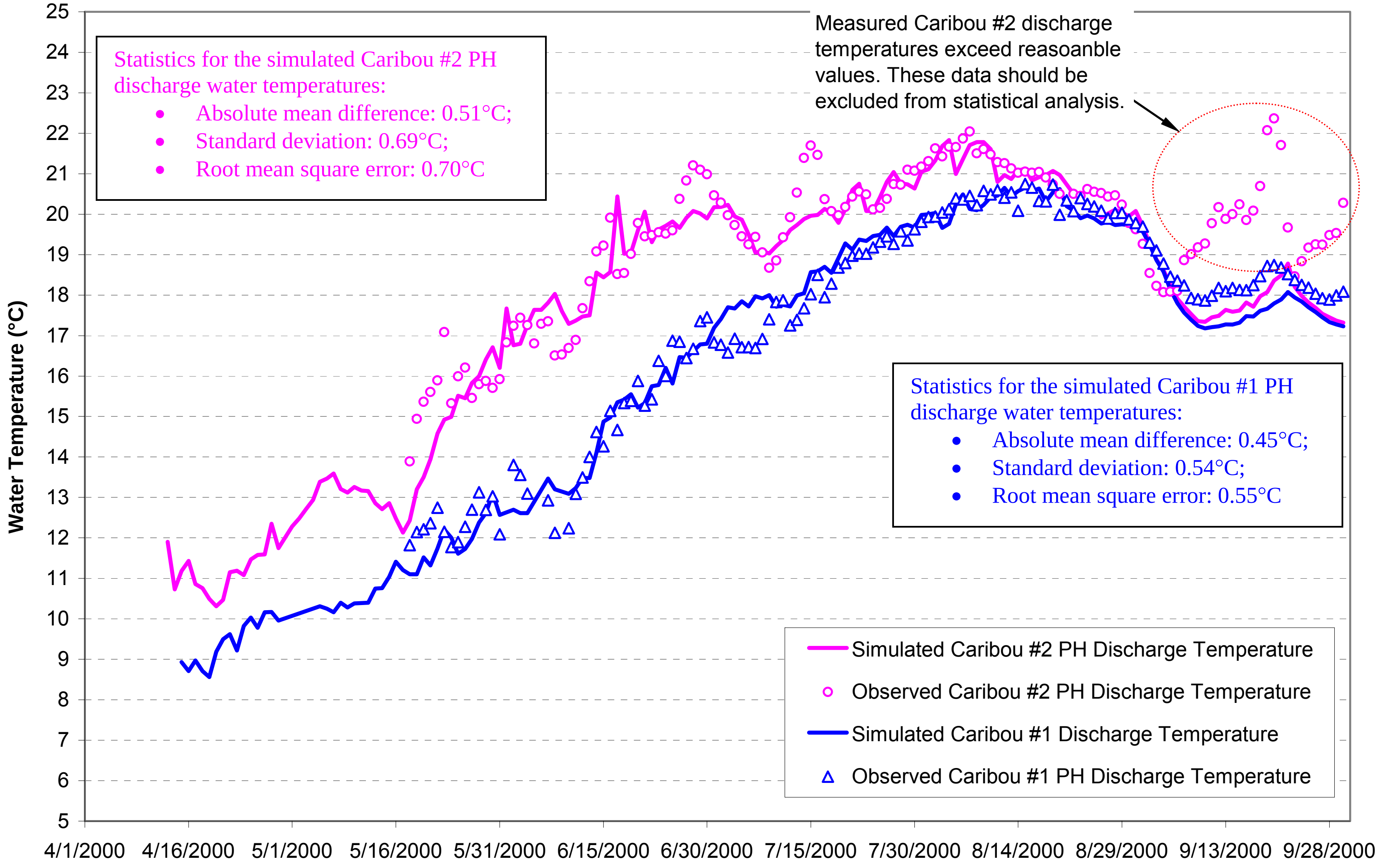


Figure 32 Model Verification Results of Butt Valley Reservoir Mean Daily Outflow Temperatures, 2000



Statistics for the simulated Caribou #2 PH discharge water temperatures:

- Absolute mean difference: 0.51°C;
- Standard deviation: 0.69°C;
- Root mean square error: 0.70°C

Measured Caribou #2 discharge temperatures exceed reasoanble values. These data should be excluded from statistical analysis.

Statistics for the simulated Caribou #1 PH discharge water temperatures:

- Absolute mean difference: 0.45°C;
- Standard deviation: 0.54°C;
- Root mean square error: 0.55°C

Figure 33 Butt Valley Reservoir Water Temperature Monitoring Stations in 2000

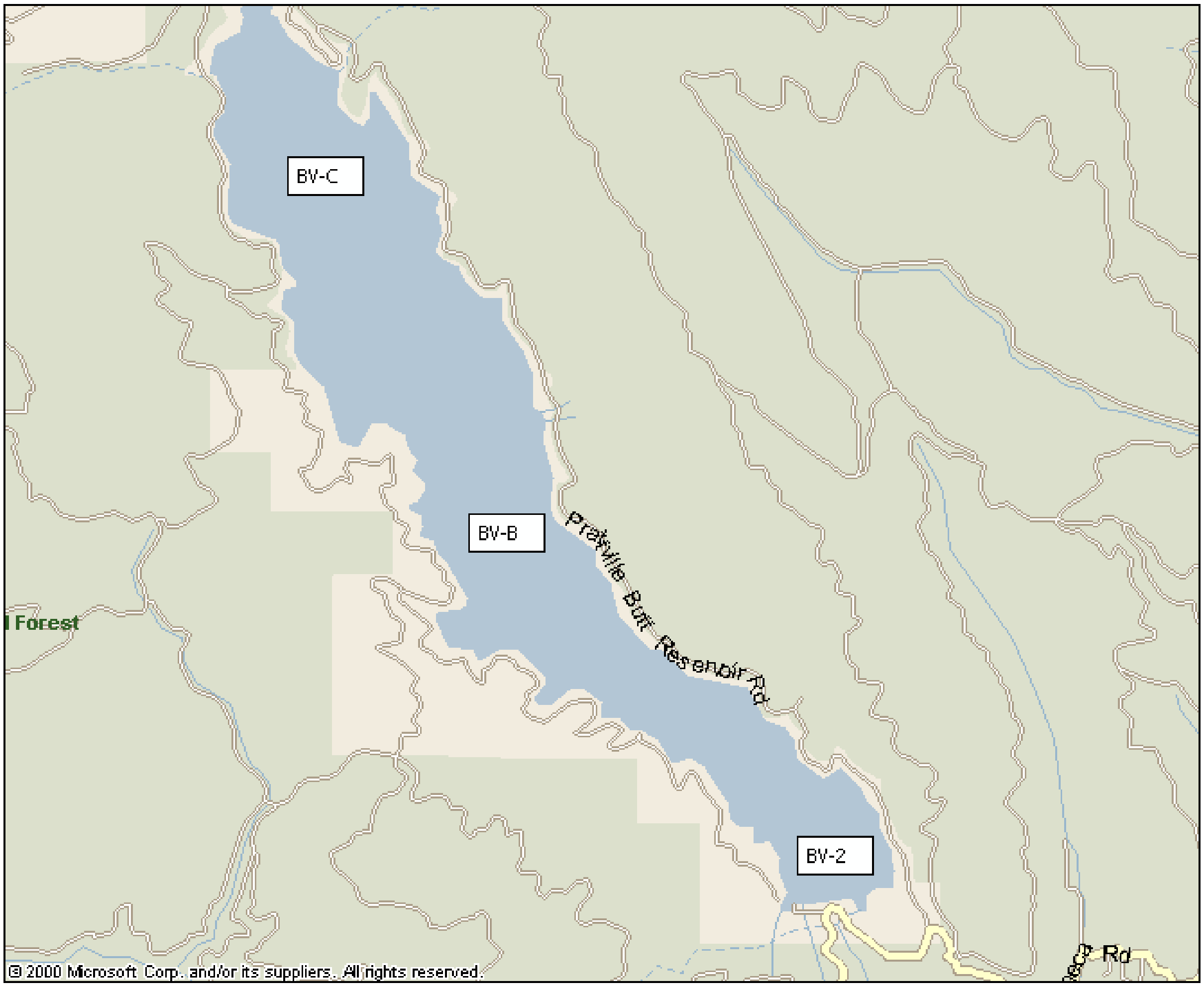


Figure 34 Observed and Simulated Water Temperature Profiles near Dam, 2000

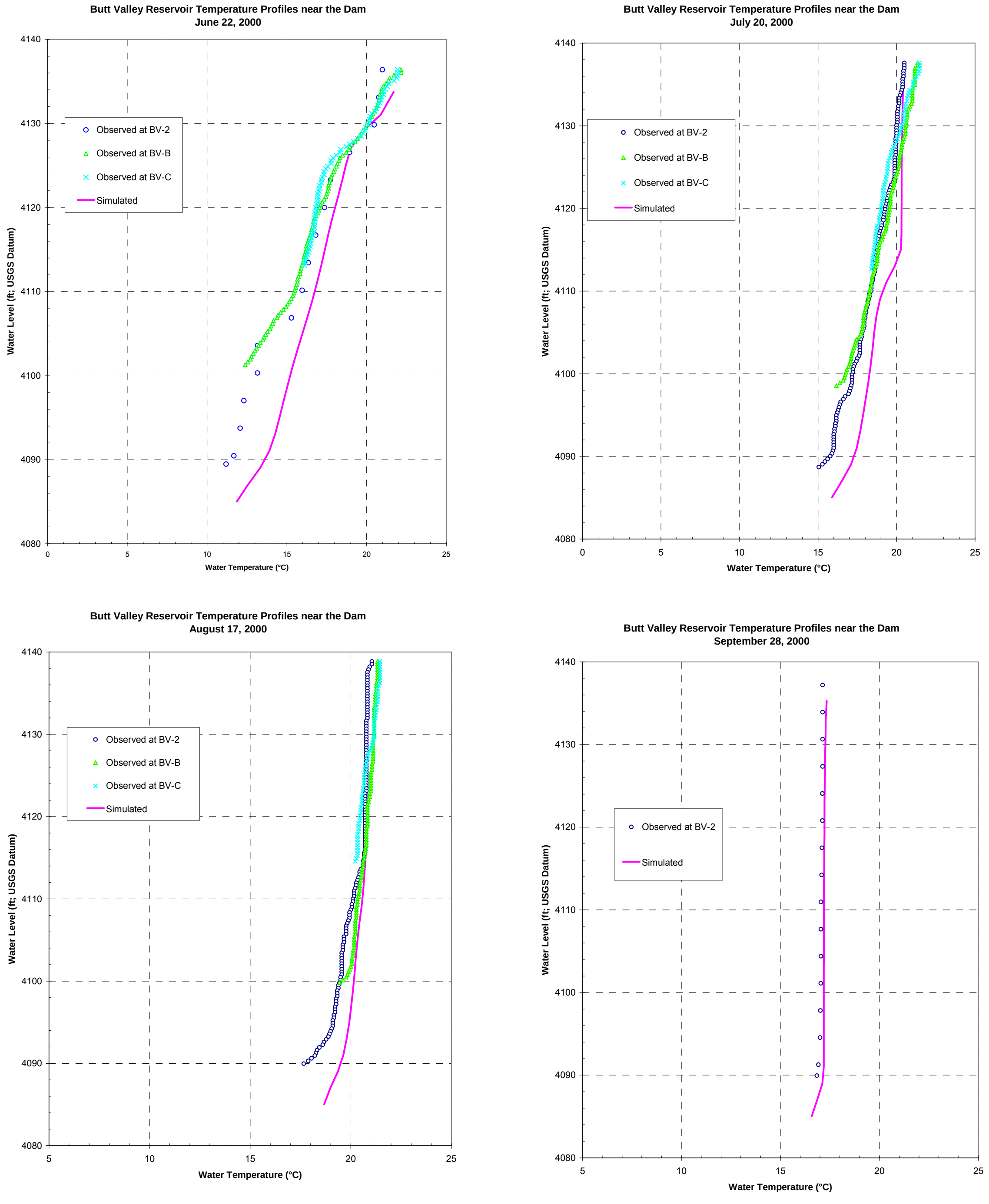
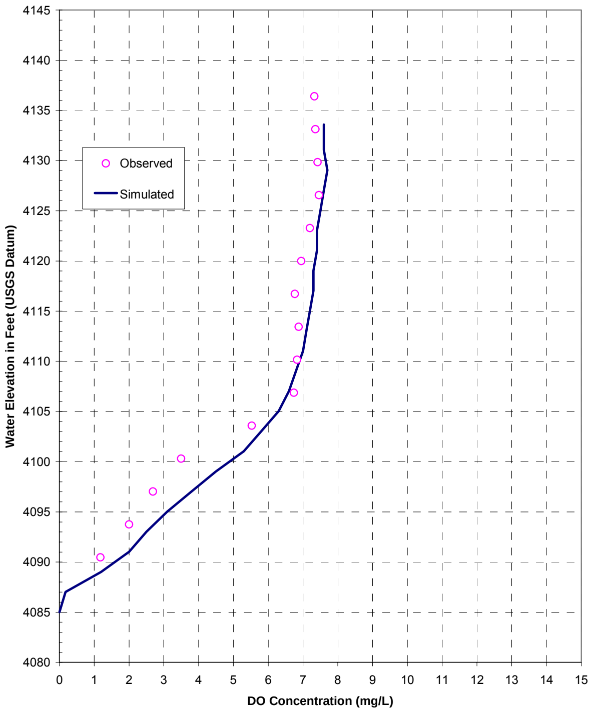
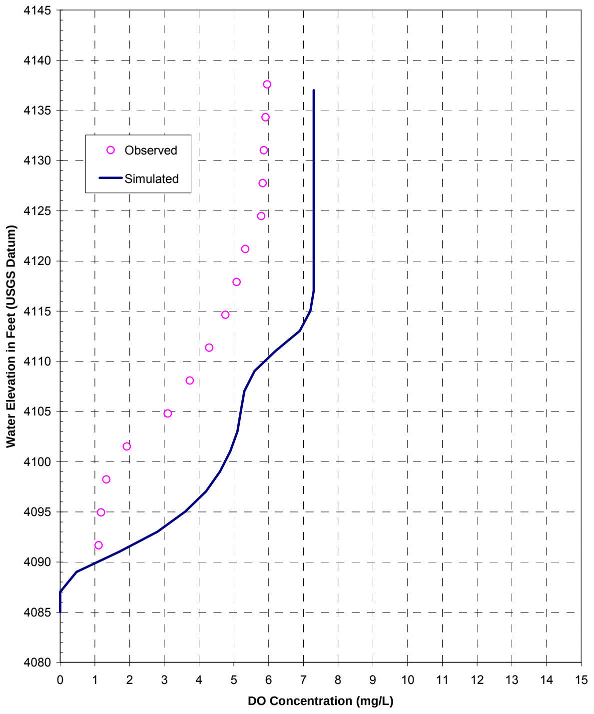


Figure 35 Observed and Simulated DO Profiles near Dam, 2000

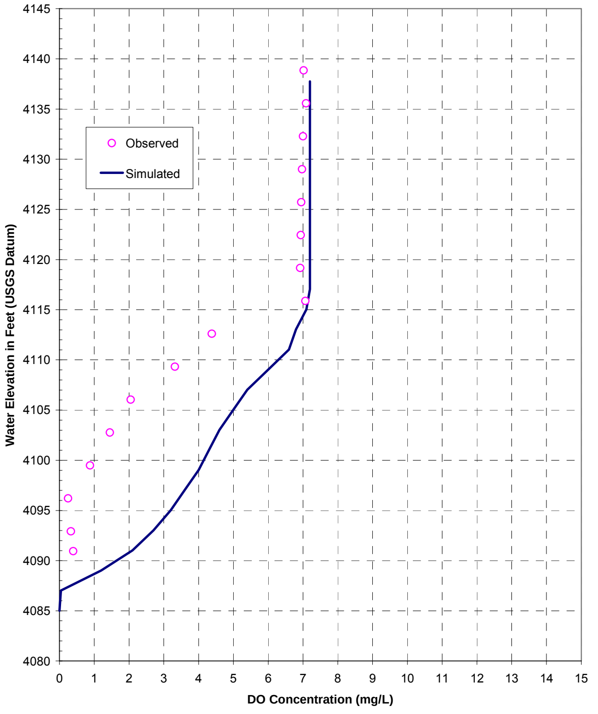
Observed and Simulated Dissolved Oxygen Profiles at BV-2
June 22, 2000



Observed and Simulated Dissolved Oxygen Profiles at BV-2
July 20, 2000



Observed and Simulated Dissolved Oxygen Profiles at BV-2
August 17, 2000



Observed and Simulated Dissolved Oxygen Profiles at BV-2
September 28, 2000

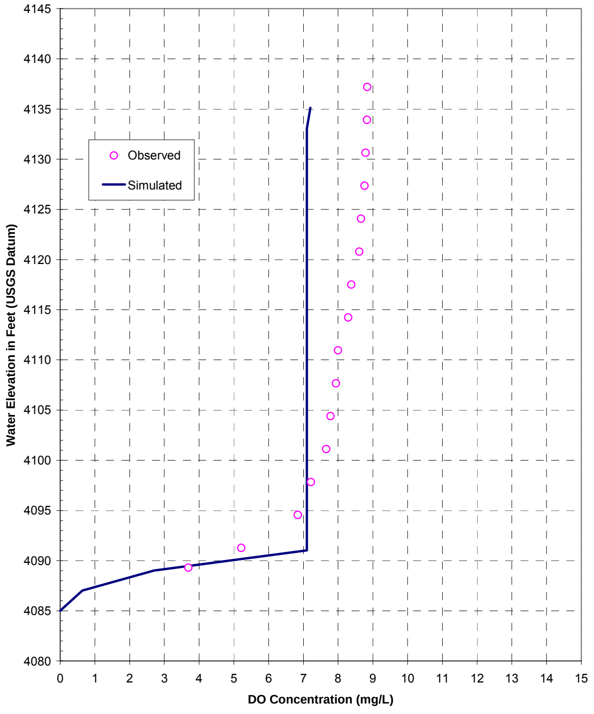


Figure 36 MITEMP Model Result of Butt Valley Reservoir Water Surface Elevations, 2000

(Source: Bechtel's MITEMP Model Calibration and Validation Report, 2002)

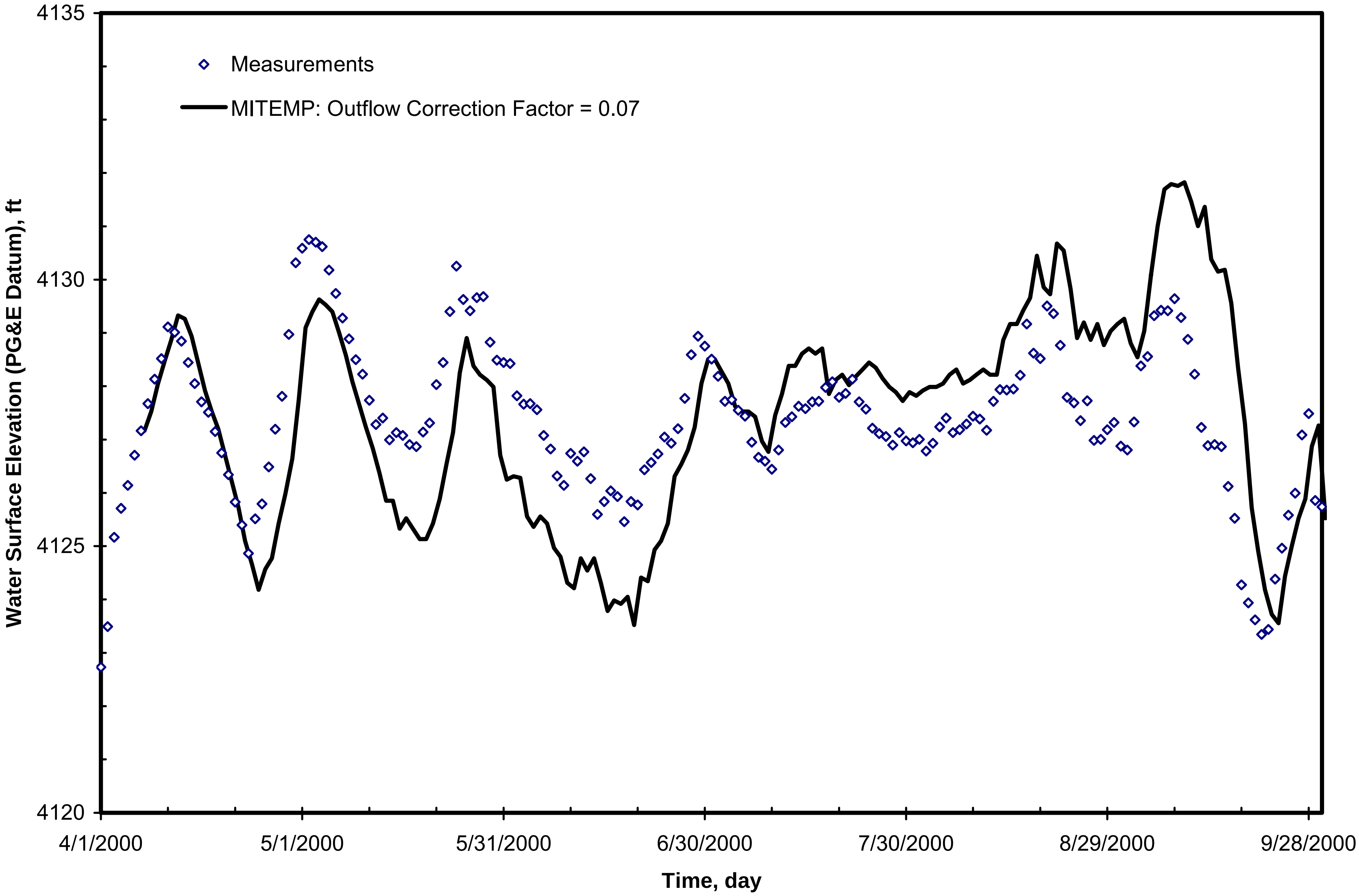


Figure 37 MITEMP Model Results of Butt Valley Reservoir Outflow Temperatures, 2000

(Source: Bechtel's MITEMP Model Calibration and Validation Report, 2002)

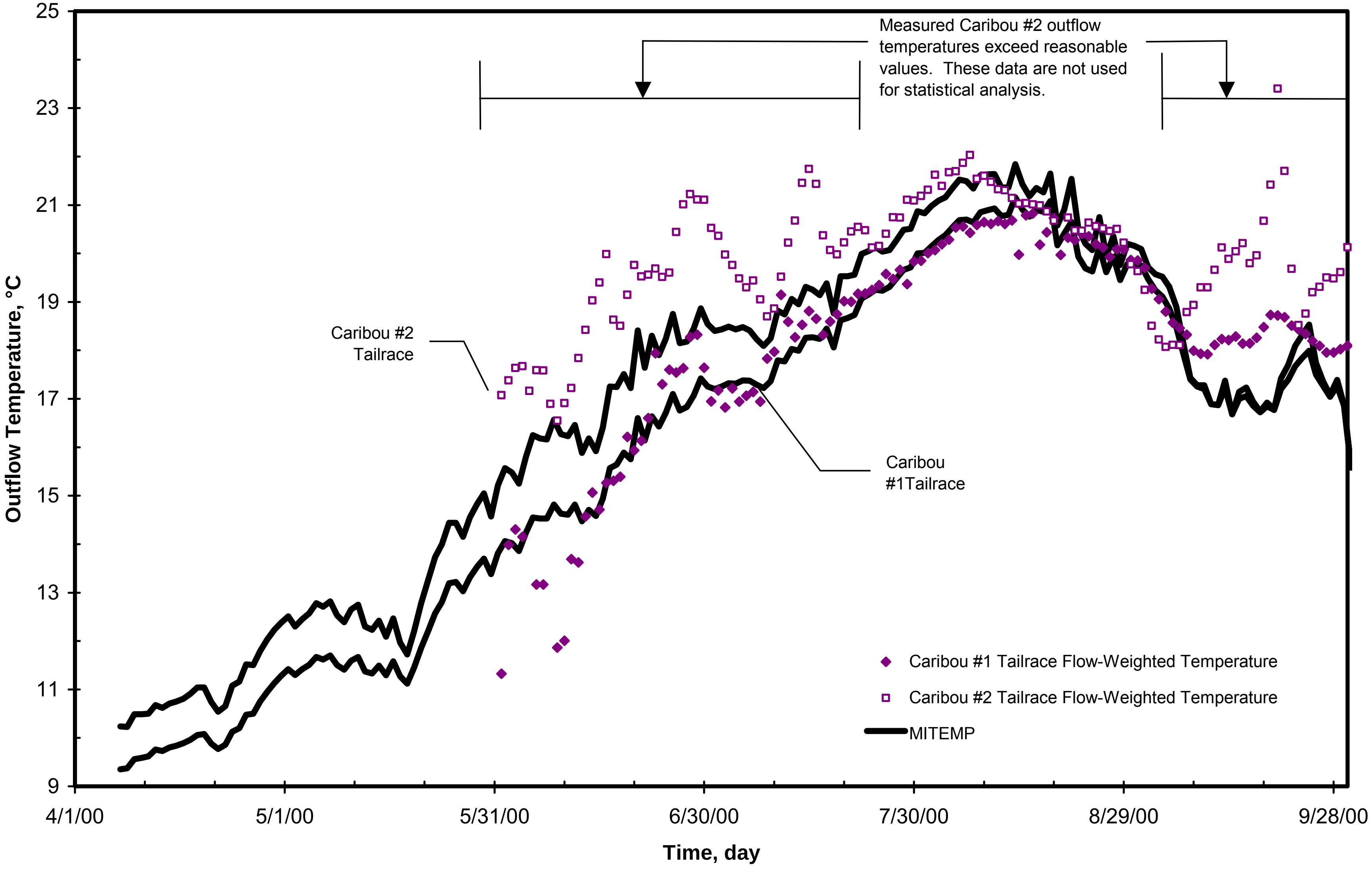
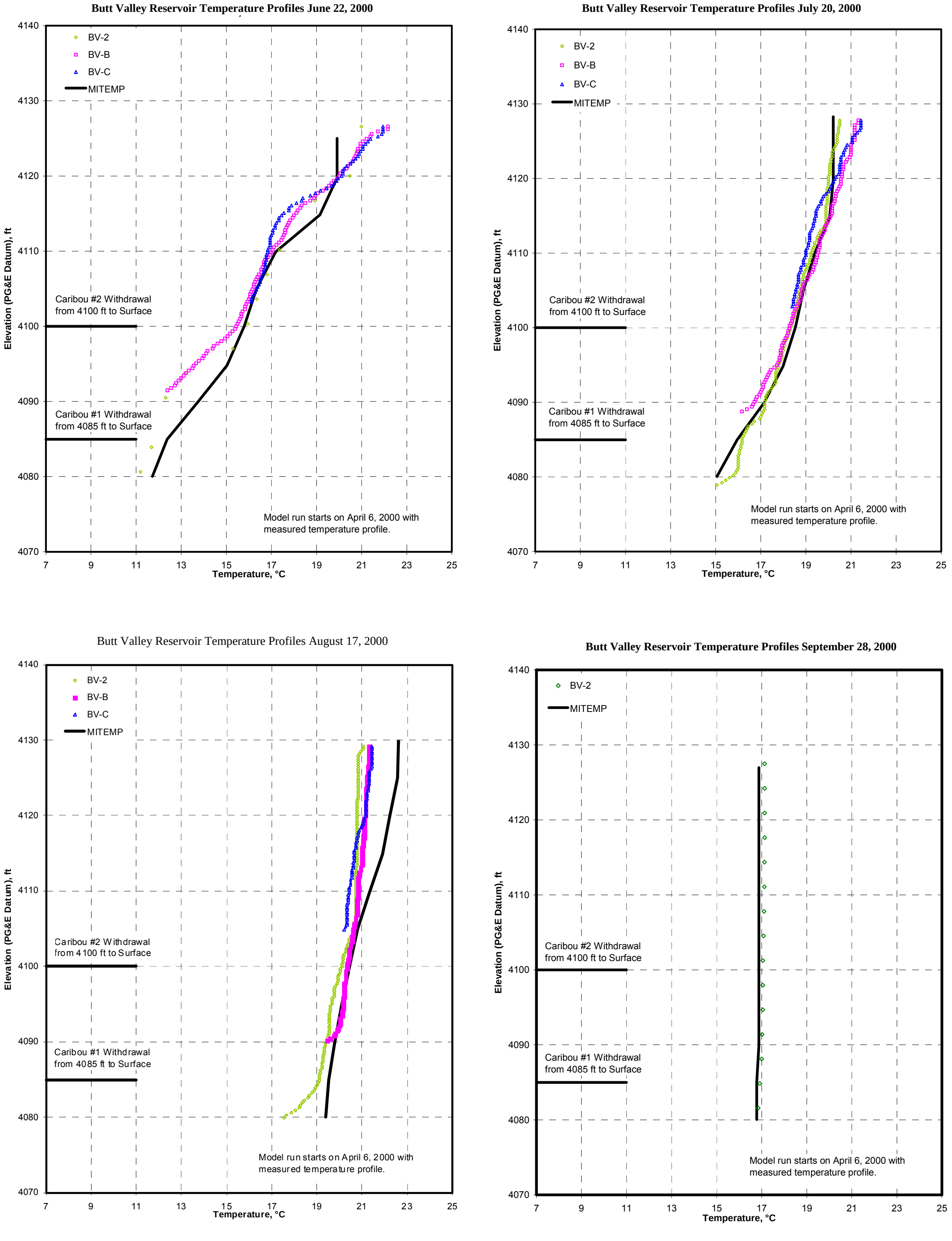


Figure 38 MITEMP Model Results of Butt Valley Reservoir Temperature Profiles, 200

(Source: Bechtel's MITEMP Model Calibration and Validation Report, 2002)

(Note the PG&E datum used in the plots)



Butt Valley Reservoir Temperature Profiles June 22, 2000

Butt Valley Reservoir Temperature Profiles July 20, 2000

Butt Valley Reservoir Temperature Profiles August 17, 2000

Butt Valley Reservoir Temperature Profiles September 28, 2000

Figure 39 Observed Mean Daily Water Temperatures in Butt Valley Reservoir in 2002 (Dry Year)

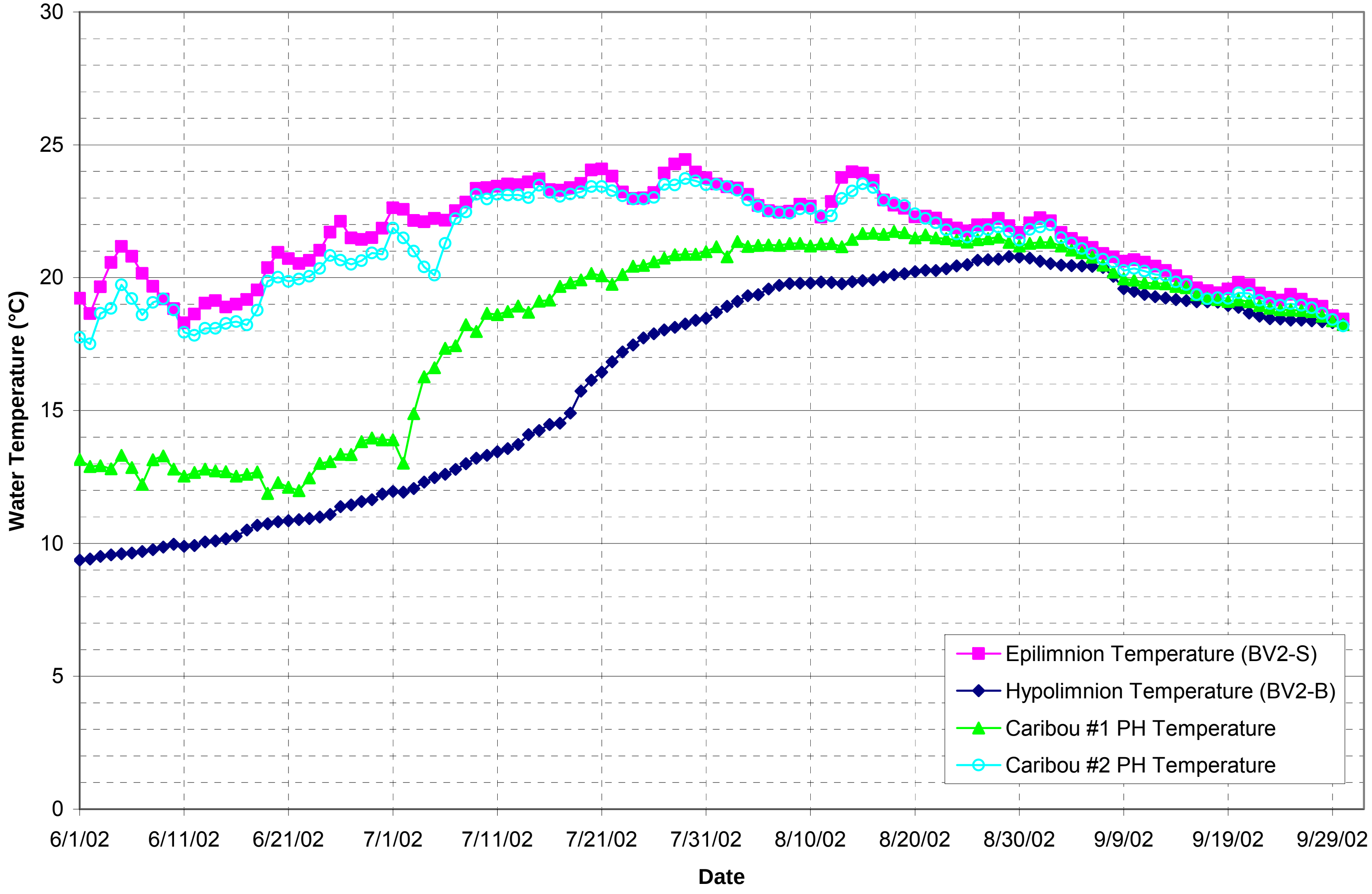
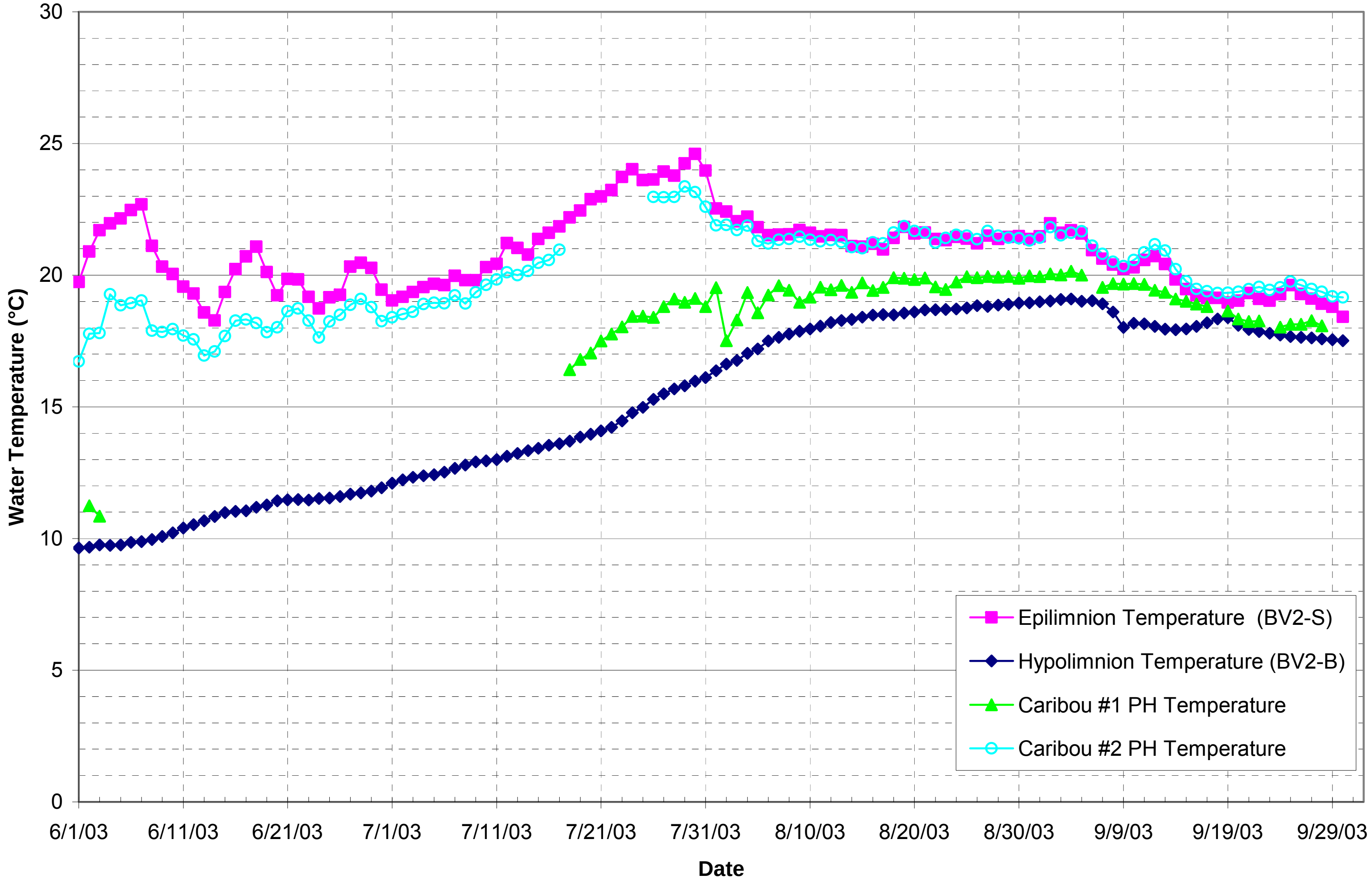


Figure 40 Observed Mean Daily Water Temperatures in Butt Valley Reservoir in 2003 (Normal Year)



APPENDIX I:

Additional Model Verification Using 2001 Data (Critical Dry Year)

APPENDIX I:

ADDITIONAL MODEL VERIFICATION USING 2001 DATA (CRITICAL DRY YEAR)

As mentioned in Section 4.0, the overall reliability of the model to predict future conditions increases in proportion to the amount of historical data that the model is able to describe successfully (Note: the data sets must come from a range of conditions, otherwise the model reliability will be limited). The data collected in 2006 (wet year) were used for model calibration and the data collected in 2000 (normal year) were used for model verification. This appendix summarizes results from an additional model verification using the data collected in 2001. Year 2001 was classified as a critical dry year and provided a good contrast to the calibration data in 2006 and the verification data in 2000, which were obtained under a wet year condition and a normal year condition respectively. The analysis period of April 1 to August 21, 2001 was selected for the additional model verification. This additional model verification period comprises the same data as the PG&E's model verification period for the Butt Valley Reservoir MITEMP water temperature model.

PG&E did not collect water temperature and water quality data in April 2001. The same water temperature and DO vertical profiles and water quality conditions measured on April 6, 2000 were used to initialize the additional verification run. The initial water temperature distribution had about 6°C temperature difference from surface (12°C) to bottom (6°C). The initial DO concentration distribution had about 2 mg/L difference from surface (10.0 mg/L) to bottom (8.0 mg/L).

As for the boundary water quality conditions of the model, since PG&E did not collect water quality data in 2001, the Butt Creek water quality conditions for the model verification year 2000 were assumed the same as the year 2001. The simulated time-series water quality concentrations at the Butt Valley PH discharges from the Stetson-improved Lake Almanor CE-QUAL-W2 verification model for 2001 were used as the upstream boundary conditions.

A.1 VERIFICATION RESULTS TO THE OBSERVED WATER SURFACE ELEVATIONS

Similar to the calibration year of 2006 and the verification year of 2000, the measured inflows and outflows of Butt Valley Reservoir in 2001 could not be well balanced due to the imperfect flow determinations and the relatively small storage volume of Butt Valley Reservoir. A sensitivity analysis was conducted to determine the most probable bias in the flow determinations. A constant 6.5% reduction to the Butt Valley PH inflows was found to yield a satisfactory prediction for the Butt Valley Reservoir water levels for year 2001. The flow reduction is in close agreement with the 7% flow reduction that Bechtel applied in their MITEMP modeling effort (Bechtel, 2002), except that Bechtel adjusted the flows for Caribou PHs. Figure A.1 shows the model verification result to the observed water surface elevations in 2001.

A.2 VERIFICATION RESULTS TO THE OBSERVED DISCHARGE WATER TEMPERATURES

Figure A.2 shows a comparison between simulated and observed water temperatures at Caribou #1 and #2 PHs discharges. As shown in the figure, the simulated discharge water temperatures are consistent with the timing and trajectory of the measured water temperatures. The absolute mean difference between the simulated and observed water temperatures of the Caribou #1 PH discharges for the verification period was 0.49°C with standard deviation of 0.65°C, and the root mean square error was 0.67°C. The absolute mean difference between simulated and observed water temperatures of the Caribou #2 PH discharges for the verification period was 0.41°C with standard deviation of 0.43°C, and the root mean square error was 0.50°C.

A.3 VERIFICATION RESULTS TO THE OBSERVED VERTICAL PROFILES OF WATER TEMPERATURE

PG&E conducted synoptic measurements at three locations along the axis of Butt Valley Reservoir in 2000 and 2001 (see Figure 33). Graphical presentations of simulated and observed vertical water temperature profiles at the three measurement locations are shown in Figure A.3. An overview of all of the graphical comparisons indicates that the model satisfactorily captures the observed patterns of overall thermal structure.

A.4 COMPARISON BETWEEN THE CE-QUAL-W2 AND EXISTING MITEMP MODELING RESULTS IN WATER TEMPERATURE

Figures A.4, A.5, and A.6 show the existing Butt Valley Reservoir MITEMP model results of reservoir water surface elevations[16], Caribou #1 and #2 discharge water temperatures, and vertical profiles of water temperature for year 2001. Comparing the MITEMP model results to the CE-QUAL-W2 model results (see the corresponding Figures A.1, A.2, and A.3), the CE-QUAL-W2 model-simulated discharge water temperatures at the Caribou #1 and Caribou #2 PHs are apparently better than the MITEMP model results. The possible reasons for this were explained in Section 4.5.

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[16] In the MITEMP model, Bechtel increased the Caribou #1 and #2 PH discharges by 7% to allow the simulated water surface elevations to satisfactorily match the observed water surface elevations. In the CE-QUAL-W2 model, Stetson decreased the Butt Valley PH discharges by 6.5% to yield a satisfactory prediction for the reservoir water levels. It was judged better not to adjust the Caribou #1 and #2 PH discharges because such an adjustment would have highly affected Belden Forebay water balance, a small reservoir with a reported storage volume of 2,477 acre-ft. Adjusting Butt Valley PH discharges would not have significantly affected Lake Almanor water levels because the lake has a large storage volume.

Figure A.1 Model Verification Results of Butt Valley Reservoir Water Surface Elevations, 2001

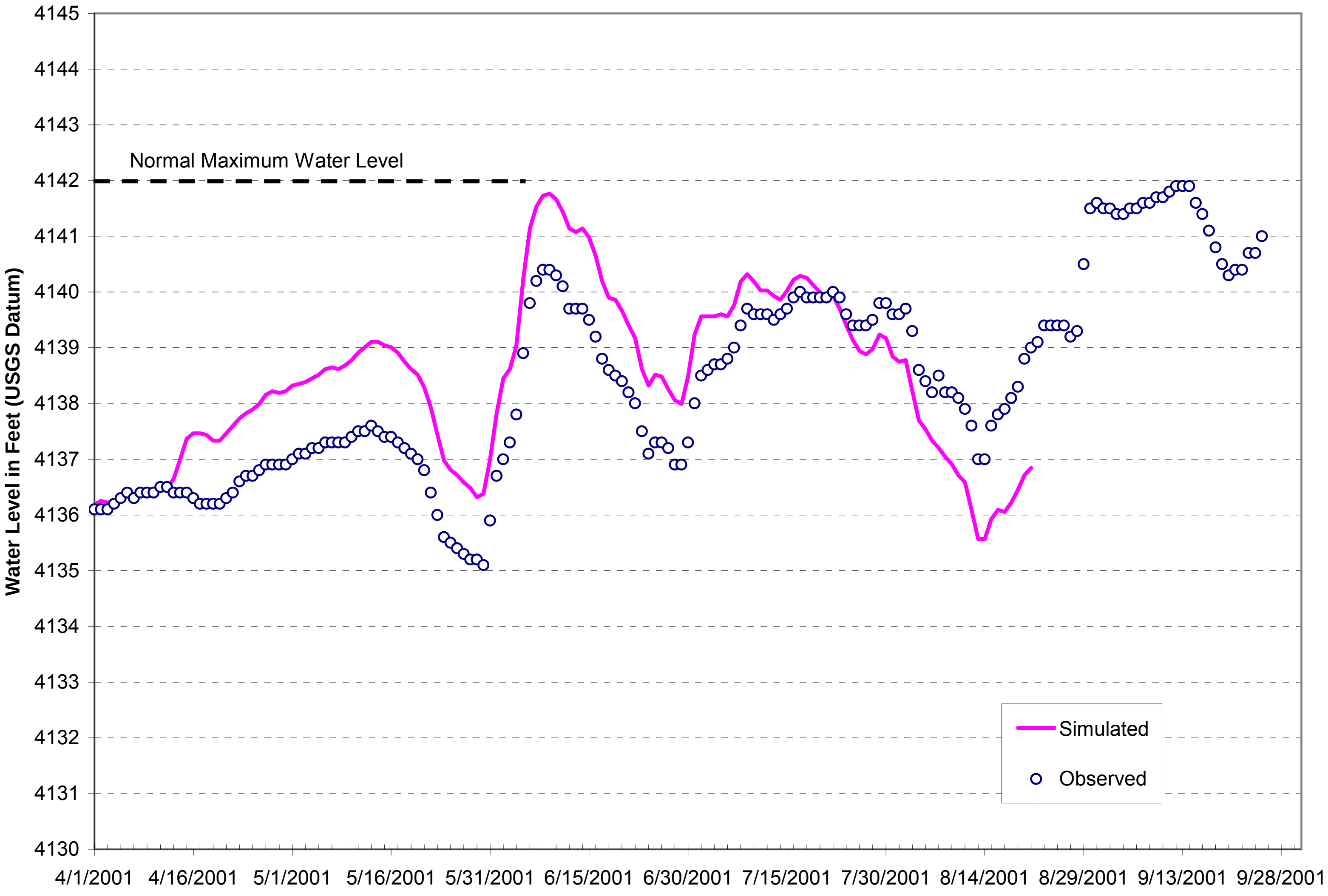
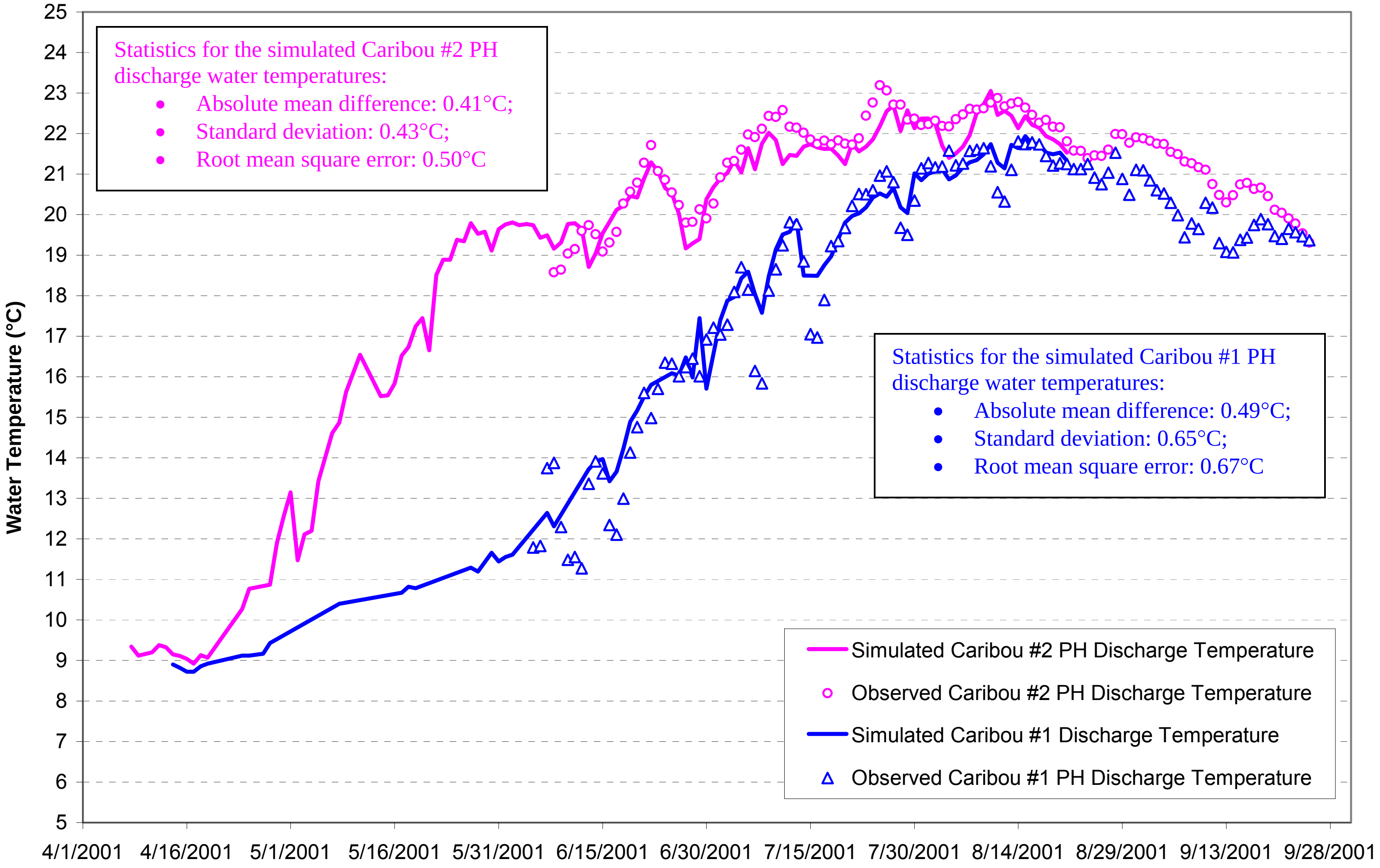


Figure A.2 Model Verification Results of Butt Valley Reservoir Mean Daily Outflow Temperatures, 2001



Statistics for the simulated Caribou #2 PH discharge water temperatures:

- Absolute mean difference: 0.41°C;
- Standard deviation: 0.43°C;
- Root mean square error: 0.50°C

Statistics for the simulated Caribou #1 PH discharge water temperatures:

- Absolute mean difference: 0.49°C;
- Standard deviation: 0.65°C;
- Root mean square error: 0.67°C

Figure A.3 Observed and Simulated Water Temperature Profiles near Dam, 2001

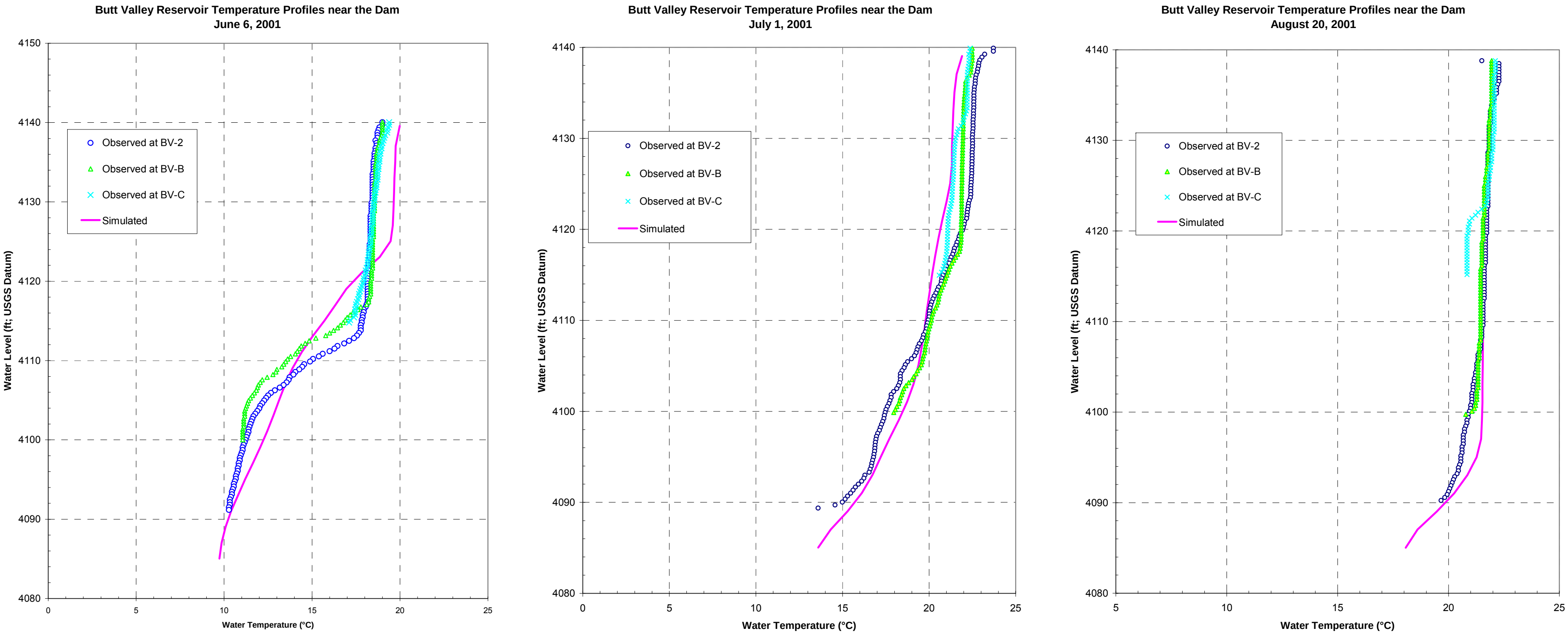


Figure A.4 MITEMP Model Result of Butt Valley Reservoir Water Surface Elevations, 2001

(Source: Bechtel's MITEMP Model Calibration and Validation Report, 2002)

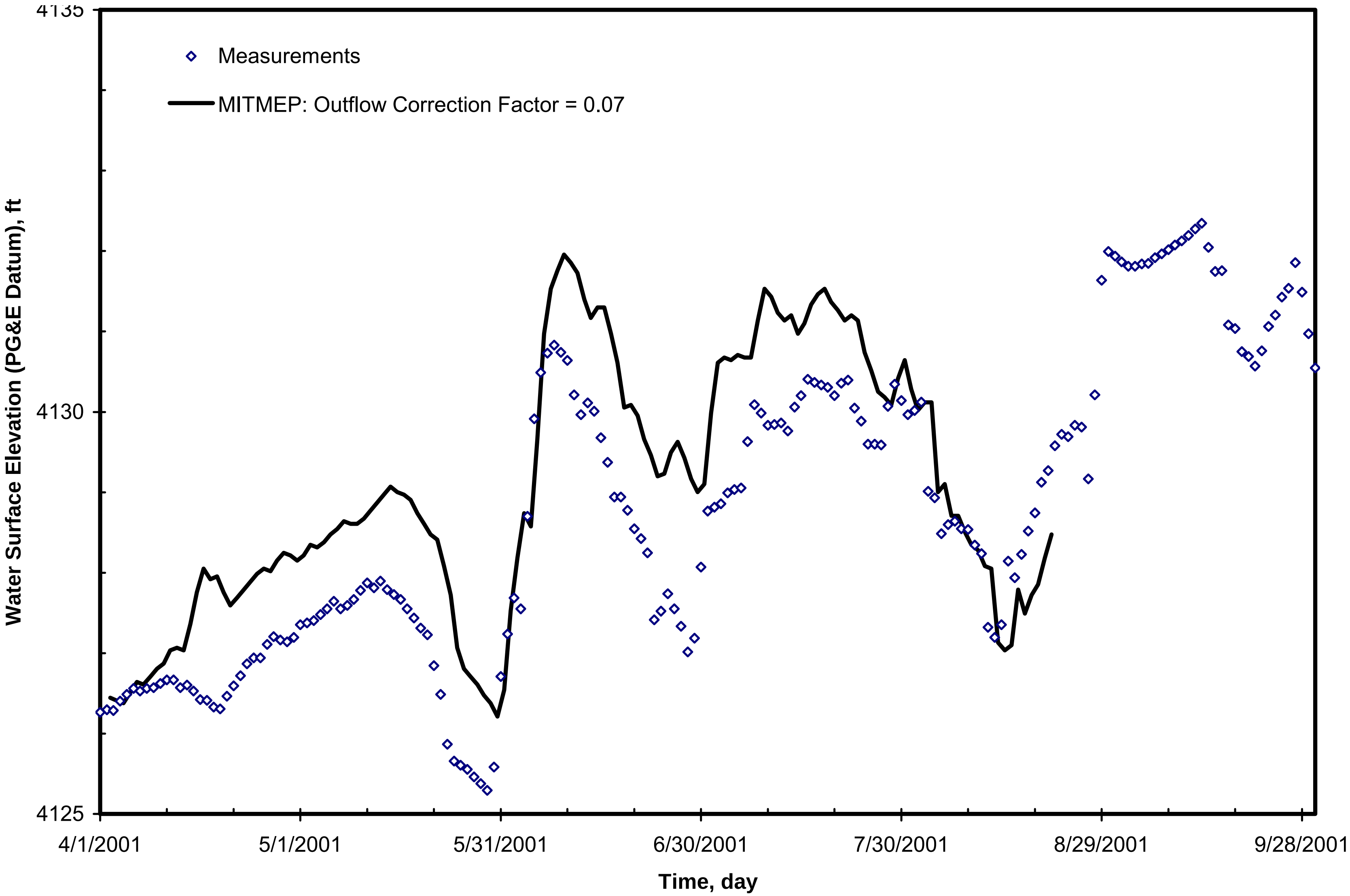


Figure A.5 MITEMP Model Results of Butt Valley Reservoir Outflow Temperatures, 2001

(Source: Bechtel's MITEMP Model Calibration and Validation Report, 2002)

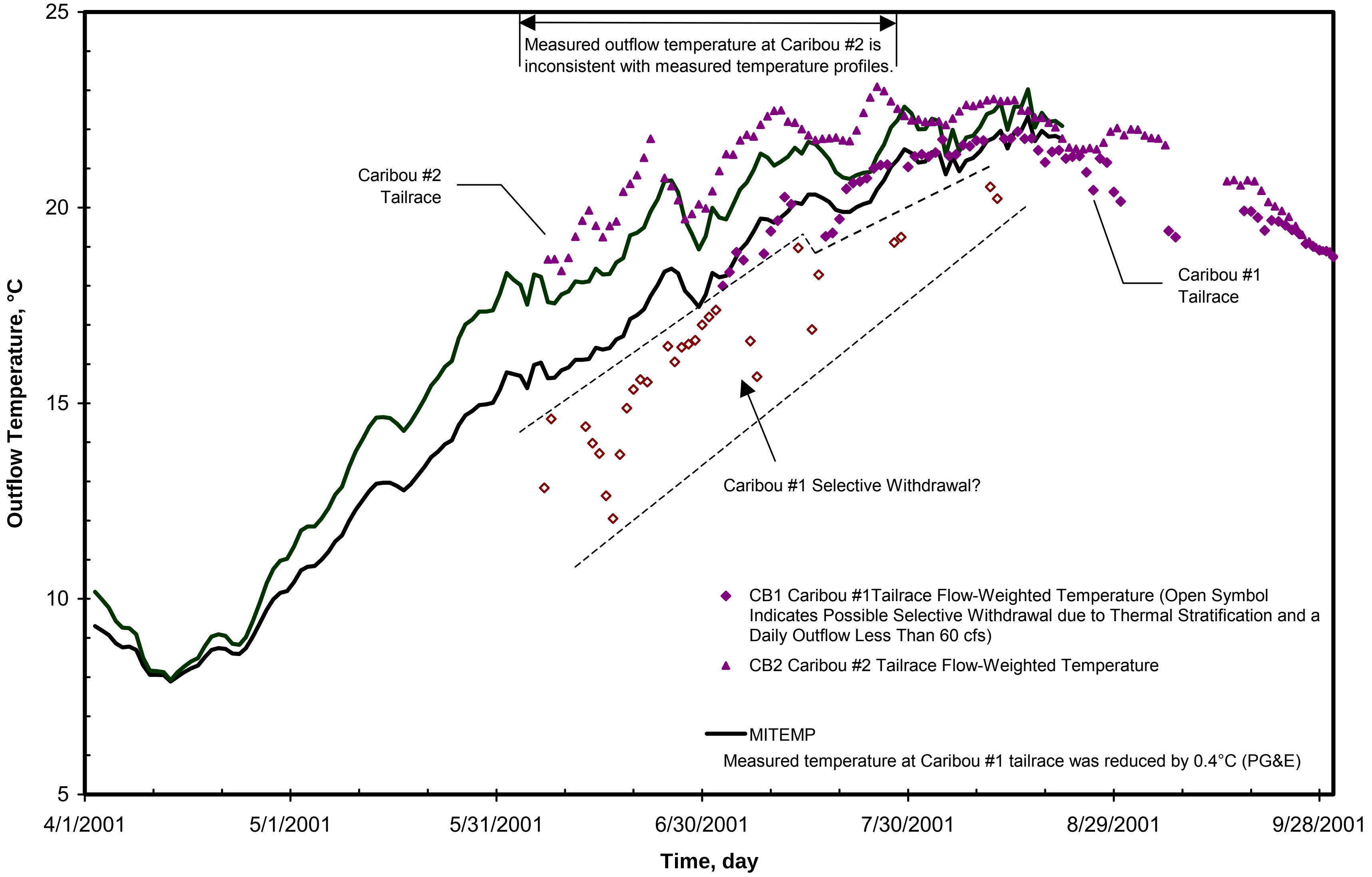
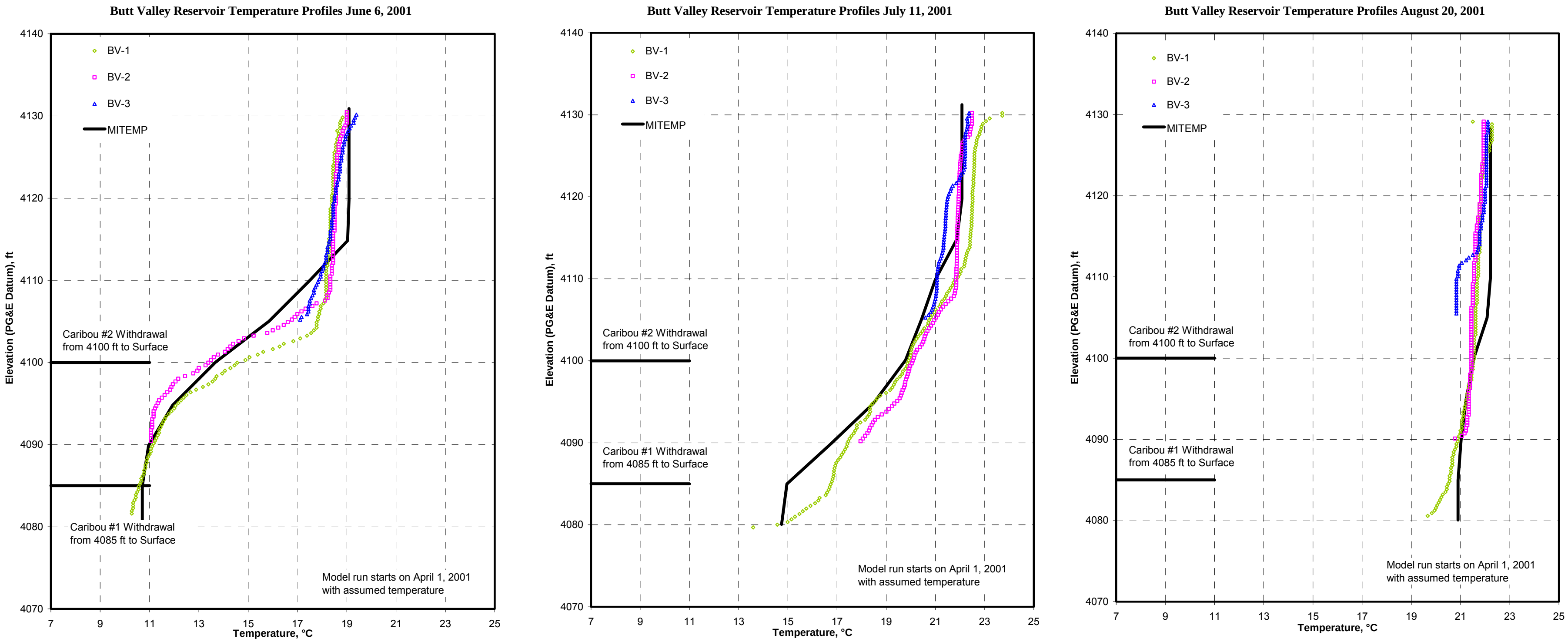


Figure A.6 MITEMP Model Results of Butt Valley Reservoir Temperature Profiles, 2001

(Source: Bechtel's MITEMP Model Calibration and Validation Report, 2002)

(Note the PG&E datum used in the plots)



APPENDIX II:

CE-QUAL-W2 Withdrawal Algorithm

(Directly extracted from CE-QUAL-W2 User Manual)

AUXILLIARY FUNCTIONS

Selective Withdrawal

The latest verson includes selective withdrawal for all outflows where layer locations and outflows at each layer are calculated based on the total outflow **[QOUT]**, structure type **[SINKC]**, elevation **[ESTR]**, and computed upstream density gradients. The selective withdrawal computation uses these values to compute vertical withdrawal zone limits and outflows. It also sums the outflows for multiple structures.

Outflow distribution is calculated in the subroutine SELECTIVE_WITHDRAWAL. This routine first calculates limits of withdrawal based on either a user specified point or line sink approximation for outlet geometry **[SINKC]**. The empirical expression for point sink withdrawal limits is:

$$d = (c_{bi} Q/N)^{0.3333} \qquad \textbf{(A-238)}$$

and for a line sink:

$$d = (c_{bi} 2\, q/N)^{0.5} \qquad \textbf{(A-239)}$$

where:

d = withdrawal zone half height, m
Q = total outflow, $m^3\ s^{-1}$
N = internal buoyancy frequency, Hz
q = outflow per unit width, $m^2\ s^{-1}$
c_{bi} = boundary interference coefficient

The width is the outlet width. The point sink approximation assumes approach flow is radial both longitudinally and vertically while the line sink approximation assumes flow approaches the outlet radially in the vertical. The boundary interference coefficient is two near a physical boundary and one elsewhere.

Velocities are determined using a quadratic shape function:

$$V_k = 1 - \left[\frac{(\rho_k - \rho_o)}{(\rho_l - \rho_o)} \right]^2 \tag{A-240}$$

where:

V_k = normalized velocity in layer k
ρ_k = density in layer k, $kg\ m^{-3}$
ρ_o = density in the outlet layer, $kg\ m^{-3}$
ρ_l = density of the withdrawal limit layer, $kg\ m^{-3}$

The shape function generates a maximum velocity at the outlet level with velocities approaching zero at withdrawal limits. During non-stratified periods, outflow from top to bottom is uniform. Uniform flows also result from large outflows during periods of mild stratification. As stratification develops, withdrawal limits decrease and outflow is weighted towards the outlet elevation.

Withdrawal limits can be varied by specifying a line sink and changing the effective width. Small outlet widths result in nearly uniform outflows, while large widths limit outflows to the outlet layer.

Appendix C:

Detailed Effect Analysis of Level 3 Alternatives on Lake Almanor Cold Freshwater Habitat

- **Tables 1a – 15b summarize the simulated Lake Almanor elevation range and habitat volume of the water layer that meets the three different temperature and DO criteria (i.e., T ≤ 20°C and DO ≥ 5 mg/L; T≤ 21°C and DO ≥ 5 mg/L; or T ≤ 22°C and DO ≥ 5 mg/L) for different alternatives for year 2000 (normal hydrologic year)**

- **Tables 16a – 30b summarize the simulated Lake Almanor elevation range and habitat volume of the water layer that meets the three different temperature and DO criteria (i.e., T ≤ 20°C and DO ≥ 5 mg/L; T≤ 21°C and DO ≥ 5 mg/L; or T ≤ 22°C and DO ≥ 5 mg/L) for different alternatives for year 2001 (critical dry year)**

- **Figures 1a – 3d compare the simulated Lake Almanor elevation range of the water layer that meets the three different temperature and DO criteria (i.e., T ≤ 20°C and DO ≥ 5 mg/L; T≤ 21°C and DO ≥ 5 mg/L; or T ≤ 22°C and DO ≥ 5 mg/L) between Baseline and Alternative 3x for year 2000 (graphical presentation of Tables 1a – 15a)**

- **Figures 4a – 6d compare the simulated Lake Almanor elevation range of the water layer that meets the three different temperature and DO criteria (i.e., T ≤ 20°C and DO ≥ 5 mg/L; T≤ 21°C and DO ≥ 5 mg/L; or T ≤ 22°C and DO ≥ 5 mg/L) between Baseline and Alternative 3x for year 2001 (graphical presentation of Tables 16a – 30a)**

- **Figures 7a – 7f compare the simulated water temperature profiles of Lake Almanor near Canyon Dam (model segment 9) between alternatives for year 2000**

- **Figures 8a – 8f compare the simulated water temperature profiles of Lake Almanor near Canyon Dam (model segment 9) between alternatives for year 2001**

Table 1a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2
	4,486.9	4,467.2	4,447.5	4,449.2	4,444.3	4,427.9	4,408.2	4,408.2	4,439.9	4,436.2	4,434.4	
June 7	4,500.4	4,500.3	4,500.3	4,500.3	4,500.3	4,500.3	4,500.3	4,500.3	4,500.3	4,500.3	4,500.3	4,500.3
	4,486.9	4,467.2	4,467.2	4,462.3	4,453.6	4,451.6	4,446.2	4,444.3	4,444.8	4,446.3	4,449.2	
Jun 22	4,491.5	4,490.8	4,488.2	4,484.5	4,483.3	4,481.5	4,476.4	4,476.9	4,484.6	4,481.9	4,483.1	4,500.1
	4,486.9	4,476.2	4,473.4	4,463.6	4,460.3	4,456.2	4,456.4	4,451.9	4,448.6	4,450.0	4,455.5	
July 7	4,499.0	4,472.3	4,474.8	4,473.1	4,471.6	4,472.2	4,468.4	4,465.4	4,476.8	4,476.7	4,474.6	4,499.5
	4,486.9	4,469.2	4,472.4	4,467.7	4,463.3	4,460.0	4,451.6	4,453.0	4,452.8	4,454.8	4,459.2	
Jul 20	4,489.7			4,470.9	4,469.1	4,466.7	4,462.9	4,463.4	4,471.9	4,470.7	4,469.9	4,497.2
	4,486.9			4,467.2	4,462.9	4,457.7	4,457.4	4,458.5	4,453.3	4,454.9	4,457.4	
Aug 7	4,489.3				4,465.4	4,463.4	4,459.9	4,460.5	4,464.0	4,465.2	4,464.3	4,496.2
	4,486.9				4,462.3	4,459.6	4,457.2	4,457.6	4,454.1	4,457.6	4,458.6	
Aug 17	4,493.9				4,462.2	4,460.4	4,458.2	4,458.2	4,462.6	4,463.0	4,462.9	4,493.9
	4,486.9				4,461.0	4,458.7	4,456.7	4,456.7	4,455.6	4,457.2	4,459.7	
Sep 7	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9
	4,486.9	4,467.2	4,447.5	4,449.9	4,453.9	4,453.0	4,456.2	4,454.4	4,462.8	4,460.1	4,455.0	
Sep 28	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3
	4,486.9	4,467.2	4,449.0	4,455.9	4,458.4	4,452.9	4,454.4	4,450.8	4,455.4	4,453.8	4,451.5	
Oct 15	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6
	4,486.9	4,467.2	4,447.5	4,437.7	4,445.3	4,445.3	4,444.4	4,443.2	4,434.4	4,448.9	4,445.7	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 1b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15	6,450	37,120	146,860	146,710	78,230	49,840	41,620	25,390	102,950	213,250	145,130	**993,600**
Jun 7	6,640	37,620	138,400	123,370	69,830	45,030	31,730	19,560	98,780	184,260	121,290	**876,500**
Jun 22	770	14,350	61,490	65,760	33,790	21,670	11,460	8,280	62,960	107,270	64,640	**452,400**
Jul 7	5,410	340	7,270	16,640	11,890	10,180	9,240	3,950	41,830	73,620	35,840	**216,200**
Jul 20	360			11,130	8,880	6,880	3,040	1,620	32,210	52,600	28,910	**145,600**
Aug 7	250				4,380	2,910	1,520	920	16,980	25,130	12,950	**65,000**
Aug 17	1,850				1,540	1,220	840	470	11,990	19,180	7,300	**44,400**
Sep 7	1,380	19,680	108,490	121,070	57,270	35,750	21,860	13,460	54,910	112,630	90,100	**636,600**
Sep 28	500	14,840	95,010	104,170	47,480	32,980	21,120	13,540	62,550	124,090	91,100	**607,400**
Oct 15	330	13,600	91,300	111,520	60,080	36,020	25,510	15,470	83,530	137,580	101,220	**676,200**

Table 2a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment – "Present Day" (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1
	4,486.9	4,467.2	4,447.5	4,449.2	4,444.3	4,427.9	4,408.2	4,409.1	4,440.2	4,436.6	4,434.8	
June 7	4,500.3	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2
	4,486.9	4,467.2	4,467.2	4,462.3	4,453.6	4,451.6	4,446.2	4,445.1	4,444.9	4,446.3	4,448.8	
Jun 22	4,491.1	4,490.7	4,487.9	4,484.3	4,483.1	4,481.2	4,476.3	4,477.5	4,484.2	4,481.6	4,482.9	4,500.0
	4,486.9	4,475.8	4,473.3	4,463.3	4,460.0	4,456.2	4,456.4	4,451.9	4,448.6	4,449.9	4,455.3	
July 7	4,498.9	4,471.4	4,474.3	4,472.9	4,471.2	4,471.9	4,468.1	4,465.3	4,476.5	4,476.4	4,474.3	4,499.4
	4,486.9	4,468.7	4,471.9	4,467.2	4,463.2	4,460.0	4,451.6	4,453.0	4,452.5	4,454.5	4,459.0	
Jul 20	4,489.7			4,470.5	4,468.9	4,466.4	4,462.6	4,463.3	4,471.5	4,470.3	4,469.6	4,497.1
	4,486.9			4,467.0	4,462.7	4,457.4	4,457.4	4,458.3	4,453.1	4,454.7	4,457.1	
Aug 7	4,489.3				4,465.0	4,463.0	4,459.7	4,460.2	4,463.6	4,464.8	4,464.0	4,496.1
	4,486.9				4,462.0	4,459.2	4,457.0	4,457.4	4,453.9	4,457.4	4,458.4	
Aug 17	4,493.8					4,459.9	4,458.0	4,458.1	4,462.3	4,462.5	4,462.6	4,493.8
	4,486.9					4,458.3	4,456.5	4,456.7	4,455.6	4,457.0	4,459.5	
Sep 7	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8
	4,486.9	4,467.2	4,447.5	4,449.2	4,453.1	4,452.5	4,455.5	4,454.1	4,462.3	4,459.8	4,454.3	
Sep 28	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2
	4,486.9	4,467.2	4,447.9	4,455.6	4,457.6	4,452.6	4,453.9	4,450.3	4,454.7	4,453.7	4,451.3	
Oct 15	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5
	4,486.9	4,467.2	4,447.5	4,437.7	4,444.5	4,444.3	4,442.8	4,442.9	4,434.4	4,448.3	4,444.7	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 2b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment - "Present Day" (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15	6,360	36,850	146,340	146,370	78,070	49,730	41,560	25,330	102,570	211,940	144,550	**989,670**
Jun 7	6,550	37,360	137,880	123,030	69,670	44,920	31,660	19,290	98,500	183,910	121,700	**874,470**
Jun 22	680	14,250	60,560	65,610	33,770	21,440	11,360	8,460	62,350	106,670	64,600	**449,750**
Jul 7	5,290	260	7,080	17,270	11,400	9,880	9,070	3,920	41,790	73,470	35,510	**214,940**
Jul 20	360			10,500	8,820	6,850	2,910	1,620	31,840	52,010	28,880	**143,790**
Aug 7	270				4,140	2,840	1,480	910	16,620	24,570	12,860	**63,690**
Aug 17	1,800					1,150	790	440	11,480	18,180	7,070	**40,910**
Sep 7	1,330	19,450	107,910	121,300	57,920	35,990	22,140	13,500	55,500	113,110	91,330	**639,480**
Sep 28	470	14,660	94,470	104,370	48,220	33,020	21,330	13,670	63,440	124,240	91,240	**609,130**
Oct 15	300	13,410	90,710	111,130	60,410	36,280	26,110	15,500	83,320	139,070	102,700	**678,940**

Table 3a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment – Alternative 3x (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1
	4,486.9	4,467.2	4,447.5	4,449.2	4,444.3	4,427.9	4,408.2	4,409.1	4,441.0	4,436.6	4,434.8	
June 7	4,500.3	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2
	4,486.9	4,467.2	4,465.6	4,461.6	4,453.0	4,450.8	4,445.6	4,444.3	4,444.6	4,445.9	4,448.2	
Jun 22	4,491.0	4,490.6	4,487.7	4,484.1	4,482.9	4,481.0	4,476.1	4,477.5	4,484.2	4,481.4	4,482.7	4,500.0
	4,486.9	4,475.1	4,472.4	4,462.3	4,458.1	4,454.5	4,455.0	4,450.3	4,447.5	4,448.5	4,454.1	
July 7	4,498.9	4,468.7	4,473.1	4,472.2	4,469.9	4,470.8	4,467.6	4,464.7	4,475.5	4,475.2	4,473.4	4,499.4
	4,486.9	4,467.2	4,469.8	4,466.1	4,461.1	4,456.6	4,449.9	4,451.2	4,450.5	4,451.8	4,456.1	
Jul 20	4,489.7			4,469.2	4,466.8	4,464.3	4,460.5	4,462.0	4,468.8	4,468.2	4,468.0	4,497.1
	4,486.9			4,465.6	4,460.4	4,454.1	4,454.9	4,456.3	4,450.5	4,451.4	4,453.8	
Aug 7	4,489.3				4,460.9	4,458.7	4,457.2	4,458.3	4,460.1	4,460.7	4,460.5	4,496.1
	4,486.9				4,458.5	4,454.7	4,454.1	4,455.1	4,450.7	4,452.9	4,454.7	
Aug 17	4,493.8								4,456.8	4,457.1	4,458.4	4,493.8
	4,486.9								4,451.3	4,452.5	4,455.7	
Sep 7	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8
	4,486.9	4,467.2	4,447.5	4,437.7	4,445.8	4,447.2	4,449.4	4,450.5	4,456.2	4,452.8	4,449.2	
Sep 28	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2
	4,486.9	4,467.2	4,447.5	4,446.9	4,451.3	4,449.1	4,447.5	4,445.3	4,448.8	4,448.8	4,447.9	
Oct 15	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4
	4,486.9	4,467.2	4,447.5	4,437.7	4,427.9	4,435.7	4,441.3	4,440.5	4,434.4	4,442.3	4,438.9	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 3b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment - Alternative 3x (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15	6,360	36,850	146,340	146,370	78,070	49,730	41,560	25,330	102,010	211,940	144,550	**989,110**
Jun 7	6,550	37,360	140,230	124,790	70,390	45,370	31,960	19,510	98,890	185,270	123,030	**883,350**
Jun 22	650	14,270	62,440	67,980	35,960	22,220	12,000	8,990	63,900	110,340	66,850	**465,600**
Jul 7	5,260	40	7,800	18,280	12,350	11,300	9,690	4,300	43,330	78,340	40,080	**230,770**
Jul 20	360			10,820	8,860	7,270	3,100	1,830	31,430	55,770	32,330	**151,770**
Aug 7	260				3,220	2,620	1,650	1,000	15,980	25,670	13,010	**63,410**
Aug 17	1,800								9,190	15,430	6,070	**32,490**
Sep 7	1,300	19,350	107,660	122,360	64,970	38,680	25,250	14,600	65,830	136,200	102,140	**698,340**
Sep 28	460	14,570	94,210	112,890	55,540	34,920	24,440	15,110	73,190	139,900	98,220	**663,450**
Oct 15	290	13,320	90,430	110,940	63,090	37,640	26,700	16,110	83,210	157,790	112,560	**712,080**

Table 4a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1
	4,486.9	4,467.2	4,447.5	4,449.2	4,444.3	4,427.9	4,408.2	4,409.1	4,441.0	4,436.6	4,434.8	
June 7	4,500.3	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2
	4,486.9	4,467.2	4,466.1	4,461.9	4,453.0	4,450.8	4,445.6	4,444.3	4,444.6	4,445.9	4,448.2	
Jun 22	4,491.0	4,490.6	4,487.7	4,484.1	4,482.9	4,481.0	4,476.1	4,477.5	4,484.1	4,481.4	4,482.7	4,500.0
	4,486.9	4,475.1	4,472.4	4,462.5	4,458.5	4,454.9	4,455.5	4,450.4	4,447.9	4,448.8	4,454.1	
July 7	4,498.9	4,469.1	4,473.1	4,472.2	4,469.9	4,470.9	4,467.3	4,464.3	4,475.6	4,475.3	4,473.4	4,499.4
	4,486.9	4,467.2	4,469.9	4,466.1	4,461.1	4,456.6	4,450.0	4,451.5	4,451.0	4,452.3	4,456.3	
Jul 20	4,489.7			4,469.2	4,466.9	4,464.2	4,460.6	4,462.0	4,469.0	4,468.3	4,467.9	4,497.1
	4,486.9			4,465.6	4,460.4	4,454.1	4,455.3	4,456.5	4,451.1	4,452.1	4,454.1	
Aug 7	4,489.3				4,461.3	4,459.6	4,457.3	4,458.4	4,460.3	4,461.2	4,461.0	4,496.1
	4,486.9				4,458.6	4,455.5	4,454.4	4,455.0	4,451.6	4,453.9	4,455.3	
Aug 17	4,493.8					4,456.2	4,455.2		4,458.1	4,458.0	4,458.9	4,493.8
	4,486.9					4,454.7	4,454.1		4,452.8	4,453.2	4,455.9	
Sep 7	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8
	4,486.9	4,467.2	4,447.5	4,440.3	4,448.1	4,448.9	4,450.8	4,451.1	4,458.5	4,454.6	4,450.3	
Sep 28	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2
	4,486.9	4,467.2	4,447.5	4,450.2	4,452.9	4,449.6	4,449.5	4,446.5	4,450.4	4,450.5	4,448.9	
Oct 15	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5
	4,486.9	4,467.2	4,447.5	4,437.7	4,433.9	4,439.7	4,440.9	4,440.2	4,434.4	4,444.7	4,440.7	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 4b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15	6,360	36,850	146,340	146,370	78,070	49,730	41,560	25,330	102,010	211,940	144,550	**989,110**
Jun 7	6,550	37,360	139,430	124,040	70,390	45,370	31,960	19,510	98,890	185,270	123,030	**881,800**
Jun 22	650	14,330	62,440	67,430	35,500	21,980	11,740	8,930	63,270	109,390	66,850	**462,510**
Jul 7	5,260	60	7,750	18,390	12,440	11,390	9,430	4,060	42,520	76,960	39,480	**227,740**
Jul 20	360			10,820	9,000	7,190	2,930	1,750	30,750	54,070	31,530	**148,400**
Aug 7	260				3,630	2,780	1,570	1,080	14,800	24,180	12,850	**61,150**
Aug 17	1,800					960	570		9,080	15,880	6,740	**35,030**
Sep 7	1,320	19,430	107,880	122,470	63,060	37,950	24,560	14,400	61,950	130,420	99,810	**683,250**
Sep 28	470	14,640	94,430	111,490	54,000	34,700	23,520	14,800	70,650	134,720	96,330	**649,750**
Oct 15	300	13,390	90,640	111,100	63,110	37,410	26,890	16,210	83,300	150,530	109,800	**702,680**

Table 5a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment – Alternative 4c (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1
	4,486.9	4,467.2	4,447.5	4,449.2	4,444.3	4,427.9	4,408.2	4,409.1	4,440.2	4,436.6	4,434.8	
June 7	4,500.3	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2
	4,486.9	4,467.2	4,467.2	4,462.3	4,453.6	4,451.6	4,446.2	4,445.1	4,444.9	4,446.3	4,448.8	
Jun 22	4,491.1	4,490.7	4,487.9	4,484.3	4,483.1	4,481.2	4,476.3	4,477.5	4,484.2	4,481.6	4,482.9	4,500.0
	4,486.9	4,475.8	4,473.3	4,463.3	4,460.0	4,456.2	4,456.4	4,451.9	4,448.6	4,449.9	4,455.3	
July 7	4,498.9	4,470.7	4,474.1	4,472.8	4,471.0	4,471.8	4,468.1	4,465.3	4,476.3	4,476.2	4,474.1	4,499.4
	4,486.9	4,468.5	4,471.7	4,467.2	4,463.0	4,460.0	4,451.6	4,452.9	4,452.1	4,454.1	4,459.0	
Jul 20	4,489.7			4,470.1	4,468.5	4,465.8	4,462.3	4,463.2	4,470.9	4,469.7	4,469.2	4,497.1
	4,486.9			4,466.6	4,462.4	4,456.7	4,456.9	4,458.0	4,452.5	4,453.8	4,456.4	
Aug 7	4,489.3				4,463.6	4,461.8	4,458.9	4,459.5	4,462.4	4,463.4	4,463.1	4,496.1
	4,486.9				4,461.0	4,457.9	4,456.3	4,456.8	4,452.9	4,455.9	4,457.4	
Aug 17	4,493.8					4,458.4	4,457.0	4,457.4	4,460.6	4,460.4	4,461.2	4,493.8
	4,486.9					4,456.8	4,455.8	4,456.3	4,454.4	4,455.3	4,458.3	
Sep 7	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8
	4,486.9	4,467.2	4,447.5	4,444.9	4,450.6	4,450.4	4,453.3	4,452.8	4,460.5	4,457.1	4,452.4	
Sep 28	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2
	4,486.9	4,467.2	4,447.5	4,454.7	4,455.7	4,451.6	4,451.6	4,448.8	4,452.6	4,452.8	4,450.3	
Oct 15	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4
	4,486.9	4,467.2	4,447.5	4,437.7	4,434.4	4,441.5	4,441.8	4,440.7	4,434.4	4,445.8	4,442.4	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 5b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment – Alternative 4c (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15	6,360	36,850	146,340	146,370	78,070	49,730	41,560	25,330	102,570	211,940	144,550	**989,670**
Jun 7	6,550	37,360	137,880	123,030	69,670	44,920	31,660	19,290	98,500	183,910	121,700	**874,470**
Jun 22	680	14,250	60,560	65,610	33,770	21,440	11,360	8,460	62,350	106,670	64,600	**449,750**
Jul 7	5,290	200	6,640	16,960	11,480	9,760	9,070	3,960	42,090	74,300	35,200	**214,950**
Jul 20	360			10,550	8,570	6,840	3,000	1,650	31,720	52,920	29,430	**145,040**
Aug 7	260				3,680	2,770	1,400	870	16,160	24,940	13,030	**63,110**
Aug 17	1,800					1,070	610	340	10,640	17,040	6,740	**38,240**
Sep 7	1,310	19,350	107,680	122,160	60,560	37,110	23,280	13,890	58,560	121,960	95,320	**661,180**
Sep 28	460	14,580	94,240	105,650	50,610	33,530	22,480	14,090	66,880	127,090	93,350	**622,960**
Oct 15	290	13,330	90,460	110,960	63,040	37,010	26,500	16,060	83,220	147,030	106,930	**694,830**

Table 6a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2
	4,486.9	4,467.2	4,447.5	4,449.2	4,444.3	4,427.9	4,408.2	4,408.2	4,439.9	4,436.2	4,486.9	
June 7	4,500.4	4,500.3	4,500.3	4,500.3	4,500.3	4,500.3	4,500.3	4,500.3	4,500.3	4,500.3	4,500.4	4,500.3
	4,486.9	4,467.2	4,467.2	4,462.3	4,453.6	4,451.6	4,446.2	4,444.3	4,444.8	4,446.3	4,486.9	
Jun 22	4,493.9	4,493.3	4,493.4	4,493.1	4,494.5	4,497.2	4,497.4	4,494.1	4,495.2	4,494.6	4,493.9	4,500.1
	4,486.9	4,476.2	4,473.4	4,463.6	4,460.3	4,456.2	4,456.4	4,451.9	4,448.6	4,450.0	4,486.9	
July 7	4,499.5	4,497.7	4,496.7	4,497.3	4,497.7	4,494.8	4,497.4	4,498.4	4,480.0	4,481.2	4,499.5	4,499.5
	4,486.9	4,469.2	4,472.4	4,467.7	4,463.3	4,460.0	4,451.6	4,453.0	4,452.8	4,454.8	4,486.9	
Jul 20	4,495.1		4,478.4	4,474.9	4,472.3	4,470.3	4,480.3	4,470.5	4,480.3	4,475.4	4,495.1	4,497.2
	4,486.9		4,476.1	4,467.2	4,462.9	4,457.7	4,457.4	4,458.5	4,453.3	4,454.9	4,486.9	
Aug 7	4,489.9			4,470.2	4,467.8	4,465.3	4,461.7	4,462.4	4,466.4	4,467.3	4,489.9	4,496.2
	4,486.9			4,467.5	4,462.3	4,459.6	4,457.2	4,457.6	4,454.1	4,457.6	4,486.9	
Aug 17	4,493.9				4,464.1	4,462.5	4,460.0	4,459.8	4,465.8	4,465.5	4,493.9	4,493.9
	4,486.9				4,461.0	4,458.7	4,456.7	4,456.7	4,455.6	4,457.2	4,486.9	
Sep 7	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9
	4,486.9	4,467.2	4,447.5	4,449.9	4,453.9	4,453.0	4,456.2	4,454.4	4,462.8	4,460.1	4,486.9	
Sep 28	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3
	4,486.9	4,467.2	4,449.0	4,455.9	4,458.4	4,452.9	4,454.4	4,450.8	4,455.4	4,453.8	4,486.9	
Oct 15	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6
	4,486.9	4,467.2	4,447.5	4,437.7	4,445.3	4,445.3	4,444.4	4,443.2	4,434.4	4,448.9	4,486.9	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 6b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15	6,450	37,120	146,860	146,710	78,230	49,840	41,620	25,390	102,950	213,250	145,130	**993,550**
Jun 7	6,640	37,620	138,400	123,370	69,830	45,030	31,730	19,560	98,780	184,260	121,290	**876,510**
Jun 22	1,860	19,130	88,350	94,810	51,710	38,670	24,650	14,670	83,050	151,910	100,690	**669,500**
Jul 7	5,800	30,340	108,990	97,360	53,000	33,200	27,160	16,050	47,570	88,990	75,950	**584,410**
Jul 20	2,430		8,800	23,730	13,590	10,060	13,300	3,980	47,470	68,680	36,490	**228,530**
Aug 7	390			8,130	7,760	4,410	2,490	1,520	21,150	32,080	19,190	**97,120**
Aug 17	1,850				4,180	2,810	1,800	970	17,470	27,740	12,220	**69,040**
Sep 7	1,380	19,680	108,490	121,070	57,270	35,750	21,860	13,460	54,910	112,630	90,100	**636,600**
Sep 28	500	14,840	95,010	104,170	47,480	32,980	21,120	13,540	62,550	124,090	91,100	**607,380**
Oct 15	330	13,600	91,300	111,520	60,080	36,020	25,510	15,470	83,530	137,580	101,220	**676,160**

Table 7a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment – "Present Day" (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1
	4,486.9	4,467.2	4,447.5	4,449.2	4,444.3	4,427.9	4,408.2	4,409.1	4,440.2	4,436.6	4,486.9	
June 7	4,500.3	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.3	4,500.2
	4,486.9	4,467.2	4,467.2	4,462.3	4,453.6	4,451.6	4,446.2	4,445.1	4,444.9	4,446.3	4,486.9	
Jun 22	4,493.1	4,493.1	4,493.1	4,492.5	4,493.9	4,497.1	4,497.3	4,490.9	4,494.1	4,493.8	4,493.1	4,500.0
	4,486.9	4,475.8	4,473.3	4,463.3	4,460.0	4,456.2	4,456.4	4,451.9	4,448.6	4,449.9	4,486.9	
July 7	4,499.4	4,497.5	4,496.5	4,497.2	4,497.6	4,494.6	4,497.3	4,498.2	4,479.9	4,480.9	4,499.4	4,499.4
	4,486.9	4,468.7	4,471.9	4,467.2	4,463.2	4,460.0	4,451.6	4,453.0	4,452.5	4,454.5	4,486.9	
Jul 20	4,495.2		4,478.1	4,474.5	4,472.0	4,470.1	4,478.1	4,467.2	4,480.0	4,475.0	4,495.2	4,497.1
	4,486.9		4,475.9	4,467.0	4,462.7	4,457.4	4,457.4	4,458.3	4,453.1	4,454.7	4,486.9	
Aug 7	4,489.9			4,469.9	4,467.3	4,464.9	4,461.3	4,462.1	4,466.1	4,466.9	4,489.9	4,496.1
	4,486.9			4,467.5	4,462.0	4,459.2	4,457.0	4,457.4	4,453.9	4,457.4	4,486.9	
Aug 17	4,493.8				4,463.7	4,462.1	4,459.8	4,459.7	4,465.4	4,465.0	4,493.8	4,493.8
	4,486.9				4,460.9	4,458.3	4,456.5	4,456.7	4,455.6	4,457.0	4,486.9	
Sep 7	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8
	4,486.9	4,467.2	4,447.5	4,449.2	4,453.1	4,452.5	4,455.5	4,454.1	4,462.3	4,459.8	4,486.9	
Sep 28	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2
	4,486.9	4,467.2	4,447.9	4,455.6	4,457.6	4,452.6	4,453.9	4,450.3	4,454.7	4,453.7	4,486.9	
Oct 15	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5
	4,486.9	4,467.2	4,447.5	4,437.7	4,444.5	4,444.3	4,442.8	4,442.9	4,434.4	4,448.3	4,486.9	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 7b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment - "Present Day" (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15	6,360	36,850	146,340	146,370	78,070	49,730	41,560	25,330	102,570	211,940	144,550	**989,670**
Jun 7	6,550	37,360	137,880	123,030	69,670	44,920	31,660	19,290	98,500	183,910	121,700	**874,470**
Jun 22	1,480	18,900	86,840	93,290	51,190	38,520	24,580	13,440	80,920	149,200	100,790	**659,150**
Jul 7	5,700	30,060	108,950	98,490	52,880	33,020	27,070	15,970	48,000	89,060	76,150	**585,350**
Jul 20	2,480		8,310	23,060	13,340	10,100	11,970	2,890	47,080	68,090	36,610	**223,930**
Aug 7	400			7,320	7,410	4,340	2,410	1,520	20,850	31,620	19,170	**95,040**
Aug 17	1,800				3,900	2,750	1,780	950	16,890	26,750	11,770	**66,590**
Sep 7	1,330	19,450	107,910	121,300	57,920	35,990	22,140	13,500	55,500	113,110	91,330	**639,480**
Sep 28	470	14,660	94,470	104,370	48,220	33,020	21,330	13,670	63,440	124,240	91,240	**609,130**
Oct 15	300	13,410	90,710	111,130	60,410	36,280	26,110	15,500	83,320	139,070	102,700	**678,940**

Table 8a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment – Alternative 3x (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1
	4,486.9	4,467.2	4,447.5	4,449.2	4,444.3	4,427.9	4,408.2	4,409.1	4,441.0	4,436.6	4,434.8	
June 7	4,500.3	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2
	4,486.9	4,467.2	4,465.6	4,461.6	4,453.0	4,450.8	4,445.6	4,444.3	4,444.6	4,445.9	4,448.2	
Jun 22	4,493.1	4,493.1	4,492.9	4,491.8	4,493.7	4,497.1	4,497.2	4,489.6	4,494.1	4,493.5	4,497.5	4,500.0
	4,486.9	4,475.1	4,472.4	4,462.3	4,458.1	4,454.5	4,455.0	4,450.3	4,447.5	4,448.5	4,454.1	
July 7	4,499.4	4,497.4	4,495.6	4,496.9	4,497.2	4,493.5	4,497.0	4,497.9	4,479.3	4,480.0	4,488.0	4,499.4
	4,486.9	4,467.2	4,469.8	4,466.1	4,461.1	4,456.6	4,449.9	4,451.2	4,450.5	4,451.8	4,456.1	
Jul 20	4,495.1		4,476.6	4,473.2	4,470.0	4,468.7	4,471.5	4,466.3	4,478.2	4,473.2	4,471.5	4,497.1
	4,486.9		4,474.4	4,465.6	4,460.4	4,454.1	4,454.9	4,456.3	4,450.5	4,451.4	4,453.8	
Aug 7	4,489.9			4,467.5	4,463.7	4,461.1	4,459.1	4,460.4	4,463.0	4,463.3	4,463.7	4,496.1
	4,486.9			4,465.4	4,458.5	4,454.7	4,454.1	4,455.1	4,450.7	4,452.9	4,454.7	
Aug 17	4,493.8				4,459.6	4,457.8	4,456.3	4,456.8	4,459.9	4,460.1	4,460.5	4,493.8
	4,486.9				4,457.9	4,454.7	4,453.5	4,454.3	4,451.3	4,452.5	4,455.7	
Sep 7	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8
	4,486.9	4,467.2	4,447.5	4,437.7	4,445.8	4,447.2	4,449.4	4,450.5	4,456.2	4,452.8	4,449.2	
Sep 28	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2
	4,486.9	4,467.2	4,447.5	4,446.9	4,451.3	4,449.1	4,447.5	4,445.3	4,448.8	4,448.8	4,447.9	
Oct 15	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4
	4,486.9	4,467.2	4,447.5	4,437.7	4,427.9	4,435.7	4,441.3	4,440.5	4,434.4	4,442.3	4,438.9	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 8b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment - Alternative 3x (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15	6,360	36,850	146,340	146,370	78,070	49,730	41,560	25,330	102,010	211,940	144,550	**989,110**
Jun 7	6,550	37,360	140,230	124,790	70,390	45,370	31,960	19,510	98,890	185,270	123,030	**883,350**
Jun 22	1,450	19,020	88,840	93,960	53,310	39,560	25,260	13,450	82,590	152,620	103,450	**673,510**
Jul 7	5,700	29,780	108,350	100,560	55,190	34,130	27,780	16,410	50,180	94,580	75,350	**598,010**
Jul 20	2,410		7,470	23,270	13,460	10,940	9,350	3,240	48,200	72,790	40,570	**231,700**
Aug 7	390			6,370	7,120	4,370	2,690	1,690	20,900	34,420	20,400	**98,350**
Aug 17	1,800				2,260	2,000	1,440	790	14,610	25,210	10,860	**58,970**
Sep 7	1,300	19,350	107,660	122,360	64,970	38,680	25,250	14,600	65,830	136,200	102,140	**698,340**
Sep 28	460	14,570	94,210	112,890	55,540	34,920	24,440	15,110	73,190	139,900	98,220	**663,450**
Oct 15	290	13,320	90,430	110,940	63,090	37,640	26,700	16,110	83,210	157,790	112,560	**712,080**

Table 9a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1
	4,486.9	4,467.2	4,447.5	4,449.2	4,444.3	4,427.9	4,408.2	4,409.1	4,441.0	4,436.6	4,434.8	
June 7	4,500.3	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2
	4,486.9	4,467.2	4,466.1	4,461.9	4,453.0	4,450.8	4,445.6	4,444.3	4,444.6	4,445.9	4,448.2	
Jun 22	4,493.1	4,493.1	4,492.9	4,491.8	4,493.7	4,497.1	4,497.2	4,489.6	4,493.9	4,493.5	4,497.5	4,500.0
	4,486.9	4,475.1	4,472.4	4,462.5	4,458.5	4,454.9	4,455.5	4,450.4	4,447.9	4,448.8	4,454.1	
July 7	4,499.4	4,497.4	4,495.6	4,496.9	4,497.2	4,493.5	4,497.0	4,497.9	4,479.3	4,480.0	4,488.0	4,499.4
	4,486.9	4,467.2	4,469.9	4,466.1	4,461.1	4,456.6	4,450.0	4,451.5	4,451.0	4,452.3	4,456.3	
Jul 20	4,495.1		4,476.6	4,473.2	4,470.0	4,468.5	4,471.7	4,465.8	4,478.4	4,473.2	4,471.3	4,497.1
	4,486.9		4,474.4	4,465.6	4,460.4	4,454.1	4,455.3	4,456.5	4,451.1	4,452.1	4,454.1	
Aug 7	4,489.9			4,467.5	4,464.1	4,461.8	4,459.1	4,460.4	4,463.0	4,463.6	4,464.0	4,496.1
	4,486.9			4,465.4	4,458.6	4,455.5	4,454.4	4,455.0	4,451.6	4,453.9	4,455.3	
Aug 17	4,493.8				4,460.1	4,458.3	4,456.8	4,457.1	4,461.0	4,460.6	4,460.9	4,493.8
	4,486.9				4,457.9	4,454.7	4,454.1	4,454.7	4,452.8	4,453.2	4,455.9	
Sep 7	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8
	4,486.9	4,467.2	4,447.5	4,440.3	4,448.1	4,448.9	4,450.8	4,451.1	4,458.5	4,454.6	4,450.3	
Sep 28	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2
	4,486.9	4,467.2	4,447.5	4,450.2	4,452.9	4,449.6	4,449.5	4,446.5	4,450.4	4,450.5	4,448.9	
Oct 15	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5
	4,486.9	4,467.2	4,447.5	4,437.7	4,433.9	4,439.7	4,440.9	4,440.2	4,434.4	4,444.7	4,440.7	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 9b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15	6,360	36,850	146,340	146,370	78,070	49,730	41,560	25,330	102,010	211,940	144,550	**989,110**
Jun 7	6,550	37,360	139,430	124,040	70,390	45,370	31,960	19,510	98,890	185,270	123,030	**881,800**
Jun 22	1,450	19,020	88,840	93,410	52,850	39,320	25,020	13,420	81,700	151,670	103,450	**670,150**
Jul 7	5,700	29,780	108,200	100,560	55,240	34,130	27,720	16,300	49,370	92,980	74,830	**594,810**
Jul 20	2,410		7,350	23,170	13,550	10,800	9,290	3,030	47,530	70,660	39,380	**227,170**
Aug 7	390			6,370	7,420	4,450	2,570	1,710	19,430	32,290	19,720	**94,350**
Aug 17	1,800				2,830	2,340	1,450	750	13,900	24,370	11,310	**58,750**
Sep 7	1,320	19,430	107,880	122,470	63,060	37,950	24,560	14,400	61,950	130,420	99,810	**683,250**
Sep 28	470	14,640	94,430	111,490	54,000	34,700	23,520	14,800	70,650	134,720	96,330	**649,750**
Oct 15	300	13,390	90,640	111,100	63,110	37,410	26,890	16,210	83,300	150,530	109,800	**702,680**

Table 10a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment – Alternative 4c (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1
	4,486.9	4,467.2	4,447.5	4,449.2	4,444.3	4,427.9	4,408.2	4,409.1	4,440.2	4,436.6	4,434.8	
June 7	4,500.3	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2
	4,486.9	4,467.2	4,467.2	4,462.3	4,453.6	4,451.6	4,446.2	4,445.1	4,444.9	4,446.3	4,448.8	
Jun 22	4,493.1	4,493.1	4,493.1	4,492.5	4,493.9	4,497.1	4,497.3	4,490.9	4,494.1	4,493.8	4,497.5	4,500.0
	4,486.9	4,475.8	4,473.3	4,463.3	4,460.0	4,456.2	4,456.4	4,451.9	4,448.6	4,449.9	4,455.3	
July 7	4,499.4	4,497.5	4,496.5	4,497.2	4,497.6	4,494.5	4,497.3	4,498.2	4,479.8	4,480.8	4,491.0	4,499.4
	4,486.9	4,468.5	4,471.7	4,467.2	4,463.0	4,460.0	4,451.6	4,452.9	4,452.1	4,454.1	4,459.0	
Jul 20	4,495.1		4,477.7	4,473.9	4,471.4	4,469.8	4,476.4	4,467.2	4,479.5	4,474.3	4,472.5	4,497.1
	4,486.9		4,475.6	4,466.6	4,462.4	4,456.7	4,456.9	4,458.0	4,452.5	4,453.8	4,456.4	
Aug 7	4,489.9			4,469.1	4,466.1	4,463.7	4,460.5	4,461.4	4,464.9	4,465.7	4,465.9	4,496.1
	4,486.9			4,466.6	4,461.0	4,457.9	4,456.3	4,456.8	4,452.9	4,455.9	4,457.4	
Aug 17	4,493.8				4,462.6	4,460.2	4,459.0	4,459.2	4,463.8	4,463.1	4,463.2	4,493.8
	4,486.9				4,459.9	4,456.8	4,455.8	4,456.3	4,454.4	4,455.3	4,458.3	
Sep 7	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8
	4,486.9	4,467.2	4,447.5	4,444.9	4,450.6	4,450.4	4,453.3	4,452.8	4,460.5	4,457.1	4,452.4	
Sep 28	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2
	4,486.9	4,467.2	4,447.5	4,454.7	4,455.7	4,451.6	4,451.6	4,448.8	4,452.6	4,452.8	4,450.3	
Oct 15	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4
	4,486.9	4,467.2	4,447.5	4,437.7	4,434.4	4,441.5	4,441.8	4,440.7	4,434.4	4,445.8	4,442.4	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 10b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment – Alternative 4c (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15	6,360	36,850	146,340	146,370	78,070	49,730	41,560	25,330	102,570	211,940	144,550	**989,670**
Jun 7	6,550	37,360	137,880	123,030	69,670	44,920	31,660	19,290	98,500	183,910	121,700	**874,470**
Jun 22	1,480	18,900	86,840	93,290	51,190	38,520	24,580	13,440	80,920	149,200	100,790	**659,150**
Jul 7	5,700	30,060	109,300	98,380	53,240	32,870	27,070	16,010	48,430	89,890	76,150	**587,100**
Jul 20	2,450		7,820	22,250	12,790	10,310	11,190	3,010	47,340	68,540	37,230	**222,930**
Aug 7	390			7,510	7,170	4,270	2,310	1,490	20,550	32,850	19,630	**96,170**
Aug 17	1,800				3,620	2,390	1,720	920	16,080	26,000	11,180	**63,710**
Sep 7	1,310	19,350	107,680	122,160	60,560	37,110	23,280	13,890	58,560	121,960	95,320	**661,180**
Sep 28	460	14,580	94,240	105,650	50,610	33,530	22,480	14,090	66,880	127,090	93,350	**622,960**
Oct 15	290	13,330	90,460	110,960	63,040	37,010	26,500	16,060	83,220	147,030	106,930	**694,830**

Table 11a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2
	4,486.9	4,467.2	4,447.5	4,449.2	4,444.3	4,427.9	4,408.2	4,408.2	4,439.9	4,436.2	4,434.4	
June 7	4,500.4	4,500.3	4,500.3	4,500.3	4,500.3	4,500.3	4,500.3	4,500.3	4,500.3	4,500.3	4,500.3	4,500.3
	4,486.9	4,467.2	4,467.2	4,462.3	4,453.6	4,451.6	4,446.2	4,444.3	4,444.8	4,446.3	4,449.2	
Jun 22	4,499.6	4,498.6	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,499.9	4,500.1	4,500.1	4,500.1	4,500.1
	4,486.9	4,476.2	4,473.4	4,463.6	4,460.3	4,456.2	4,456.4	4,451.9	4,448.6	4,450.0	4,455.5	
July 7	4,499.5	4,499.5	4,499.5	4,499.5	4,499.5	4,499.5	4,499.5	4,499.5	4,499.3	4,499.5	4,499.5	4,499.5
	4,486.9	4,469.2	4,472.4	4,467.7	4,463.3	4,460.0	4,451.6	4,453.0	4,452.8	4,454.8	4,459.2	
Jul 20	4,497.2	4,493.5	4,495.0	4,496.2	4,497.0	4,497.2	4,497.2	4,497.2	4,494.4	4,494.5	4,495.8	4,497.2
	4,486.9	4,482.4	4,476.1	4,467.2	4,462.9	4,457.7	4,457.4	4,458.5	4,453.3	4,454.9	4,457.4	
Aug 7	4,495.2		4,476.1	4,473.5	4,470.4	4,467.5	4,463.6	4,464.5	4,469.6	4,470.1	4,470.3	4,496.2
	4,486.9		4,474.9	4,467.5	4,462.3	4,459.6	4,457.2	4,457.6	4,454.1	4,457.6	4,458.6	
Aug 17	4,493.9	4,493.2	4,493.1	4,491.5	4,490.8	4,490.2	4,490.7	4,487.4	4,475.4	4,477.1	4,483.6	4,493.9
	4,486.9	4,470.2	4,471.6	4,466.1	4,461.0	4,458.7	4,456.7	4,456.7	4,455.6	4,457.2	4,459.7	
Sep 7	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9	4,492.9
	4,486.9	4,467.2	4,447.5	4,449.9	4,453.9	4,453.0	4,456.2	4,454.4	4,462.8	4,460.1	4,455.0	
Sep 28	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3	4,490.3
	4,486.9	4,467.2	4,449.0	4,455.9	4,458.4	4,452.9	4,454.4	4,450.8	4,455.4	4,453.8	4,451.5	
Oct 15	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6	4,489.6
	4,486.9	4,467.2	4,447.5	4,437.7	4,445.3	4,445.3	4,444.4	4,443.2	4,434.4	4,448.9	4,445.7	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 11b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15	6,450	37,120	146,860	146,710	78,230	49,840	41,620	25,390	102,950	213,250	145,130	**993,550**
Jun 7	6,640	37,620	138,400	123,370	69,830	45,030	31,730	19,560	98,780	184,260	121,290	**876,510**
Jun 22	5,930	31,460	124,040	118,980	61,120	42,020	26,460	17,130	92,880	171,630	107,000	**798,650**
Jul 7	5,800	35,090	123,540	104,990	55,960	38,590	28,520	16,560	84,430	153,440	96,940	**743,860**
Jul 20	3,950	16,140	88,180	95,090	52,500	37,590	23,980	13,870	73,860	135,340	91,900	**632,400**
Aug 7	2,530		4,110	18,470	11,580	6,280	3,580	2,210	26,700	41,610	27,100	**144,170**
Aug 17	1,850	19,970	91,820	81,990	44,790	29,050	20,120	10,590	34,600	66,960	56,430	**458,170**
Sep 7	1,380	19,680	108,490	121,070	57,270	35,750	21,860	13,460	54,910	112,630	90,100	**636,600**
Sep 28	500	14,840	95,010	104,170	47,480	32,980	21,120	13,540	62,550	124,090	91,100	**607,380**
Oct 15	330	13,600	91,300	111,520	60,080	36,020	25,510	15,470	83,530	137,580	101,220	**676,160**

Table 12a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment – “Present Day” (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1
	4,486.9	4,467.2	4,447.5	4,449.2	4,444.3	4,427.9	4,408.2	4,409.1	4,440.2	4,436.6	4,434.8	
June 7	4,500.3	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2
	4,486.9	4,467.2	4,467.2	4,462.3	4,453.6	4,451.6	4,446.2	4,445.1	4,444.9	4,446.3	4,448.8	
Jun 22	4,499.9	4,498.5	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0
	4,486.9	4,475.8	4,473.3	4,463.3	4,460.0	4,456.2	4,456.4	4,451.9	4,448.6	4,449.9	4,455.3	
July 7	4,499.4	4,499.4	4,499.4	4,499.4	4,499.4	4,499.4	4,499.4	4,499.4	4,499.0	4,499.4	4,499.4	4,499.4
	4,486.9	4,468.7	4,471.9	4,467.2	4,463.2	4,460.0	4,451.6	4,453.0	4,452.5	4,454.5	4,459.0	
Jul 20	4,497.1	4,493.2	4,494.8	4,495.9	4,496.7	4,497.1	4,497.1	4,497.1	4,494.3	4,494.4	4,495.6	4,497.1
	4,486.9	4,482.0	4,475.9	4,467.0	4,462.7	4,457.4	4,457.4	4,458.3	4,453.1	4,454.7	4,457.1	
Aug 7	4,495.3		4,475.8	4,473.2	4,470.1	4,467.0	4,463.4	4,464.2	4,469.2	4,469.7	4,470.2	4,496.1
	4,486.9		4,474.3	4,467.5	4,462.0	4,459.2	4,457.0	4,457.4	4,453.9	4,457.4	4,458.4	
Aug 17	4,493.8	4,492.9	4,492.7	4,491.1	4,490.6	4,489.8	4,490.4	4,486.9	4,473.8	4,473.8	4,482.5	4,493.8
	4,486.9	4,469.9	4,470.7	4,465.9	4,460.9	4,458.3	4,456.5	4,456.7	4,455.6	4,457.0	4,459.5	
Sep 7	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8
	4,486.9	4,467.2	4,447.5	4,449.2	4,453.1	4,452.5	4,455.5	4,454.1	4,462.3	4,459.8	4,454.3	
Sep 28	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2
	4,486.9	4,467.2	4,447.9	4,455.6	4,457.6	4,452.6	4,453.9	4,450.3	4,454.7	4,453.7	4,451.3	
Oct 15	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5
	4,486.9	4,467.2	4,447.5	4,437.7	4,444.5	4,444.3	4,442.8	4,442.9	4,434.4	4,448.3	4,444.7	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 12b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment - “Present Day” (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15	6,360	36,850	146,340	146,370	78,070	49,730	41,560	25,330	102,570	211,940	144,550	**989,670**
Jun 7	6,550	37,360	137,880	123,030	69,670	44,920	31,660	19,290	98,500	183,910	121,700	**874,470**
Jun 22	6,170	31,180	123,680	119,340	61,340	41,900	26,390	17,170	92,670	171,680	107,180	**798,700**
Jul 7	5,700	34,830	124,150	105,990	55,880	38,470	28,450	16,520	84,360	154,020	97,200	**745,570**
Jul 20	3,870	15,810	87,720	94,530	52,180	37,690	23,910	13,870	73,940	135,630	91,990	**631,140**
Aug 7	2,550		4,830	17,640	11,400	6,130	3,580	2,200	26,390	41,370	27,230	**143,320**
Aug 17	1,800	19,390	91,610	81,460	44,690	28,920	20,000	10,420	31,650	56,390	54,320	**440,650**
Sep 7	1,330	19,450	107,910	121,300	57,920	35,990	22,140	13,500	55,500	113,110	91,330	**639,480**
Sep 28	470	14,660	94,470	104,370	48,220	33,020	21,330	13,670	63,440	124,240	91,240	**609,130**
Oct 15	300	13,410	90,710	111,130	60,410	36,280	26,110	15,500	83,320	139,070	102,700	**678,940**

Table 13a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment – Alternative 3x (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1
	4,486.9	4,467.2	4,447.5	4,449.2	4,444.3	4,427.9	4,408.2	4,409.1	4,441.0	4,436.6	4,434.8	
June 7	4,500.3	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2
	4,486.9	4,467.2	4,465.6	4,461.6	4,453.0	4,450.8	4,445.6	4,444.3	4,444.6	4,445.9	4,448.2	
Jun 22	4,499.8	4,498.4	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0
	4,486.9	4,475.1	4,472.4	4,462.3	4,458.1	4,454.5	4,455.0	4,450.3	4,447.5	4,448.5	4,454.1	
July 7	4,499.4	4,499.4	4,499.4	4,499.4	4,499.4	4,499.4	4,499.4	4,499.4	4,498.8	4,499.4	4,499.4	4,499.4
	4,486.9	4,467.2	4,469.8	4,466.1	4,461.1	4,456.6	4,449.9	4,451.2	4,450.5	4,451.8	4,456.1	
Jul 20	4,497.1	4,492.3	4,494.5	4,495.5	4,496.3	4,496.8	4,497.1	4,496.7	4,494.1	4,494.1	4,495.1	4,497.1
	4,486.9	4,481.4	4,474.4	4,465.6	4,460.4	4,454.1	4,454.9	4,456.3	4,450.5	4,451.4	4,453.8	
Aug 7	4,495.1		4,473.9	4,471.5	4,467.0	4,463.8	4,461.3	4,462.9	4,466.8	4,466.7	4,467.6	4,496.1
	4,486.9		4,471.5	4,465.4	4,458.5	4,454.7	4,454.1	4,455.1	4,450.7	4,452.9	4,454.7	
Aug 17	4,493.8	4,492.1	4,490.8	4,485.3	4,483.6	4,481.4	4,477.1	4,460.3	4,467.1	4,465.6	4,465.6	4,493.8
	4,486.9	4,467.2	4,467.4	4,463.2	4,457.9	4,454.7	4,453.5	4,454.3	4,451.3	4,452.5	4,455.7	
Sep 7	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8
	4,486.9	4,467.2	4,447.5	4,437.7	4,445.8	4,447.2	4,449.4	4,450.5	4,456.2	4,452.8	4,449.2	
Sep 28	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2
	4,486.9	4,467.2	4,447.5	4,446.9	4,451.3	4,449.1	4,447.5	4,445.3	4,448.8	4,448.8	4,447.9	
Oct 15	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4
	4,486.9	4,467.2	4,447.5	4,437.7	4,427.9	4,435.7	4,441.3	4,440.5	4,434.4	4,442.3	4,438.9	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 13b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment - Alternative 3x (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15	6,360	36,850	146,340	146,370	78,070	49,730	41,560	25,330	102,010	211,940	144,550	**989,110**
Jun 7	6,550	37,360	140,230	124,790	70,390	45,370	31,960	19,510	98,890	185,270	123,030	**883,350**
Jun 22	6,140	31,280	126,530	122,260	63,840	42,940	27,130	17,670	94,340	176,140	109,920	**818,190**
Jul 7	5,700	34,870	128,600	109,200	58,740	40,860	29,330	17,080	87,210	162,950	103,860	**778,400**
Jul 20	3,870	14,330	91,010	97,330	54,630	39,450	25,270	14,330	77,930	145,320	98,110	**661,580**
Aug 7	2,450		6,690	18,340	11,750	6,510	3,940	2,510	27,530	45,750	29,620	**155,090**
Aug 17	1,800	17,910	87,850	69,350	37,390	22,550	13,370	1,900	27,020	43,720	22,490	**345,350**
Sep 7	1,300	19,350	107,660	122,360	64,970	38,680	25,250	14,600	65,830	136,200	102,140	**698,340**
Sep 28	460	14,570	94,210	112,890	55,540	34,920	24,440	15,110	73,190	139,900	98,220	**663,450**
Oct 15	290	13,320	90,430	110,940	63,090	37,640	26,700	16,110	83,210	157,790	112,560	**712,080**

Table 14a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1
	4,486.9	4,467.2	4,447.5	4,449.2	4,444.3	4,427.9	4,408.2	4,409.1	4,441.0	4,436.6	4,434.8	
June 7	4,500.3	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2
	4,486.9	4,467.2	4,466.1	4,461.9	4,453.0	4,450.8	4,445.6	4,444.3	4,444.6	4,445.9	4,448.2	
Jun 22	4,499.8	4,498.4	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0
	4,486.9	4,475.1	4,472.4	4,462.5	4,458.5	4,454.9	4,455.5	4,450.4	4,447.9	4,448.8	4,454.1	
July 7	4,499.4	4,499.4	4,499.4	4,499.4	4,499.4	4,499.4	4,499.4	4,499.4	4,498.8	4,499.4	4,499.4	4,499.4
	4,486.9	4,467.2	4,469.9	4,466.1	4,461.1	4,456.6	4,450.0	4,451.5	4,451.0	4,452.3	4,456.3	
Jul 20	4,497.1	4,492.3	4,494.5	4,495.5	4,496.3	4,496.8	4,497.1	4,496.7	4,494.0	4,494.1	4,495.1	4,497.1
	4,486.9	4,481.2	4,474.4	4,465.6	4,460.4	4,454.1	4,455.3	4,456.5	4,451.1	4,452.1	4,454.1	
Aug 7	4,495.1		4,473.8	4,471.4	4,467.2	4,464.6	4,461.3	4,462.9	4,466.7	4,466.9	4,467.9	4,496.1
	4,486.9		4,471.5	4,465.4	4,458.6	4,455.5	4,454.4	4,455.0	4,451.6	4,453.9	4,455.3	
Aug 17	4,493.8	4,492.1	4,490.8	4,485.6	4,483.6	4,481.4	4,478.1	4,460.4	4,468.0	4,465.8	4,465.6	4,493.8
	4,486.9	4,467.2	4,468.1	4,463.3	4,457.9	4,454.7	4,454.1	4,454.7	4,452.8	4,453.2	4,455.9	
Sep 7	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8
	4,486.9	4,467.2	4,447.5	4,440.3	4,448.1	4,448.9	4,450.8	4,451.1	4,458.5	4,454.6	4,450.3	
Sep 28	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2
	4,486.9	4,467.2	4,447.5	4,450.2	4,452.9	4,449.6	4,449.5	4,446.5	4,450.4	4,450.5	4,448.9	
Oct 15	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5	4,489.5
	4,486.9	4,467.2	4,447.5	4,437.7	4,433.9	4,439.7	4,440.9	4,440.2	4,434.4	4,444.7	4,440.7	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 14b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15	6,360	36,850	146,340	146,370	78,070	49,730	41,560	25,330	102,010	211,940	144,550	**989,110**
Jun 7	6,550	37,360	139,430	124,040	70,390	45,370	31,960	19,510	98,890	185,270	123,030	**881,800**
Jun 22	6,140	31,280	126,530	121,710	63,380	42,690	26,890	17,640	93,840	175,190	109,920	**815,210**
Jul 7	5,700	34,870	128,460	109,200	58,780	40,860	29,270	16,970	86,340	161,340	103,340	**775,130**
Jul 20	3,870	14,500	91,010	97,330	54,670	39,450	25,040	14,290	76,770	143,080	97,460	**657,470**
Aug 7	2,450		6,400	18,240	11,820	6,630	3,820	2,520	25,780	43,070	28,710	**149,440**
Aug 17	1,800	17,910	86,860	70,000	37,390	22,550	13,720	1,810	26,120	42,020	22,200	**342,380**
Sep 7	1,320	19,430	107,880	122,470	63,060	37,950	24,560	14,400	61,950	130,420	99,810	**683,250**
Sep 28	470	14,640	94,430	111,490	54,000	34,700	23,520	14,800	70,650	134,720	96,330	**649,750**
Oct 15	300	13,390	90,640	111,100	63,110	37,410	26,890	16,210	83,300	150,530	109,800	**702,680**

Table 15a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment – Alternative 4c
(2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1	4,500.1
	4,486.9	4,467.2	4,447.5	4,449.2	4,444.3	4,427.9	4,408.2	4,409.1	4,440.2	4,436.6	4,434.8	
June 7	4,500.3	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2	4,500.2
	4,486.9	4,467.2	4,467.2	4,462.3	4,453.6	4,451.6	4,446.2	4,445.1	4,444.9	4,446.3	4,448.8	
Jun 22	4,499.9	4,498.5	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0	4,500.0
	4,486.9	4,475.8	4,473.3	4,463.3	4,460.0	4,456.2	4,456.4	4,451.9	4,448.6	4,449.9	4,455.3	
July 7	4,499.4	4,499.4	4,499.4	4,499.4	4,499.4	4,499.4	4,499.4	4,499.4	4,499.0	4,499.4	4,499.4	4,499.4
	4,486.9	4,468.5	4,471.7	4,467.2	4,463.0	4,460.0	4,451.6	4,452.9	4,452.1	4,454.1	4,459.0	
Jul 20	4,497.1	4,492.9	4,494.7	4,495.8	4,496.7	4,497.1	4,497.1	4,497.1	4,494.2	4,494.4	4,495.5	4,497.1
	4,486.9	4,481.8	4,475.6	4,466.6	4,462.4	4,456.7	4,456.9	4,458.0	4,452.5	4,453.8	4,456.4	
Aug 7	4,495.2		4,475.2	4,472.6	4,469.1	4,466.3	4,462.8	4,463.6	4,468.3	4,468.8	4,469.6	4,496.1
	4,486.9		4,473.5	4,466.6	4,461.0	4,457.9	4,456.3	4,456.8	4,452.9	4,455.9	4,457.4	
Aug 17	4,493.8	4,492.5	4,491.9	4,490.2	4,488.8	4,487.6	4,487.9	4,480.3	4,471.9	4,469.3	4,475.4	4,493.8
	4,486.9	4,469.1	4,469.4	4,464.9	4,459.9	4,456.8	4,455.8	4,456.3	4,454.4	4,455.3	4,458.3	
Sep 7	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8	4,492.8
	4,486.9	4,467.2	4,447.5	4,444.9	4,450.6	4,450.4	4,453.3	4,452.8	4,460.5	4,457.1	4,452.4	
Sep 28	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2	4,490.2
	4,486.9	4,467.2	4,447.5	4,454.7	4,455.7	4,451.6	4,451.6	4,448.8	4,452.6	4,452.8	4,450.3	
Oct 15	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4	4,489.4
	4,486.9	4,467.2	4,447.5	4,437.7	4,434.4	4,441.5	4,441.8	4,440.7	4,434.4	4,445.8	4,442.4	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 15b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment – Alternative 4c
(2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15	6,360	36,850	146,340	146,370	78,070	49,730	41,560	25,330	102,570	211,940	144,550	**989,670**
Jun 7	6,550	37,360	137,880	123,030	69,670	44,920	31,660	19,290	98,500	183,910	121,700	**874,470**
Jun 22	6,170	31,180	123,680	119,340	61,340	41,900	26,390	17,170	92,670	171,680	107,180	**798,700**
Jul 7	5,700	34,840	124,500	105,990	56,240	38,470	28,450	16,560	84,900	155,420	97,200	**748,270**
Jul 20	3,870	15,320	88,650	95,360	52,440	38,140	24,180	13,960	74,860	138,310	93,210	**638,300**
Aug 7	2,500		5,110	18,270	11,460	6,440	3,620	2,210	26,420	43,130	28,140	**147,300**
Aug 17	1,800	18,790	90,420	81,210	42,990	27,590	18,800	8,130	30,390	46,740	39,940	**406,800**
Sep 7	1,310	19,350	107,680	122,160	60,560	37,110	23,280	13,890	58,560	121,960	95,320	**661,180**
Sep 28	460	14,580	94,240	105,650	50,610	33,530	22,480	14,090	66,880	127,090	93,350	**622,960**
Oct 15	290	13,330	90,460	110,960	63,040	37,010	26,500	16,060	83,220	147,030	106,930	**694,830**

Table 16a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15		4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6
		4,467.2	4,450.8	4,450.2	4,427.9	4,427.9	4,408.2	4,408.2	4,434.4	4,433.5	4,432.6	
June 6		4,487.8	4,487.8	4,487.8	4,487.8	4,487.8	4,487.8	4,487.8	4,487.8	4,487.8	4,487.8	4,487.8
		4,467.2	4,465.6	4,460.4	4,453.4	4,451.0	4,447.1	4,445.6	4,446.1	4,446.9	4,449.4	
Jun 22		4,477.6	4,474.9	4,471.4	4,468.7	4,464.8	4,463.7	4,466.1	4,467.4	4,467.4	4,467.9	4,487.5
		4,467.2	4,466.6	4,462.0	4,457.4	4,452.7	4,455.5	4,454.1	4,449.8	4,448.3	4,451.2	
July 10		4,469.2		4,464.3	4,461.3	4,462.1	4,455.2	4,452.8	4,463.0	4,463.0	4,462.9	4,486.9
		4,467.2		4,462.1	4,457.4	4,456.9	4,450.6	4,449.8	4,449.6	4,453.6	4,456.9	
Jul 20						4,455.7	4,458.4	4,458.2	4,460.2	4,461.0	4,459.6	4,486.6
						4,453.9	4,455.0	4,453.7	4,454.1	4,455.7	4,455.6	
Aug 9								4,454.7				4,484.3
								4,453.6				
Aug 17												4,484.0
Sep 12		4,483.6	4,483.6	4,483.6	4,483.6	4,483.6	4,483.6	4,483.6	4,480.8	4,481.2	4,483.1	4,483.6
		4,467.2	4,447.5	4,452.4	4,452.4	4,446.0	4,448.0	4,444.4	4,454.1	4,451.1	4,448.2	
Sep 28		4,483.2	4,483.2	4,483.2	4,483.2	4,483.2	4,483.2	4,483.2	4,483.2	4,483.2	4,483.2	4,483.2
		4,467.2	4,447.5	4,437.7	4,444.4	4,443.9	4,446.8	4,449.0	4,444.1	4,446.4	4,445.5	
Oct 15		4,480.8	4,480.8	4,480.8	4,480.8	4,480.8	4,480.8	4,480.8	4,480.8	4,480.8	4,480.8	4,480.8
		4,467.2	4,447.5	4,437.7	4,427.9	4,427.9	4,439.9	4,437.2	4,434.4	4,439.9	4,437.6	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 16b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15		10,570	81,030	102,620	60,130	35,750	33,430	20,330	79,750	173,530	115,090	**712,230**
Jun 6		10,820	75,110	85,160	49,390	31,290	23,110	14,130	72,870	137,720	89,300	**588,900**
Jun 22		1,850	18,420	27,270	15,480	8,540	4,540	3,860	29,930	63,240	37,770	**210,900**
Jul 10		80		5,960	5,220	3,700	2,400	930	22,530	31,060	13,540	**85,420**
Jul 20						1,110	1,800	1,420	10,290	17,280	8,970	**40,870**
Aug 9								360				**360**
Aug 17												**0**
Sep 12		5,940	62,290	87,410	44,060	29,500	20,140	12,900	46,930	100,920	80,140	**490,230**
Sep 28		5,510	60,230	90,000	50,480	29,820	20,420	11,400	66,680	123,300	85,860	**543,700**
Oct 15		3,580	49,610	82,020	49,450	28,760	21,870	13,690	67,120	134,800	93,260	**544,160**

Table 17a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment – “Present Day” (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15		4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5
		4,467.2	4,451.3	4,450.2	4,427.9	4,427.9	4,408.2	4,408.2	4,434.4	4,433.8	4,432.8	
June 6		4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6
		4,467.2	4,465.8	4,460.4	4,453.2	4,450.8	4,446.8	4,445.9	4,446.1	4,446.9	4,449.2	
Jun 22		4,477.3	4,474.6	4,471.0	4,468.3	4,464.2	4,463.4	4,465.7	4,467.1	4,467.1	4,467.7	4,487.3
		4,467.2	4,466.6	4,461.9	4,457.1	4,452.5	4,455.3	4,453.7	4,449.7	4,448.1	4,451.1	
July 10		4,469.2		4,463.9	4,461.0	4,461.6	4,454.9	4,452.6	4,462.5	4,462.7	4,462.4	4,486.7
		4,467.2		4,462.0	4,457.2	4,456.6	4,450.4	4,449.5	4,449.6	4,453.3	4,456.6	
Jul 20						4,455.0	4,458.2	4,458.3	4,459.9	4,460.4	4,458.8	4,486.4
						4,453.5	4,455.5	4,454.1	4,454.1	4,455.3	4,454.9	
Aug 9												4,484.1
Aug 17												4,483.8
Sep 12		4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,480.4	4,480.9	4,482.4	4,483.4
		4,467.2	4,447.5	4,452.1	4,452.3	4,445.0	4,446.0	4,443.8	4,452.7	4,450.3	4,447.4	
Sep 28		4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0
		4,467.2	4,447.5	4,437.7	4,442.1	4,442.9	4,445.7	4,448.2	4,443.5	4,446.2	4,444.3	
Oct 15		4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6
		4,467.2	4,447.5	4,437.7	4,427.9	4,427.9	4,438.4	4,436.0	4,434.4	4,439.9	4,437.1	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 17b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment - “Present Day” (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15		10,400	80,360	102,190	59,930	35,610	33,350	20,280	79,510	172,660	114,720	**709,010**
Jun 6		10,600	74,000	84,600	49,390	31,230	23,160	13,970	72,570	137,140	89,310	**585,970**
Jun 22		1,750	17,730	26,490	15,210	8,220	4,480	3,850	29,630	62,660	37,380	**207,400**
Jul 10		80		5,200	5,030	3,540	2,290	950	21,670	30,820	13,140	**82,720**
Jul 20						950	1,460	1,310	9,840	16,820	8,690	**39,070**
Aug 9												**0**
Aug 17												**0**
Sep 12		5,750	61,370	87,010	43,810	29,660	20,960	13,010	48,690	102,570	80,210	**493,040**
Sep 28		5,310	59,290	89,320	51,470	29,940	20,820	11,570	67,090	123,130	87,690	**545,630**
Oct 15		3,450	48,750	81,360	49,140	28,560	22,300	13,900	66,750	134,290	93,410	**541,910**

Table 18a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment – Alternative 3x (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15		4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5
		4,467.2	4,451.3	4,450.2	4,427.9	4,427.9	4,408.2	4,408.2	4,434.4	4,433.8	4,432.8	
June 6		4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6
		4,467.2	4,465.2	4,459.8	4,452.5	4,450.4	4,446.7	4,445.6	4,446.1	4,446.9	4,448.8	
Jun 22		4,476.9	4,474.1	4,470.5	4,467.7	4,463.7	4,462.8	4,465.3	4,466.5	4,466.5	4,467.2	4,487.2
		4,467.2	4,465.8	4,461.0	4,456.0	4,451.4	4,454.3	4,452.7	4,449.2	4,447.3	4,450.2	
July 10		4,468.8	4,468.1	4,462.8	4,459.8	4,460.1	4,453.5	4,451.7	4,460.3	4,461.3	4,461.1	4,486.6
		4,467.2	4,466.9	4,460.9	4,456.0	4,454.7	4,448.7	4,448.5	4,448.1	4,451.6	4,454.9	
Jul 20							4,456.3	4,457.6	4,458.8	4,457.9	4,455.7	4,486.3
							4,454.1	4,453.5	4,452.9	4,453.1	4,452.2	
Aug 9												4,484.0
Aug 17												4,483.7
Sep 12		4,483.3	4,483.3	4,482.2	4,480.9	4,480.6	4,480.9	4,480.9	4,450.5	4,452.5	4,475.4	4,483.3
		4,467.2	4,447.5	4,445.6	4,446.4	4,439.9	4,442.0	4,440.1	4,449.1	4,447.1	4,443.2	
Sep 28		4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9
		4,467.2	4,447.5	4,437.7	4,427.9	4,438.7	4,440.5	4,443.2	4,439.2	4,440.4	4,441.3	
Oct 15		4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5
		4,467.2	4,447.5	4,437.7	4,427.9	4,427.9	4,428.1	4,430.2	4,434.4	4,439.4	4,435.7	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 18b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment - Alternative 3x (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15		10,400	80,360	102,190	59,930	35,610	33,350	20,280	79,510	172,660	114,720	**709,010**
Jun 6		10,600	74,660	86,110	50,270	31,460	23,210	14,060	72,570	137,140	89,970	**590,050**
Jun 22		1,590	17,490	27,200	15,830	8,360	4,660	4,030	29,520	63,310	38,320	**210,310**
Jul 10		40	1,650	4,790	4,950	3,690	2,400	990	20,390	31,920	14,010	**84,830**
Jul 20							1,170	1,260	9,970	15,550	7,690	**35,640**
Aug 9												**0**
Aug 17												**0**
Sep 12		5,660	60,950	86,510	45,620	28,150	21,150	13,060	2,330	17,240	71,500	**352,170**
Sep 28		5,220	58,850	89,000	52,720	30,620	22,910	12,950	70,200	140,830	92,620	**575,920**
Oct 15		3,390	48,350	81,040	48,990	28,460	25,590	15,070	66,570	135,240	95,050	**547,750**

Table 19a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15		4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5
		4,467.2	4,451.3	4,450.2	4,427.9	4,427.9	4,408.2	4,408.2	4,434.4	4,433.8	4,432.8	
June 6		4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6
		4,467.2	4,465.2	4,459.8	4,452.8	4,450.6	4,446.7	4,445.6	4,446.1	4,446.9	4,448.8	
Jun 22		4,476.9	4,474.2	4,470.5	4,467.7	4,463.7	4,462.9	4,465.3	4,466.5	4,466.6	4,467.2	4,487.3
		4,467.2	4,465.9	4,461.2	4,456.4	4,451.6	4,454.6	4,453.0	4,449.3	4,447.5	4,450.5	
July 10		4,468.8	4,468.1	4,462.9	4,459.9	4,460.3	4,453.8	4,452.0	4,460.8	4,461.5	4,461.3	4,486.7
		4,467.2	4,467.0	4,461.1	4,456.2	4,454.9	4,449.3	4,448.8	4,448.6	4,452.2	4,455.3	
Jul 20						4,453.3	4,456.5	4,457.1	4,458.8	4,458.7	4,456.8	4,486.4
						4,452.1	4,453.6	4,452.7	4,453.2	4,453.9	4,453.1	
Aug 9												4,484.1
Aug 17												4,483.8
Sep 12		4,483.4	4,483.4	4,483.0	4,482.3	4,482.4	4,482.4	4,482.6	4,471.6	4,475.1	4,481.1	4,483.4
		4,467.2	4,447.5	4,449.3	4,449.4	4,443.7	4,445.3	4,442.5	4,451.6	4,449.2	4,446.2	
Sep 28		4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0
		4,467.2	4,447.5	4,437.7	4,440.6	4,441.8	4,443.3	4,446.3	4,442.6	4,443.4	4,443.7	
Oct 15		4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6
		4,467.2	4,447.5	4,437.7	4,427.9	4,427.9	4,438.2	4,436.1	4,434.4	4,439.7	4,436.8	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 19b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15		10,400	80,360	102,190	59,930	35,610	33,350	20,280	79,510	172,660	114,720	**709,010**
Jun 6		10,600	74,660	85,940	49,890	31,350	23,210	14,060	72,570	137,140	89,970	**589,390**
Jun 22		1,600	17,400	26,530	15,370	8,260	4,580	3,930	29,360	62,800	37,690	**207,520**
Jul 10		40	1,700	4,650	4,790	3,700	2,310	940	20,480	30,760	13,530	**82,900**
Jul 20						760	1,530	1,370	9,360	15,790	8,280	**37,090**
Aug 9												**0**
Aug 17												**0**
Sep 12		5,740	61,360	88,160	45,050	29,110	20,600	13,050	34,360	86,240	79,330	**463,000**
Sep 28		5,300	59,260	89,310	52,000	30,210	21,840	12,130	68,110	131,830	88,710	**558,700**
Oct 15		3,440	48,720	81,340	49,130	28,550	22,390	13,870	66,740	134,860	93,890	**542,930**

Table 20a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment – Alternative 4c (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15		4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5
		4,467.2	4,451.3	4,450.2	4,427.9	4,427.9	4,408.2	4,408.2	4,434.4	4,433.8	4,432.8	
June 6		4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6
		4,467.2	4,465.8	4,460.4	4,453.2	4,450.8	4,446.8	4,445.9	4,446.1	4,446.9	4,449.2	
Jun 22		4,477.3	4,474.6	4,471.0	4,468.3	4,464.2	4,463.4	4,465.7	4,467.1	4,467.1	4,467.7	4,487.2
		4,467.2	4,466.6	4,461.9	4,457.1	4,452.5	4,455.3	4,453.7	4,449.7	4,448.1	4,451.1	
July 10		4,469.1		4,463.6	4,460.7	4,461.2	4,454.4	4,452.3	4,461.9	4,462.3	4,462.0	4,486.6
		4,467.2		4,461.7	4,457.0	4,456.1	4,449.9	4,449.2	4,448.7	4,452.7	4,456.1	
Jul 20						4,453.8	4,457.4	4,458.2	4,459.5	4,459.3	4,457.3	4,486.3
						4,452.8	4,455.0	4,454.1	4,453.6	4,454.4	4,453.7	
Aug 9												4,484.0
Aug 17												4,483.7
Sep 12		4,483.3	4,483.3	4,482.7	4,481.7	4,481.6	4,481.8	4,481.9	4,465.6	4,470.5	4,480.4	4,483.3
		4,467.2	4,447.5	4,446.8	4,449.5	4,440.9	4,443.1	4,441.7	4,450.7	4,448.1	4,444.7	
Sep 28		4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9
		4,467.2	4,447.5	4,437.7	4,432.1	4,439.9	4,441.3	4,444.3	4,440.3	4,443.2	4,441.8	
Oct 15		4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5
		4,467.2	4,447.5	4,437.7	4,427.9	4,427.9	4,424.3	4,432.8	4,434.4	4,439.5	4,436.1	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 20b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment – Alternative 4c (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15		10,400	80,360	102,190	59,930	35,610	33,350	20,280	79,510	172,660	114,720	**709,010**
Jun 6		10,600	74,000	84,600	49,390	31,230	23,160	13,970	72,570	137,140	89,310	**585,970**
Jun 22		1,750	17,730	26,490	15,210	8,220	4,480	3,850	29,630	62,660	37,380	**207,400**
Jul 10		70		5,060	4,880	3,560	2,330	960	22,180	31,770	13,430	**84,240**
Jul 20						650	1,290	1,280	9,990	16,460	8,100	**37,770**
Aug 9												**0**
Aug 17												**0**
Sep 12		5,660	60,970	87,770	44,010	29,000	21,190	12,970	25,400	74,400	80,630	**442,000**
Sep 28		5,220	58,870	89,020	52,700	30,470	22,610	12,670	69,520	132,350	91,930	**565,360**
Oct 15		3,390	48,360	81,060	49,000	28,470	26,630	14,560	66,580	135,050	94,690	**547,790**

Table 21a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15		4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6
		4,467.2	4,450.8	4,450.2	4,427.9	4,427.9	4,408.2	4,408.2	4,434.4	4,433.5	4,432.6	
June 6		4,487.8	4,487.8	4,487.8	4,487.8	4,487.8	4,487.8	4,487.8	4,487.8	4,487.8	4,487.8	4,487.8
		4,467.2	4,465.6	4,460.4	4,453.4	4,451.0	4,447.1	4,445.6	4,446.1	4,446.9	4,449.4	
Jun 22		4,482.7	4,479.9	4,476.7	4,475.1	4,481.1	4,471.8	4,469.8	4,475.3	4,473.0	4,473.3	4,487.5
		4,467.2	4,466.6	4,462.0	4,457.4	4,452.7	4,455.5	4,454.1	4,449.8	4,448.3	4,451.2	
July 10		4,475.3	4,472.6	4,467.1	4,463.3	4,464.5	4,458.0	4,454.3	4,469.3	4,466.5	4,465.1	4,486.9
		4,467.2	4,468.5	4,462.1	4,457.4	4,456.9	4,450.6	4,449.8	4,449.6	4,453.6	4,456.9	
Jul 20		4,469.9			4,462.5	4,460.0	4,465.6	4,463.6	4,462.9	4,463.5	4,463.1	4,486.6
		4,467.2			4,460.1	4,453.9	4,455.0	4,453.7	4,454.1	4,455.7	4,455.6	
Aug 9		4,469.1			4,460.5	4,457.2	4,457.0	4,459.2	4,460.4	4,460.3	4,460.7	4,484.3
		4,467.2			4,456.4	4,452.7	4,452.5	4,453.6	4,454.8	4,454.8	4,455.5	
Aug 17		4,469.8				4,457.0	4,456.4	4,456.8	4,457.9	4,458.6	4,458.0	4,484.0
		4,467.2				4,455.4	4,454.5	4,455.1	4,453.8	4,455.7	4,456.1	
Sep 12		4,483.6	4,483.6	4,483.6	4,483.6	4,483.6	4,483.6	4,483.6	4,483.6	4,483.6	4,483.6	4,483.6
		4,467.2	4,447.5	4,452.4	4,452.4	4,446.0	4,448.0	4,444.4	4,454.1	4,451.1	4,448.2	
Sep 28		4,483.2	4,483.2	4,483.2	4,483.2	4,483.2	4,483.2	4,483.2	4,483.2	4,483.2	4,483.2	4,483.2
		4,467.2	4,447.5	4,437.7	4,444.4	4,443.9	4,446.8	4,449.0	4,444.1	4,446.4	4,445.5	
Oct 15		4,480.8	4,480.8	4,480.8	4,480.8	4,480.8	4,480.8	4,480.8	4,480.8	4,480.8	4,480.8	4,480.8
		4,467.2	4,447.5	4,437.7	4,427.9	4,427.9	4,439.9	4,437.2	4,434.4	4,439.9	4,437.6	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 21b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15		10,570	81,030	102,620	60,130	35,750	33,430	20,330	79,750	173,530	115,090	**712,230**
Jun 6		10,820	75,110	85,160	49,390	31,290	23,110	14,130	72,870	137,720	89,300	**588,900**
Jun 22		5,040	37,450	44,300	24,930	23,430	9,210	5,110	44,110	82,140	50,580	**326,300**
Jul 10		1,030	8,910	14,160	7,820	5,610	3,870	1,380	33,660	42,830	18,690	**137,960**
Jul 20		150			3,270	4,080	5,880	3,160	14,930	25,810	16,950	**74,230**
Aug 9		60			5,330	2,840	2,400	1,780	9,530	18,220	11,740	**51,900**
Aug 17		140				1,050	1,000	540	6,810	9,430	4,290	**23,260**
Sep 12		5,940	62,290	87,410	44,060	29,500	20,140	12,900	52,150	109,470	81,510	**505,370**
Sep 28		5,510	60,230	90,000	50,480	29,820	20,420	11,400	66,680	123,300	85,860	**543,700**
Oct 15		3,580	49,610	82,020	49,450	28,760	21,870	13,690	67,120	134,800	93,260	**544,160**

Table 22a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment – “Present Day” (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15		4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5
		4,467.2	4,451.3	4,450.2	4,427.9	4,427.9	4,408.2	4,408.2	4,434.4	4,433.8	4,432.8	
June 6		4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6
		4,467.2	4,465.8	4,460.4	4,453.2	4,450.8	4,446.8	4,445.9	4,446.1	4,446.9	4,449.2	
Jun 22		4,482.5	4,479.7	4,476.5	4,474.6	4,480.9	4,472.1	4,469.6	4,474.9	4,472.7	4,473.4	4,487.3
		4,467.2	4,466.6	4,461.9	4,457.1	4,452.5	4,455.3	4,453.7	4,449.7	4,448.1	4,451.1	
July 10		4,474.8	4,472.3	4,466.9	4,463.0	4,463.9	4,457.5	4,454.0	4,468.8	4,466.2	4,464.5	4,486.7
		4,467.2	4,468.5	4,462.0	4,457.2	4,456.6	4,450.4	4,449.5	4,449.6	4,453.3	4,456.6	
Jul 20		4,470.0			4,462.3	4,459.5	4,465.4	4,463.7	4,462.6	4,463.1	4,462.4	4,486.4
		4,467.2			4,460.0	4,453.5	4,455.5	4,454.1	4,454.1	4,455.3	4,454.9	
Aug 9		4,468.9			4,460.1	4,456.7	4,456.7	4,459.0	4,459.9	4,459.7	4,459.9	4,484.1
		4,467.2			4,456.2	4,452.3	4,452.4	4,453.5	4,454.5	4,454.5	4,454.8	
Aug 17		4,470.0				4,456.5	4,455.8	4,456.2	4,457.3	4,457.9	4,457.0	4,483.8
		4,467.2				4,455.0	4,454.1	4,454.3	4,453.8	4,455.3	4,455.5	
Sep 12		4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4
		4,467.2	4,447.5	4,452.1	4,452.3	4,445.0	4,446.0	4,443.8	4,452.7	4,450.3	4,447.4	
Sep 28		4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0
		4,467.2	4,447.5	4,437.7	4,442.1	4,442.9	4,445.7	4,448.2	4,443.5	4,446.2	4,444.3	
Oct 15		4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6
		4,467.2	4,447.5	4,437.7	4,427.9	4,427.9	4,438.4	4,436.0	4,434.4	4,439.9	4,437.1	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 22b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment - “Present Day” (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15		10,400	80,360	102,190	59,930	35,610	33,350	20,280	79,510	172,660	114,720	**709,010**
Jun 6		10,600	74,000	84,600	49,390	31,230	23,160	13,970	72,570	137,140	89,310	**585,970**
Jun 22		4,850	36,570	43,990	24,530	23,400	9,520	5,150	43,630	81,880	50,810	**324,330**
Jul 10		940	8,130	13,820	7,750	5,340	3,700	1,380	32,730	42,580	17,990	**134,360**
Jul 20		160			3,080	4,000	5,530	3,060	14,530	25,680	17,020	**73,060**
Aug 9		50			5,090	2,730	2,310	1,710	9,290	17,220	11,450	**49,850**
Aug 17		170				940	910	580	5,810	8,450	3,390	**20,250**
Sep 12		5,750	61,370	87,010	43,810	29,660	20,960	13,010	54,200	111,450	82,620	**509,840**
Sep 28		5,310	59,290	89,320	51,470	29,940	20,820	11,570	67,090	123,130	87,690	**545,630**
Oct 15		3,450	48,750	81,360	49,140	28,560	22,300	13,900	66,750	134,290	93,410	**541,910**

Table 23a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment – Alternative 3x

(2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15		4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5
		4,467.2	4,451.3	4,450.2	4,427.9	4,427.9	4,408.2	4,408.2	4,434.4	4,433.8	4,432.8	
June 6		4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6
		4,467.2	4,465.2	4,459.8	4,452.5	4,450.4	4,446.7	4,445.6	4,446.1	4,446.9	4,448.8	
Jun 22		4,482.3	4,479.4	4,476.3	4,474.0	4,480.5	4,470.5	4,469.4	4,474.6	4,472.4	4,473.2	4,487.2
		4,467.2	4,465.8	4,461.0	4,456.0	4,451.4	4,454.3	4,452.7	4,449.2	4,447.3	4,450.2	
July 10		4,474.2	4,471.7	4,466.0	4,462.2	4,462.9	4,456.5	4,453.4	4,466.9	4,464.9	4,463.2	4,486.6
		4,467.2	4,466.9	4,460.9	4,456.0	4,454.7	4,448.7	4,448.5	4,448.1	4,451.6	4,454.9	
Jul 20		4,469.9			4,460.9	4,456.7	4,463.6	4,463.0	4,461.6	4,460.9	4,459.4	4,486.3
		4,467.2			4,459.7	4,451.6	4,454.1	4,453.5	4,452.9	4,453.1	4,452.2	
Aug 9		4,468.5			4,457.2	4,453.6	4,453.8	4,455.3	4,455.9	4,455.3	4,454.7	4,484.0
		4,467.2			4,454.6	4,450.0	4,450.5	4,451.7	4,452.2	4,451.2	4,450.6	
Aug 17		4,469.8							4,453.1	4,453.7		4,483.7
		4,467.2							4,451.2	4,452.3		
Sep 12		4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3
		4,467.2	4,447.5	4,445.6	4,446.4	4,439.9	4,442.0	4,440.1	4,449.1	4,447.1	4,443.2	
Sep 28		4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9
		4,467.2	4,447.5	4,437.7	4,427.9	4,438.7	4,440.5	4,443.2	4,439.2	4,440.4	4,441.3	
Oct 15		4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5
		4,467.2	4,447.5	4,437.7	4,427.9	4,427.9	4,428.1	4,430.2	4,434.4	4,439.4	4,435.7	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 23b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment - Alternative 3x

(2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15		10,400	80,360	102,190	59,930	35,610	33,350	20,280	79,510	172,660	114,720	**709,010**
Jun 6		10,600	74,660	86,110	50,270	31,460	23,210	14,060	72,570	137,140	89,970	**590,050**
Jun 22		4,630	36,320	45,780	25,120	23,620	9,070	5,410	43,910	83,400	52,350	**329,610**
Jul 10		810	9,000	13,980	8,160	5,790	3,970	1,500	31,880	43,980	18,840	**137,910**
Jul 20		160			1,590	3,120	5,210	3,010	14,920	25,680	16,000	**69,690**
Aug 9		30			3,220	2,090	1,700	1,120	6,280	13,650	9,010	**37,100**
Aug 17		150							3,280	4,730		**8,160**
Sep 12		5,660	60,950	90,260	49,360	30,930	22,620	13,940	59,910	121,420	90,570	**545,620**
Sep 28		5,220	58,850	89,000	52,720	30,620	22,910	12,950	70,200	140,830	92,620	**575,920**
Oct 15		3,390	48,350	81,040	48,990	28,460	25,590	15,070	66,570	135,240	95,050	**547,750**

Table 24a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15		4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5
		4,467.2	4,451.3	4,450.2	4,427.9	4,427.9	4,408.2	4,408.2	4,434.4	4,433.8	4,432.8	
June 6		4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6
		4,467.2	4,465.2	4,459.8	4,452.8	4,450.6	4,446.7	4,445.6	4,446.1	4,446.9	4,448.8	
Jun 22		4,482.3	4,479.4	4,476.3	4,473.8	4,480.5	4,470.5	4,469.3	4,474.6	4,472.4	4,473.2	4,487.3
		4,467.2	4,465.9	4,461.2	4,456.4	4,451.6	4,454.6	4,453.0	4,449.3	4,447.5	4,450.5	
July 10		4,474.1	4,471.7	4,466.1	4,462.2	4,463.1	4,456.7	4,453.5	4,467.2	4,465.1	4,463.3	4,486.7
		4,467.2	4,467.0	4,461.1	4,456.2	4,454.9	4,449.3	4,448.8	4,448.6	4,452.2	4,455.3	
Jul 20		4,469.9			4,460.7	4,457.1	4,463.4	4,462.4	4,461.4	4,461.6	4,460.2	4,486.4
		4,467.2			4,459.3	4,452.1	4,453.6	4,452.7	4,453.2	4,453.9	4,453.1	
Aug 9		4,468.6			4,458.2	4,454.7	4,454.6	4,456.4	4,457.3	4,457.0	4,457.1	4,484.1
		4,467.2			4,454.8	4,450.6	4,451.0	4,452.2	4,453.1	4,452.6	4,452.8	
Aug 17		4,469.8				4,454.3	4,453.6		4,455.0	4,455.6	4,454.9	4,483.8
		4,467.2				4,453.2	4,452.6		4,452.5	4,453.7	4,453.6	
Sep 12		4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4
		4,467.2	4,447.5	4,449.3	4,449.4	4,443.7	4,445.3	4,442.5	4,451.6	4,449.2	4,446.2	
Sep 28		4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0
		4,467.2	4,447.5	4,437.7	4,440.6	4,441.8	4,443.3	4,446.3	4,442.6	4,443.4	4,443.7	
Oct 15		4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6
		4,467.2	4,447.5	4,437.7	4,427.9	4,427.9	4,438.2	4,436.1	4,434.4	4,439.7	4,436.8	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 24b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15		10,400	80,360	102,190	59,930	35,610	33,350	20,280	79,510	172,660	114,720	**709,010**
Jun 6		10,600	74,660	85,940	49,890	31,350	23,210	14,060	72,570	137,140	89,970	**589,390**
Jun 22		4,630	36,270	45,110	24,320	23,490	8,950	5,270	43,750	82,660	51,720	**326,170**
Jul 10		800	8,950	13,670	7,920	5,760	3,830	1,430	31,590	42,600	18,130	**134,680**
Jul 20		160			1,760	3,170	5,340	3,090	13,870	25,490	16,020	**68,900**
Aug 9		40			4,210	2,430	1,840	1,320	7,080	14,460	9,670	**41,050**
Aug 17		140				710	530		4,290	6,250	2,810	**14,730**
Sep 12		5,740	61,360	89,470	46,800	30,110	21,230	13,370	55,890	114,970	85,070	**524,010**
Sep 28		5,300	59,260	89,310	52,000	30,210	21,840	12,130	68,110	131,830	88,710	**558,700**
Oct 15		3,440	48,720	81,340	49,130	28,550	22,390	13,870	66,740	134,860	93,890	**542,930**

Table 25a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment – Alternative 4c (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15		4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5
		4,467.2	4,451.3	4,450.2	4,427.9	4,427.9	4,408.2	4,408.2	4,434.4	4,433.8	4,432.8	
June 6		4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6
		4,467.2	4,465.8	4,460.4	4,453.2	4,450.8	4,446.8	4,445.9	4,446.1	4,446.9	4,449.2	
Jun 22		4,482.5	4,479.7	4,476.5	4,474.6	4,480.9	4,472.1	4,469.6	4,474.9	4,472.7	4,473.4	4,487.2
		4,467.2	4,466.6	4,461.9	4,457.1	4,452.5	4,455.3	4,453.7	4,449.7	4,448.1	4,451.1	
July 10		4,474.6	4,472.2	4,466.7	4,462.8	4,463.6	4,457.2	4,453.8	4,468.3	4,465.9	4,464.0	4,486.6
		4,467.2	4,467.9	4,461.7	4,457.0	4,456.1	4,449.9	4,449.2	4,448.7	4,452.7	4,456.1	
Jul 20		4,470.0			4,461.8	4,458.3	4,464.9	4,463.5	4,462.3	4,462.4	4,461.0	4,486.3
		4,467.2			4,460.0	4,452.8	4,455.0	4,454.1	4,453.6	4,454.4	4,453.7	
Aug 9		4,468.7			4,458.8	4,455.1	4,455.4	4,457.0	4,457.6	4,457.1	4,456.9	4,484.0
		4,467.2			4,455.5	4,450.8	4,451.5	4,452.8	4,453.1	4,452.5	4,452.3	
Aug 17		4,470.0						4,452.5	4,455.0	4,455.4	4,454.2	4,483.7
		4,467.2						4,451.4	4,452.5	4,453.7	4,453.1	
Sep 12		4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3
		4,467.2	4,447.5	4,446.8	4,449.5	4,440.9	4,443.1	4,441.7	4,450.7	4,448.1	4,444.7	
Sep 28		4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9
		4,467.2	4,447.5	4,437.7	4,432.1	4,439.9	4,441.3	4,444.3	4,440.3	4,443.2	4,441.8	
Oct 15		4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5
		4,467.2	4,447.5	4,437.7	4,427.9	4,427.9	4,424.3	4,432.8	4,434.4	4,439.5	4,436.1	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 25b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment – Alternative 4c (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15		10,400	80,360	102,190	59,930	35,610	33,350	20,280	79,510	172,660	114,720	**709,010**
Jun 6		10,600	74,000	84,600	49,390	31,230	23,160	13,970	72,570	137,140	89,310	**585,970**
Jun 22		4,850	36,570	43,990	24,530	23,400	9,520	5,150	43,630	81,880	50,810	**324,330**
Jul 10		900	8,580	13,730	7,730	5,440	3,820	1,410	33,280	43,640	17,890	**136,420**
Jul 20		160			2,420	3,570	5,470	3,020	14,780	26,490	16,450	**72,360**
Aug 9		40			4,120	2,530	2,040	1,320	7,690	15,210	10,140	**43,090**
Aug 17		160						320	4,290	5,710	2,450	**12,930**
Sep 12		5,660	60,970	90,000	46,600	30,750	22,150	13,520	57,360	118,480	87,660	**533,150**
Sep 28		5,220	58,870	89,020	52,700	30,470	22,610	12,670	69,520	132,350	91,930	**565,360**
Oct 15		3,390	48,360	81,060	49,000	28,470	26,630	14,560	66,580	135,050	94,690	**547,790**

Table 26a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15		4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6
		4,467.2	4,450.8	4,450.2	4,427.9	4,427.9	4,408.2	4,408.2	4,434.4	4,433.5	4,432.6	
June 6		4,487.8	4,487.8	4,487.8	4,487.8	4,487.8	4,487.8	4,487.8	4,487.8	4,487.8	4,487.8	4,487.8
		4,467.2	4,465.6	4,460.4	4,453.4	4,451.0	4,447.1	4,445.6	4,446.1	4,446.9	4,449.4	
Jun 22		4,486.7	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,485.8	4,487.3	4,486.5	4,487.5	4,487.5
		4,467.2	4,466.6	4,462.0	4,457.4	4,452.7	4,455.5	4,454.1	4,449.8	4,448.3	4,451.2	
July 10		4,486.6	4,484.0	4,483.7	4,483.7	4,482.4	4,484.0	4,484.3	4,484.5	4,482.4	4,478.1	4,486.9
		4,467.2	4,468.5	4,462.1	4,457.4	4,456.9	4,450.6	4,449.8	4,449.6	4,453.6	4,456.9	
Jul 20		4,486.6	4,483.6	4,484.4	4,485.9	4,486.3	4,486.6	4,486.6	4,475.1	4,481.4	4,485.2	4,486.6
		4,467.2	4,464.3	4,463.5	4,460.1	4,453.9	4,455.0	4,453.7	4,454.1	4,455.7	4,455.6	
Aug 9		4,470.2		4,469.3	4,466.6	4,472.5	4,470.5	4,467.7	4,469.8	4,468.3	4,467.2	4,484.3
		4,467.2		4,462.5	4,456.4	4,452.7	4,452.5	4,453.6	4,454.8	4,454.8	4,455.5	
Aug 17		4,484.0	4,475.1	4,473.8	4,477.1	4,477.1	4,482.2	4,482.6	4,480.8	4,474.6	4,472.7	4,484.0
		4,467.2	4,468.0	4,460.5	4,457.1	4,455.4	4,454.5	4,455.1	4,453.8	4,455.7	4,456.1	
Sep 12		4,483.6	4,483.6	4,483.6	4,483.6	4,483.6	4,483.6	4,483.6	4,483.6	4,483.6	4,483.6	4,483.6
		4,467.2	4,447.5	4,452.4	4,452.4	4,446.0	4,448.0	4,444.4	4,454.1	4,451.1	4,448.2	
Sep 28		4,483.2	4,483.2	4,483.2	4,483.2	4,483.2	4,483.2	4,483.2	4,483.2	4,483.2	4,483.2	4,483.2
		4,467.2	4,447.5	4,437.7	4,444.4	4,443.9	4,446.8	4,449.0	4,444.1	4,446.4	4,445.5	
Oct 15		4,480.8	4,480.8	4,480.8	4,480.8	4,480.8	4,480.8	4,480.8	4,480.8	4,480.8	4,480.8	4,480.8
		4,467.2	4,447.5	4,437.7	4,427.9	4,427.9	4,439.9	4,437.2	4,434.4	4,439.9	4,437.6	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 26b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15		10,570	81,030	102,620	60,130	35,750	33,430	20,330	79,750	173,530	115,090	**712,230**
Jun 6		10,820	75,110	85,160	49,390	31,290	23,110	14,130	72,870	137,720	89,300	**588,900**
Jun 22		9,380	72,250	79,960	44,180	30,040	18,750	10,820	66,150	128,670	84,790	**544,990**
Jul 10		9,340	52,510	67,060	38,160	22,120	19,070	11,590	61,210	97,180	49,490	**427,730**
Jul 20		9,250	56,470	65,690	38,080	28,110	18,420	11,240	36,540	86,770	69,610	**420,180**
Aug 9		180		19,570	13,820	15,200	10,050	4,570	25,840	44,920	26,600	**160,750**
Aug 17		6,310	17,090	38,750	28,280	17,840	15,970	9,330	47,430	63,300	38,290	**282,590**
Sep 12		5,940	62,290	87,410	44,060	29,500	20,140	12,900	52,150	109,470	81,510	**505,370**
Sep 28		5,510	60,230	90,000	50,480	29,820	20,420	11,400	66,680	123,300	85,860	**543,700**
Oct 15		3,580	49,610	82,020	49,450	28,760	21,870	13,690	67,120	134,800	93,260	**544,160**

Table 27a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment – “Present Day” (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15		4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5
		4,467.2	4,451.3	4,450.2	4,427.9	4,427.9	4,408.2	4,408.2	4,434.4	4,433.8	4,432.8	
June 6		4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6
		4,467.2	4,465.8	4,460.4	4,453.2	4,450.8	4,446.8	4,445.9	4,446.1	4,446.9	4,449.2	
Jun 22		4,486.3	4,487.3	4,487.3	4,487.3	4,487.3	4,487.3	4,485.5	4,487.0	4,486.2	4,487.3	4,487.3
		4,467.2	4,466.6	4,461.9	4,457.1	4,452.5	4,455.3	4,453.7	4,449.7	4,448.1	4,451.1	
July 10		4,485.8	4,483.9	4,483.7	4,483.7	4,482.5	4,484.0	4,484.2	4,484.4	4,482.5	4,478.1	4,486.7
		4,467.2	4,468.5	4,462.0	4,457.2	4,456.6	4,450.4	4,449.5	4,449.6	4,453.3	4,456.6	
Jul 20		4,486.2	4,483.4	4,484.2	4,485.5	4,485.9	4,486.4	4,486.4	4,475.8	4,481.4	4,484.9	4,486.4
		4,467.2	4,463.8	4,463.2	4,460.0	4,453.5	4,455.5	4,454.1	4,454.1	4,455.3	4,454.9	
Aug 9		4,470.1		4,468.7	4,466.1	4,468.3	4,466.9	4,467.0	4,469.5	4,467.8	4,466.4	4,484.1
		4,467.2		4,462.1	4,456.2	4,452.3	4,452.4	4,453.5	4,454.5	4,454.5	4,454.8	
Aug 17		4,483.8	4,475.1	4,470.5	4,474.6	4,474.6	4,481.4	4,481.7	4,480.3	4,471.6	4,468.9	4,483.8
		4,467.2	4,463.7	4,460.3	4,456.8	4,455.0	4,454.1	4,454.3	4,453.8	4,455.3	4,455.5	
Sep 12		4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4
		4,467.2	4,447.5	4,452.1	4,452.3	4,445.0	4,446.0	4,443.8	4,452.7	4,450.3	4,447.4	
Sep 28		4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0
		4,467.2	4,447.5	4,437.7	4,442.1	4,442.9	4,445.7	4,448.2	4,443.5	4,446.2	4,444.3	
Oct 15		4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6
		4,467.2	4,447.5	4,437.7	4,427.9	4,427.9	4,438.4	4,436.0	4,434.4	4,439.9	4,437.1	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 27b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment - “Present Day” (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15		10,400	80,360	102,190	59,930	35,610	33,350	20,280	79,510	172,660	114,720	**709,010**
Jun 6		10,600	74,000	84,600	49,390	31,230	23,160	13,970	72,570	137,140	89,310	**585,970**
Jun 22		8,860	71,500	79,720	44,200	30,020	18,760	10,840	65,750	128,150	84,440	**542,240**
Jul 10		8,260	52,060	67,280	38,360	22,450	19,170	11,640	60,970	98,500	50,160	**428,850**
Jul 20		8,780	55,770	66,050	37,640	27,850	18,060	11,050	37,720	87,840	70,410	**421,170**
Aug 9		180		18,740	13,320	11,730	8,010	4,350	25,860	44,450	26,420	**153,060**
Aug 17		6,140	22,380	28,980	24,950	15,740	15,700	9,260	46,530	54,310	30,650	**254,640**
Sep 12		5,750	61,370	87,010	43,810	29,660	20,960	13,010	54,200	111,450	82,620	**509,840**
Sep 28		5,310	59,290	89,320	51,470	29,940	20,820	11,570	67,090	123,130	87,690	**545,630**
Oct 15		3,450	48,750	81,360	49,140	28,560	22,300	13,900	66,750	134,290	93,410	**541,910**

Table 28a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment – Alternative 3x (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15		4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5
		4,467.2	4,451.3	4,450.2	4,427.9	4,427.9	4,408.2	4,408.2	4,434.4	4,433.8	4,432.8	
June 6		4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6
		4,467.2	4,465.2	4,459.8	4,452.5	4,450.4	4,446.7	4,445.6	4,446.1	4,446.9	4,448.8	
Jun 22		4,486.2	4,487.3	4,487.3	4,487.3	4,487.3	4,487.3	4,485.4	4,486.9	4,486.1	4,487.3	4,487.2
		4,467.2	4,465.8	4,461.0	4,456.0	4,451.4	4,454.3	4,452.7	4,449.2	4,447.3	4,450.2	
July 10		4,485.6	4,483.6	4,482.0	4,482.2	4,480.8	4,483.7	4,483.9	4,484.2	4,481.1	4,475.4	4,486.6
		4,467.2	4,466.9	4,460.9	4,456.0	4,454.7	4,448.7	4,448.5	4,448.1	4,451.6	4,454.9	
Jul 20		4,486.1	4,482.1	4,483.7	4,484.9	4,485.5	4,486.0	4,486.1	4,467.1	4,478.7	4,484.5	4,486.3
		4,467.2	4,461.8	4,461.4	4,459.7	4,451.6	4,454.1	4,453.5	4,452.9	4,453.1	4,452.2	
Aug 9		4,469.7	4,468.7	4,465.6	4,463.8	4,462.9	4,462.9	4,464.6	4,467.3	4,465.2	4,462.9	4,484.0
		4,467.2	4,466.9	4,460.0	4,454.6	4,450.0	4,450.5	4,451.7	4,452.2	4,451.2	4,450.6	
Aug 17		4,483.8	4,469.2	4,459.9	4,458.4	4,457.4	4,463.9	4,467.2	4,465.2	4,460.7	4,457.1	4,483.7
		4,467.2	4,460.0	4,458.3	4,454.0	4,452.7	4,451.0	4,449.9	4,451.2	4,452.3	4,452.0	
Sep 12		4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3
		4,467.2	4,447.5	4,445.6	4,446.4	4,439.9	4,442.0	4,440.1	4,449.1	4,447.1	4,443.2	
Sep 28		4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9
		4,467.2	4,447.5	4,437.7	4,427.9	4,438.7	4,440.5	4,443.2	4,439.2	4,440.4	4,441.3	
Oct 15		4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5
		4,467.2	4,447.5	4,437.7	4,427.9	4,427.9	4,428.1	4,430.2	4,434.4	4,439.4	4,435.7	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 28b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment - Alternative 3x (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15		10,400	80,360	102,190	59,930	35,610	33,350	20,280	79,510	172,660	114,720	**709,010**
Jun 6		10,600	74,660	86,110	50,270	31,460	23,210	14,060	72,570	137,140	89,970	**590,050**
Jun 22		8,730	72,630	82,150	45,660	30,610	19,260	11,110	66,510	130,460	86,530	**553,650**
Jul 10		8,000	53,310	64,390	37,600	21,940	19,850	11,850	63,040	98,970	47,440	**426,390**
Jul 20		8,560	51,890	68,820	37,000	28,520	18,560	11,090	24,450	85,870	75,260	**410,020**
Aug 9		140	2,590	15,240	12,020	8,540	6,700	4,090	25,900	46,360	27,520	**149,100**
Aug 17		6,090	9,940	3,940	5,460	3,010	6,980	5,520	23,850	27,710	11,220	**103,720**
Sep 12		5,660	60,950	90,260	49,360	30,930	22,620	13,940	59,910	121,420	90,570	**545,620**
Sep 28		5,220	58,850	89,000	52,720	30,620	22,910	12,950	70,200	140,830	92,620	**575,920**
Oct 15		3,390	48,350	81,040	48,990	28,460	25,590	15,070	66,570	135,240	95,050	**547,750**

Table 29a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15		4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5
		4,467.2	4,451.3	4,450.2	4,427.9	4,427.9	4,408.2	4,408.2	4,434.4	4,433.8	4,432.8	
June 6		4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6
		4,467.2	4,465.2	4,459.8	4,452.8	4,450.6	4,446.7	4,445.6	4,446.1	4,446.9	4,448.8	
Jun 22		4,486.2	4,487.3	4,487.3	4,487.3	4,487.3	4,487.3	4,485.4	4,486.9	4,486.1	4,487.3	4,487.3
		4,467.2	4,465.9	4,461.2	4,456.4	4,451.6	4,454.6	4,453.0	4,449.3	4,447.5	4,450.5	
July 10		4,485.6	4,483.6	4,482.0	4,482.2	4,480.8	4,483.7	4,484.0	4,484.2	4,480.8	4,475.4	4,486.7
		4,467.2	4,467.0	4,461.1	4,456.2	4,454.9	4,449.3	4,448.8	4,448.6	4,452.2	4,455.3	
Jul 20		4,486.1	4,482.2	4,483.7	4,484.9	4,485.4	4,486.1	4,486.2	4,467.1	4,478.9	4,484.5	4,486.4
		4,467.2	4,462.3	4,461.7	4,459.3	4,452.1	4,453.6	4,452.7	4,453.2	4,453.9	4,453.1	
Aug 9		4,469.8	4,469.1	4,466.6	4,463.9	4,463.6	4,463.8	4,465.4	4,467.7	4,466.0	4,464.4	4,484.1
		4,467.2	4,467.8	4,460.4	4,454.8	4,450.6	4,451.0	4,452.2	4,453.1	4,452.6	4,452.8	
Aug 17		4,483.8	4,469.8	4,461.1	4,460.3	4,459.7	4,475.4	4,477.1	4,468.9	4,462.9	4,459.9	4,483.8
		4,467.2	4,462.8	4,459.3	4,455.3	4,453.2	4,452.6	4,452.7	4,452.5	4,453.7	4,453.6	
Sep 12		4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4	4,483.4
		4,467.2	4,447.5	4,449.3	4,449.4	4,443.7	4,445.3	4,442.5	4,451.6	4,449.2	4,446.2	
Sep 28		4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0	4,483.0
		4,467.2	4,447.5	4,437.7	4,440.6	4,441.8	4,443.3	4,446.3	4,442.6	4,443.4	4,443.7	
Oct 15		4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6	4,480.6
		4,467.2	4,447.5	4,437.7	4,427.9	4,427.9	4,438.2	4,436.1	4,434.4	4,439.7	4,436.8	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 29b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15		10,400	80,360	102,190	59,930	35,610	33,350	20,280	79,510	172,660	114,720	**709,010**
Jun 6		10,600	74,660	85,940	49,890	31,350	23,210	14,060	72,570	137,140	89,970	**589,390**
Jun 22		8,730	72,440	81,480	45,200	30,480	19,140	11,020	66,350	129,830	85,910	**550,580**
Jul 10		8,000	53,270	63,890	37,310	21,780	19,580	11,740	62,170	96,130	46,510	**420,380**
Jul 20		8,560	52,050	67,980	37,530	28,250	18,850	11,410	23,850	84,190	73,320	**405,990**
Aug 9		140	2,120	16,790	11,980	8,740	6,910	4,210	25,160	44,400	26,330	**146,780**
Aug 17		6,130	9,540	4,520	6,440	4,310	12,860	8,080	28,170	30,190	14,120	**124,360**
Sep 12		5,740	61,360	89,470	46,800	30,110	21,230	13,370	55,890	114,970	85,070	**524,010**
Sep 28		5,300	59,260	89,310	52,000	30,210	21,840	12,130	68,110	131,830	88,710	**558,700**
Oct 15		3,440	48,720	81,340	49,130	28,550	22,390	13,870	66,740	134,860	93,890	**542,930**

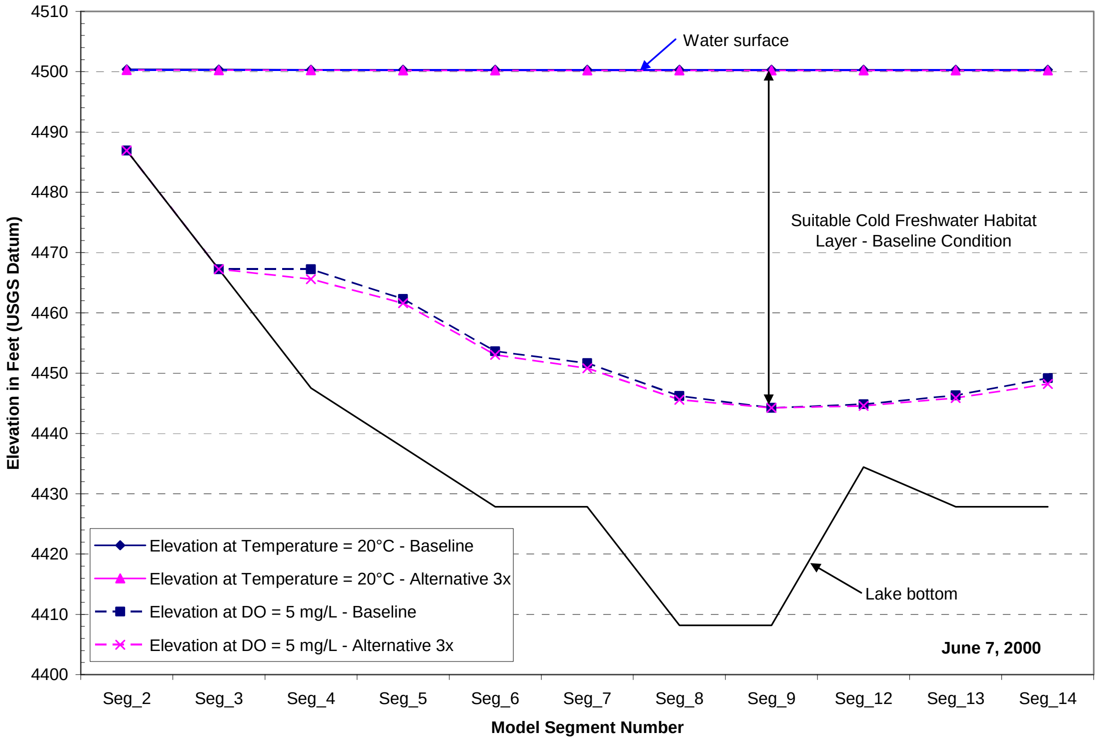
Table 30a Simulated Lake Almanor Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment – Alternative 4c (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	WSE
May 15		4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5	4,487.5
		4,467.2	4,451.3	4,450.2	4,427.9	4,427.9	4,408.2	4,408.2	4,434.4	4,433.8	4,432.8	
June 6		4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6	4,487.6
		4,467.2	4,465.8	4,460.4	4,453.2	4,450.8	4,446.8	4,445.9	4,446.1	4,446.9	4,449.2	
Jun 22		4,486.3	4,487.3	4,487.3	4,487.3	4,487.3	4,487.3	4,485.5	4,487.0	4,486.2	4,487.3	4,487.2
		4,467.2	4,466.6	4,461.9	4,457.1	4,452.5	4,455.3	4,453.7	4,449.7	4,448.1	4,451.1	
July 10		4,485.8	4,483.8	4,483.6	4,483.6	4,482.4	4,483.9	4,484.2	4,484.4	4,482.5	4,478.1	4,486.6
		4,467.2	4,467.9	4,461.7	4,457.0	4,456.1	4,449.9	4,449.2	4,448.7	4,452.7	4,456.1	
Jul 20		4,486.2	4,483.1	4,484.0	4,485.3	4,485.8	4,486.4	4,486.4	4,473.8	4,480.6	4,484.8	4,486.3
		4,467.2	4,462.9	4,462.2	4,460.0	4,452.8	4,455.0	4,454.1	4,453.6	4,454.4	4,453.7	
Aug 9		4,469.9		4,467.1	4,465.1	4,465.4	4,464.8	4,465.7	4,468.6	4,466.5	4,464.4	4,484.0
		4,467.2		4,460.7	4,455.5	4,450.8	4,451.5	4,452.8	4,453.1	4,452.5	4,452.3	
Aug 17		4,483.8	4,471.2	4,462.9	4,460.6	4,460.5	4,476.2	4,477.1	4,472.7	4,463.4	4,459.9	4,483.7
		4,467.2	4,462.9	4,459.6	4,455.3	4,453.5	4,452.5	4,451.4	4,452.5	4,453.7	4,453.1	
Sep 12		4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3	4,483.3
		4,467.2	4,447.5	4,446.8	4,449.5	4,440.9	4,443.1	4,441.7	4,450.7	4,448.1	4,444.7	
Sep 28		4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9	4,482.9
		4,467.2	4,447.5	4,437.7	4,432.1	4,439.9	4,441.3	4,444.3	4,440.3	4,443.2	4,441.8	
Oct 15		4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5	4,480.5
		4,467.2	4,447.5	4,437.7	4,427.9	4,427.9	4,424.3	4,432.8	4,434.4	4,439.5	4,436.1	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 30b Simulated Lake Almanor Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment – Alternative 4c (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_12	Seg_13	Seg_14	Total
May 15		10,400	80,360	102,190	59,930	35,610	33,350	20,280	79,510	172,660	114,720	**709,010**
Jun 6		10,600	74,000	84,600	49,390	31,230	23,160	13,970	72,570	137,140	89,310	**585,970**
Jun 22		8,860	71,500	79,720	44,200	30,020	18,760	10,840	65,750	128,150	84,440	**542,240**
Jul 10		8,220	52,850	67,760	38,560	22,650	19,410	11,730	62,440	100,550	51,270	**435,440**
Jul 20		8,690	55,230	67,820	37,320	28,210	18,300	11,050	35,010	88,460	72,750	**422,840**
Aug 9		150		17,660	12,700	10,060	7,220	4,160	26,660	46,710	27,390	**152,710**
Aug 17		6,090	12,210	8,500	6,710	4,670	13,440	8,460	34,990	32,270	15,190	**142,530**
Sep 12		5,660	60,970	90,000	46,600	30,750	22,150	13,520	57,360	118,480	87,660	**533,150**
Sep 28		5,220	58,870	89,020	52,700	30,470	22,610	12,670	69,520	132,350	91,930	**565,360**
Oct 15		3,390	48,360	81,060	49,000	28,470	26,630	14,560	66,580	135,050	94,690	**547,790**



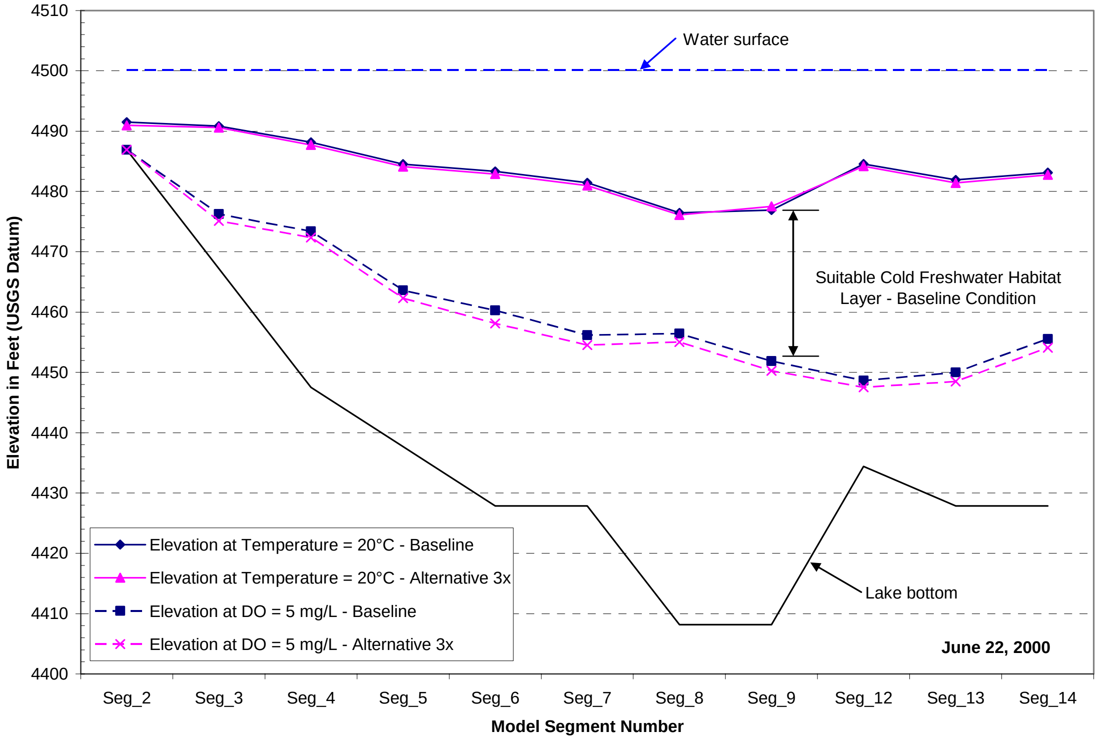
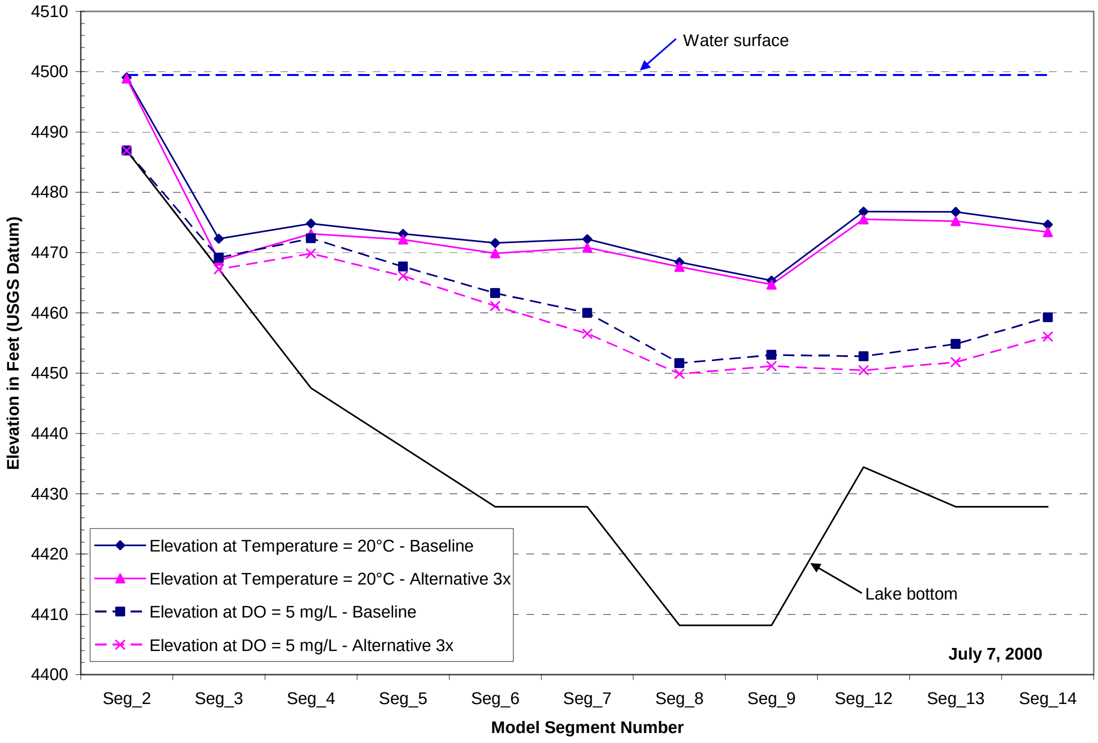


Figure 1a Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, June 2000



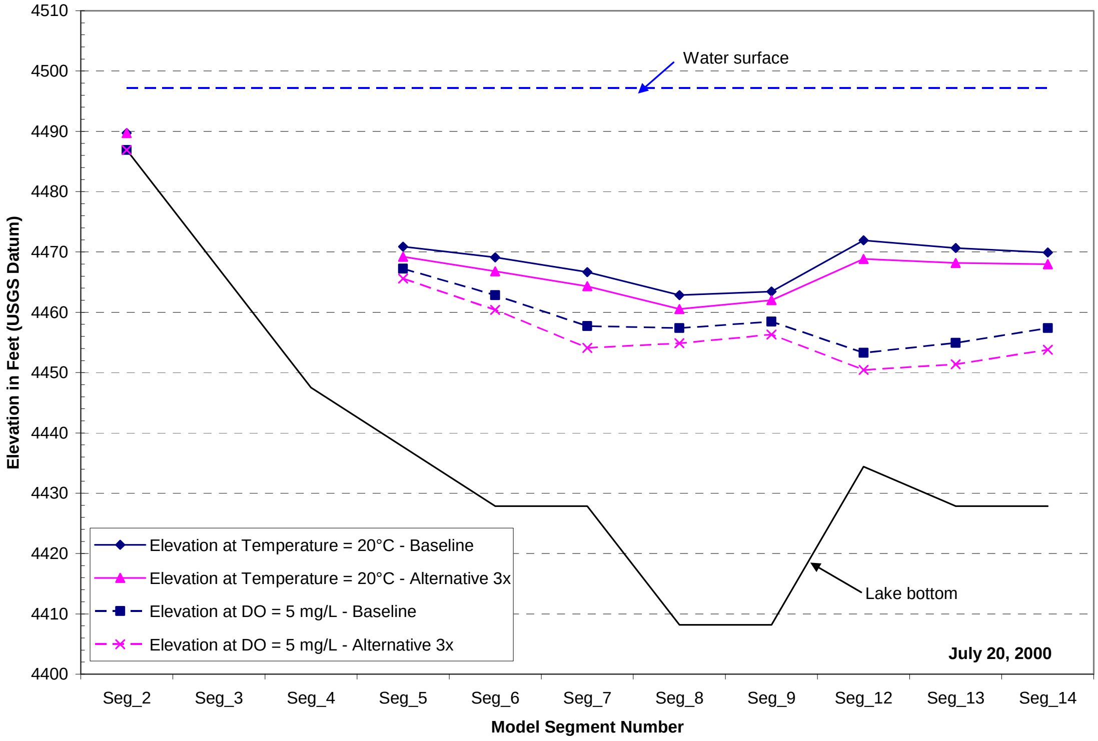
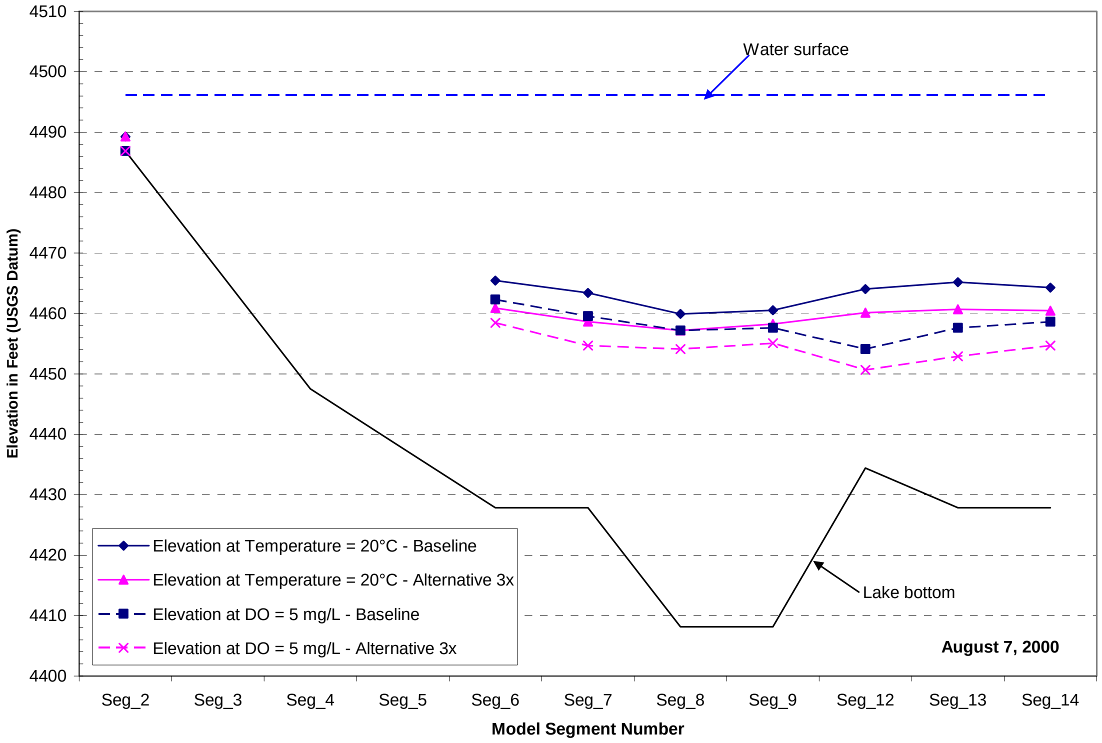


Figure 1b Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, July 2000



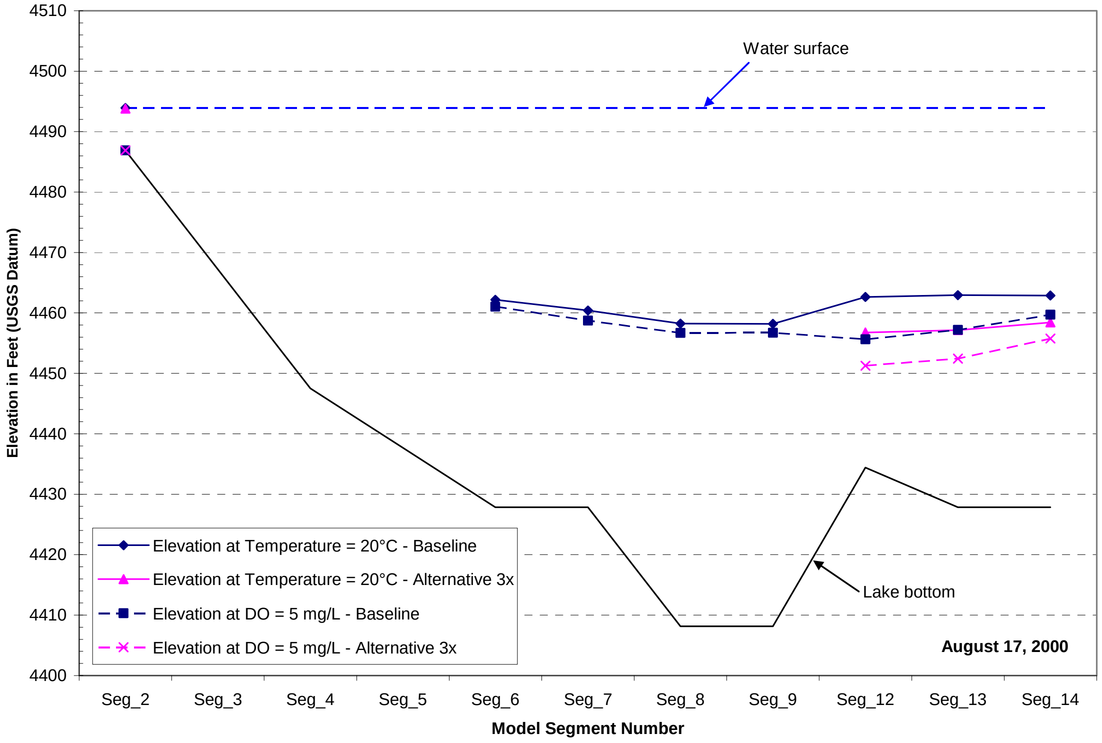
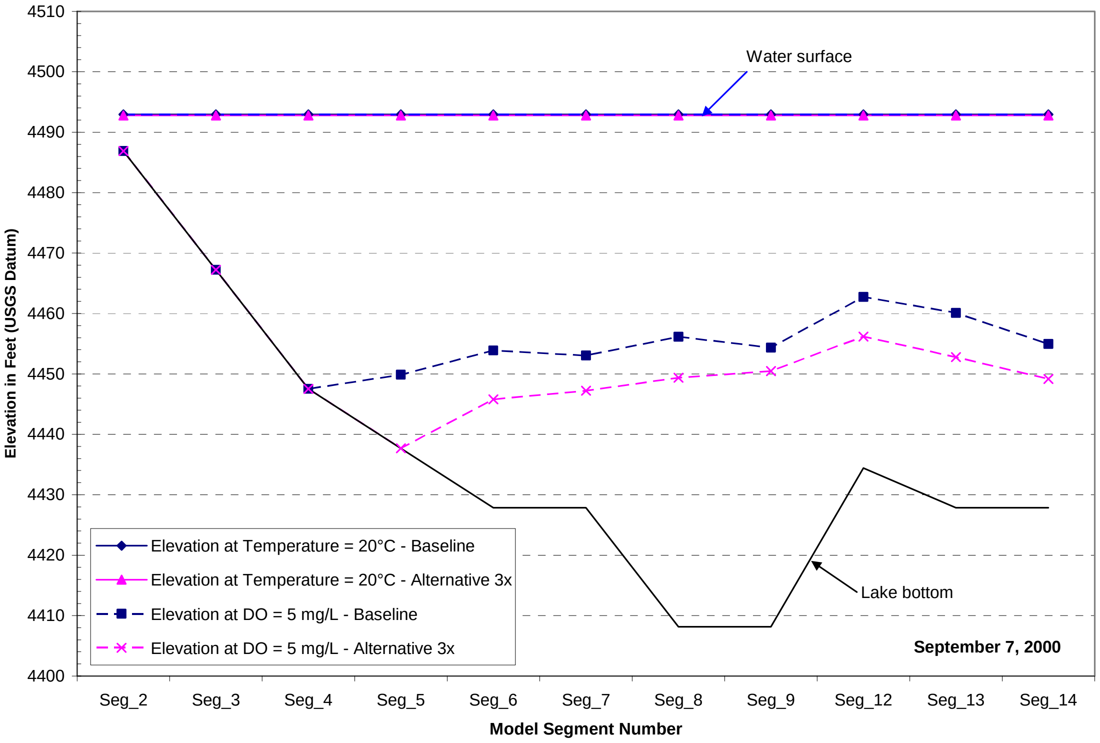


Figure 1c Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, August 2000



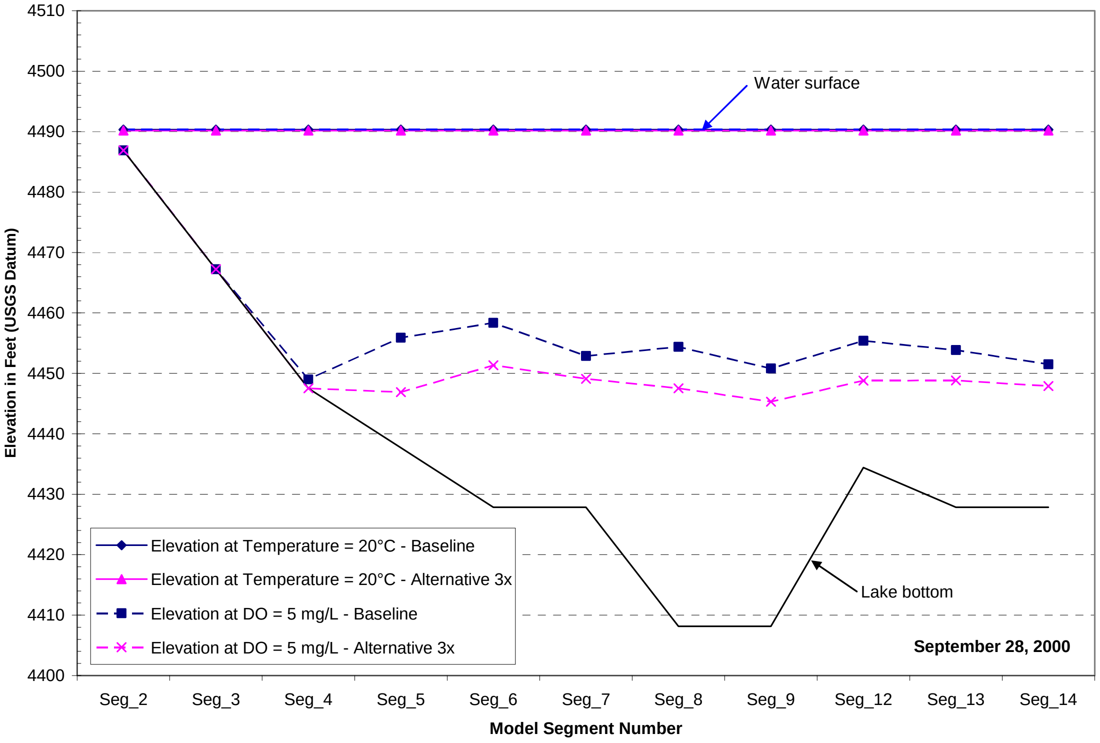


Figure 1d Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, September 2000

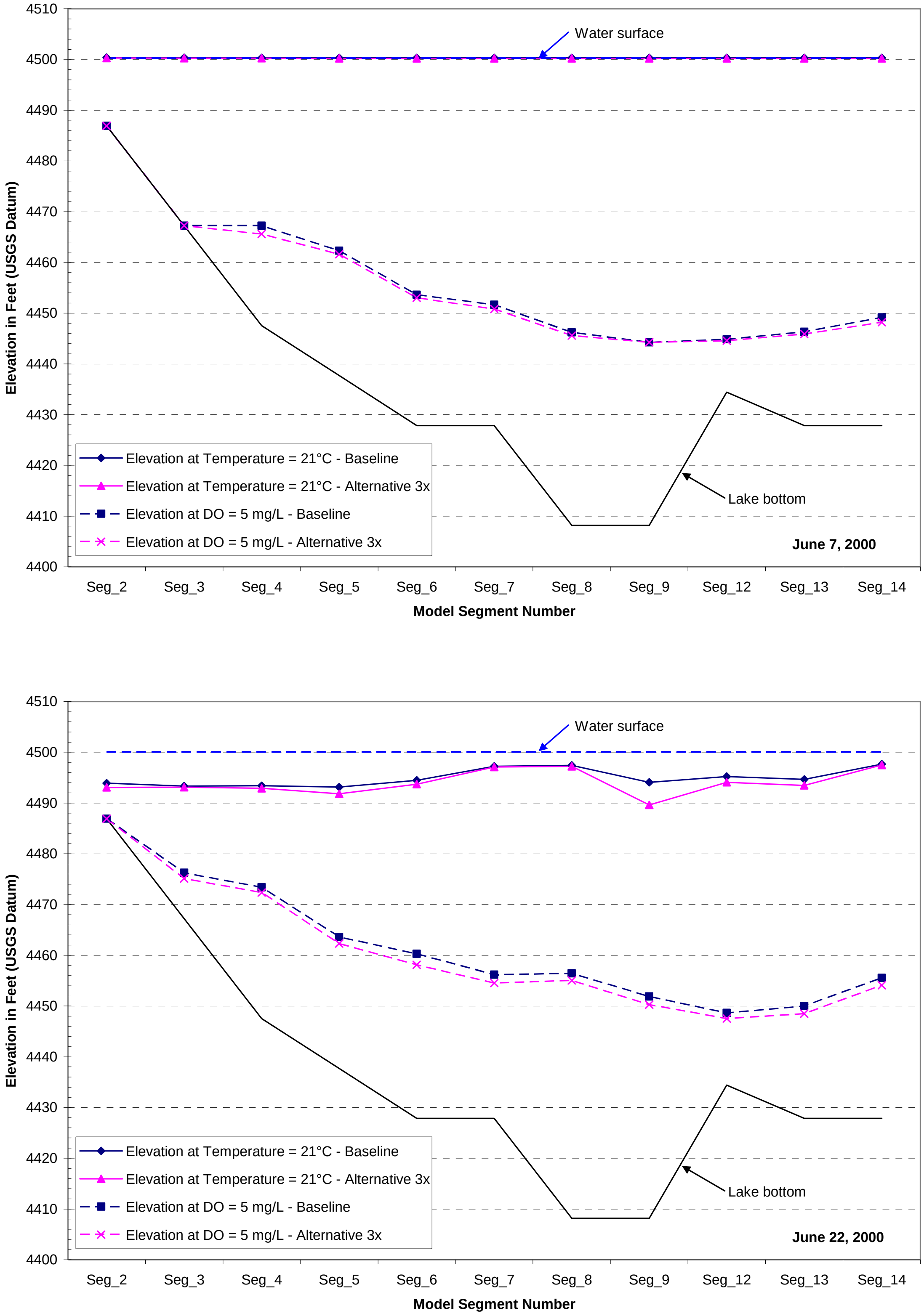
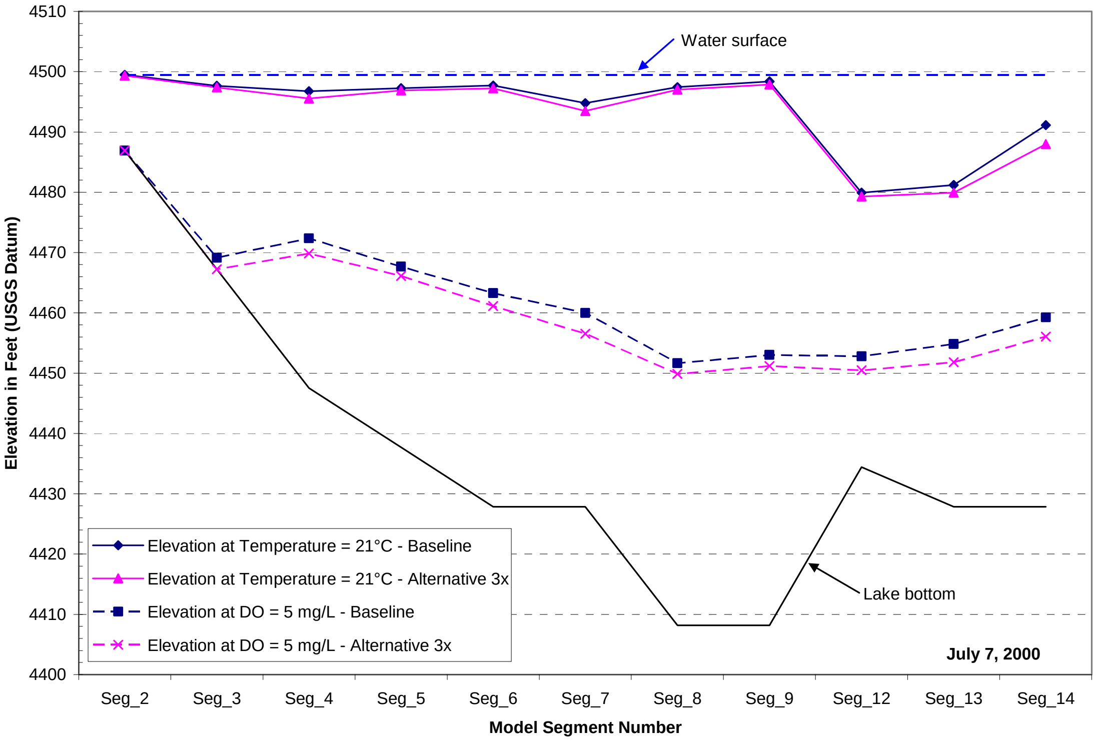


Figure 2a Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, June 2000



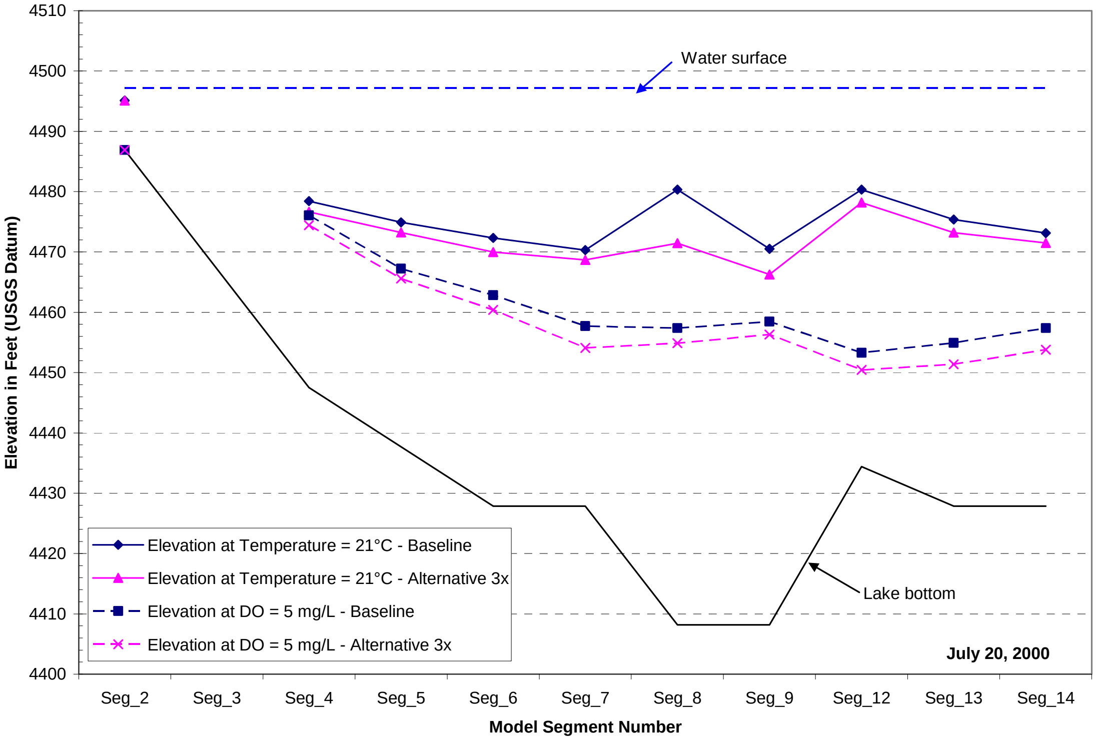
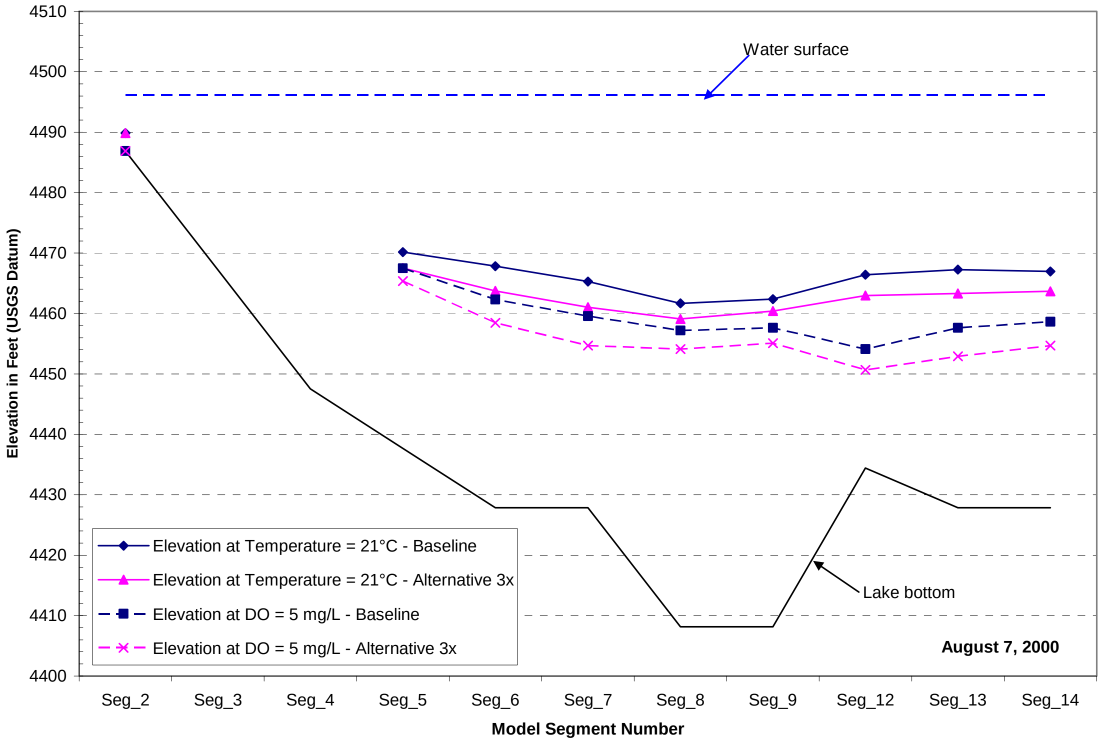


Figure 2b Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, July 2000



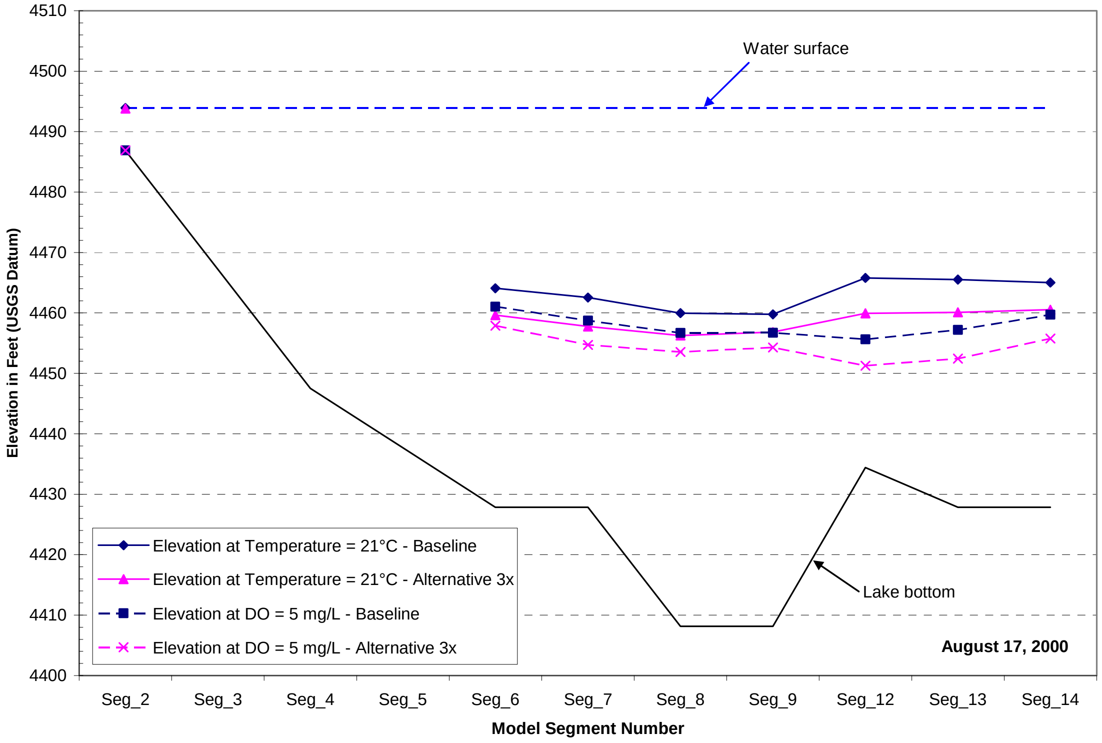
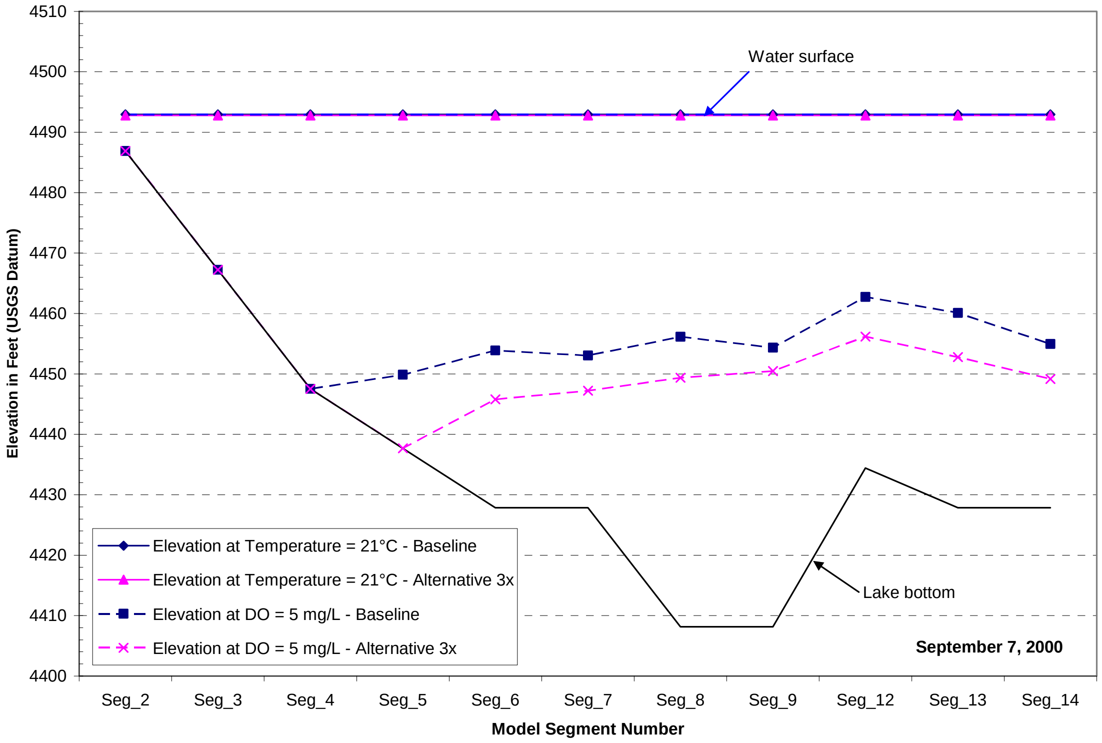


Figure 2c Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, August 2000



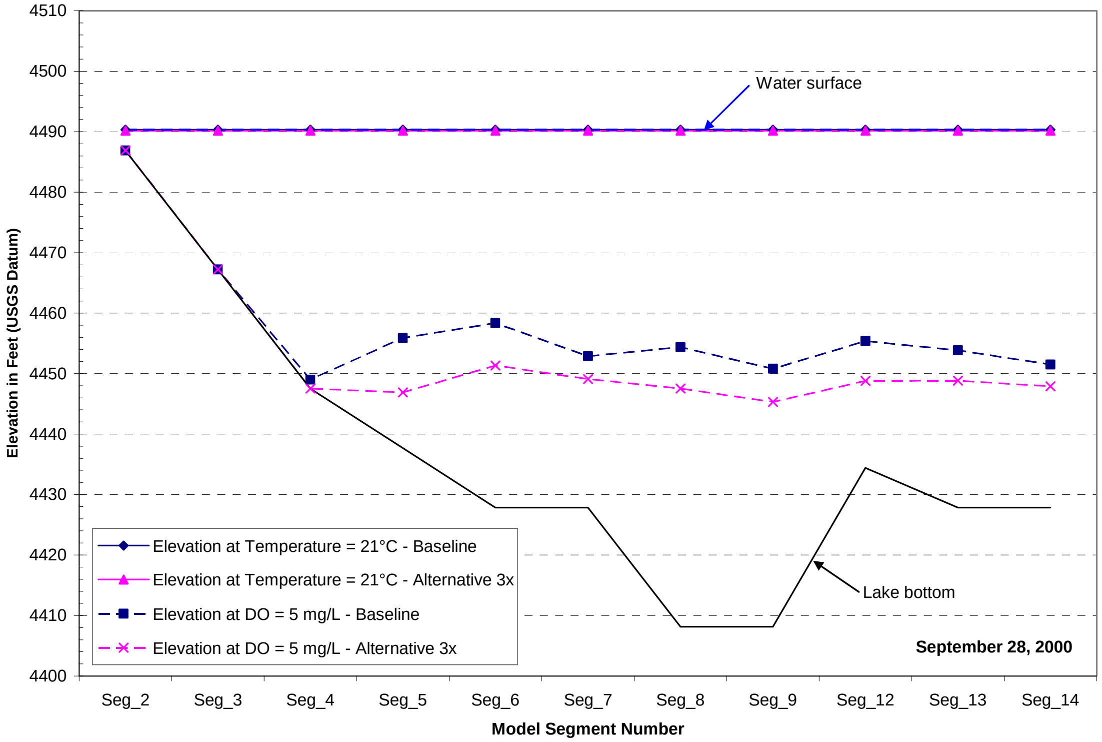
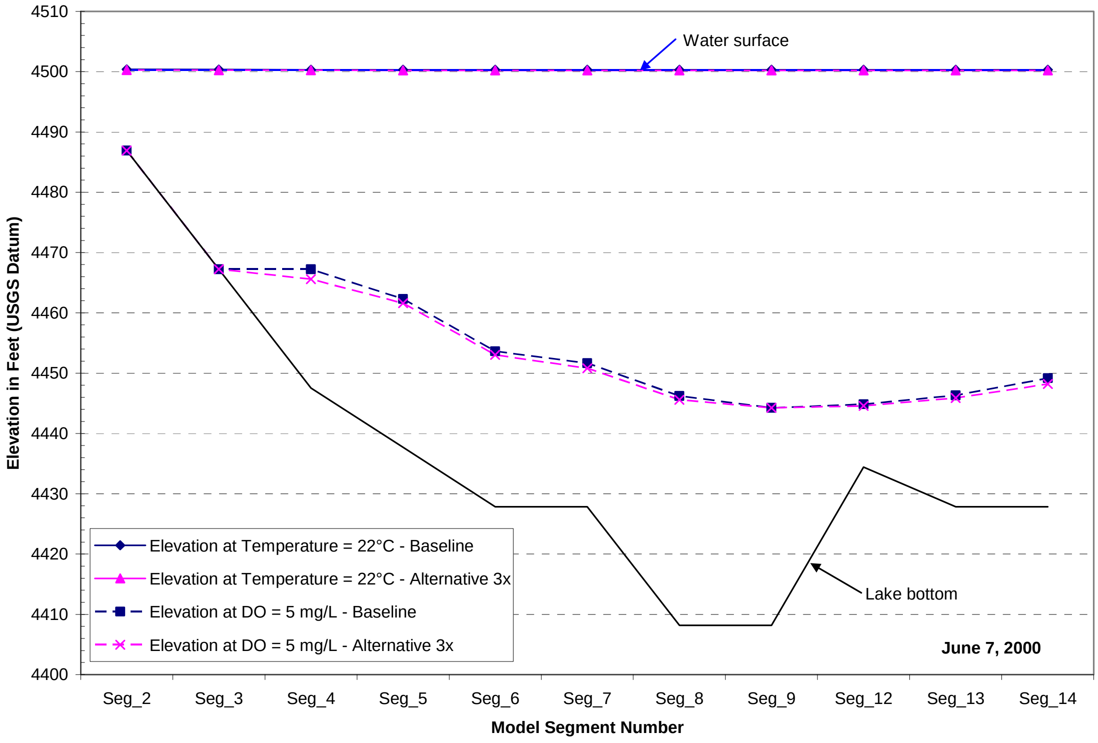


Figure 2d Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, September 2000



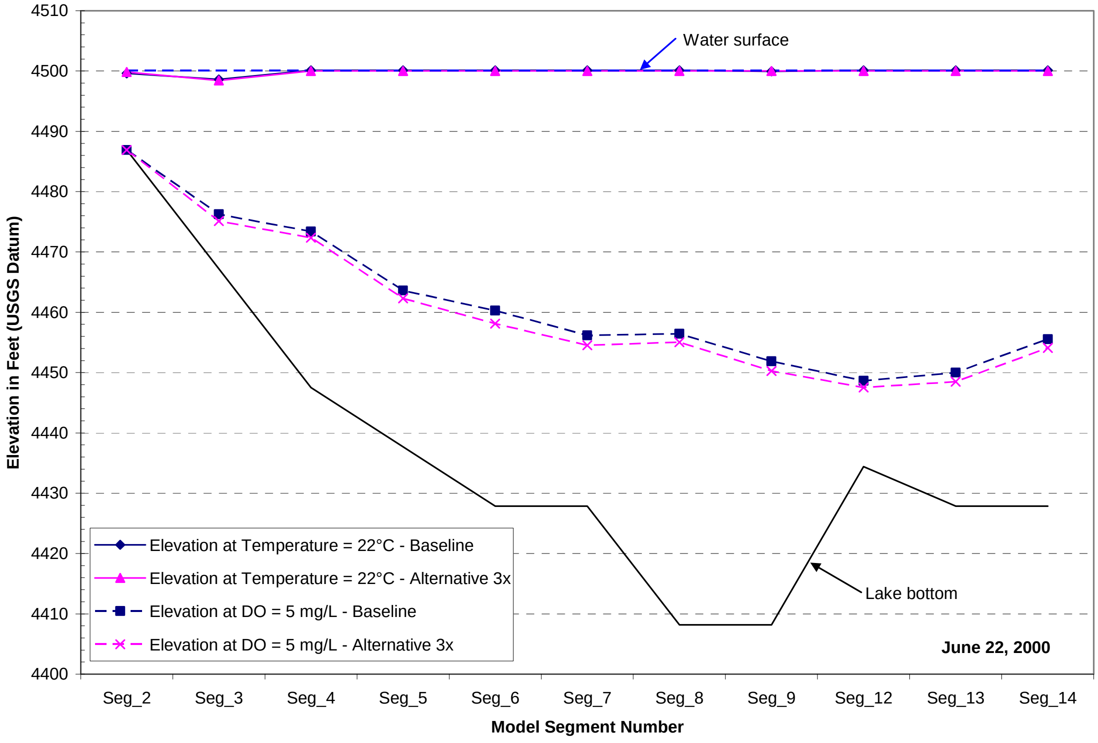
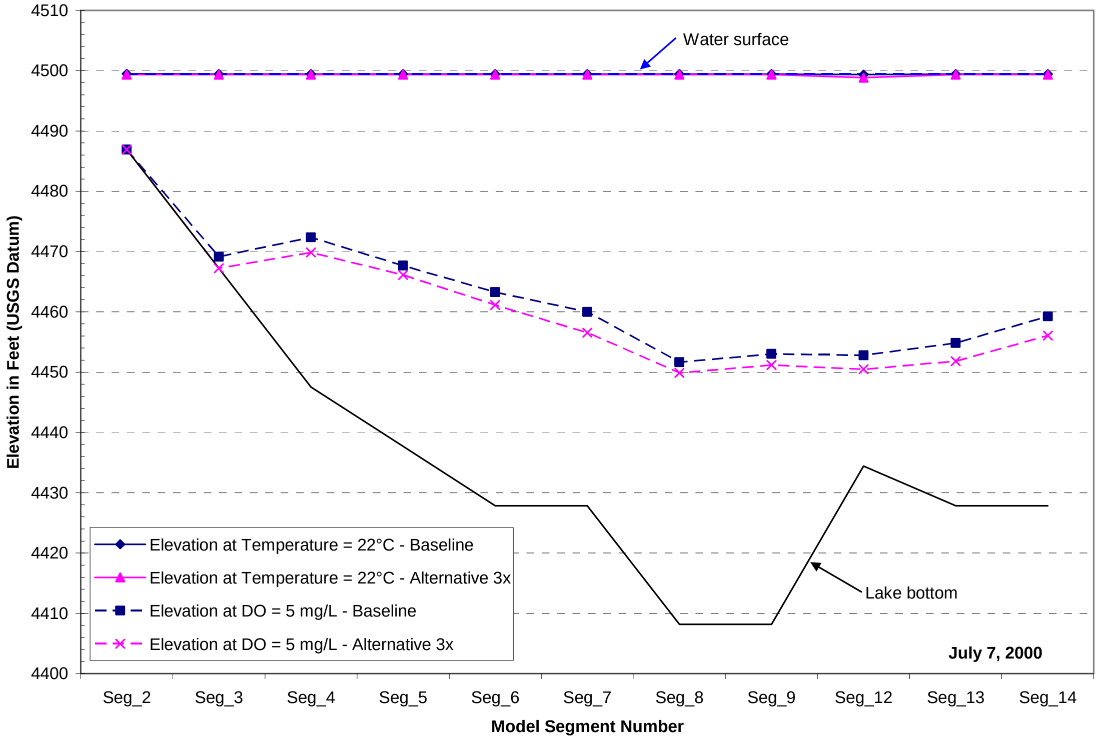


Figure 3a Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, June 2000



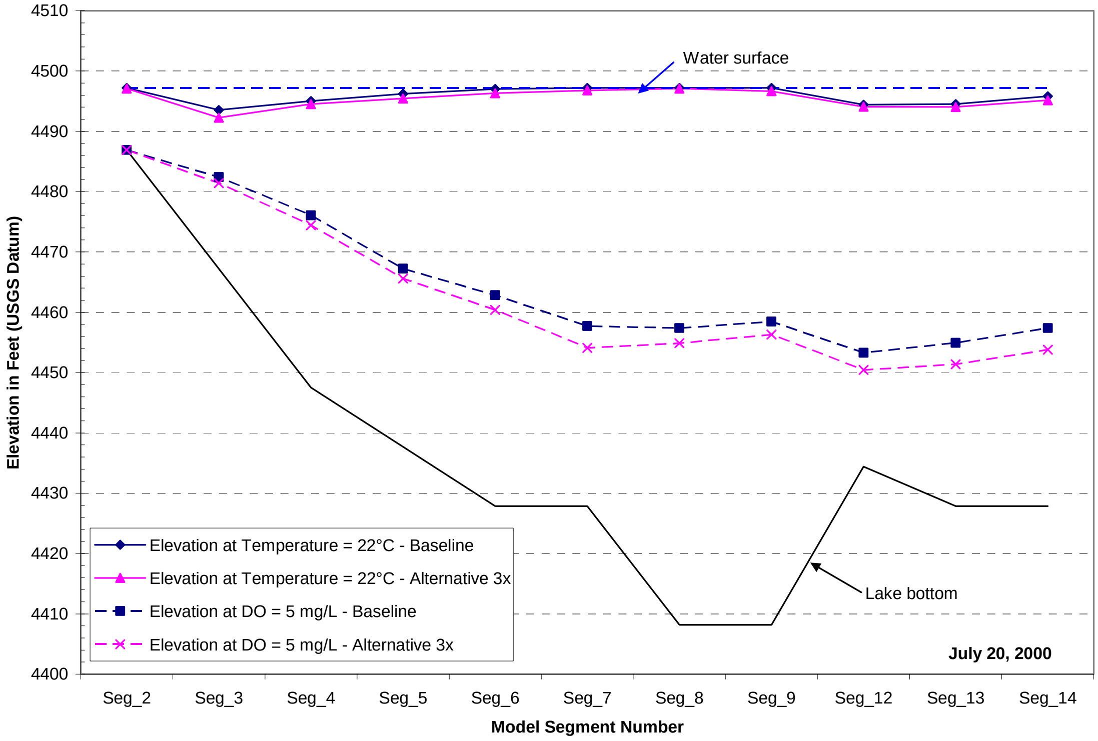
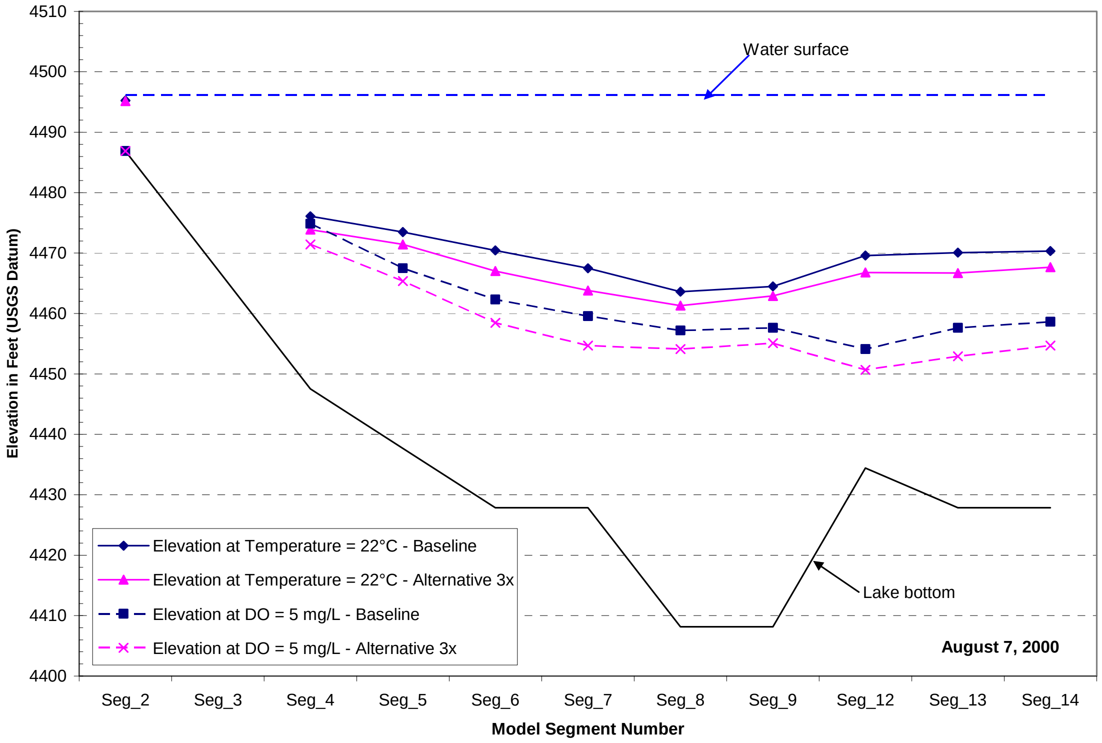


Figure 3b Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, July 2000



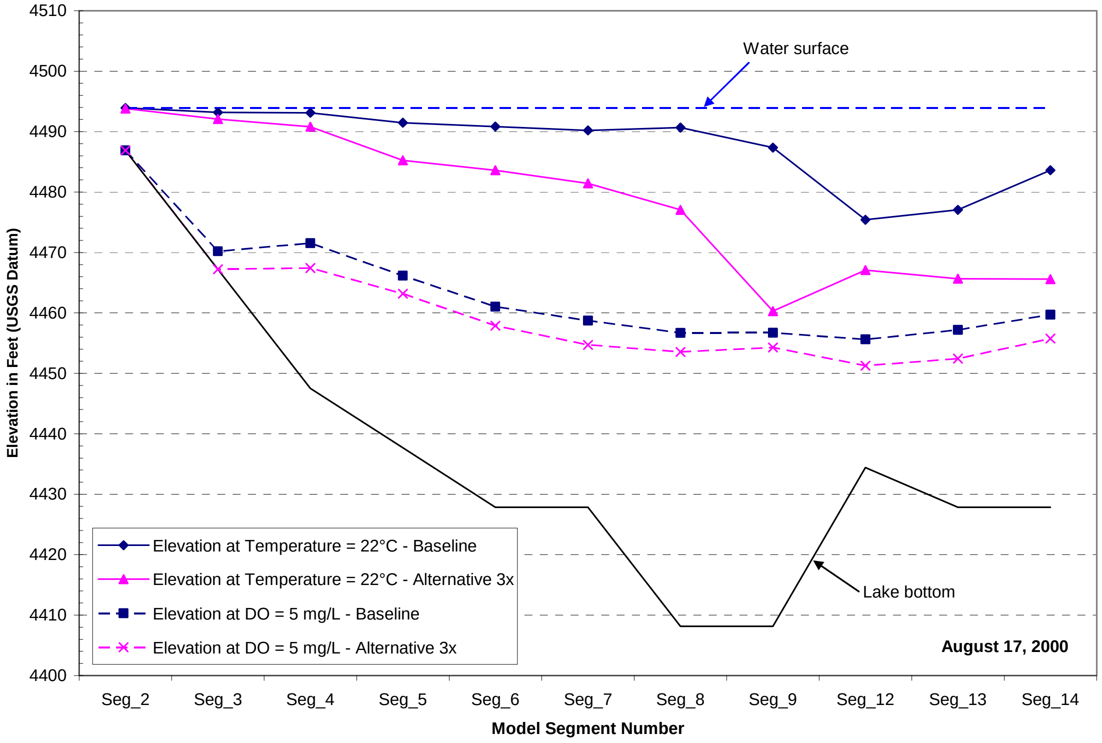
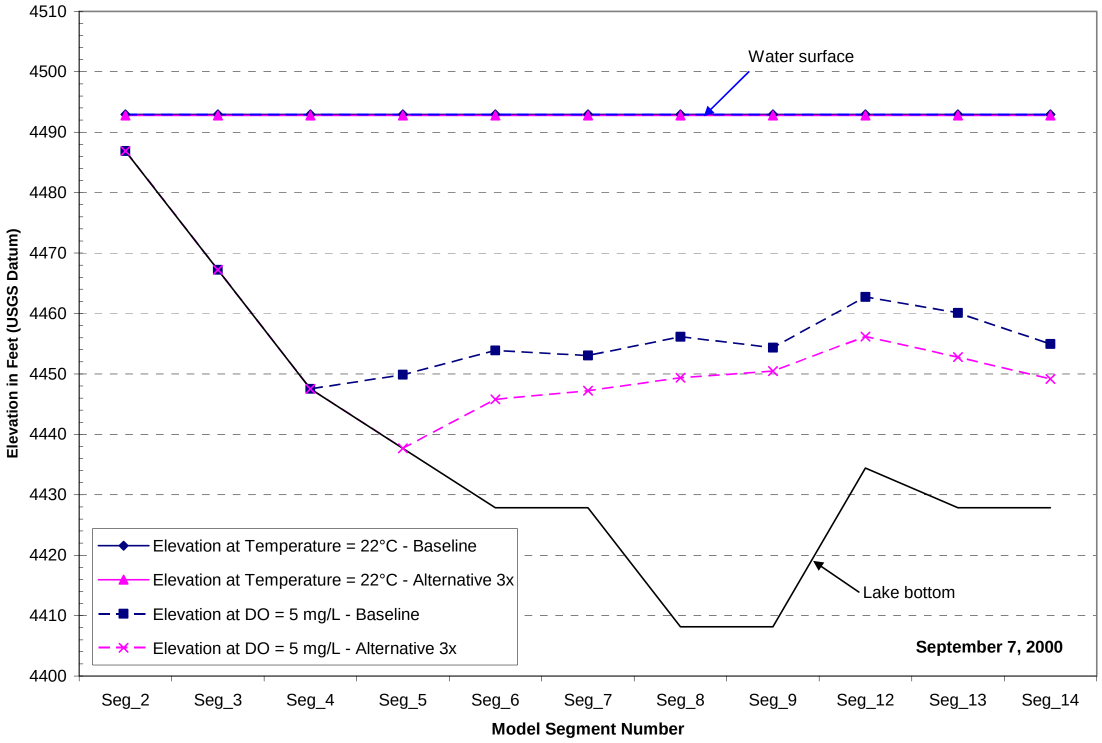


Figure 3c Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, August 2000



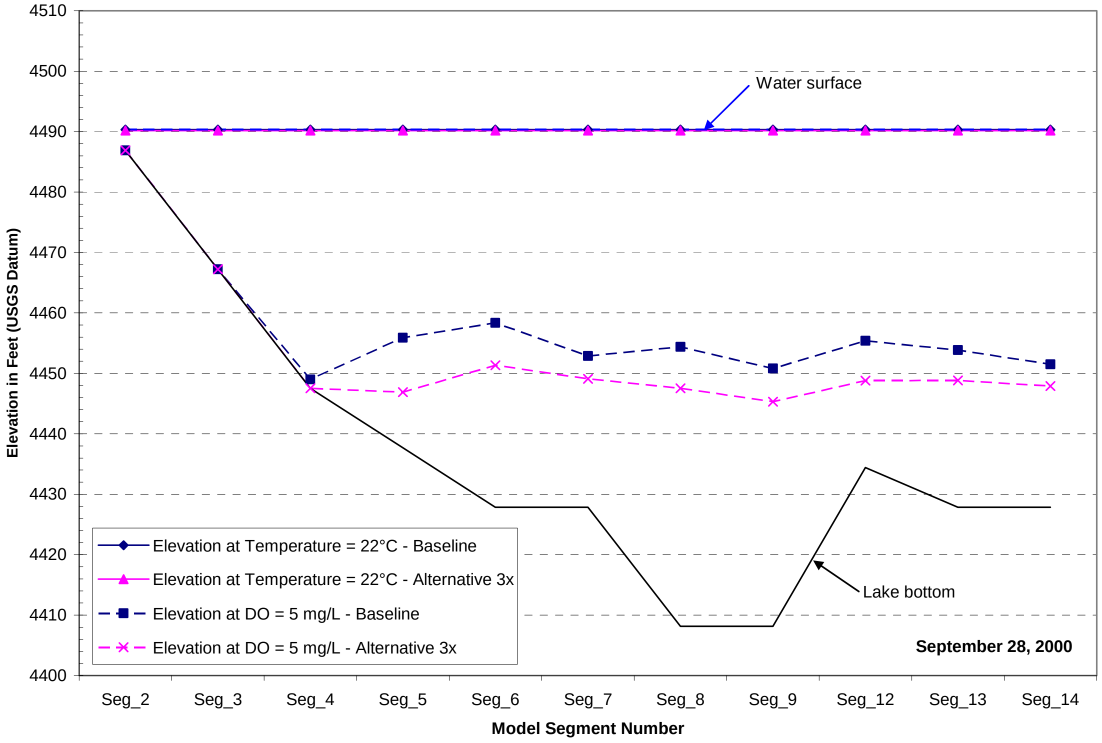
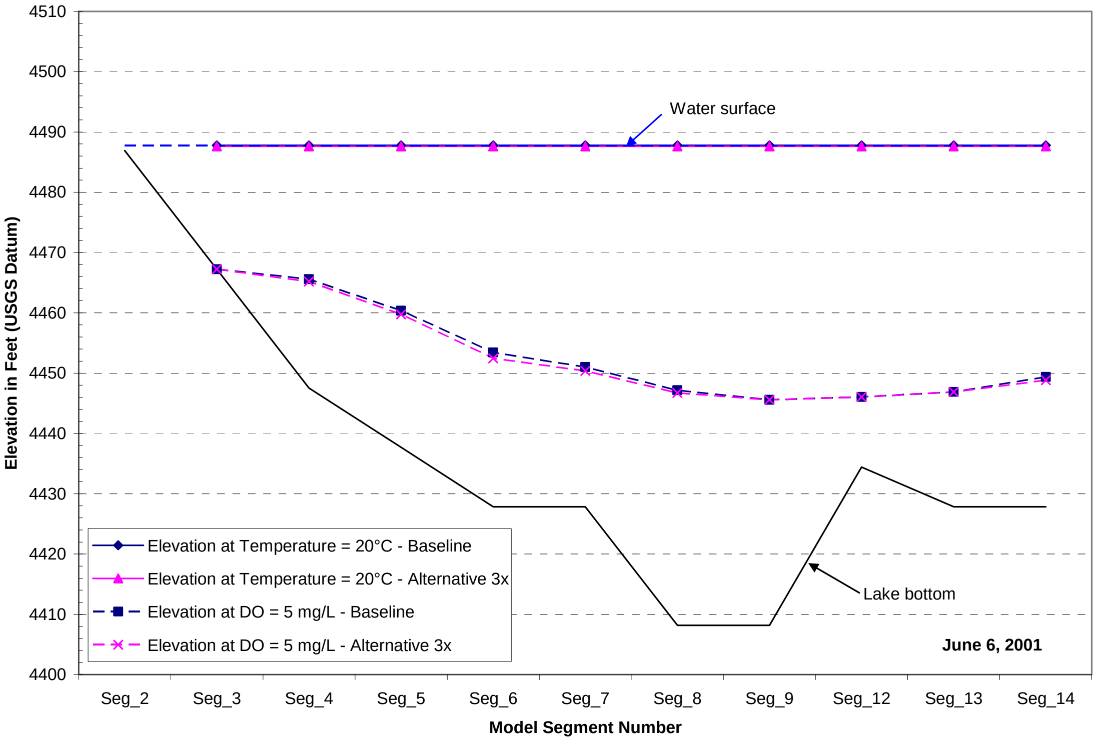


Figure 3d Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, September 2000



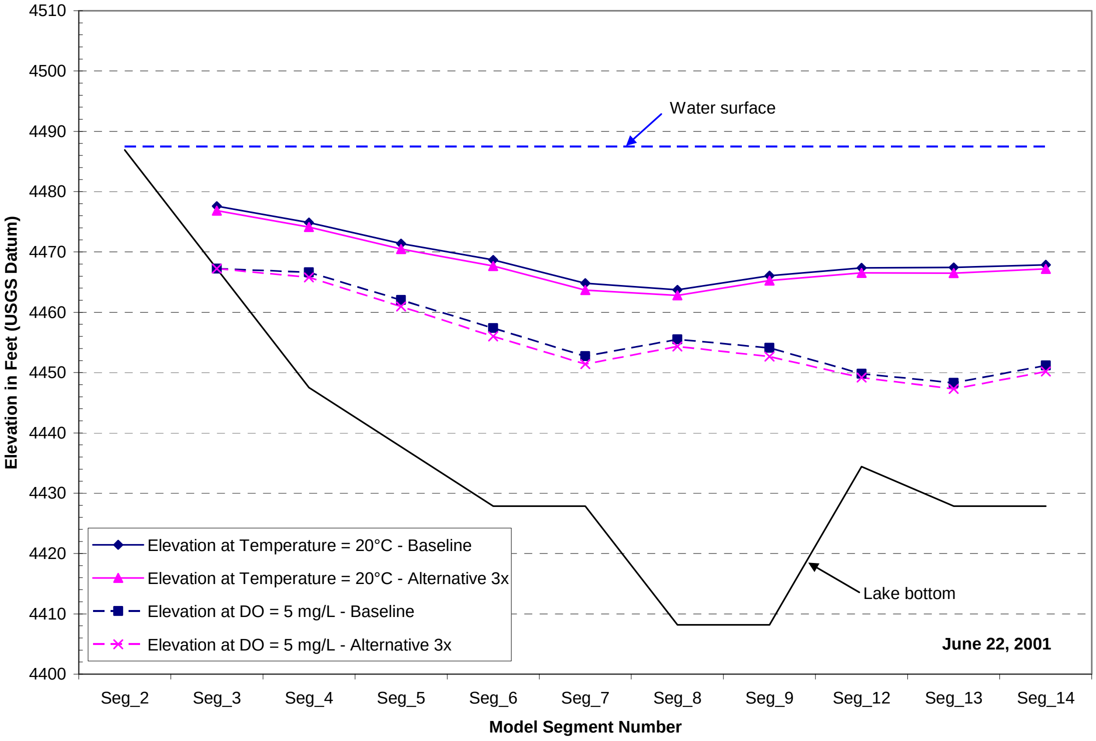
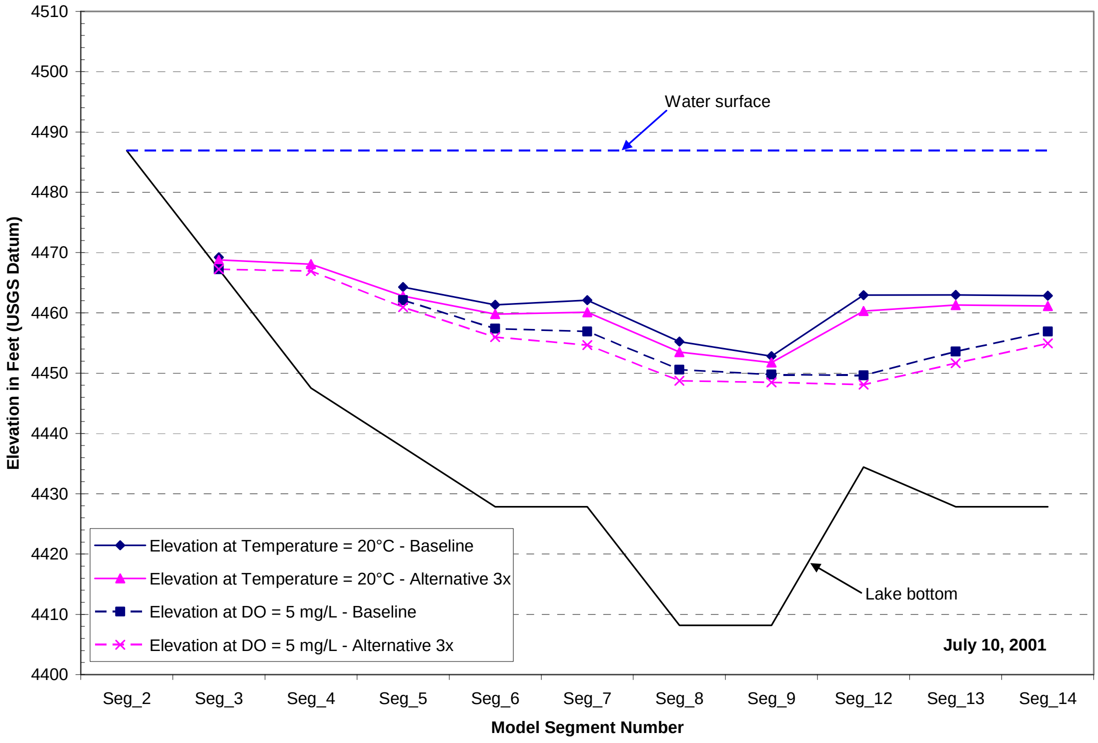


Figure 4a Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, June 2001



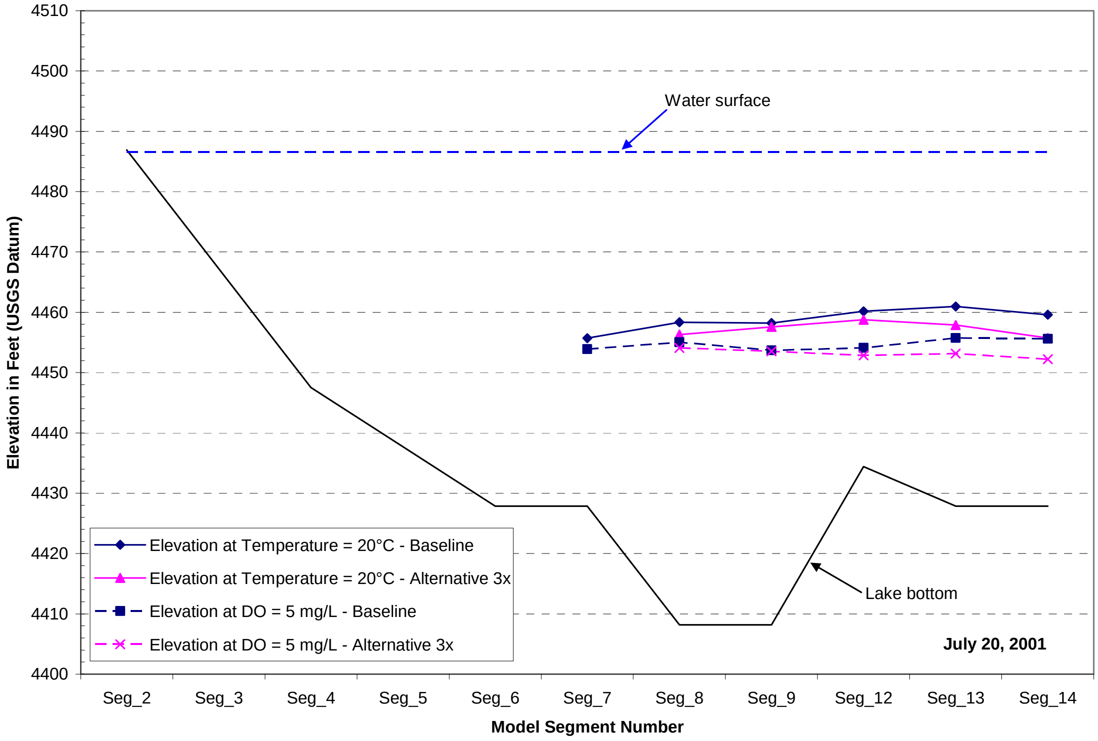
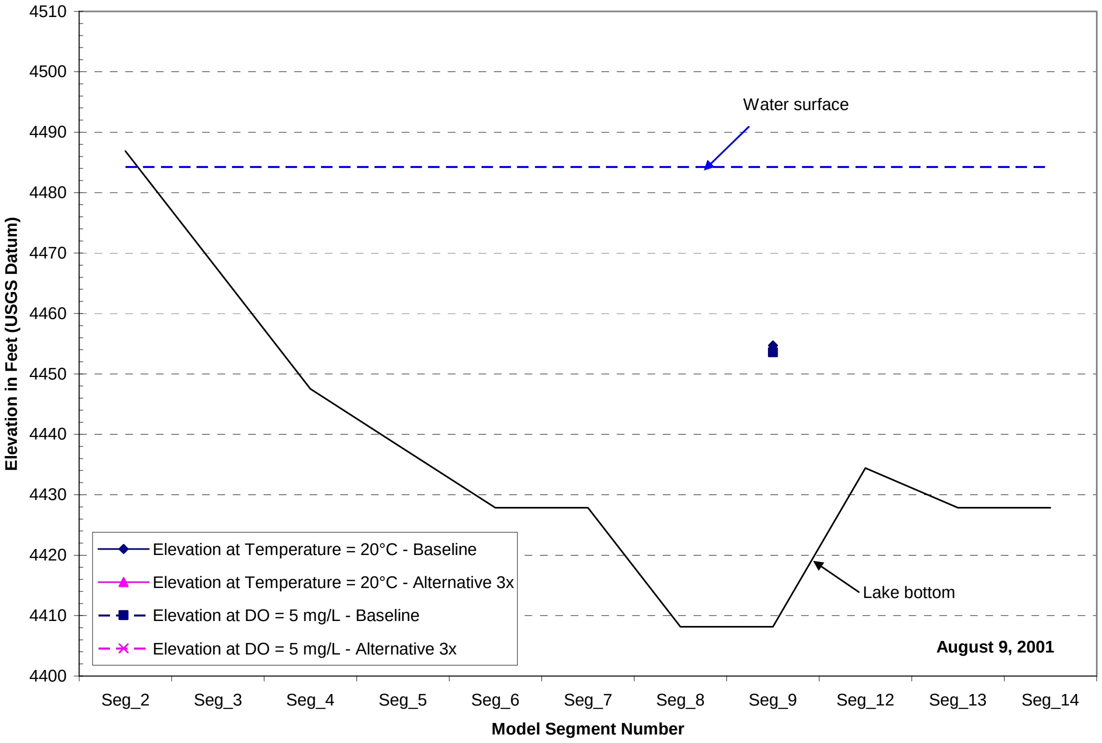


Figure 4b Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, July 2001



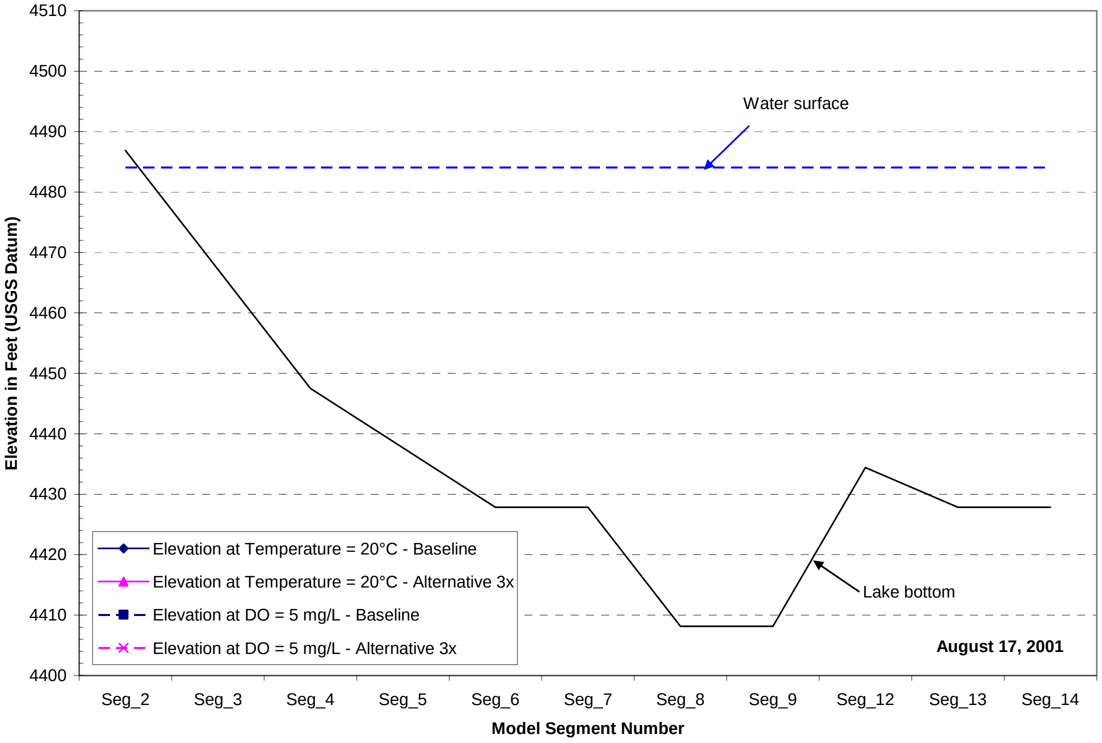
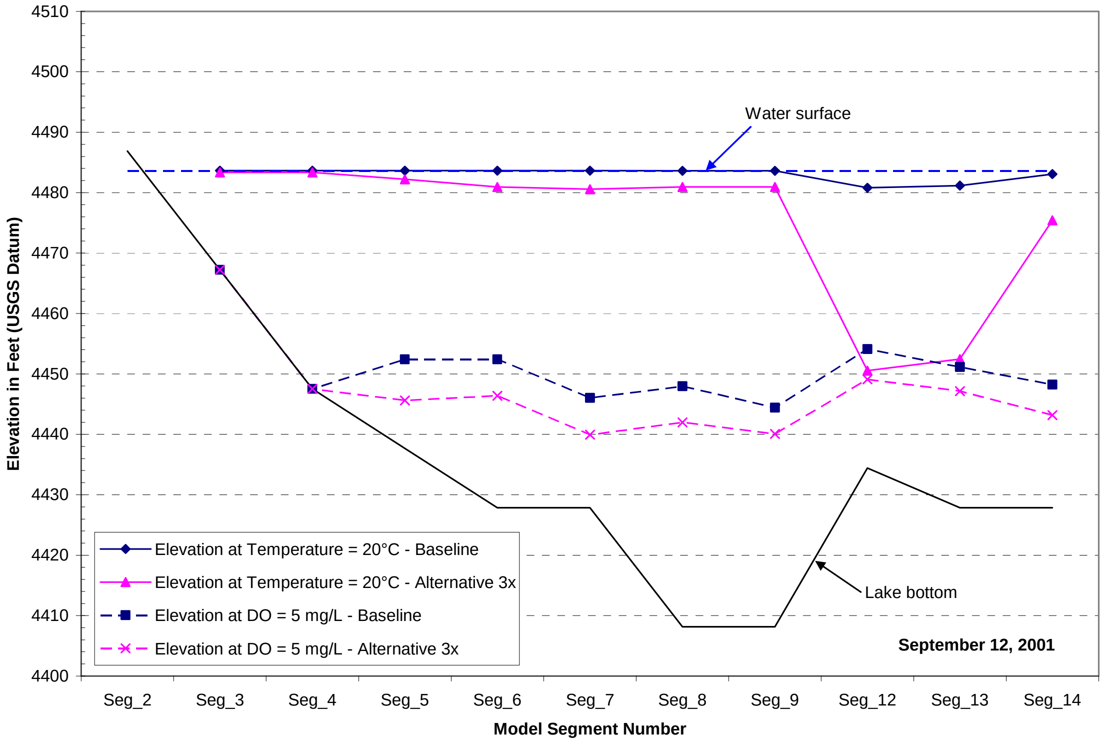


Figure 4c Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, August 2001



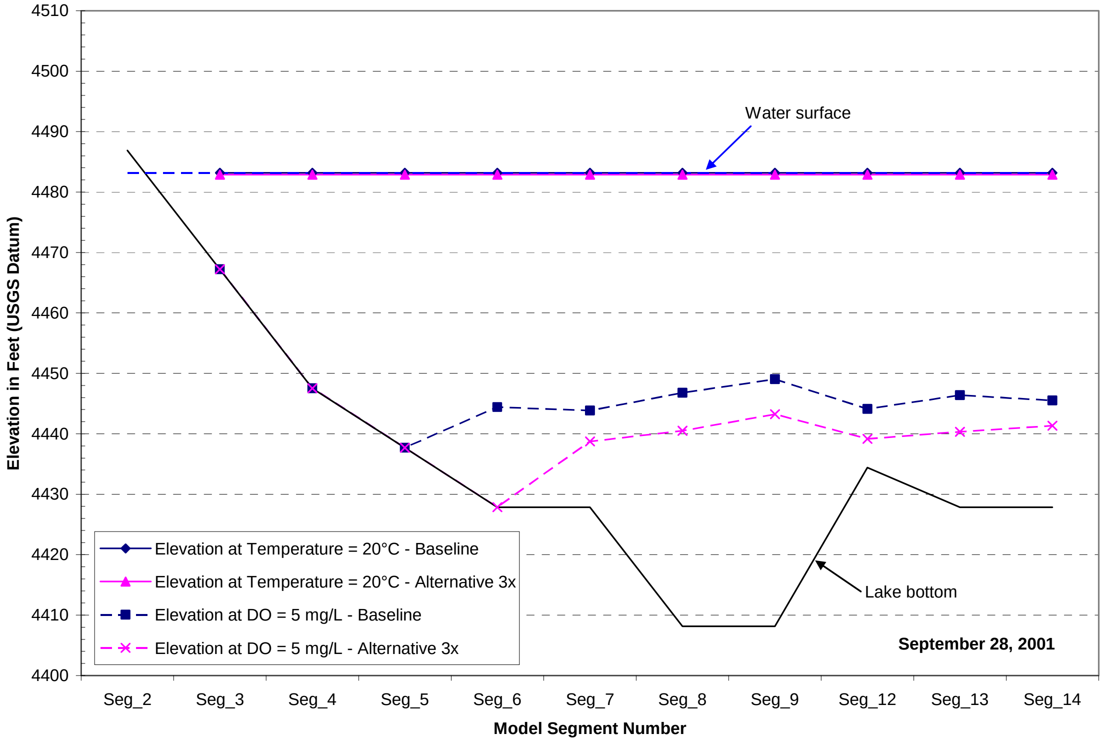
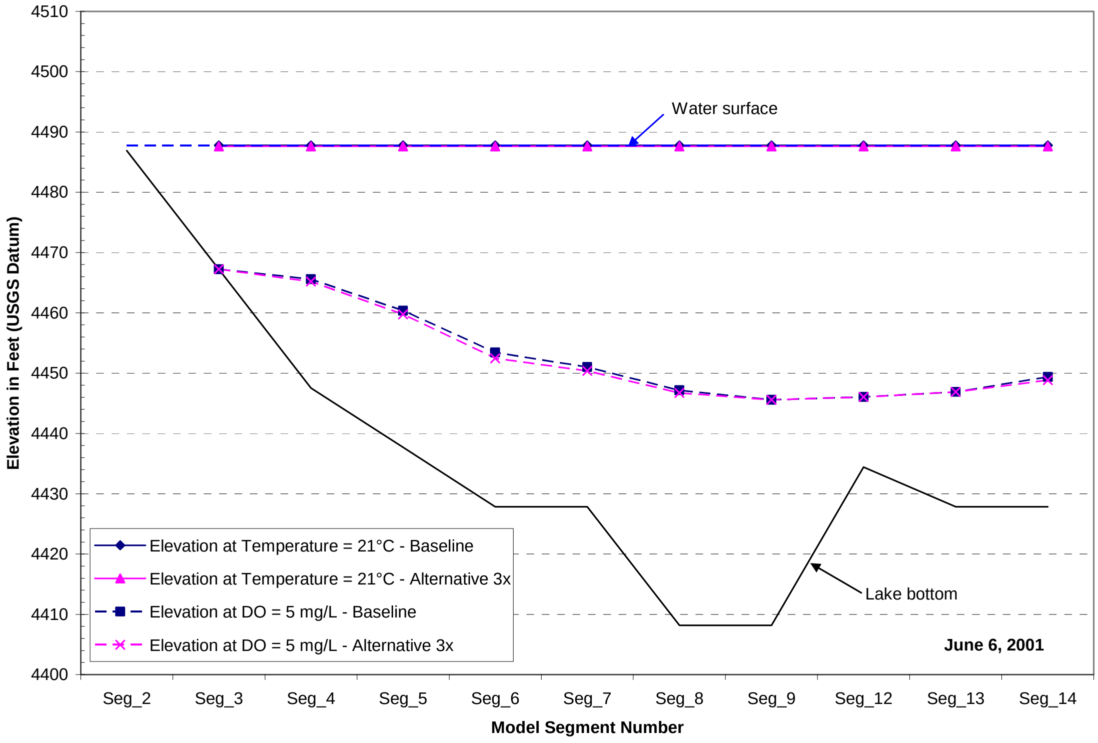


Figure 4d Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, September 2001



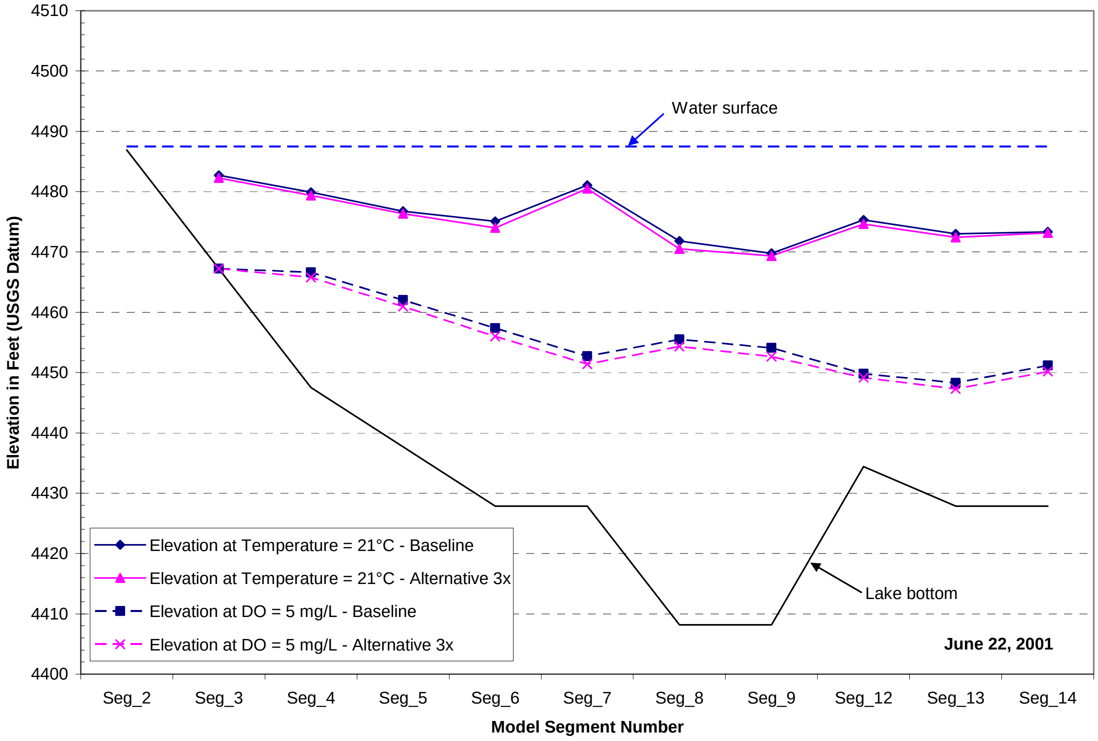
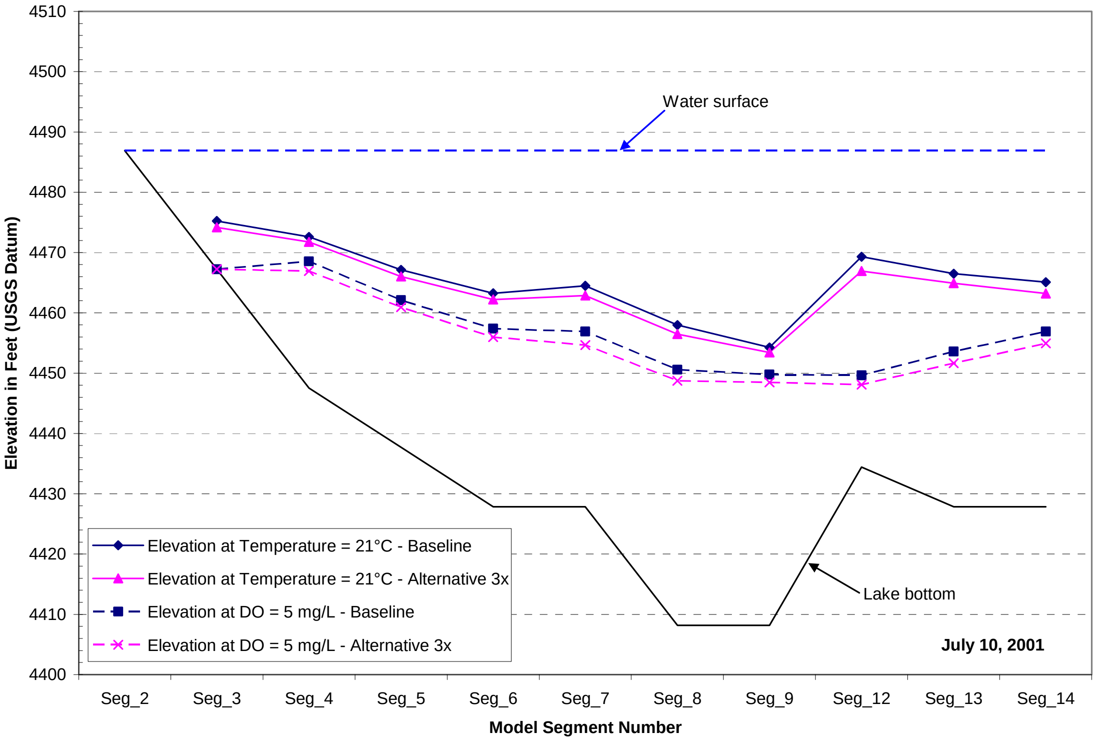


Figure 5a Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, June 2001



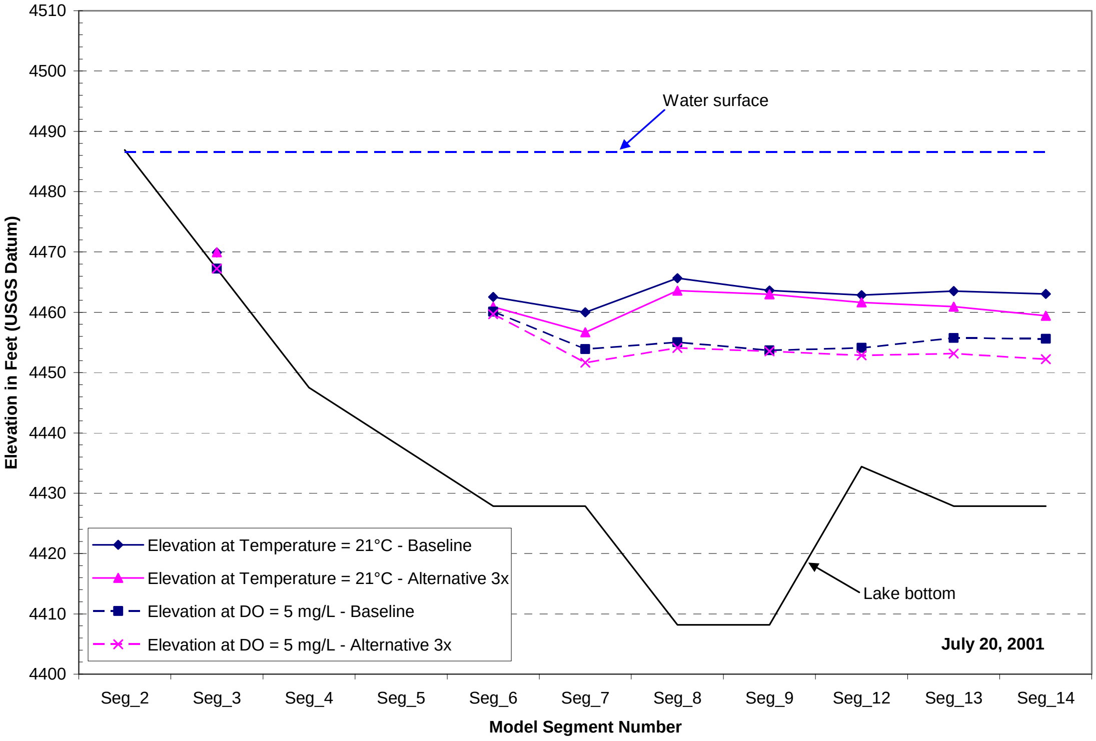
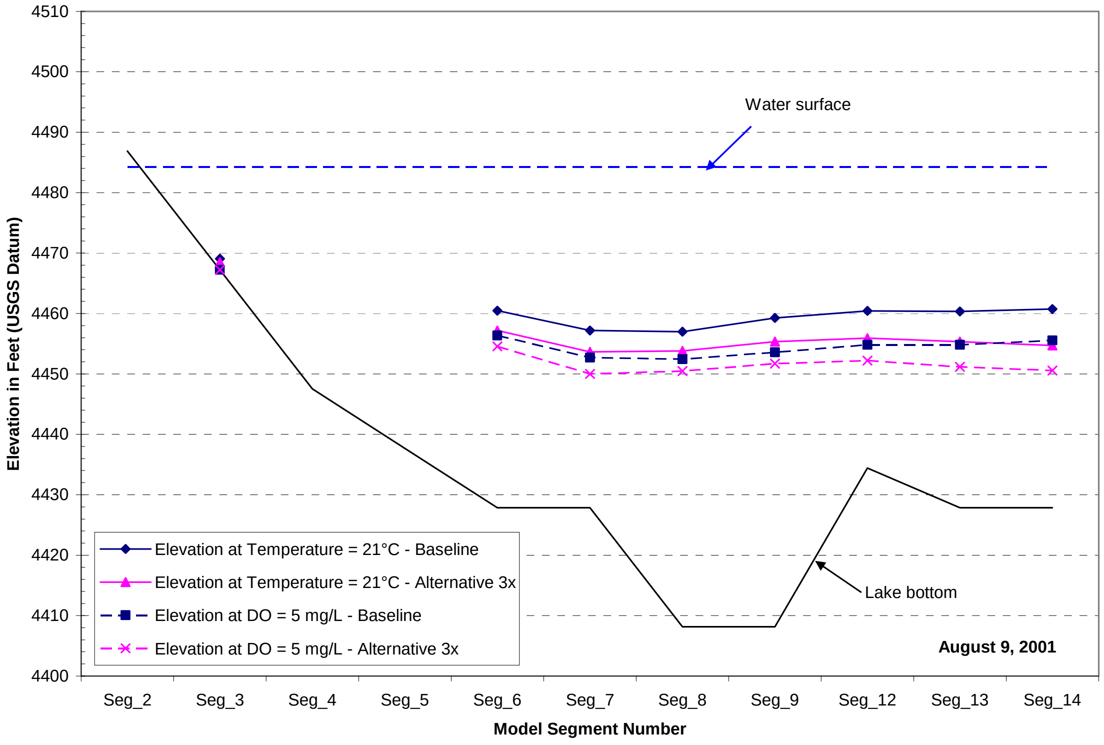


Figure 5b Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, July 2001



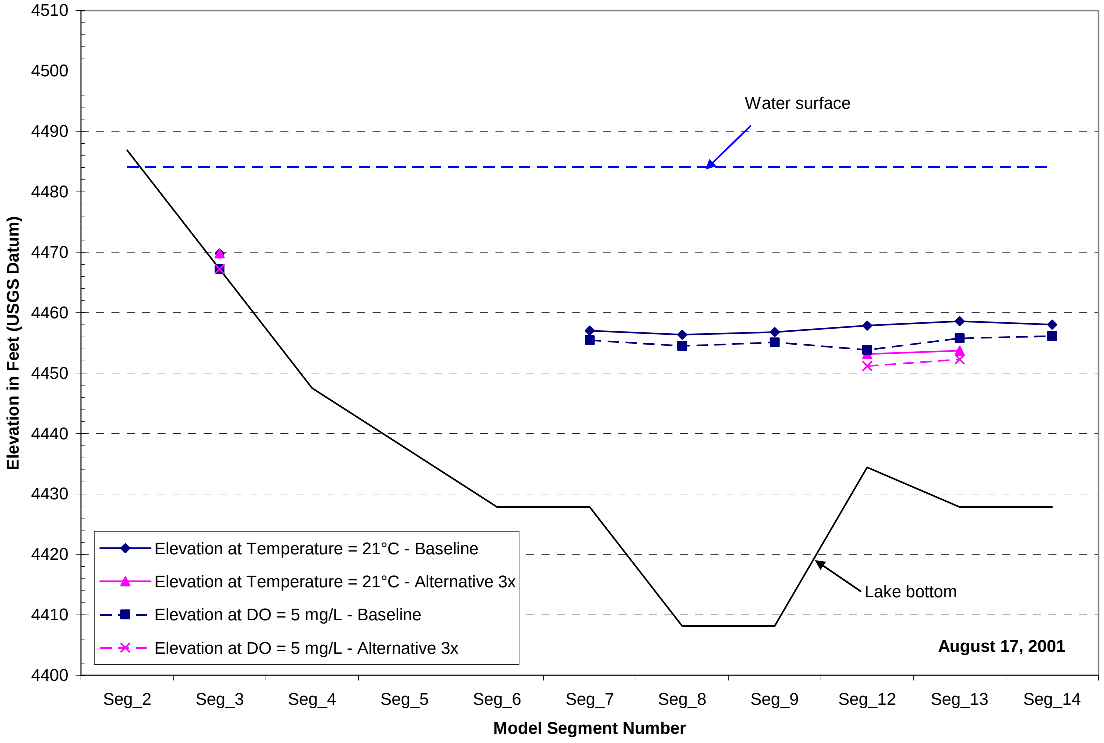
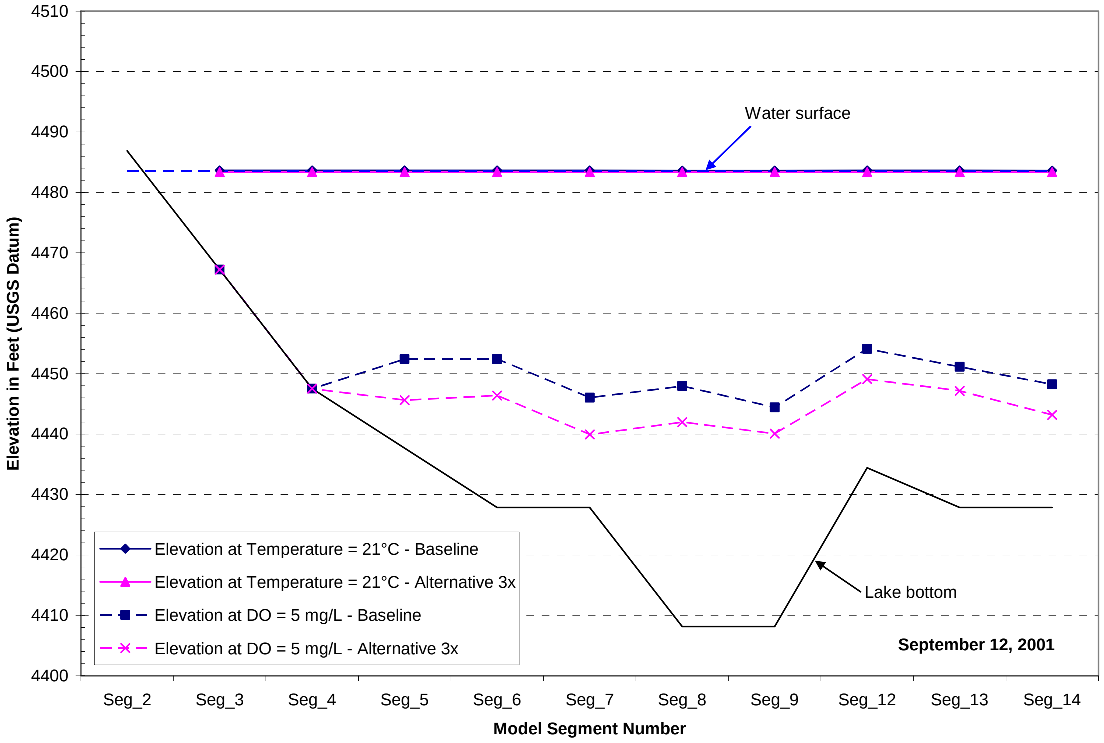


Figure 5c Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, August 2001



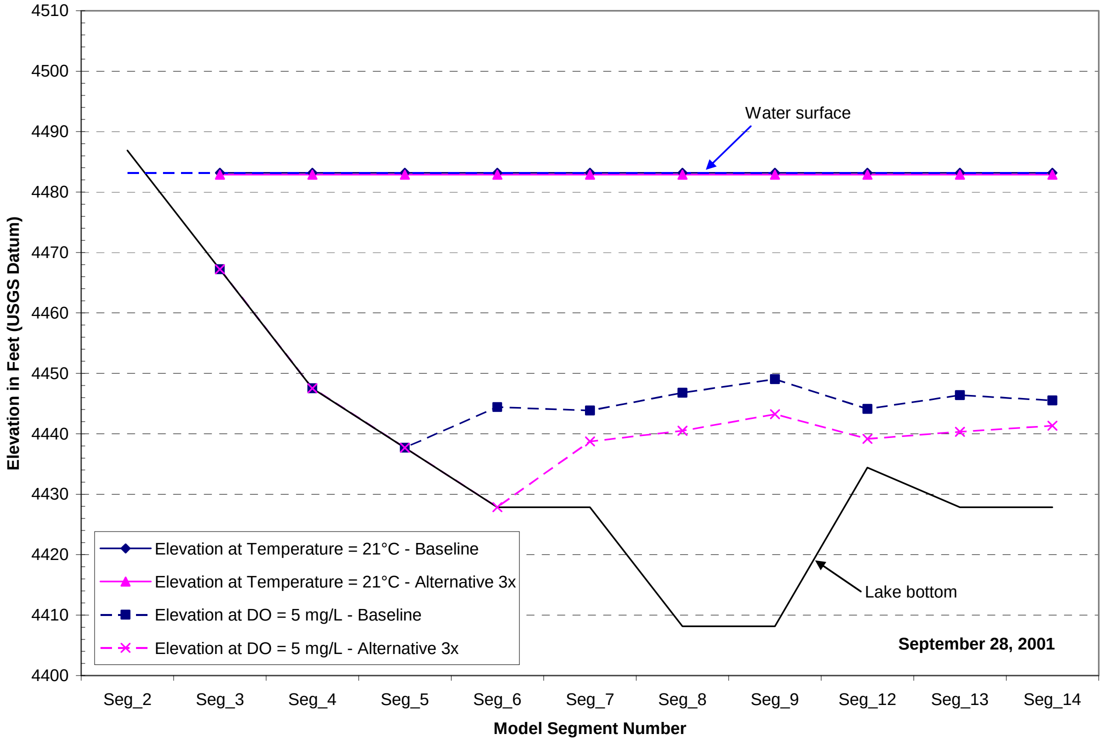
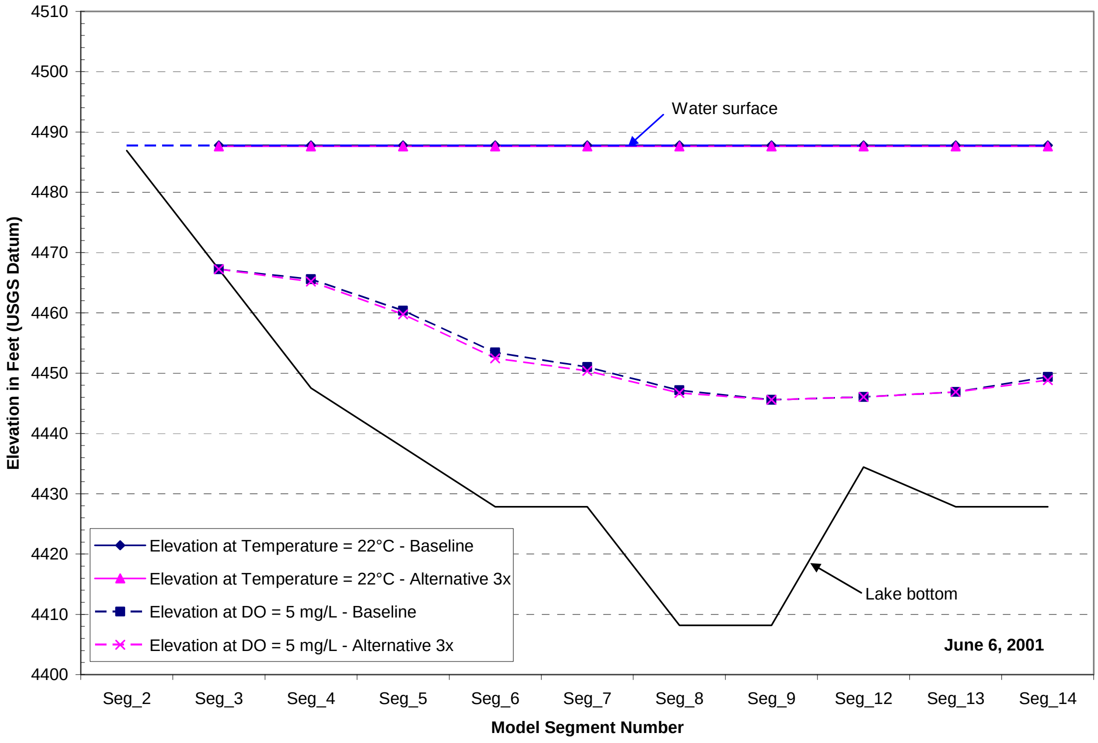


Figure 5d Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, September 2001



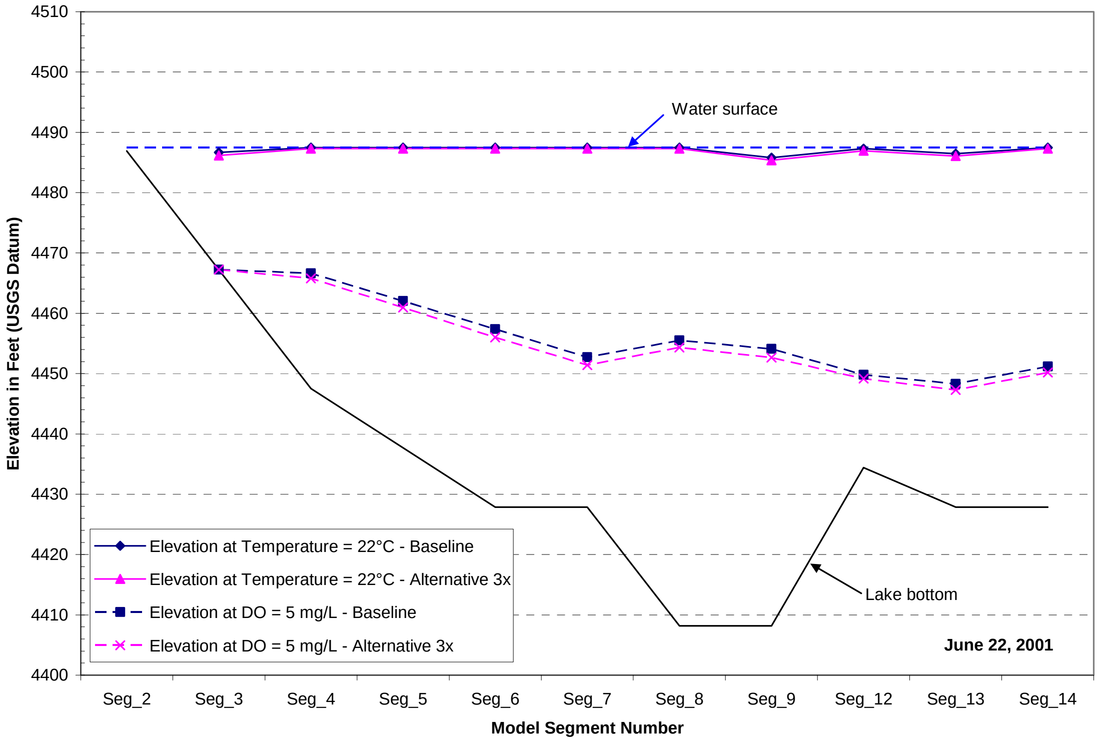
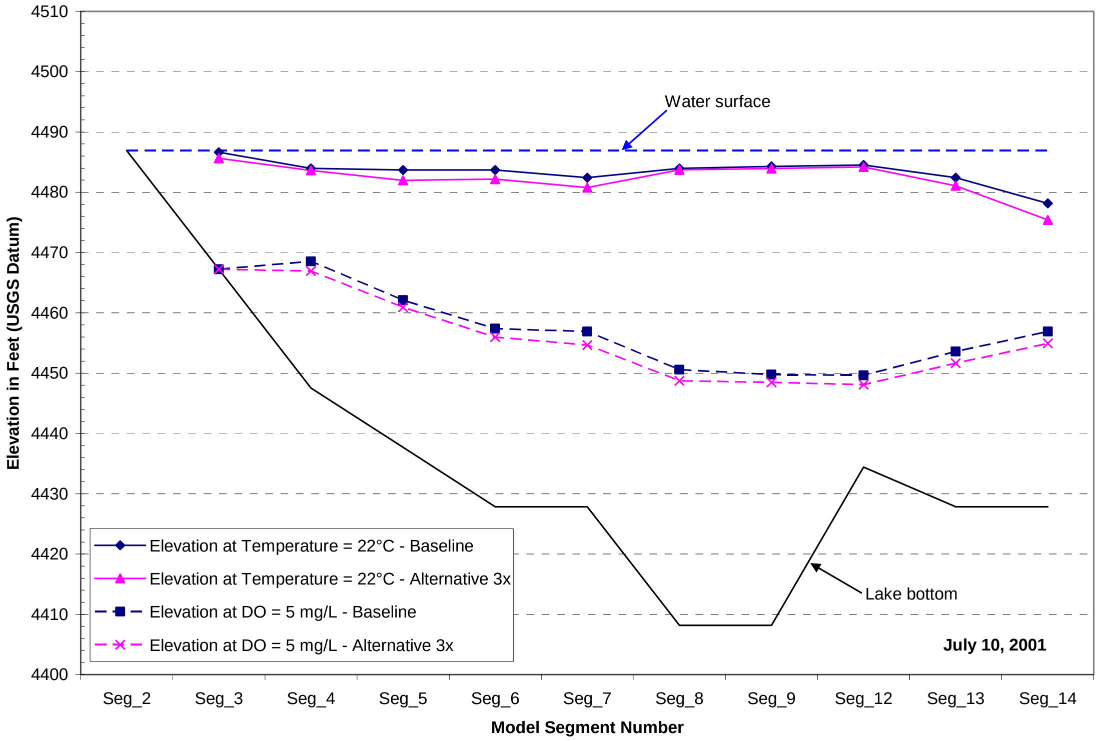


Figure 6a Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, June 2001



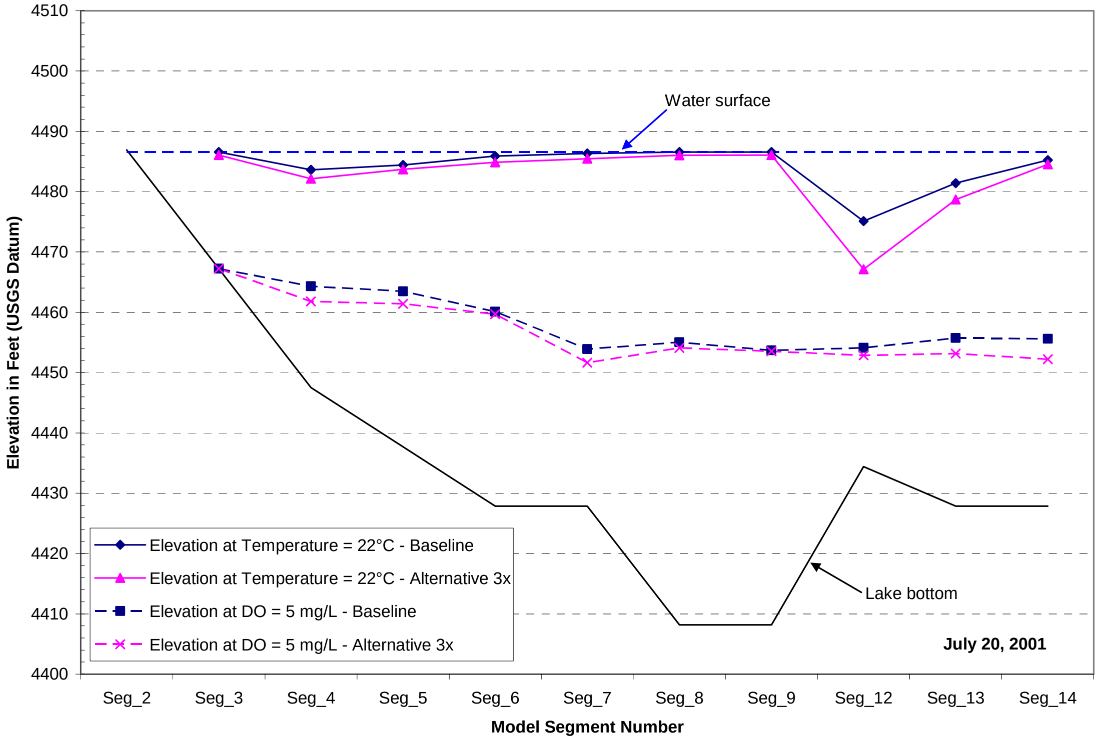
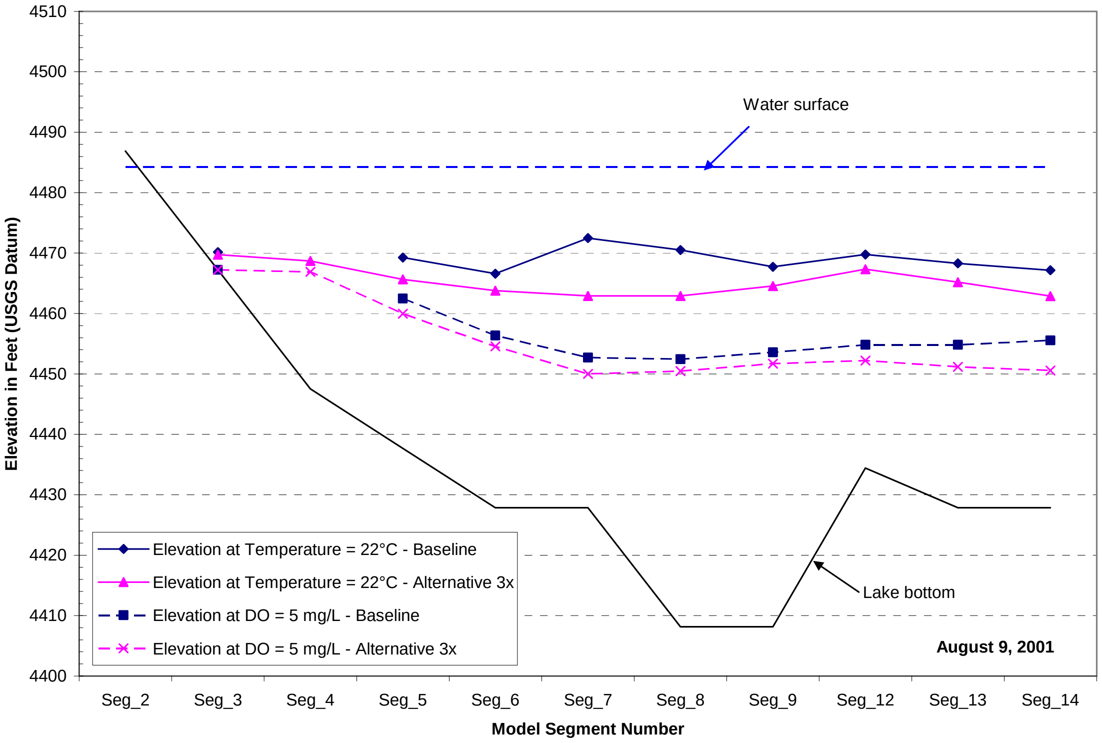


Figure 6b Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, July 2001



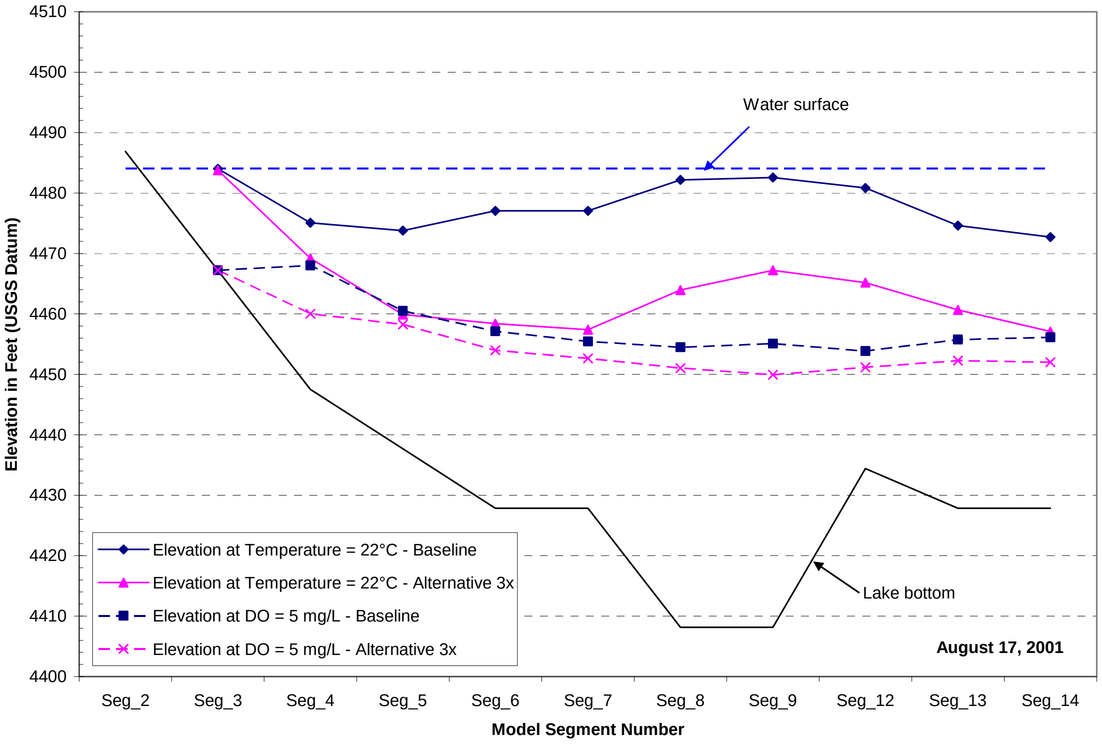
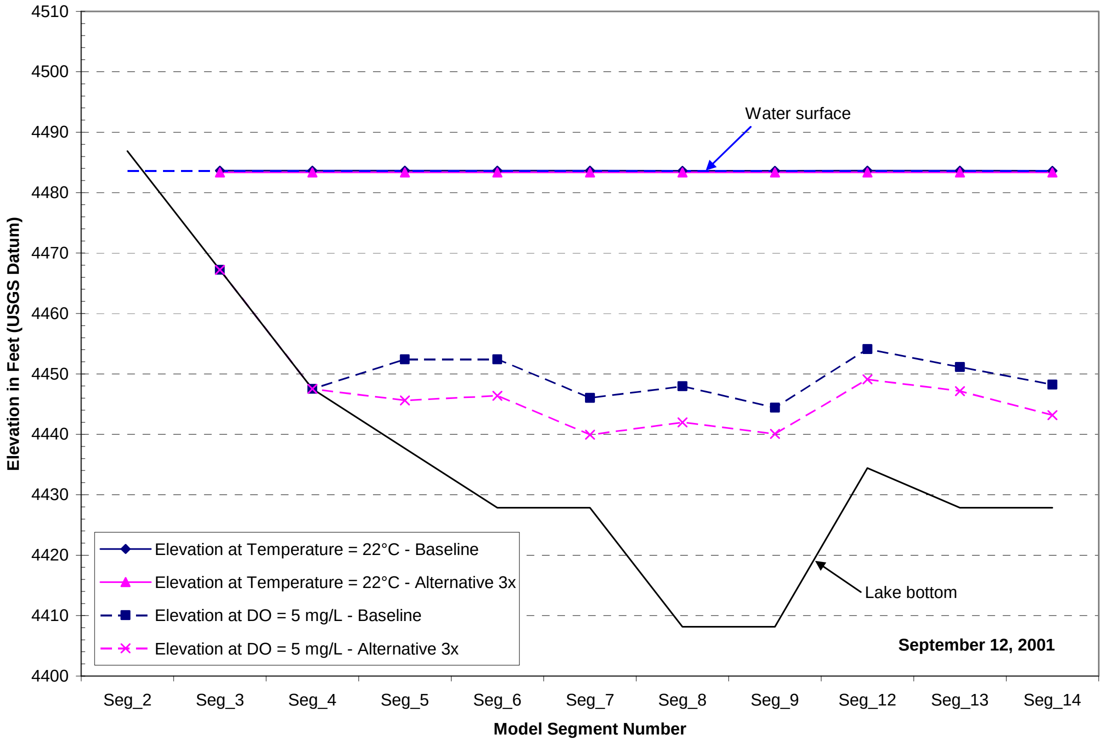


Figure 6c Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, August 2001



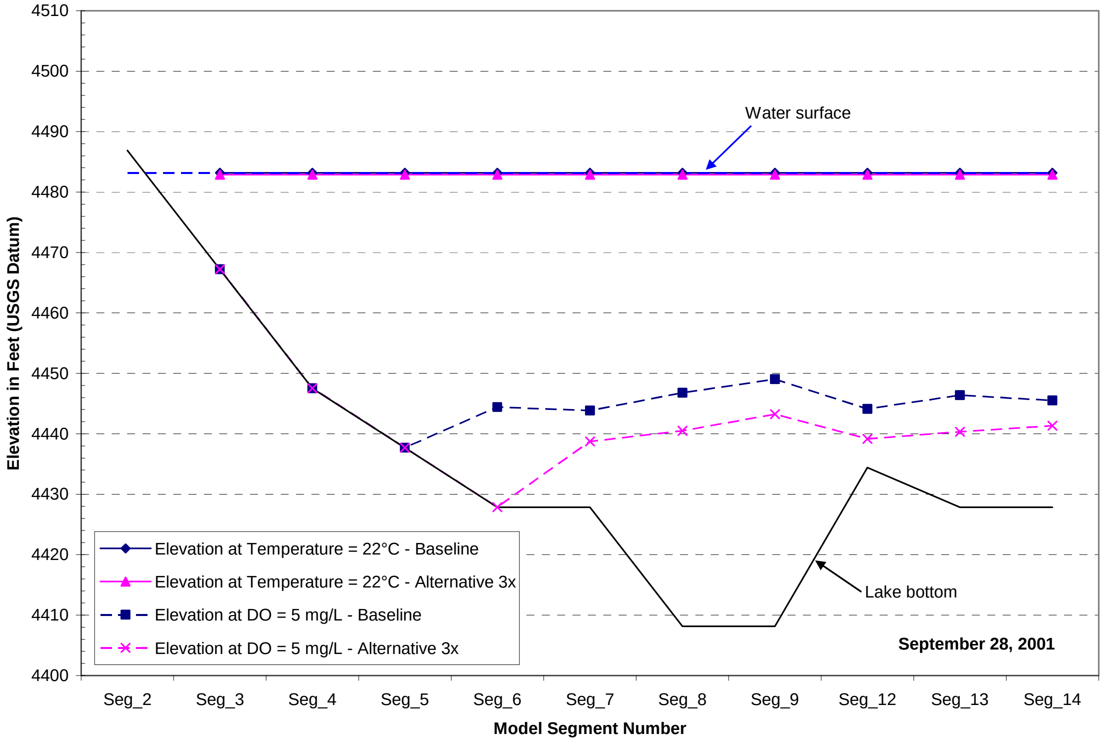


Figure 6d Comparison of Simulated Lake Almanor Elevation Range of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 3x, September 2001

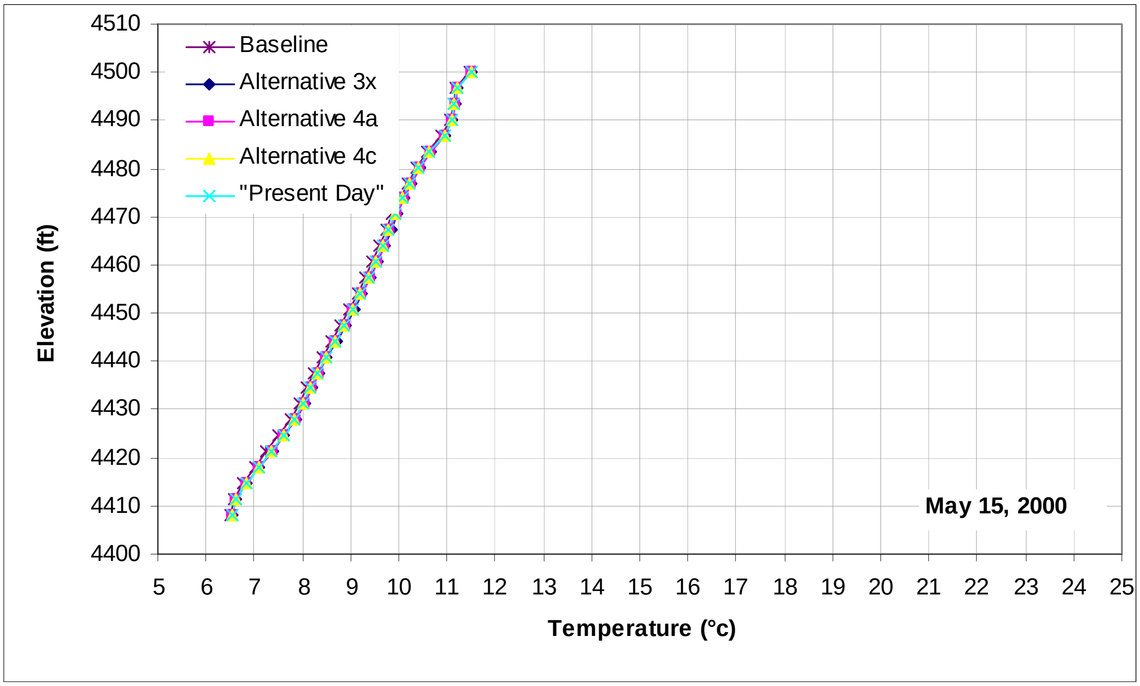


Figure 7a Comparison of Simulated Water Temperature Profiles near Canyon Dam (Model Segment 9) between Alternatives
May 2000

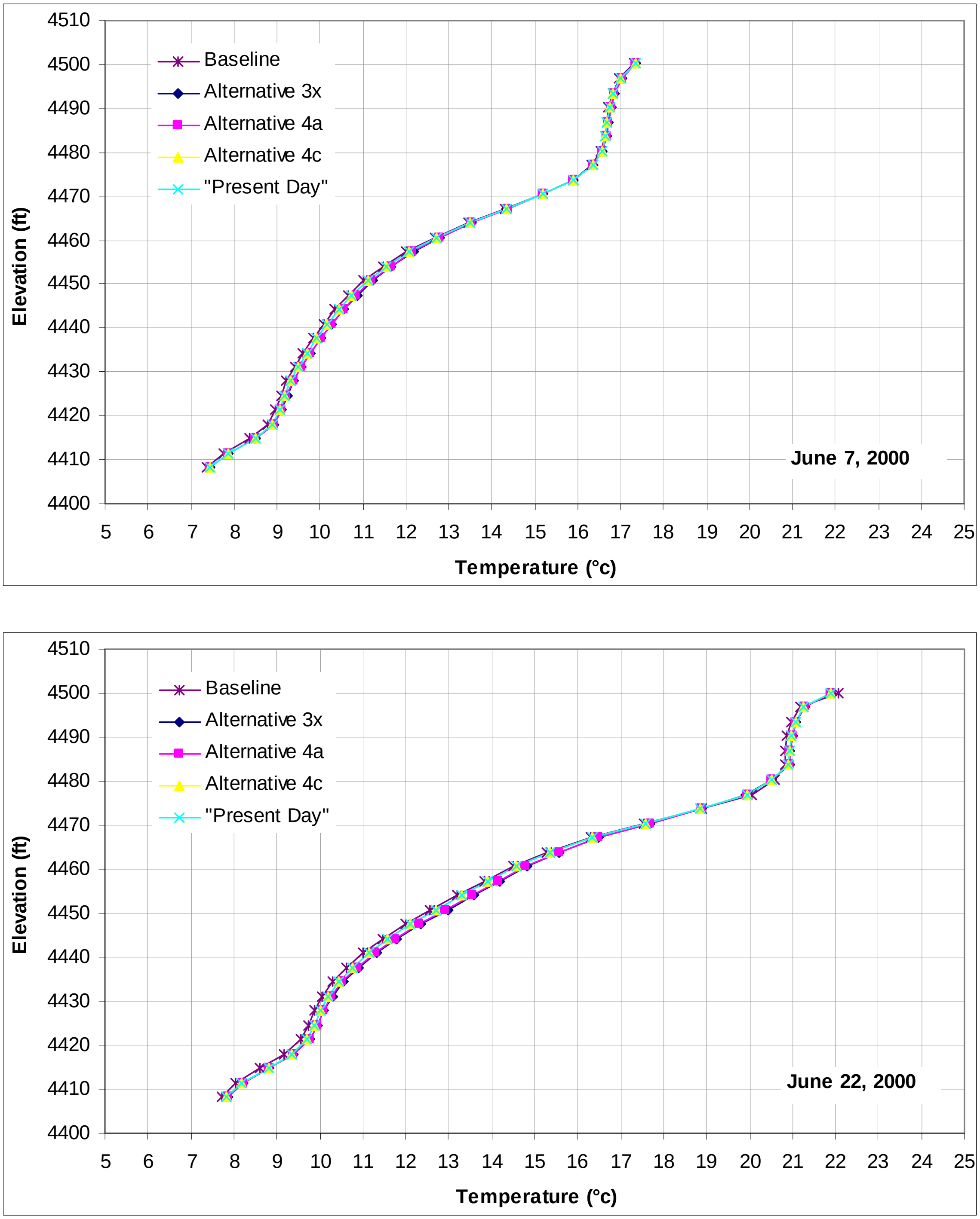
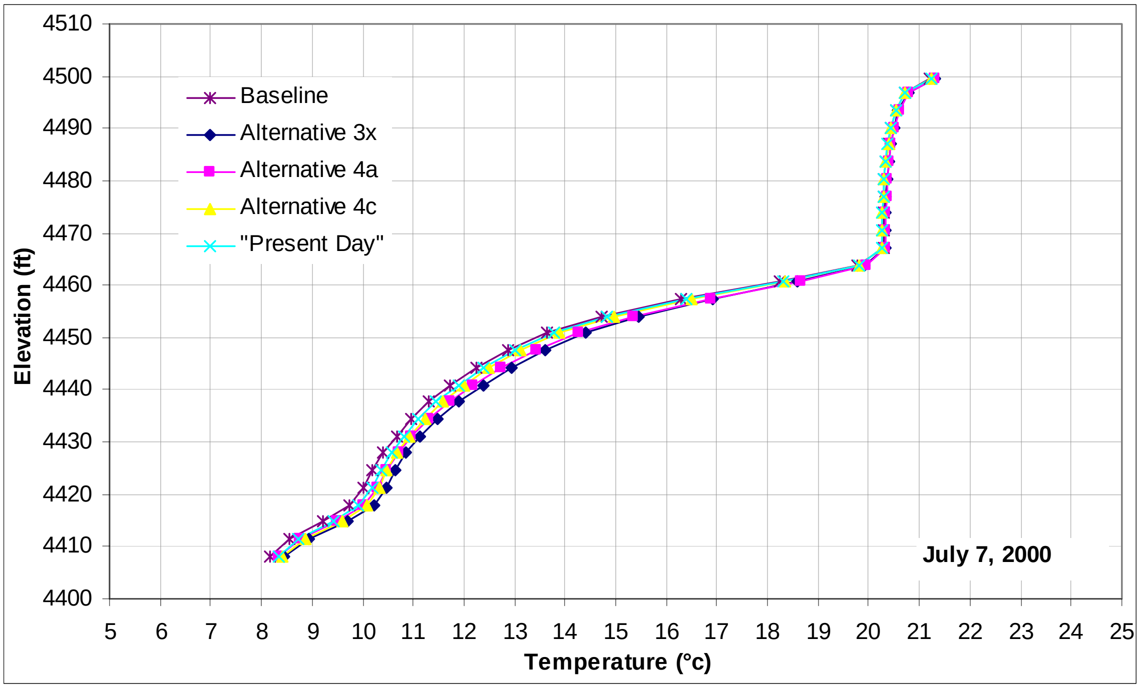


Figure 7b Comparison of Simulated Water Temperature Profiles near Canyon Dam (Model Segment 9) between Alternatives June 2000



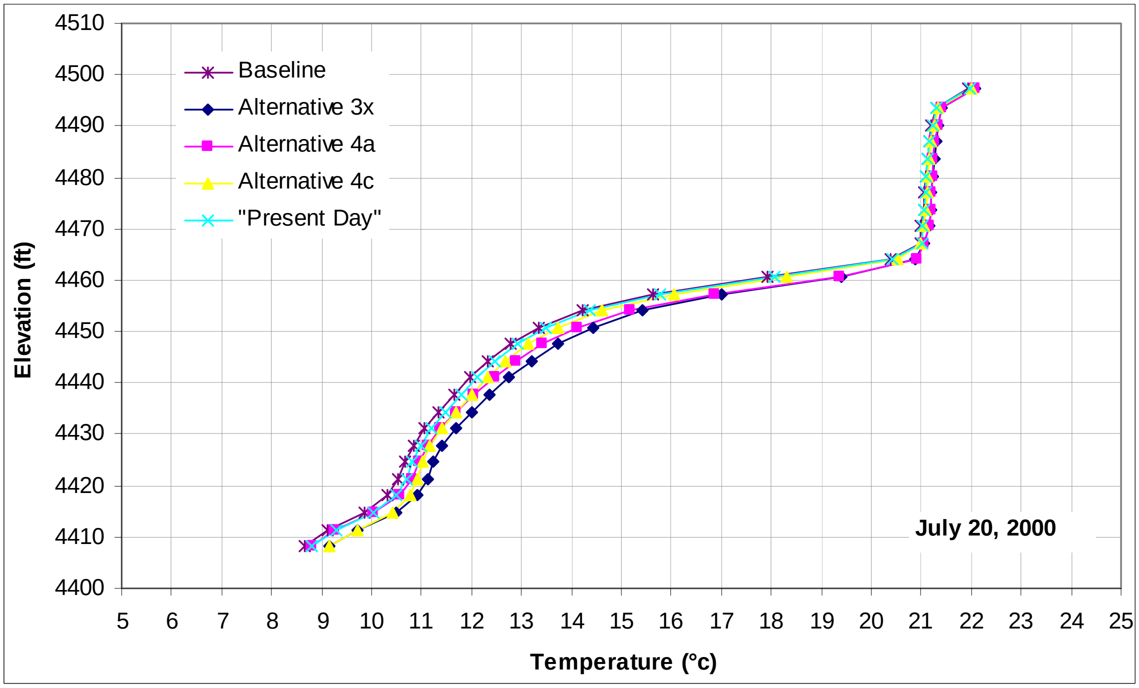
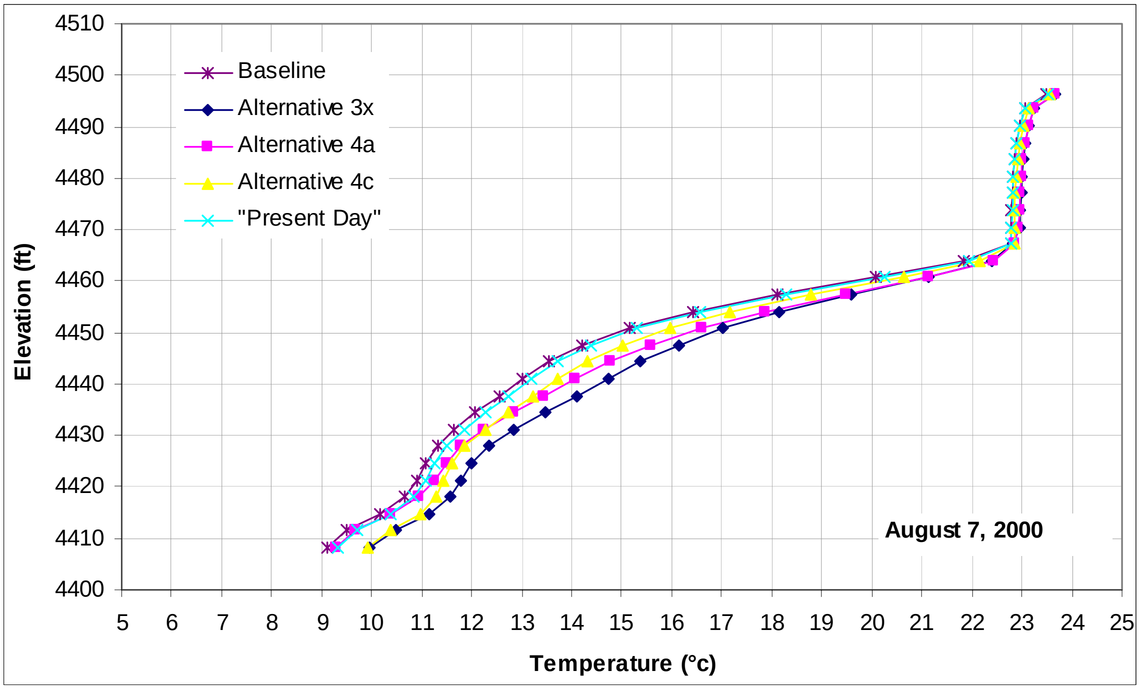


Figure 7c Comparison of Simulated Water Temperature Profiles near Canyon Dam (Model Segment 9) between Alternatives July 2000



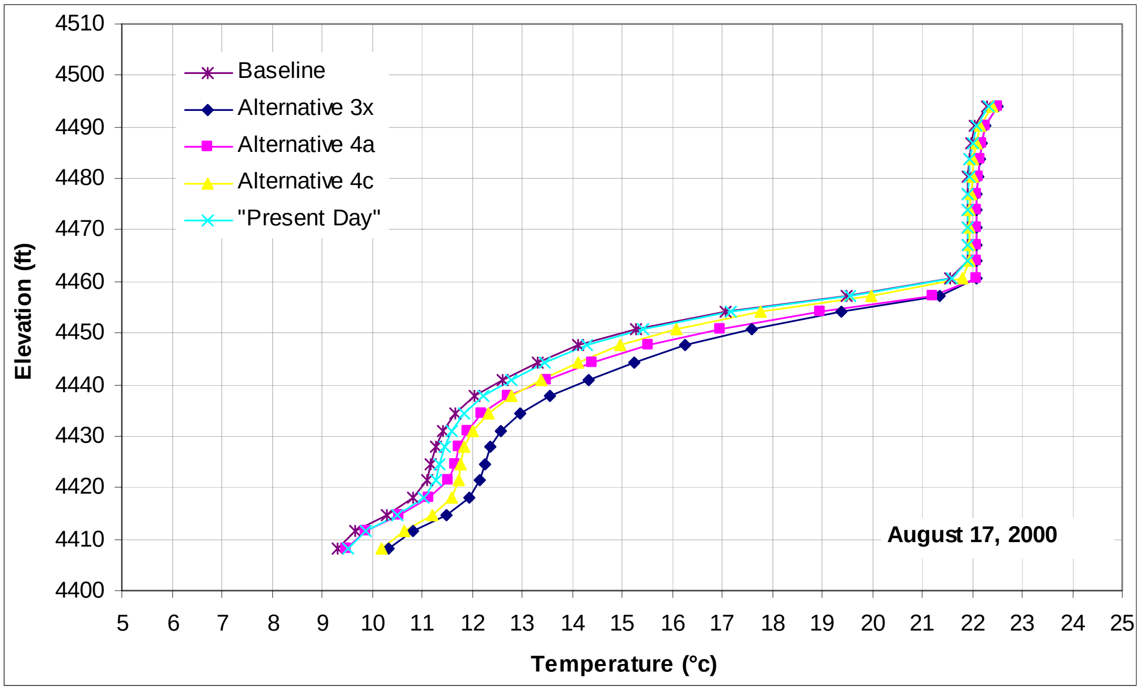
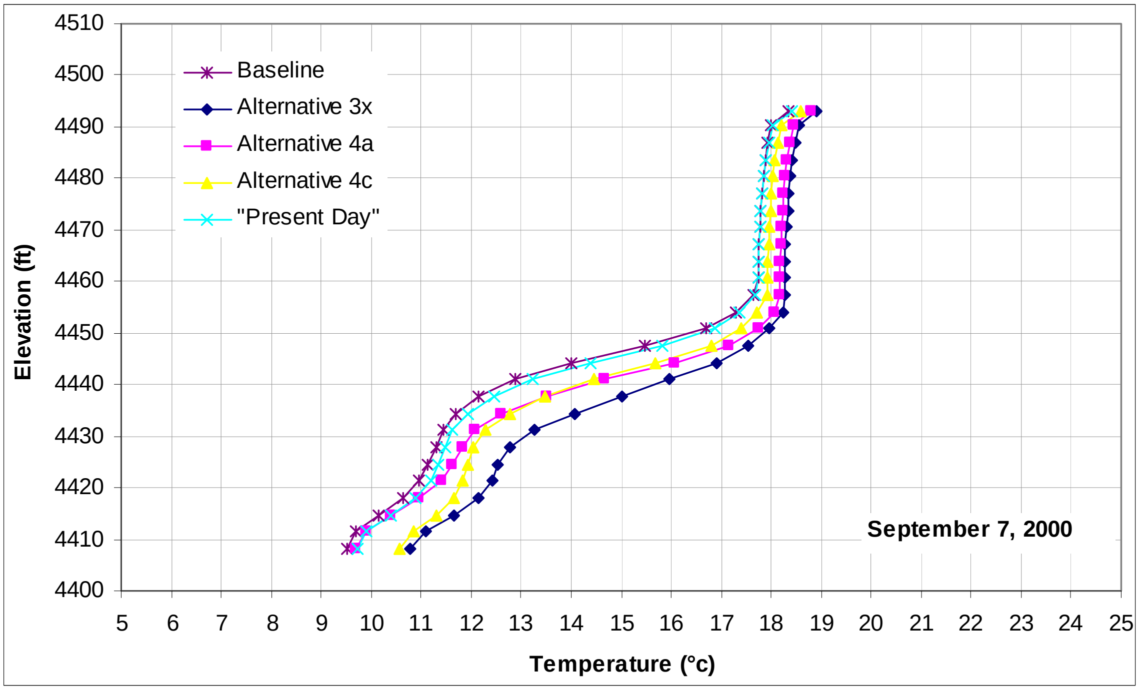


Figure 7d Comparison of Simulated Water Temperature Profiles near Canyon Dam (Model Segment 9) between Alternatives August 2000



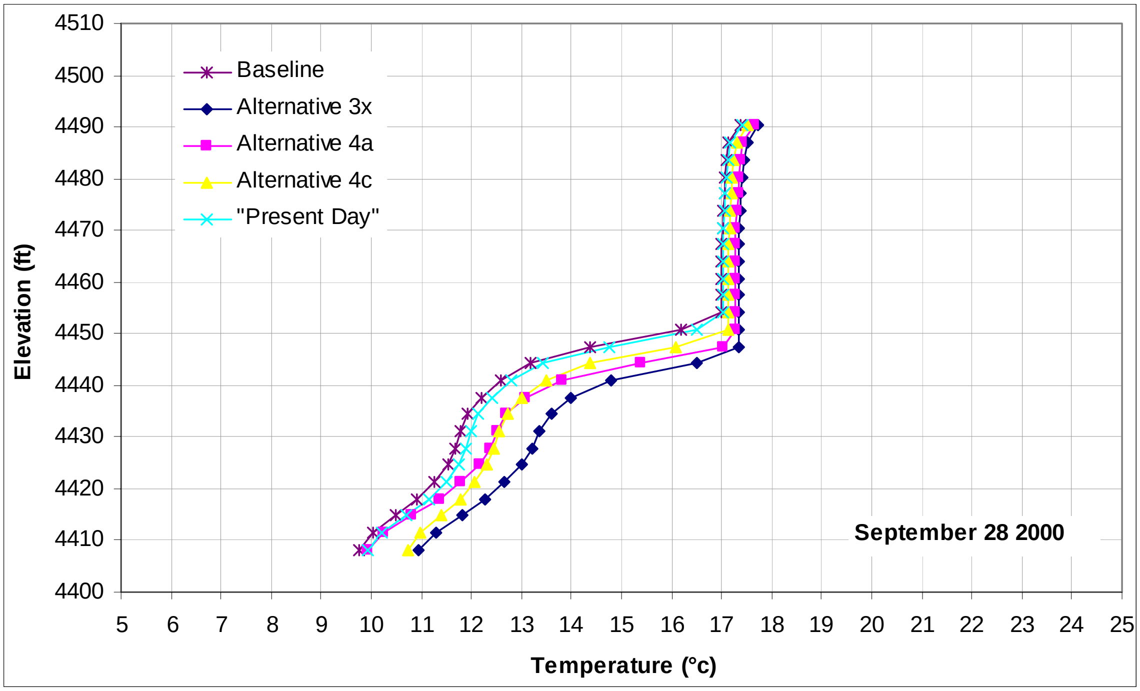


Figure 7e Comparison of Simulated Water Temperature Profiles near Canyon Dam (Model Segment 9) between Alternatives September 2000

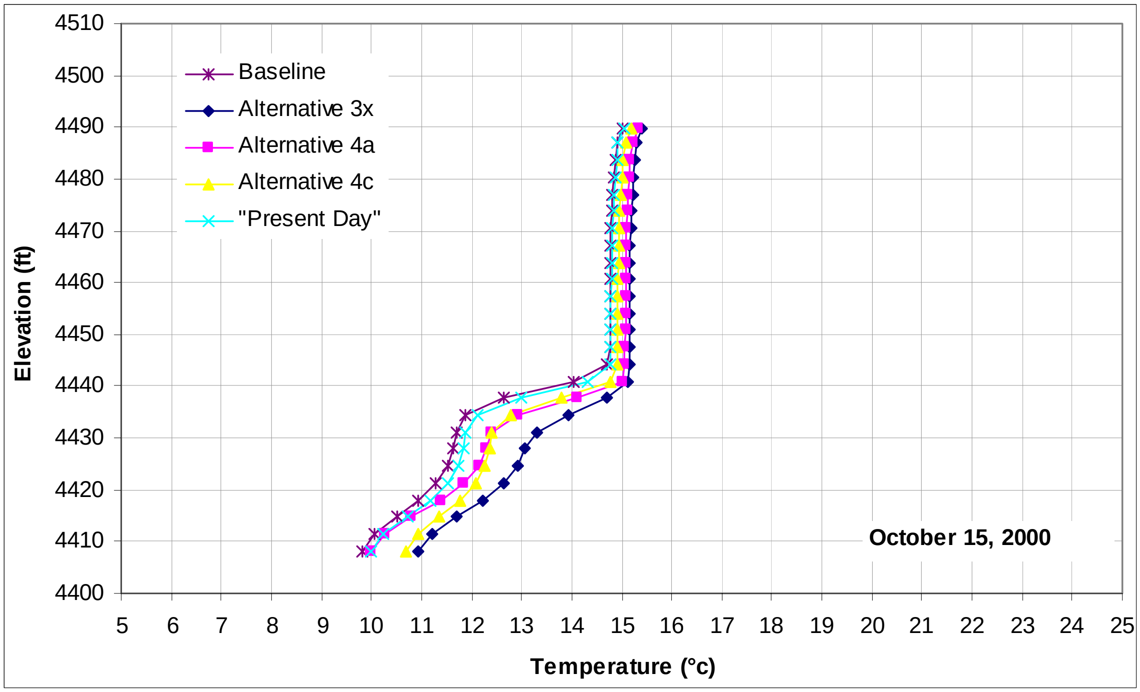


Figure 7f Comparison of Simulated Water Temperature Profiles near Canyon Dam (Model Segment 9) between Alternatives October 2000

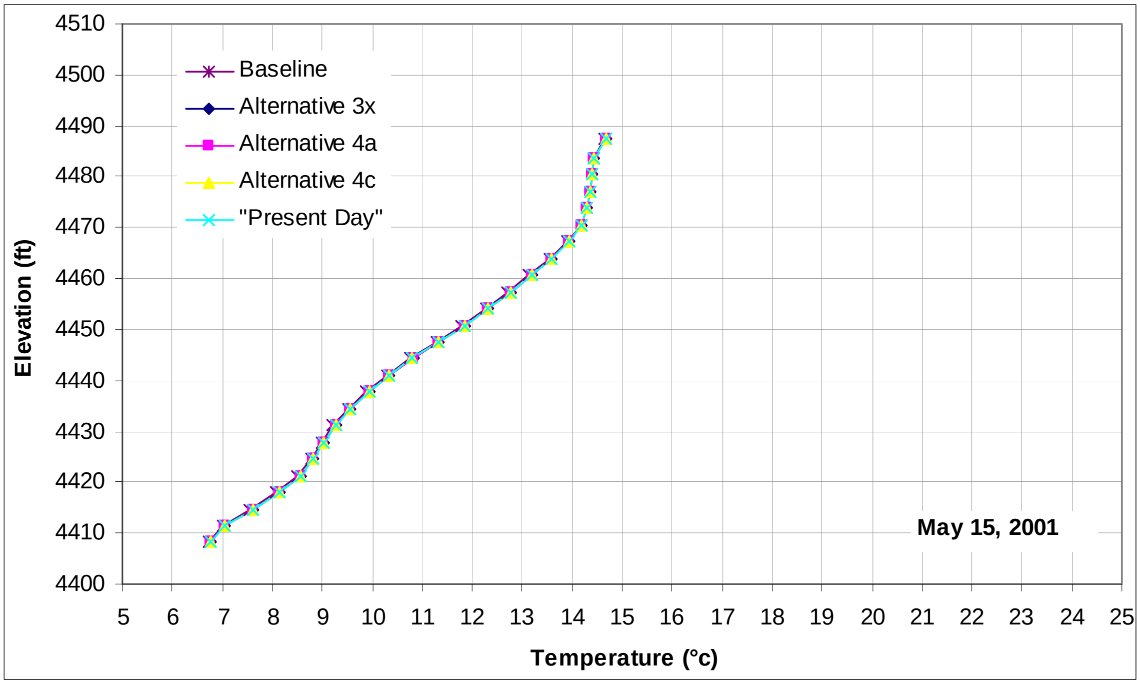
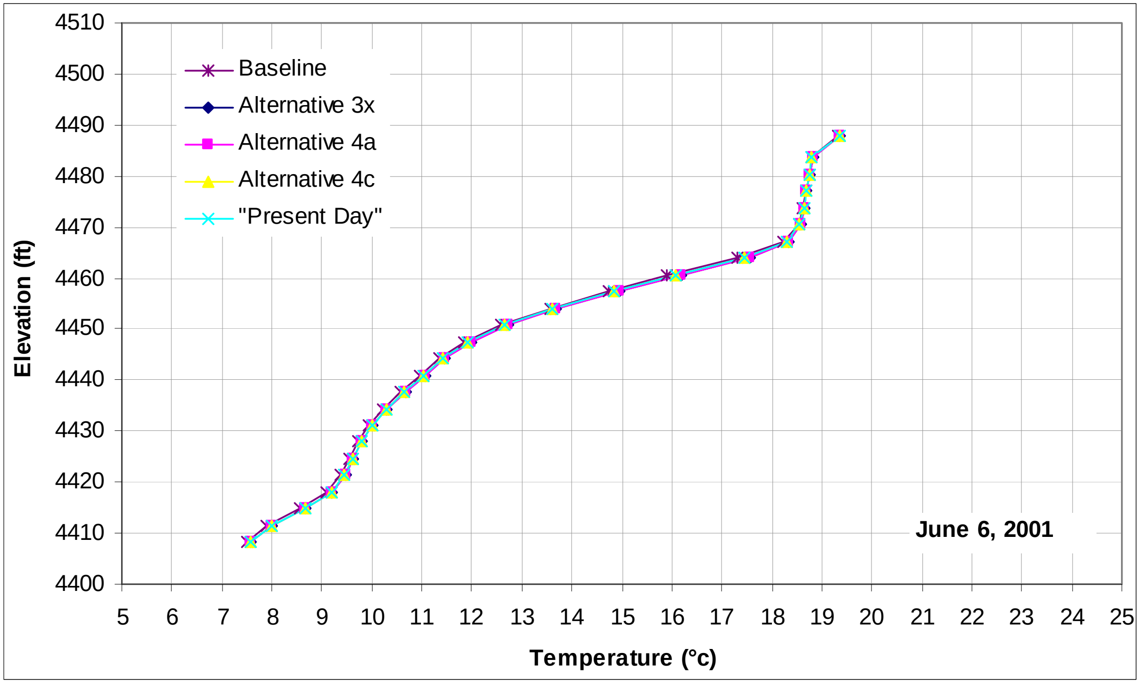


Figure 8a Comparison of Simulated Water Temperature Profiles near Canyon Dam (Model Segment 9) between Alternatives May 2001



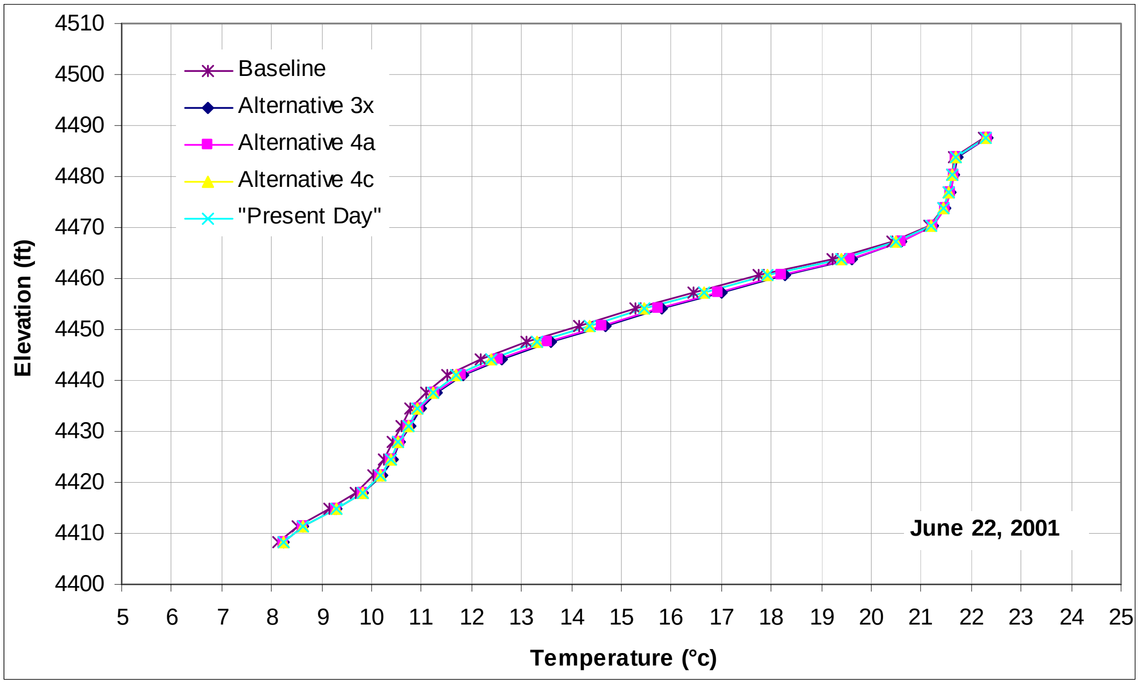
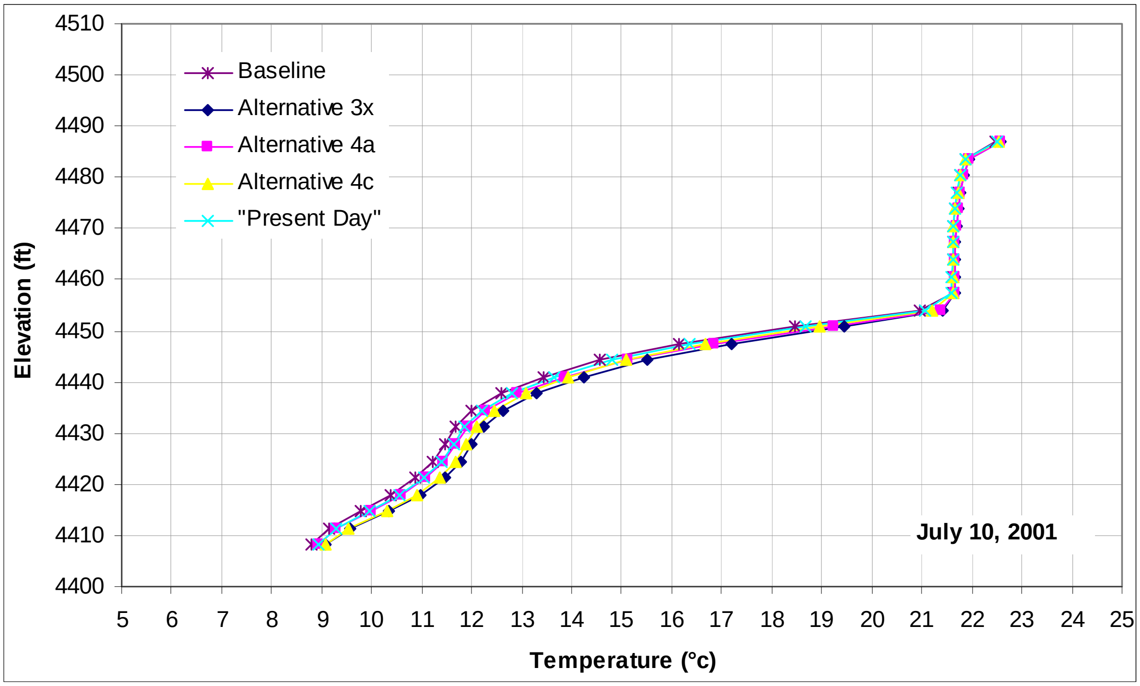


Figure 8b Comparison of Simulated Water Temperature Profiles near Canyon Dam (Model Segment 9) between Alternatives June 2001



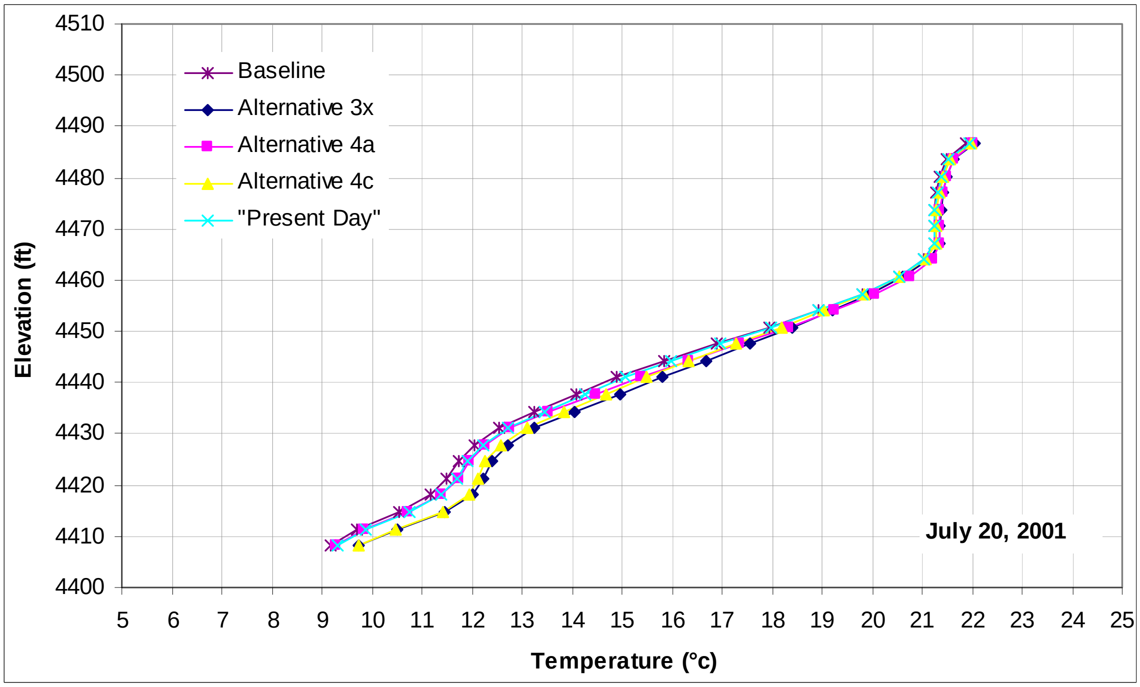
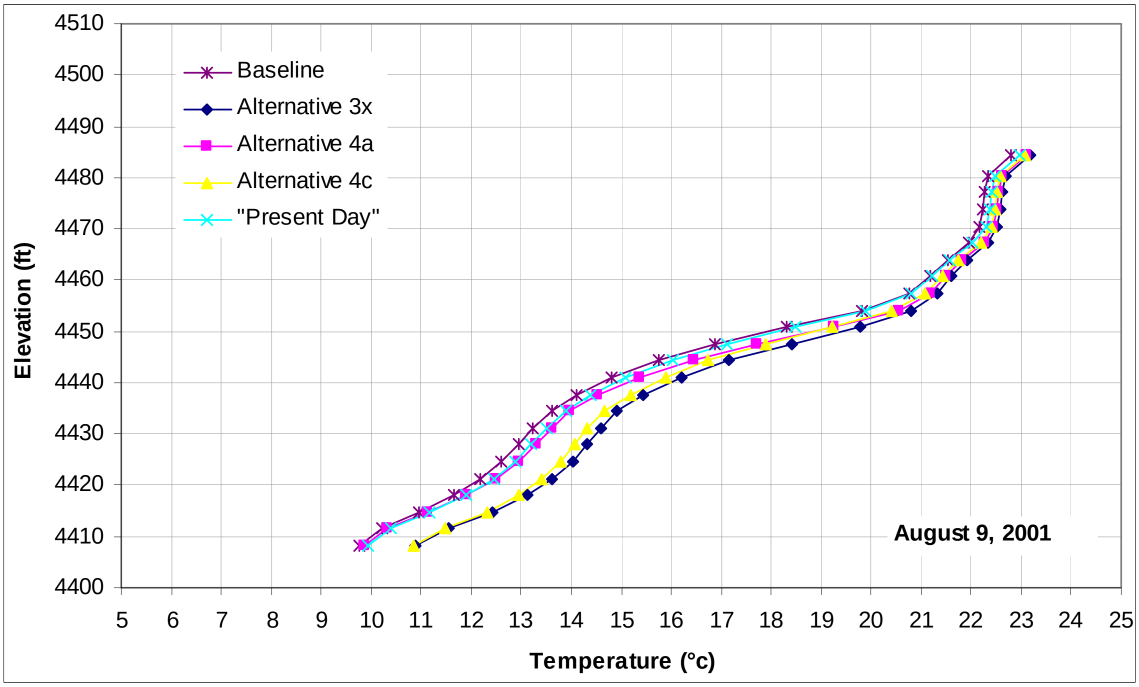


Figure 8c Comparison of Simulated Water Temperature Profiles near Canyon Dam (Model Segment 9) between Alternatives July 2001



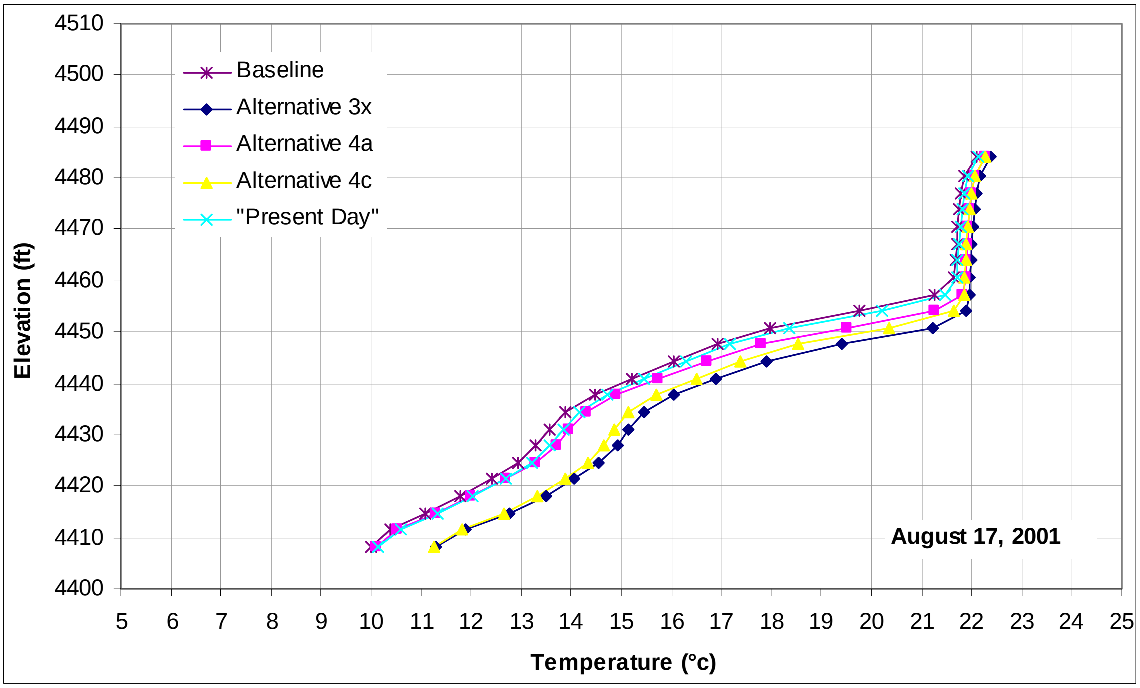
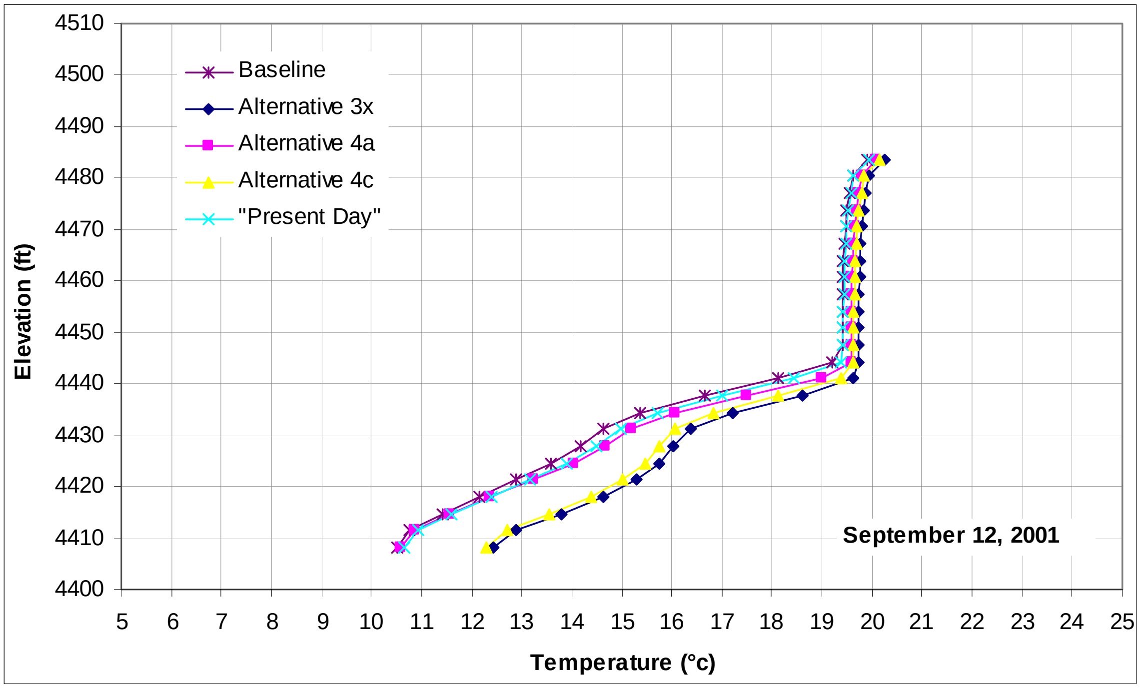


**Figure 8d Comparison of Simulated Water Temperature Profiles near Canyon Dam (Model Segment 9) between Alternatives
August 2001**



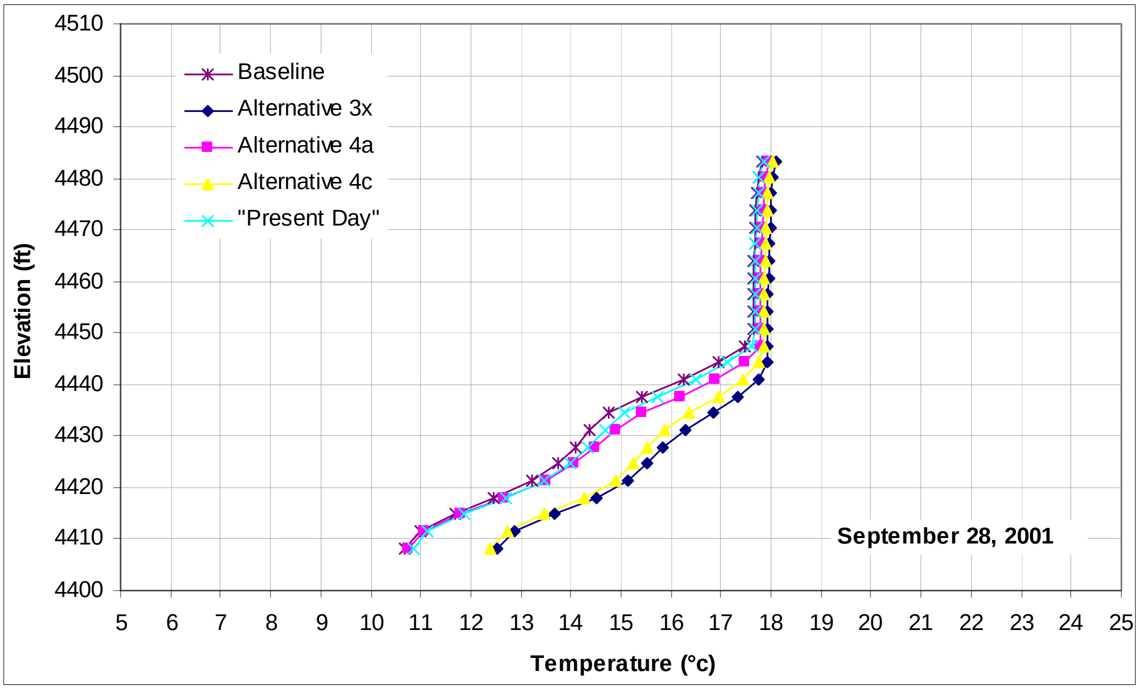


Figure 8e Comparison of Simulated Water Temperature Profiles near Canyon Dam (Model Segment 9) between Alternatives September 2001

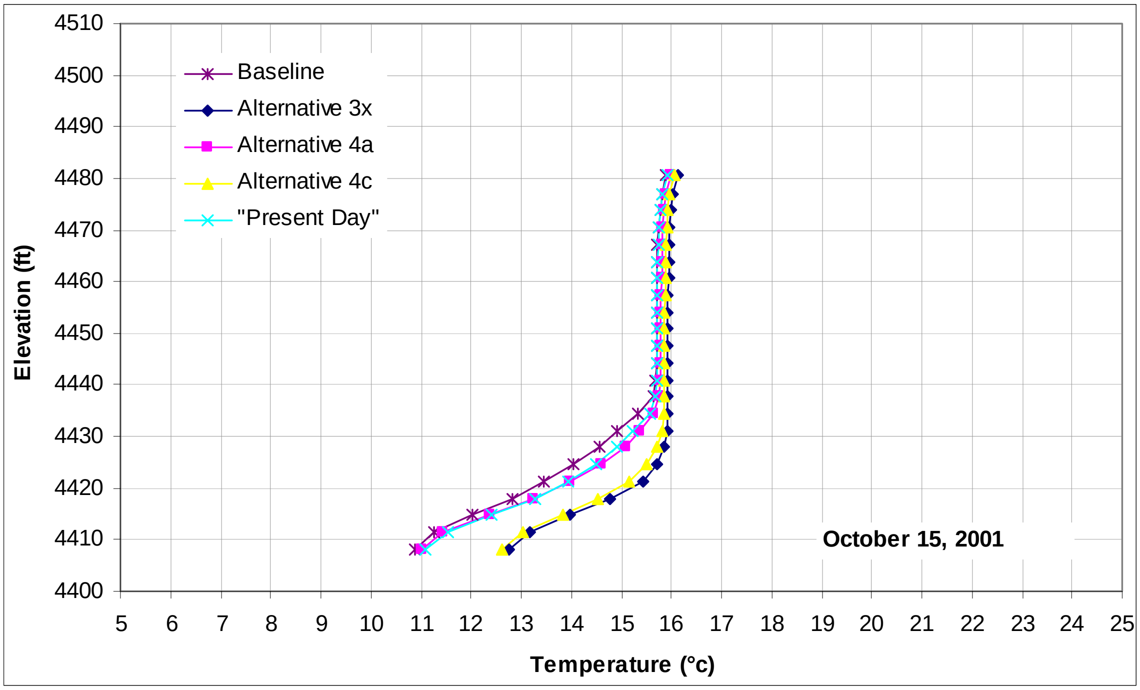


Figure 8f Comparison of Simulated Water Temperature Profiles near Canyon Dam (Model Segment 9) between Alternatives October 2001

Appendix D:

Detailed Effect Analysis of Level 3 Alternatives on Butt Valley Reservoir Cold Freshwater Habitat

- **Tables 1a – 6b summarize the simulated Butt Valley Reservoir elevation range and habitat volume of the water layer that meets the three different temperature and DO criteria (i.e., T ≤ 20°C and DO ≥ 5 mg/L; T≤ 21°C and DO ≥ 5 mg/L; or T ≤ 22°C and DO ≥ 5 mg/L) for Baseline and Alternative 4a for year 2000 (normal hydrologic year)**

- **Tables 7a – 12b summarize the simulated Butt Valley Reservoir elevation range and habitat volume of the water layer that meets the three different temperature and DO criteria (i.e., T ≤ 20°C and DO ≥ 5 mg/L; T≤ 21°C and DO ≥ 5 mg/L; or T ≤ 22°C and DO ≥ 5 mg/L) for Baseline and Alternative 4a for year 2001 (critical dry year)**

- **Figures 1a – 3d compare the simulated Butt Valley Reservoir elevation range of the water layer that meets the three different temperature and DO criteria (i.e., T ≤ 20°C and DO ≥ 5 mg/L; T≤ 21°C and DO ≥ 5 mg/L; or T ≤ 22°C and DO ≥ 5 mg/L) between Baseline and Alternative 4a for year 2000 (graphical presentation of Tables 1a – 6a)**

- **Figures 4a – 6c compare the simulated Butt Valley Reservoir elevation range of the water layer that meets the three different temperature and DO criteria (i.e., T ≤ 20°C and DO ≥ 5 mg/L; T≤ 21°C and DO ≥ 5 mg/L; or T ≤ 22°C and DO ≥ 5 mg/L) between Baseline and Alternative 4a for year 2001 (graphical presentation of Tables 7a – 12a)**

- **Figures 7a – 7e compare the simulated water temperature profiles of Butt Valley Reservoir near Caribou #1 Intake (model segment 17) between Baseline and Alternative 4a for year 2000**

- **Figures 8a – 8d compare the simulated water temperature profiles of Butt Valley Reservoir near Caribou #1 Intake (model segment 17) between Baseline and Alternative 4a for year 2001**

Table 1a Butt Valley Reservoir Simulated Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition

(2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	WSE
May 15	4,134.9	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,102.3	4,095.0	4,093.0	4,087.9	4,087.9	4,087.9	4,087.9	
Jun 7	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,108.4	4,107.2	4,105.2	4,104.4	4,102.9	4,100.0	4,097.3	4,095.8	4,095.7	
Jun 22	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,129.9	4,128.6	4,128.5	4,128.4	4,128.3	4,129.2	4,129.4	4,129.4	4,129.5	4,129.5	4,129.3	4,129.0	4,133.6
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,106.0	4,105.0	4,104.0	4,102.9	4,102.4	4,101.5	4,100.3	4,099.7	
Jul 7	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.2	4,135.9	4,136.1	4,136.1	4,135.9	4,136.0	4,135.9	4,135.9	4,135.9	4,135.9	4,135.8	4,135.8	4,136.6
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,106.0	4,106.7	4,104.6	4,103.7	4,102.6	4,101.9	4,100.5	4,099.0	4,098.8	
Jul 20	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,135.2	4,133.8	4,133.3	4,131.1	4,127.0	4,123.9	4,121.9	4,119.3	4,115.7	4,114.0	4,114.1	4,114.7	4,137.0
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,106.3	4,107.4	4,107.4	4,107.5	4,106.6	4,105.0	4,104.0	4,103.1	4,102.0	
Aug 7		4,136.9				4,131.6	4,127.5	4,119.7	4,114.0	4,111.3	4,109.1	4,108.2	4,109.2	4,108.9	4,108.0	4,107.9	4,107.9	4,107.7	4,136.9
		4,125.0				4,115.0	4,111.0	4,111.0	4,109.0	4,106.0	4,107.1	4,106.4	4,106.4	4,105.7	4,104.0	4,102.0	4,101.0	4,101.0	
Aug 17	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,131.7	4,124.5	4,114.2										4,137.8
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0										
Sep 7	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.0	4,093.0	4,087.0	4,085.0	4,085.0	4,085.0	
Sep 28	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.0	4,093.0	4,088.1	4,089.4	4,090.1	4,090.0	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 1b Butt Valley Reservoir Simulated Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition

(2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	Total
May 15	7	33	29	101	160	542	683	826	1,762	1,970	6,387	7,164	3,487	3,430	2,957	2,167	1,126	1,154	**33,980**
Jun 7	7	32	28	95	153	524	665	810	1,738	1,874	5,931	6,595	3,193	3,036	2,687	1,976	1,030	1,047	**31,420**
Jun 22	5	28	24	77	131	464	378	473	1,237	1,421	4,601	5,284	2,531	2,444	2,074	1,479	766	773	**24,190**
Jul 7	9	40	36	135	200	653	771	890	1,869	2,062	6,348	7,070	3,416	3,208	2,745	1,978	1,028	1,046	**33,510**
Jul 20	10	42	38	143	210	679	707	762	1,632	1,626	4,063	3,550	1,382	1,118	727	457	254	293	**17,690**
Aug 7		41				341	268	62	189	170	325	352	222	250	232	239	141	139	**2,970**
Aug 17	11	45	41	159	229	730	484	270	202										**2,170**
Sep 7	14	53	49	194	271	845	992	1,138	2,160	2,381	7,557	8,631	4,142	3,990	3,457	2,540	1,321	1,355	**41,090**
Sep 28	7	34	30	106	166	560	701	843	1,786	1,995	6,458	7,491	3,526	3,464	2,986	2,174	1,121	1,146	**34,600**

Table 2a Butt Valley Reservoir Simulated Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	WSE
May 15	4,134.9	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.0	4,093.0	4,087.0	4,085.0	4,085.0	4,085.0	
Jun 7	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,101.9	4,100.0	4,098.0	4,094.0	4,088.5	4,089.7	4,087.5	
Jun 22						4,133.3	4,128.1	4,126.4	4,127.3	4,127.3	4,127.1	4,127.7	4,128.0	4,128.1	4,128.1	4,126.0	4,133.6	4,133.6	4,133.6
						4,127.1	4,122.2	4,114.4	4,112.4	4,111.1	4,109.8	4,107.1	4,106.0	4,104.4	4,101.0	4,085.0	4,085.0	4,087.0	
Jul 7						4,136.6	4,136.0	4,136.0	4,136.2	4,136.1	4,136.1	4,136.1	4,136.0	4,136.1	4,136.1	4,136.6		4,136.6	4,136.6
						4,131.1	4,125.1	4,117.7	4,114.0	4,112.7	4,112.7	4,111.5	4,110.5	4,109.1	4,107.1	4,105.0		4,135.6	
Jul 20						4,137.0	4,135.8	4,135.8	4,135.8	4,135.6	4,135.3	4,133.4	4,131.4	4,132.7	4,134.2	4,133.6	4,137.0	4,137.0	4,137.0
						4,131.1	4,125.1	4,119.0	4,115.7	4,114.5	4,113.1	4,113.1	4,113.1	4,113.1	4,109.7	4,107.1	4,135.7	4,135.7	
Aug 7						4,136.9	4,130.7	4,125.5	4,122.3	4,121.5	4,120.6	4,120.2	4,118.9	4,117.1	4,115.5	4,116.6	4,136.9	4,136.9	4,136.9
						4,134.8	4,126.4	4,119.0	4,115.6	4,114.0	4,112.5	4,111.7	4,111.1	4,110.0	4,109.1	4,105.0	4,135.8	4,135.7	
Aug 17						4,137.8	4,136.0	4,134.6	4,134.2	4,132.3	4,126.4	4,123.0	4,120.9	4,119.9	4,118.0	4,116.6	4,137.8	4,137.8	4,137.8
						4,132.5	4,124.2	4,112.4	4,113.1	4,115.1	4,115.1	4,113.7	4,113.1	4,111.1	4,108.4	4,107.1	4,134.1	4,135.1	
Sep 7		4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5
		4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.0	4,093.0	4,087.0	4,085.0	4,085.0	4,085.0	
Sep 28	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.1
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.7	4,093.0	4,087.0	4,085.0	4,085.0	4,085.0	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 2b Butt Valley Reservoir Simulated Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	Total
May 15	7	33	29	101	160	542	683	826	1,762	1,970	6,387	7,418	3,487	3,430	2,959	2,178	1,134	1,163	**34,270**
Jun 7	7	32	28	95	153	524	665	810	1,738	1,946	6,317	7,145	3,401	3,310	2,868	2,140	1,102	1,144	**33,420**
Jun 22						318	229	348	1,036	1,154	3,701	4,533	2,222	2,200	2,002	1,561	1,085	1,109	**21,500**
Jul 7						340	595	851	1,682	1,824	5,335	5,774	2,919	2,745	2,485	1,867		42	**26,460**
Jul 20						367	582	827	1,550	1,666	5,068	4,778	2,065	2,013	2,108	1,554	52	53	**22,680**
Aug 7						134	207	262	478	538	1,724	1,859	767	630	466	556	42	50	**7,710**
Aug 17						332	626	806	1,560	1,345	2,508	2,074	804	813	711	472	148	110	**12,310**
Sep 7		53	49	194	272	847	994	1,140	2,162	2,383	7,564	8,638	4,146	3,993	3,459	2,542	1,322	1,356	**41,110**
Sep 28	7	34	30	107	167	562	703	845	1,788	1,998	6,464	7,498	3,529	3,467	2,992	2,201	1,146	1,176	**34,710**

Table 3a Butt Valley Reservoir Simulated Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	WSE
May 15	4,134.9	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,102.3	4,095.0	4,093.0	4,087.9	4,087.9	4,087.9	4,087.9	
Jun 7	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,108.4	4,107.2	4,105.2	4,104.4	4,102.9	4,100.0	4,097.3	4,095.8	4,095.7	
Jun 22	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.5	4,133.3	4,132.8	4,132.2	4,131.8	4,131.7	4,131.6	4,131.5	4,131.3	4,130.7	4,133.6
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,106.0	4,105.0	4,104.0	4,102.9	4,102.4	4,101.5	4,100.3	4,099.7	
Jul 7	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,106.0	4,106.7	4,104.6	4,103.7	4,102.6	4,101.9	4,100.5	4,099.0	4,098.8	
Jul 20	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,136.6	4,136.1	4,135.8	4,135.8	4,135.8	4,135.7	4,135.5	4,136.0	4,137.0
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,106.3	4,107.4	4,107.4	4,107.5	4,106.6	4,105.0	4,104.0	4,103.1	4,102.0	
Aug 7		4,136.9				4,136.9	4,135.4	4,132.4	4,130.3	4,128.3	4,124.6	4,121.1	4,121.5	4,119.2	4,116.2	4,115.6	4,116.5	4,117.3	4,136.9
		4,125.0				4,115.0	4,111.0	4,111.0	4,109.0	4,106.0	4,107.1	4,106.4	4,106.4	4,105.7	4,104.0	4,102.0	4,101.0	4,101.0	
Aug 17	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.6	4,136.8	4,136.0	4,136.0	4,136.1	4,135.8	4,134.6	4,133.7	4,133.9	4,137.8
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,104.0	4,105.0	4,102.5	4,101.0	4,102.6	4,105.7	4,107.1	
Sep 7	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.0	4,093.0	4,087.0	4,085.0	4,085.0	4,085.0	
Sep 28	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.0	4,093.0	4,088.1	4,089.4	4,090.1	4,090.0	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 3b Butt Valley Reservoir Simulated Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	Total
May 15	7	33	29	101	160	542	683	826	1,762	1,970	6,387	7,164	3,487	3,430	2,957	2,167	1,126	1,154	**33,980**
Jun 7	7	32	28	95	153	524	665	810	1,738	1,874	5,931	6,595	3,193	3,036	2,687	1,976	1,030	1,047	**31,420**
Jun 22	5	28	24	77	131	464	603	752	1,645	1,834	5,669	6,038	2,847	2,702	2,283	1,623	837	835	**28,400**
Jul 7	9	40	36	135	200	653	796	936	1,910	2,110	6,517	7,237	3,516	3,293	2,820	2,036	1,059	1,077	**34,380**
Jul 20	10	42	38	143	210	679	823	964	1,945	2,136	6,406	6,574	3,139	2,907	2,571	1,840	944	991	**32,360**
Aug 7		41				671	718	681	1,385	1,399	3,567	3,094	1,432	1,173	820	619	358	382	**16,340**
Aug 17	11	45	41	159	229	730	875	1,018	2,011	2,211	6,876	7,186	3,340	3,242	2,769	1,808	820	801	**34,170**
Sep 7	14	53	49	194	271	845	992	1,138	2,160	2,381	7,557	8,631	4,142	3,990	3,457	2,540	1,321	1,355	**41,090**
Sep 28	7	34	30	106	166	560	701	843	1,786	1,995	6,458	7,491	3,526	3,464	2,986	2,174	1,121	1,146	**34,600**

Table 4a Butt Valley Reservoir Simulated Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	WSE
May 15	4,134.9	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.0	4,093.0	4,087.0	4,085.0	4,085.0	4,085.0	
Jun 7	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,101.9	4,100.0	4,098.0	4,094.0	4,088.5	4,089.7	4,087.5	
Jun 22						4,133.6	4,130.8	4,131.1	4,131.1	4,130.5	4,129.9	4,130.1	4,130.2	4,130.3	4,130.3	4,133.6	4,133.6	4,133.6	4,133.6
						4,127.1	4,122.2	4,114.4	4,112.4	4,111.1	4,109.8	4,107.1	4,106.0	4,104.4	4,101.0	4,085.0	4,085.0	4,087.0	
Jul 7						4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6		4,136.6	4,136.6
						4,131.1	4,125.1	4,117.7	4,114.0	4,112.7	4,112.7	4,111.5	4,110.5	4,109.1	4,107.1	4,105.0		4,135.6	
Jul 20						4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0
						4,131.1	4,125.1	4,119.0	4,115.7	4,114.5	4,113.1	4,113.1	4,113.1	4,113.1	4,109.7	4,107.1	4,135.7	4,135.7	
Aug 7						4,136.9	4,135.1	4,134.7	4,134.7	4,133.7	4,130.6	4,125.5	4,124.0	4,122.5	4,121.9	4,122.6	4,136.9	4,136.9	4,136.9
						4,134.8	4,126.4	4,119.0	4,115.6	4,114.0	4,112.5	4,111.7	4,111.1	4,110.0	4,109.1	4,105.0	4,135.8	4,135.7	
Aug 17						4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8
						4,132.5	4,124.2	4,112.4	4,113.1	4,115.1	4,115.1	4,113.7	4,113.1	4,111.1	4,108.4	4,107.1	4,134.1	4,135.1	
Sep 7		4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5
		4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.0	4,093.0	4,087.0	4,085.0	4,085.0	4,085.0	
Sep 28	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.1
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.7	4,093.0	4,087.0	4,085.0	4,085.0	4,085.0	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 4b Butt Valley Reservoir Simulated Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	Total
May 15	7	33	29	101	160	542	683	826	1,762	1,970	6,387	7,418	3,487	3,430	2,959	2,178	1,134	1,163	**34,270**
Jun 7	7	32	28	95	153	524	665	810	1,738	1,946	6,317	7,145	3,401	3,310	2,868	2,140	1,102	1,144	**33,420**
Jun 22						338	363	590	1,340	1,424	4,354	5,131	2,508	2,440	2,215	2,084	1,085	1,109	**24,980**
Jul 7						340	634	893	1,720	1,867	5,464	5,907	3,000	2,810	2,537	1,867		42	**27,080**
Jul 20						367	661	909	1,653	1,793	5,495	5,700	2,827	2,518	2,409	1,813	52	53	**26,250**
Aug 7						134	477	764	1,465	1,539	4,043	3,092	1,340	1,167	993	907	42	50	**16,010**
Aug 17						332	749	1,013	1,870	1,828	5,288	5,769	2,938	2,787	2,582	1,874	148	110	**27,290**
Sep 7		53	49	194	272	847	994	1,140	2,162	2,383	7,564	8,638	4,146	3,993	3,459	2,542	1,322	1,356	**41,110**
Sep 28	7	34	30	107	167	562	703	845	1,788	1,998	6,464	7,498	3,529	3,467	2,992	2,201	1,146	1,176	**34,710**

Table 5a Butt Valley Reservoir Simulated Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	WSE
May 15	4,134.9	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,102.3	4,095.0	4,093.0	4,087.9	4,087.9	4,087.9	4,087.9	
Jun 7	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,108.4	4,107.2	4,105.2	4,104.4	4,102.9	4,100.0	4,097.3	4,095.8	4,095.7	
Jun 22	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,106.0	4,105.0	4,104.0	4,102.9	4,102.4	4,101.5	4,100.3	4,099.7	
Jul 7	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,106.0	4,106.7	4,104.6	4,103.7	4,102.6	4,101.9	4,100.5	4,099.0	4,098.8	
Jul 20	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,106.3	4,107.4	4,107.4	4,107.5	4,106.6	4,105.0	4,104.0	4,103.1	4,102.0	
Aug 7		4,136.9				4,136.9	4,136.9	4,136.9	4,136.9	4,136.9	4,136.8	4,136.1	4,135.6	4,135.5	4,135.5	4,135.3	4,135.1	4,135.2	4,136.9
		4,125.0				4,115.0	4,111.0	4,111.0	4,109.0	4,106.0	4,107.1	4,106.4	4,106.4	4,105.7	4,104.0	4,102.0	4,101.0	4,101.0	
Aug 17	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,104.0	4,105.0	4,102.5	4,101.0	4,102.6	4,105.7	4,107.1	
Sep 7	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.0	4,093.0	4,087.0	4,085.0	4,085.0	4,085.0	
Sep 28	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1	4,135.1
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.0	4,093.0	4,088.1	4,089.4	4,090.1	4,090.0	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 5b Butt Valley Reservoir Simulated Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	Total
May 15	7	33	29	101	160	542	683	826	1,762	1,970	6,387	7,164	3,487	3,430	2,957	2,167	1,126	1,154	**33,980**
Jun 7	7	32	28	95	153	524	665	810	1,738	1,874	5,931	6,595	3,193	3,036	2,687	1,976	1,030	1,047	**31,420**
Jun 22	5	28	24	77	131	464	603	752	1,656	1,862	5,869	6,387	3,083	2,921	2,483	1,772	921	941	**29,980**
Jul 7	9	40	36	135	200	653	796	936	1,910	2,110	6,517	7,237	3,516	3,293	2,820	2,036	1,059	1,077	**34,380**
Jul 20	10	42	38	143	210	679	823	964	1,945	2,139	6,504	6,821	3,303	3,051	2,699	1,938	1,003	1,033	**33,340**
Aug 7		41				671	815	955	1,934	2,134	6,507	6,794	3,197	2,946	2,599	1,880	965	981	**32,420**
Aug 17	11	45	41	159	229	730	875	1,018	2,011	2,228	7,120	7,643	3,596	3,441	2,984	2,051	980	959	**36,120**
Sep 7	14	53	49	194	271	845	992	1,138	2,160	2,381	7,557	8,631	4,142	3,990	3,457	2,540	1,321	1,355	**41,090**
Sep 28	7	34	30	106	166	560	701	843	1,786	1,995	6,458	7,491	3,526	3,464	2,986	2,174	1,121	1,146	**34,600**

Table 6a Butt Valley Reservoir Simulated Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	WSE
May 15	4,134.9	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8	4,134.8
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.0	4,093.0	4,087.0	4,085.0	4,085.0	4,085.0	
Jun 7	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6	4,134.6
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,101.9	4,100.0	4,098.0	4,094.0	4,088.5	4,089.7	4,087.5	
Jun 22						4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6	4,133.6
						4,127.1	4,122.2	4,114.4	4,112.4	4,111.1	4,109.8	4,107.1	4,106.0	4,104.4	4,101.0	4,085.0	4,085.0	4,087.0	
Jul 7						4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6	4,136.6		4,136.6	4,136.6
						4,131.1	4,125.1	4,117.7	4,114.0	4,112.7	4,112.7	4,111.5	4,110.5	4,109.1	4,107.1	4,105.0		4,135.6	
Jul 20						4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0	4,137.0
						4,131.1	4,125.1	4,119.0	4,115.7	4,114.5	4,113.1	4,113.1	4,113.1	4,113.1	4,109.7	4,107.1	4,135.7	4,135.7	
Aug 7						4,136.9	4,136.9	4,136.9	4,136.9	4,136.9	4,136.9	4,136.8	4,136.6	4,136.9	4,136.9	4,136.9	4,136.9	4,136.9	4,136.9
						4,134.8	4,126.4	4,119.0	4,115.6	4,114.0	4,112.5	4,111.7	4,111.1	4,110.0	4,109.1	4,105.0	4,135.8	4,135.7	
Aug 17						4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8	4,137.8
						4,132.5	4,124.2	4,112.4	4,113.1	4,115.1	4,115.1	4,113.7	4,113.1	4,111.1	4,108.4	4,107.1	4,134.1	4,135.1	
Sep 7		4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5	4,139.5
		4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.0	4,093.0	4,087.0	4,085.0	4,085.0	4,085.0	
Sep 28	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.2	4,135.1
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.7	4,093.0	4,087.0	4,085.0	4,085.0	4,085.0	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 6b Butt Valley Reservoir Simulated Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2000, Normal Hydrologic Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	Total
May 15	7	33	29	101	160	542	683	826	1,762	1,970	6,387	7,418	3,487	3,430	2,959	2,178	1,134	1,163	**34,270**
Jun 7	7	32	28	95	153	524	665	810	1,738	1,946	6,317	7,145	3,401	3,310	2,868	2,140	1,102	1,144	**33,420**
Jun 22						338	535	734	1,547	1,687	5,255	6,015	2,948	2,818	2,544	2,084	1,085	1,109	**28,700**
Jul 7						340	634	893	1,720	1,867	5,464	5,907	3,000	2,810	2,537	1,867		42	**27,080**
Jul 20						367	661	909	1,653	1,793	5,495	5,700	2,827	2,518	2,409	1,813	52	53	**26,250**
Aug 7						134	595	900	1,653	1,815	5,581	5,919	2,959	2,764	2,439	1,889	42	50	**26,740**
Aug 17						332	749	1,013	1,870	1,828	5,288	5,769	2,938	2,787	2,582	1,874	148	110	**27,290**
Sep 7		53	49	194	272	847	994	1,140	2,162	2,383	7,564	8,638	4,146	3,993	3,459	2,542	1,322	1,356	**41,110**
Sep 28	7	34	30	107	167	562	703	845	1,788	1,998	6,464	7,498	3,529	3,467	2,992	2,201	1,146	1,176	**34,710**

Table 7a Butt Valley Reservoir Simulated Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	WSE
May 15	4,137.5	4,137.5	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.5	4,137.5	4,137.5	4,137.5	4,137.5	4,137.5	4,137.5
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.0	4,093.0	4,087.0	4,087.4	4,087.6	4,087.6	
Jun 6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.2	4,138.7	4,138.1	4,137.6	4,137.4	4,137.5	4,139.6
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,106.6	4,106.0	4,103.5	4,101.5	4,095.0	4,093.0	4,092.1	4,091.5	4,091.5	
Jun 22	4,138.6	4,138.6	4,138.6	4,137.8	4,136.3	4,135.2	4,131.2	4,125.2	4,119.0	4,119.8	4,121.1	4,122.0	4,122.0	4,121.9	4,121.6	4,121.9	4,122.1	4,122.0	4,138.6
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,106.9	4,106.6	4,105.8	4,105.3	4,104.7	4,104.2	4,102.2	4,100.5	4,099.5	
Jul 11		4,128.6	4,127.8						4,111.5	4,111.7	4,112.2	4,112.2	4,111.5	4,111.8	4,111.9	4,112.2	4,112.8	4,112.6	4,139.0
		4,125.0	4,121.0						4,109.0	4,107.1	4,106.9	4,105.9	4,105.0	4,103.3	4,101.0	4,100.4	4,100.4	4,100.1	
Jul 20	4,139.0	4,139.0	4,139.0	4,138.0	4,130.6	4,125.8	4,119.4	4,113.3					4,107.1	4,106.0	4,105.0	4,104.9	4,104.5	4,104.4	4,139.0
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0					4,106.0	4,104.4	4,102.6	4,101.7	4,101.0	4,101.0	
Aug 7																			4,136.6
Aug 20																			4,135.4

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 7b Butt Valley Reservoir Simulated Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	Total
May 15	11	44	40	154	223	715	859	1002	1991	2207	7062	8117	3862	3751	3244	2377	1234	1264	**38,160**
Jun 6	14	53	49	196	273	851	998	1144	2167	2361	7372	8199	3994	3882	3256	2322	1197	1225	**39,550**
Jun 22	12	48	45	159	193	564	455	305	518	706	2847	3422	1564	1518	1254	971	529	550	**15,660**
Jul 11		10	8						75	166	931	1219	521	666	648	499	270	274	**5,290**
Jul 20	13	50	47	164	66	83	22	11					80	118	129	119	67	68	**1,040**
Aug 7																			**0**
Aug 20																			**0**

Table 8a Butt Valley Reservoir Simulated Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	WSE
May 15	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.5	4,137.5	4,137.5
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.0	4,093.0	4,087.4	4,087.9	4,087.6	4,087.7	
Jun 6		4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.4	4,139.3	4,139.1	4,139.1	4,139.6	4,139.6	4,139.6
		4,125.0	4,121.0	4,127.1	4,125.1	4,117.1	4,115.6	4,111.0	4,109.0	4,105.0	4,103.0	4,103.1	4,103.1	4,101.7	4,097.0	4,092.5	4,095.3	4,094.4	
Jun 22				4,138.0	4,135.2	4,133.2	4,128.3	4,123.8	4,120.3	4,120.6	4,122.0	4,123.5	4,123.6	4,123.7	4,123.7	4,123.6	4,138.0	4,138.3	4,138.6
				4,133.6	4,129.7	4,126.2	4,121.3	4,113.1	4,111.5	4,105.0	4,108.0	4,107.1	4,105.0	4,102.0	4,098.4	4,091.7	4,093.0	4,096.0	
Jul 11				4,139.1	4,134.1	4,130.9	4,125.7	4,120.6	4,115.2	4,114.9	4,115.6	4,115.7	4,114.7	4,113.5	4,112.5	4,113.2	4,139.1	4,139.1	4,139.0
				4,135.1	4,131.1	4,127.1	4,121.7	4,113.1	4,111.5	4,109.5	4,108.0	4,107.7	4,106.4	4,104.0	4,100.4	4,094.0	4,096.5	4,115.1	
Jul 20					4,134.1	4,128.8	4,123.0	4,115.4			4,113.1	4,111.3	4,108.6	4,105.6	4,102.4	4,096.0	4,137.9	4,135.9	4,139.0
					4,131.5	4,126.4	4,121.1	4,112.5			4,110.4	4,109.1	4,106.4	4,103.1	4,099.0	4,093.7	4,094.8	4,095.0	
Aug 7		4,136.7					4,119.1	4,112.8											4,136.6
		4,125.0					4,117.1	4,111.5											
Aug 20								4,114.3											4,135.4
								4,111.0											

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 8b Butt Valley Reservoir Simulated Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	Total
May 15	11	44	40	154	223	715	859	1002	1991	2207	7062	8117	3863	3751	3244	2374	1234	1264	**38,150**
Jun 6		53	49	183	260	848	990	1144	2168	2389	7579	8279	3943	3675	3277	2433	1239	1273	**39,780**
Jun 22				85	117	343	256	226	530	804	2842	3531	1765	1888	1697	1355	1202	1194	**17,830**
Jul 11				80	65	178	132	82	185	279	1428	1640	720	771	715	723	1199	815	**9,010**
Jul 20					58	93	44	18			528	453	176	181	142	53	1176	1108	**4,030**
Aug 7		40					8	6											**50**
Aug 20								17											**20**

Table 9a Butt Valley Reservoir Simulated Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	WSE
May 15	4,137.5	4,137.5	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.5	4,137.5	4,137.5	4,137.5	4,137.5	4,137.5	4,137.5
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.0	4,093.0	4,087.0	4,087.4	4,087.6	4,087.6	
Jun 6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,106.6	4,106.0	4,103.5	4,101.5	4,095.0	4,093.0	4,092.1	4,091.5	4,091.5	
Jun 22	4,138.6	4,138.6	4,138.6	4,138.6	4,138.1	4,137.4	4,136.9	4,136.9	4,137.1	4,136.2	4,132.3	4,127.5	4,125.9	4,124.8	4,124.0	4,124.3	4,124.8	4,125.0	4,138.6
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,106.9	4,106.6	4,105.8	4,105.3	4,104.7	4,104.2	4,102.2	4,100.5	4,099.5	
Jul 11	4,139.0	4,139.0	4,139.0	4,139.0	4,136.8	4,135.0	4,129.5	4,124.0	4,119.3	4,119.9	4,119.7	4,119.8	4,120.7	4,121.4	4,122.1	4,122.5	4,123.2	4,124.0	4,139.0
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,107.1	4,106.9	4,105.9	4,105.0	4,103.3	4,101.0	4,100.4	4,100.4	4,100.1	
Jul 20	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,133.9	4,127.5	4,120.1	4,119.2	4,119.9	4,118.5	4,115.9	4,114.5	4,115.6	4,117.6	4,119.0	4,121.7	4,120.4	4,139.0
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,106.6	4,108.2	4,107.4	4,106.0	4,104.4	4,102.6	4,101.7	4,101.0	4,101.0	
Aug 7		4,132.0	4,132.5	4,129.6	4,124.9	4,123.1	4,117.2	4,113.1	4,111.7										4,136.6
		4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0										
Aug 20		4,135.4	4,135.4	4,130.0	4,127.6	4,131.3	4,127.1	4,119.5	4,113.3										4,135.4
		4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0										

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 9b Butt Valley Reservoir Simulated Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	Total
May 15	11	44	40	154	223	715	859	1002	1991	2207	7062	8117	3862	3751	3244	2377	1234	1264	**38,160**
Jun 6	14	53	49	196	273	851	998	1144	2167	2361	7372	8199	4051	3986	3420	2483	1286	1313	**40,220**
Jun 22	12	48	45	175	237	705	815	960	1950	2057	5477	4730	2011	1824	1466	1118	613	644	**24,890**
Jul 11	13	50	47	184	205	550	359	249	539	714	2496	2878	1436	1565	1454	1073	566	600	**14,980**
Jul 20	13	50	47	184	259	484	271	72	532	723	2028	1744	729	937	1004	820	508	472	**10,870**
Aug 7		22	21	20	12	26	14	10	81										**210**
Aug 20		35	31	22	26	328	253	60	155										**910**

Table 10a Butt Valley Reservoir Simulated Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a
(2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	WSE
May 15	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.5	4,137.5	4,137.5
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.0	4,093.0	4,087.4	4,087.9	4,087.6	4,087.7	
Jun 6		4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6
		4,125.0	4,121.0	4,127.1	4,125.1	4,117.1	4,115.6	4,111.0	4,109.0	4,105.0	4,103.0	4,103.1	4,103.1	4,101.7	4,097.0	4,092.5	4,095.3	4,094.4	
Jun 22				4,138.6	4,136.7	4,136.6	4,136.0	4,135.6	4,134.4	4,131.6	4,128.2	4,127.6	4,126.9	4,126.5	4,126.2	4,125.8	4,138.6	4,138.6	4,138.6
				4,133.6	4,129.7	4,126.2	4,121.3	4,113.1	4,111.5	4,105.0	4,108.0	4,107.1	4,105.0	4,102.0	4,098.4	4,091.7	4,093.0	4,096.0	
Jul 11				4,139.1	4,136.7	4,134.5	4,130.3	4,126.0	4,123.6	4,124.0	4,123.3	4,124.2	4,125.1	4,126.9	4,131.4	4,133.6	4,139.1	4,139.1	4,139.0
				4,135.1	4,131.1	4,127.1	4,121.7	4,113.1	4,111.5	4,109.5	4,108.0	4,107.7	4,106.4	4,104.0	4,100.4	4,094.0	4,096.5	4,115.1	
Jul 20					4,139.0	4,134.8	4,128.7	4,124.4	4,123.5	4,122.2	4,120.0	4,118.8	4,123.1	4,128.2	4,133.3	4,131.7	4,139.0	4,139.0	4,139.0
					4,131.5	4,126.4	4,121.1	4,112.5	4,113.1	4,113.1	4,110.4	4,109.1	4,106.4	4,103.1	4,099.0	4,093.7	4,094.8	4,095.0	
Aug 7		4,136.7			4,135.4	4,131.5	4,124.6	4,118.4	4,114.7	4,113.8	4,114.3	4,111.7	4,107.1	4,103.6	4,099.4	4,091.9	4,094.5	4,121.1	4,136.6
		4,125.0			4,134.1	4,126.0	4,117.1	4,111.5	4,111.7	4,111.1	4,108.0	4,105.0	4,103.5	4,100.2	4,095.4	4,085.0	4,085.0	4,085.0	
Aug 20						4,135.4	4,130.3	4,124.4	4,116.5	4,114.7	4,113.5	4,110.3	4,106.7	4,105.4	4,102.2	4,090.4	4,123.1	4,125.1	4,135.4
						4,133.8	4,124.4	4,111.0	4,109.0	4,111.4	4,111.1	4,107.1	4,104.0	4,103.1	4,099.0	4,085.0	4,086.0	4,085.0	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 10b Butt Valley Reservoir Simulated Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a
(2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	Total
May 15	11	44	40	154	223	715	859	1002	1991	2207	7062	8117	3863	3751	3244	2374	1234	1264	**38,150**
Jun 6		53	49	183	260	848	990	1144	2168	2389	7579	8279	3977	3715	3327	2476	1239	1273	**39,950**
Jun 22				98	152	557	705	859	1646	1688	4265	4517	2155	2190	1932	1489	1228	1206	**24,690**
Jul 11				80	127	397	346	337	778	953	3132	3571	1844	2092	2351	1984	1199	815	**20,010**
Jul 20					175	438	279	261	704	647	1983	2063	1611	2305	2593	1855	1222	1239	**17,370**
Aug 7		40			32	247	130	47	150	146	1176	1294	240	215	126	59	74	691	**4,670**
Aug 20						99	269	267	341	188	477	623	188	169	131	37	726	816	**4,330**

Table 11a Butt Valley Reservoir Simulated Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	WSE
May 15	4,137.5	4,137.5	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.5	4,137.5	4,137.5	4,137.5	4,137.5	4,137.5	4,137.5
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.0	4,093.0	4,087.0	4,087.4	4,087.6	4,087.6	
Jun 6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,106.6	4,106.0	4,103.5	4,101.5	4,095.0	4,093.0	4,092.1	4,091.5	4,091.5	
Jun 22	4,138.6	4,138.6	4,138.6	4,138.6	4,138.6	4,138.6	4,138.2	4,138.0	4,138.0	4,137.9	4,137.7	4,137.5	4,137.4	4,137.3	4,137.2	4,137.0	4,136.2	4,135.9	4,138.6
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,106.9	4,106.6	4,105.8	4,105.3	4,104.7	4,104.2	4,102.2	4,100.5	4,099.5	
Jul 11	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,107.1	4,106.9	4,105.9	4,105.0	4,103.3	4,101.0	4,100.4	4,100.4	4,100.1	
Jul 20	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,138.3	4,137.9	4,138.0	4,138.0	4,137.9	4,138.3	4,138.7	4,138.9	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,106.6	4,108.2	4,107.4	4,106.0	4,104.4	4,102.6	4,101.7	4,101.0	4,101.0	
Aug 7	4,136.6	4,136.6	4,136.6	4,136.6	4,135.9	4,135.3	4,129.9	4,124.6	4,124.3	4,124.4	4,123.4	4,121.4	4,125.6	4,129.9	4,132.6	4,133.6	4,133.5	4,133.2	4,136.6
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,106.0	4,106.5	4,103.6	4,100.9	4,099.9	4,099.7	4,099.7	4,099.8	
Aug 20	4,135.4	4,135.4	4,135.4	4,135.4	4,135.4	4,135.4	4,135.4	4,131.7	4,131.8	4,131.6	4,131.6	4,133.1	4,134.1	4,134.7	4,134.9	4,134.7	4,135.0	4,135.4	4,135.4
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,100.9	4,101.9	4,102.0	4,099.6	4,096.8	4,095.0	4,094.9	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 11b Butt Valley Reservoir Simulated Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment - Baseline Condition (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	Total
May 15	11	44	40	154	223	715	859	1,002	1,991	2,207	7,062	8,117	3,862	3,751	3,244	2,377	1,234	1,264	**38,160**
Jun 6	14	53	49	196	273	851	998	1,144	2,167	2,361	7,372	8,199	4,051	3,986	3,420	2,483	1,286	1,313	**40,220**
Jun 22	12	48	45	175	249	785	900	1,032	2,029	2,201	6,820	7,269	3,518	3,232	2,761	2,008	1,018	1,033	**35,140**
Jul 11	13	50	47	184	259	814	960	1,105	2,120	2,302	7,108	7,636	3,776	3,543	3,121	2,230	1,136	1,154	**37,560**
Jul 20	13	50	47	184	259	812	906	1,023	2,032	2,217	6,622	7,167	3,659	3,446	3,045	2,182	1,123	1,136	**35,920**
Aug 7	9	40	36	136	184	568	380	275	909	1,096	3,459	3,139	2,085	2,618	2,494	1,831	927	924	**21,110**
Aug 20	8	35	31	111	172	576	718	639	1,506	1,693	5,579	6,863	3,265	3,117	2,740	2,003	1,057	1,091	**31,210**

Table 12a Butt Valley Reservoir Simulated Elevation Range (Feet in USGS Datum) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	WSE
May 15	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.6	4,137.5	4,137.5	4,137.5
	4,129.1	4,125.0	4,121.0	4,119.0	4,117.0	4,115.0	4,111.0	4,111.0	4,109.0	4,105.0	4,103.0	4,099.0	4,095.0	4,093.0	4,087.4	4,087.9	4,087.6	4,087.7	
Jun 6		4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6	4,139.6
		4,125.0	4,121.0	4,127.1	4,125.1	4,117.1	4,115.6	4,111.0	4,109.0	4,105.0	4,103.0	4,103.1	4,103.1	4,101.7	4,097.0	4,092.5	4,095.3	4,094.4	
Jun 22				4,138.6	4,137.9	4,138.1	4,137.9	4,137.8	4,137.8	4,137.7	4,137.6	4,137.4	4,137.3	4,137.3	4,137.3	4,134.8	4,138.6	4,138.6	4,138.6
				4,133.6	4,129.7	4,126.2	4,121.3	4,113.1	4,111.5	4,105.0	4,108.0	4,107.1	4,105.0	4,102.0	4,098.4	4,091.7	4,093.0	4,096.0	
Jul 11				4,139.1	4,139.1	4,139.1	4,139.1	4,139.1	4,139.1	4,139.1	4,139.1	4,139.1	4,139.1	4,139.1	4,139.1	4,139.1	4,139.1	4,139.1	4,139.0
				4,135.1	4,131.1	4,127.1	4,121.7	4,113.1	4,111.5	4,109.5	4,108.0	4,107.7	4,106.4	4,104.0	4,100.4	4,094.0	4,096.5	4,115.1	
Jul 20					4,139.0	4,139.0	4,138.9	4,138.8	4,138.8	4,138.8	4,138.8	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0	4,139.0
					4,131.5	4,126.4	4,121.1	4,112.5	4,113.1	4,113.1	4,110.4	4,109.1	4,106.4	4,103.1	4,099.0	4,093.7	4,094.8	4,095.0	
Aug 7		4,136.7			4,136.7	4,135.4	4,131.3	4,129.8	4,129.8	4,129.3	4,129.9	4,132.7	4,135.1	4,135.2	4,135.3	4,135.3	4,136.1	4,135.9	4,136.6
		4,125.0			4,134.1	4,126.0	4,117.1	4,111.5	4,111.7	4,111.1	4,108.0	4,105.0	4,103.5	4,100.2	4,095.4	4,085.0	4,085.0	4,085.0	
Aug 20						4,135.4	4,135.4	4,135.4	4,135.4	4,135.4	4,135.4	4,135.4	4,135.4	4,135.4	4,135.4	4,135.4	4,135.4	4,135.4	4,135.4
						4,133.8	4,124.4	4,111.0	4,109.0	4,111.4	4,111.1	4,107.1	4,104.0	4,103.1	4,099.0	4,085.0	4,086.0	4,085.0	

Notes: 1) The blanks indicate that no water layer meets the temperature and DO criteria in the segment; 2) WSE – Water surface elevation; 3) The bold dates have observed profiles.

Table 12b Butt Valley Reservoir Simulated Habitat Volume (acre-feet) of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment – Alternative 4a (2001, Critical Dry Year)

Date	Seg_2	Seg_3	Seg_4	Seg_5	Seg_6	Seg_7	Seg_8	Seg_9	Seg_10	Seg_11	Seg_12	Seg_13	Seg_14	Seg_15	Seg_16	Seg_17	Seg_18	Seg_19	Total
May 15	11	44	40	154	223	715	859	1,002	1,991	2,207	7,062	8,117	3,863	3,751	3,244	2,374	1,234	1,264	**38,150**
Jun 6		53	49	183	260	848	990	1,144	2,168	2,389	7,579	8,279	3,977	3,715	3,327	2,476	1,239	1,273	**39,950**
Jun 22				98	181	655	830	1,008	1,933	2,217	6,554	7,006	3,533	3,417	3,038	2,115	1,228	1,206	**35,020**
Jul 11				80	183	689	903	1,096	2,047	2,229	6,930	7,308	3,683	3,492	3,150	2,403	1,199	815	**36,210**
Jul 20					175	711	908	1,080	1,960	2,044	6,462	7,040	3,680	3,557	3,198	2,408	1,222	1,239	**35,680**
Aug 7		40			60	486	449	531	1,260	1,325	4,656	6,163	3,313	3,273	2,914	2,209	1,183	1,206	**29,070**
Aug 20						99	586	860	1,809	1,830	5,481	6,481	3,331	3,122	2,811	2,220	1,154	1,185	**30,970**

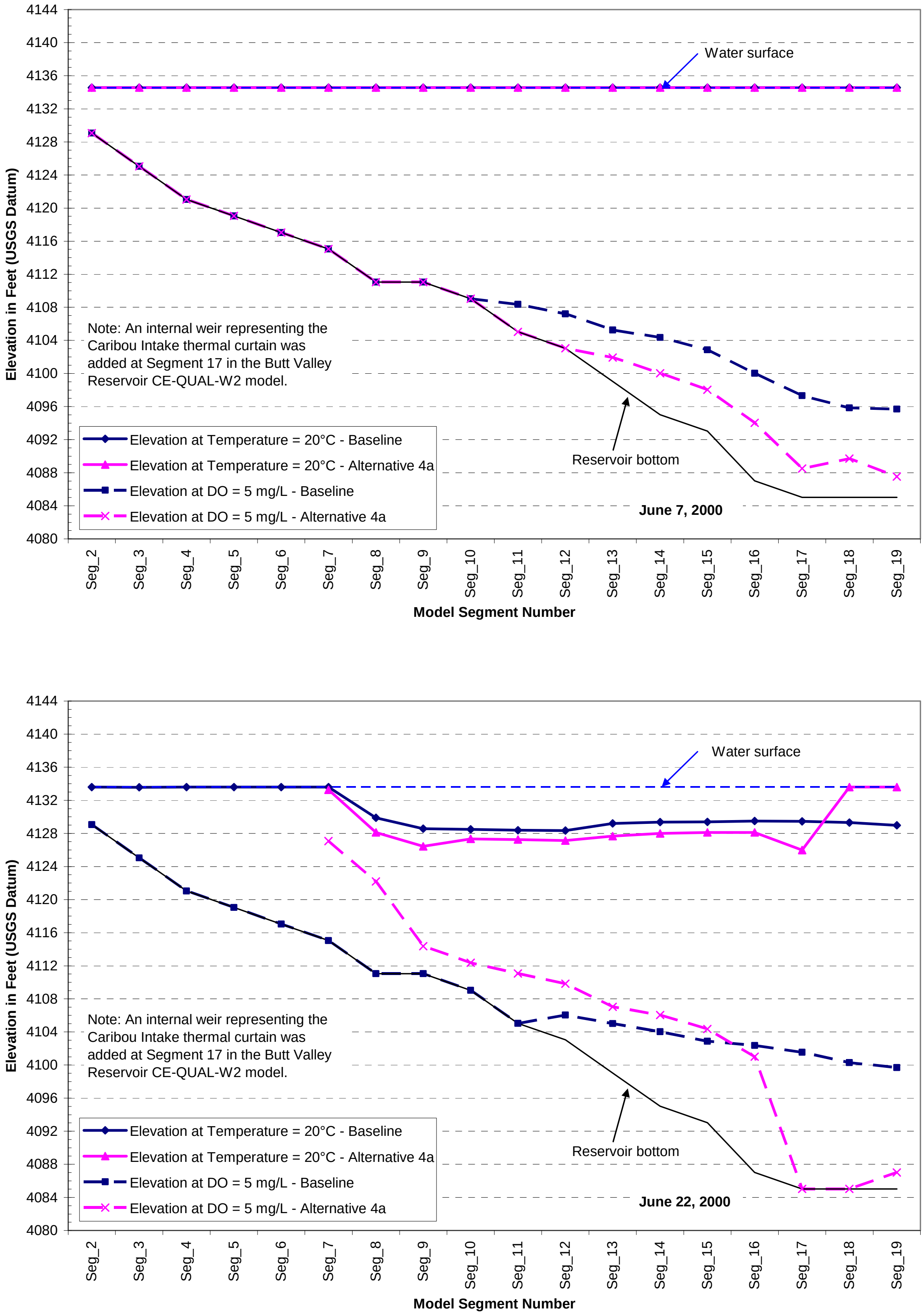
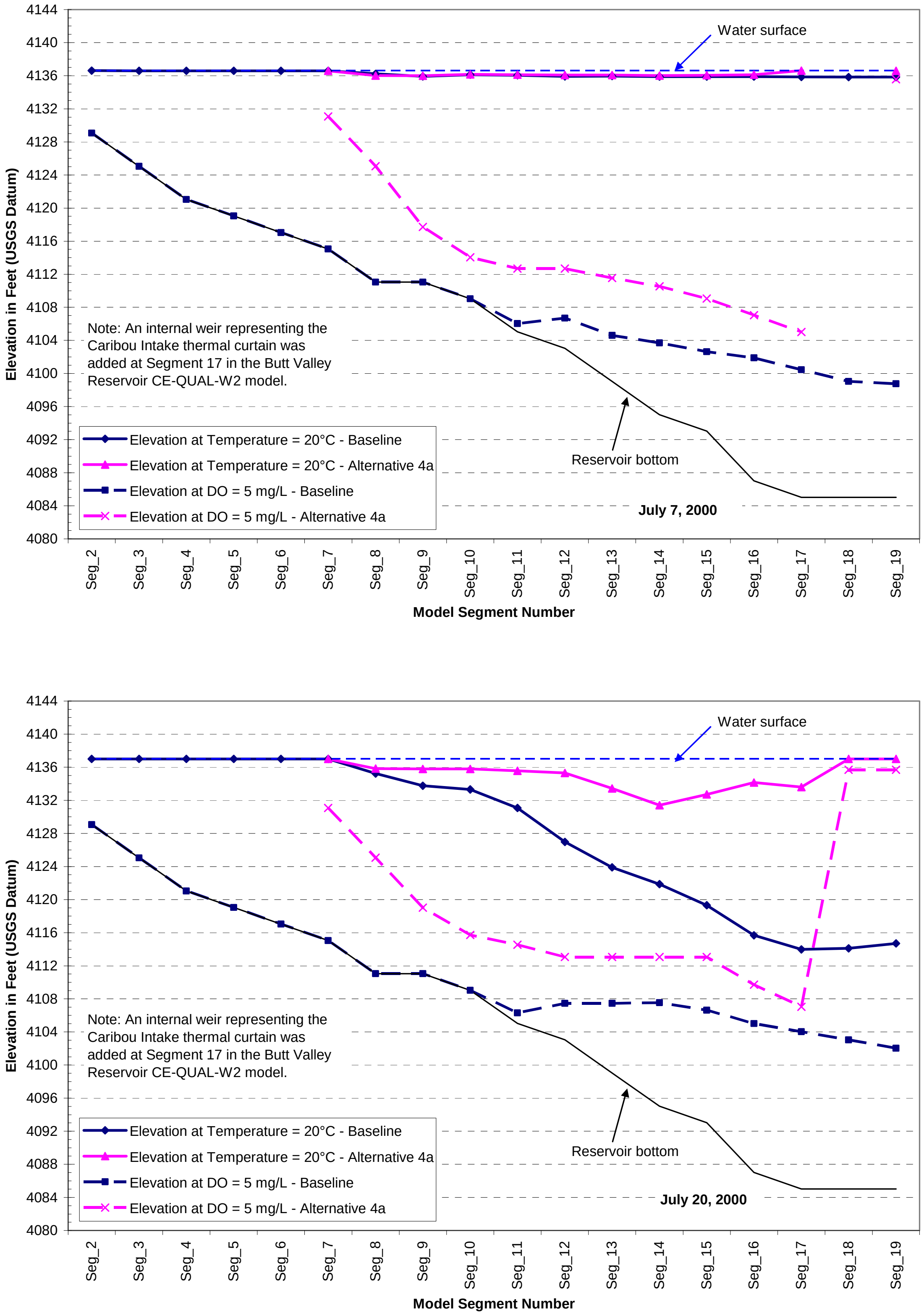


Figure 1a Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, June 2000

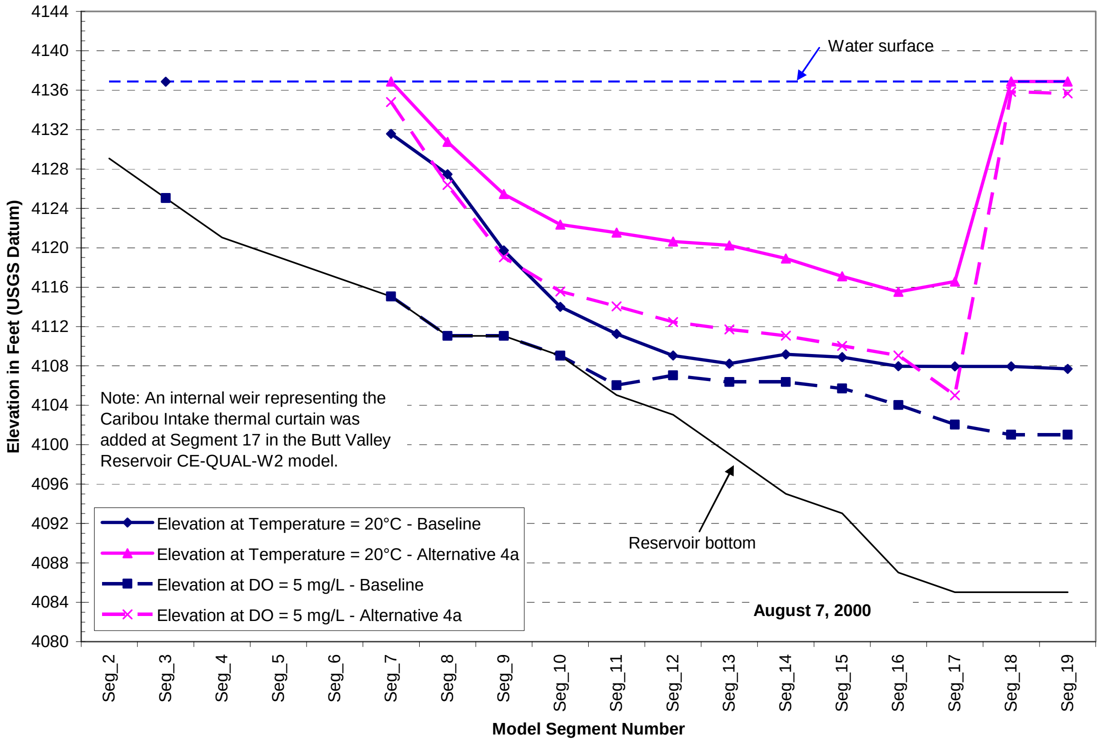


Note: An internal weir representing the Caribou Intake thermal curtain was added at Segment 17 in the Butt Valley Reservoir CE-QUAL-W2 model.

July 7, 2000

July 20, 2000

Figure 1b Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, July 2000



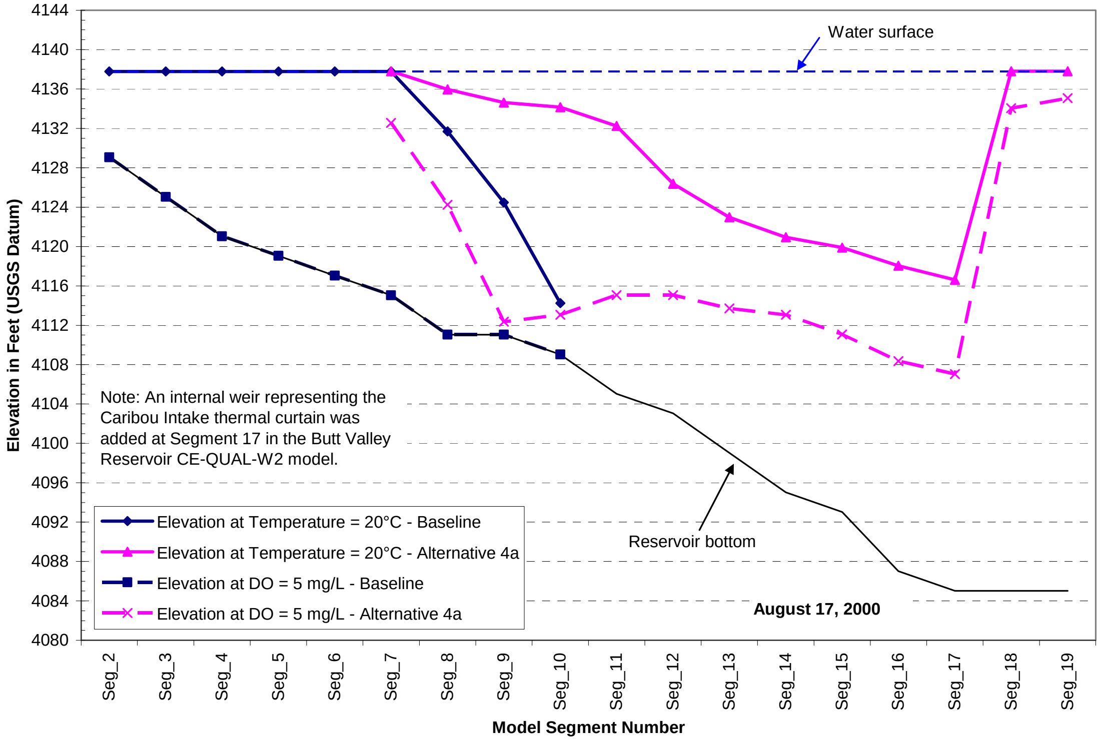


Figure 1c Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, August 2000

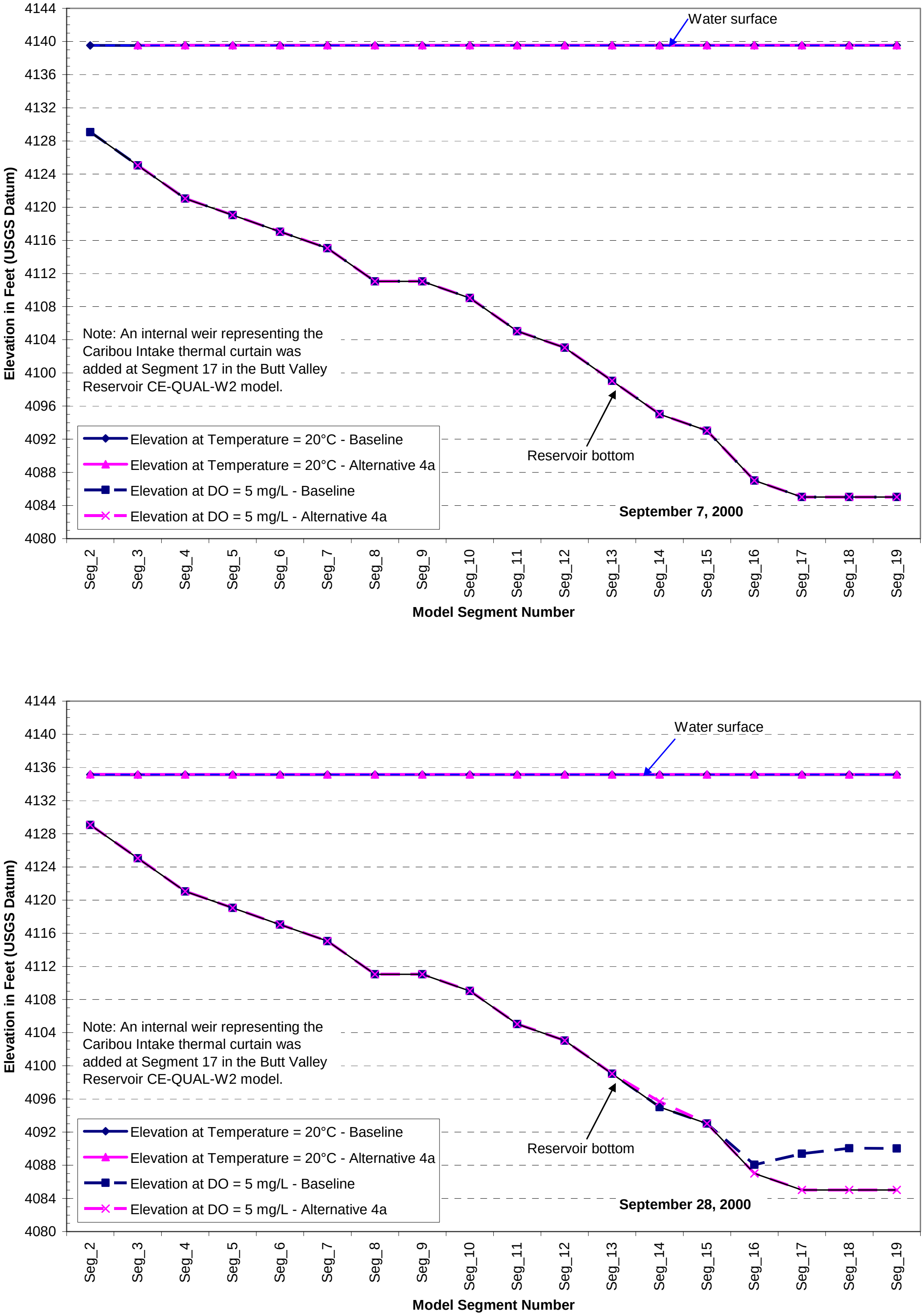


Figure 1d Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, September 2000

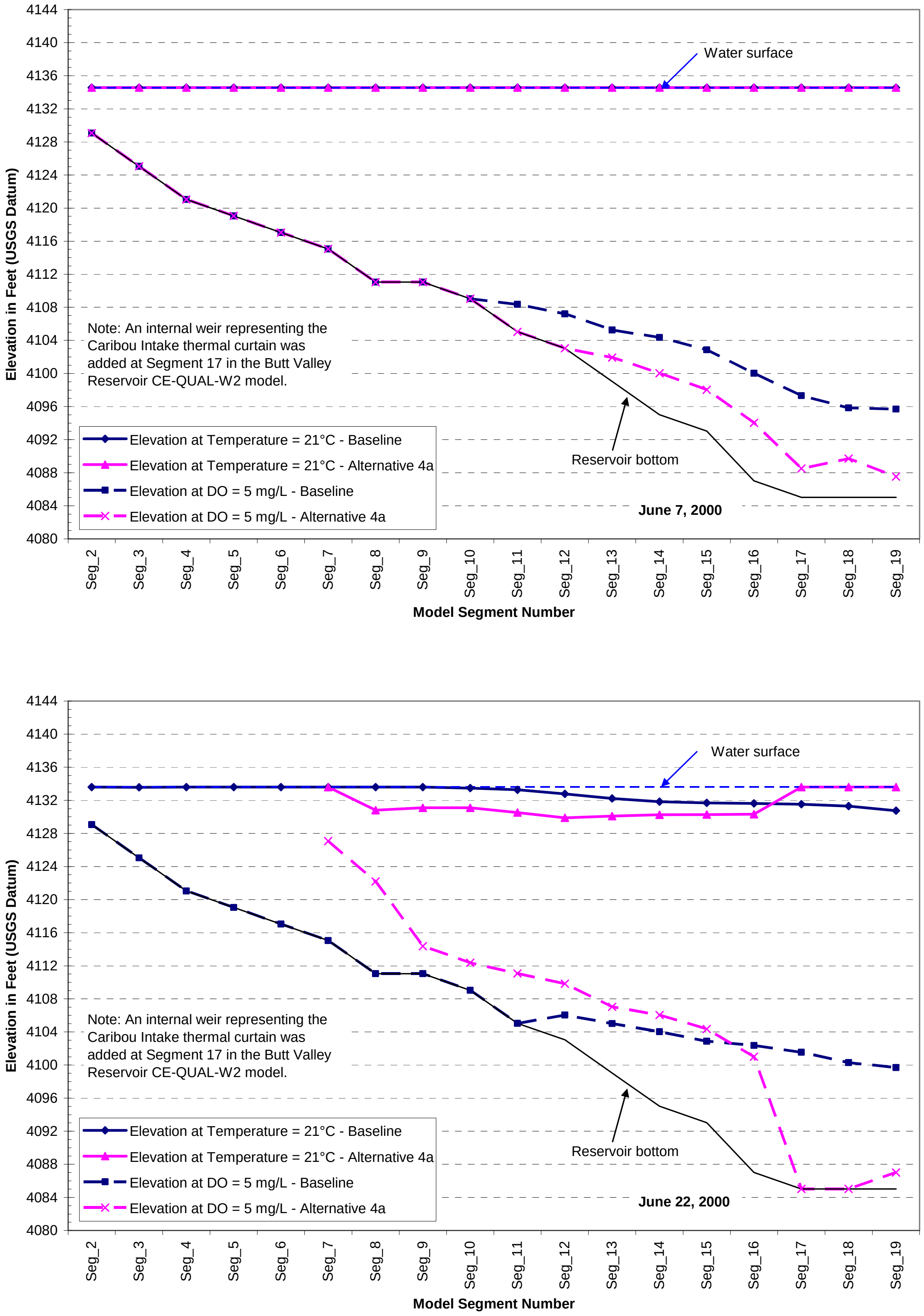
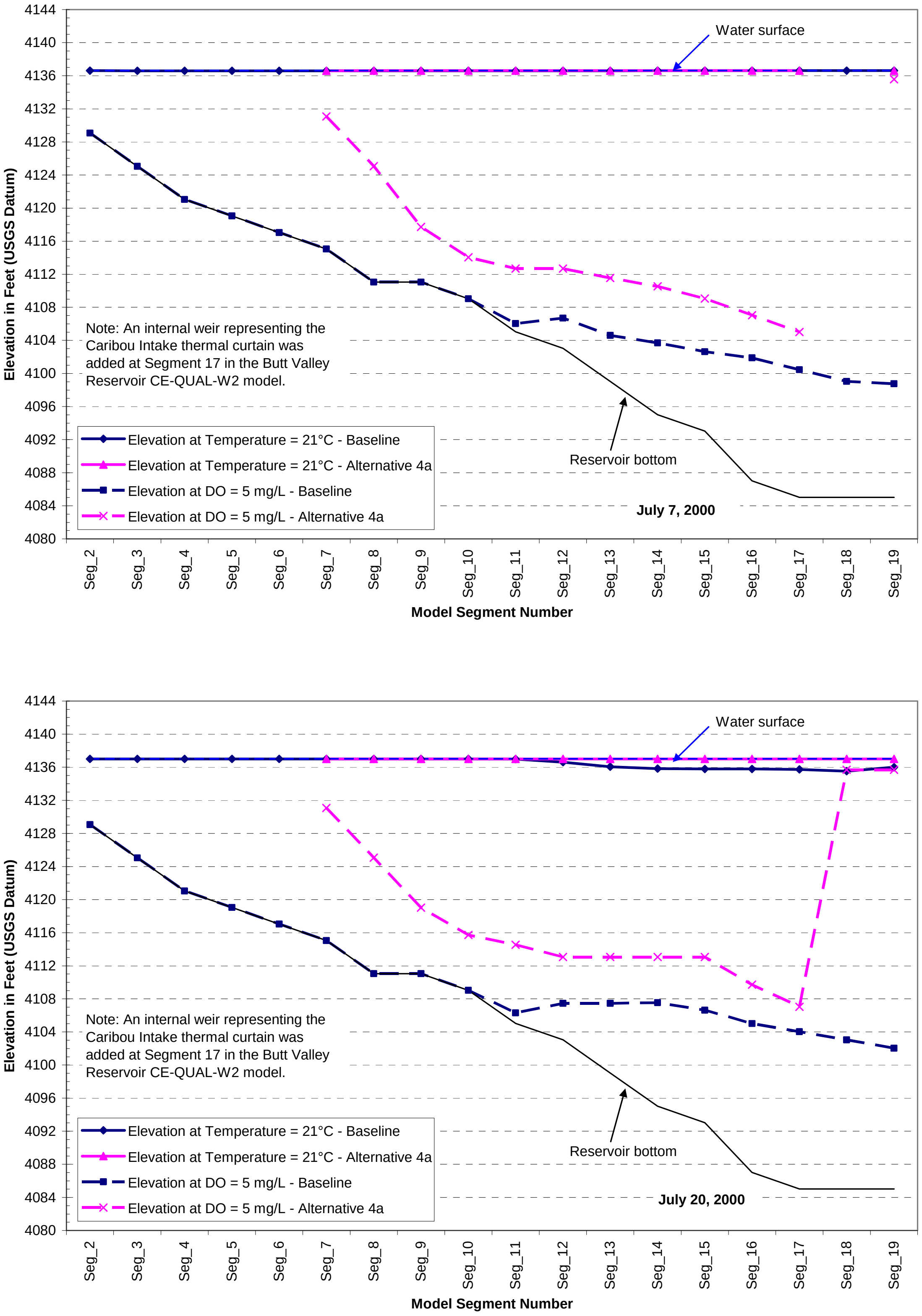


Figure 2a Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, June 2000



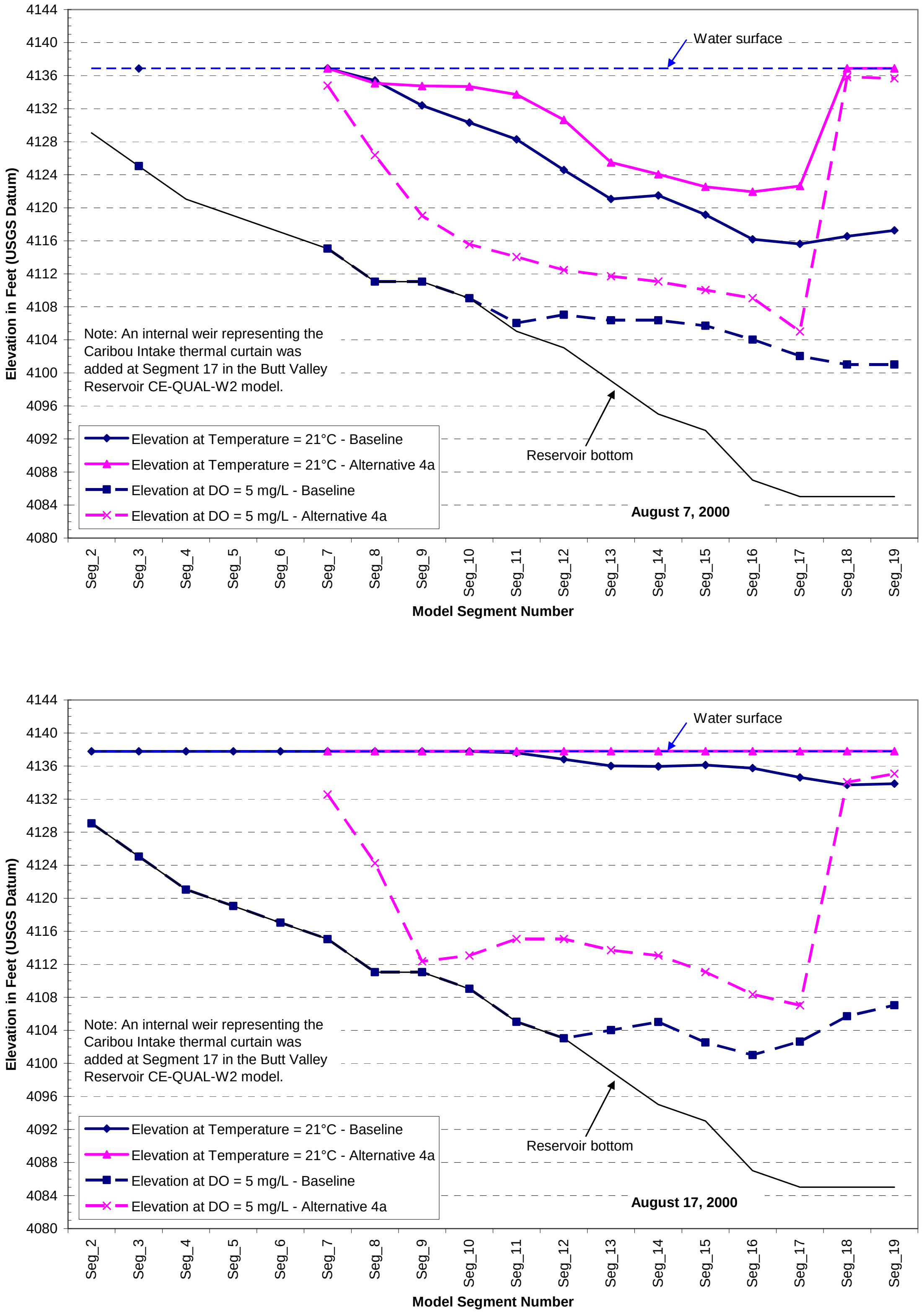
Note: An internal weir representing the Caribou Intake thermal curtain was added at Segment 17 in the Butt Valley Reservoir CE-QUAL-W2 model.

July 7, 2000

Note: An internal weir representing the Caribou Intake thermal curtain was added at Segment 17 in the Butt Valley Reservoir CE-QUAL-W2 model.

July 20, 2000

Figure 2b Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, July 2000



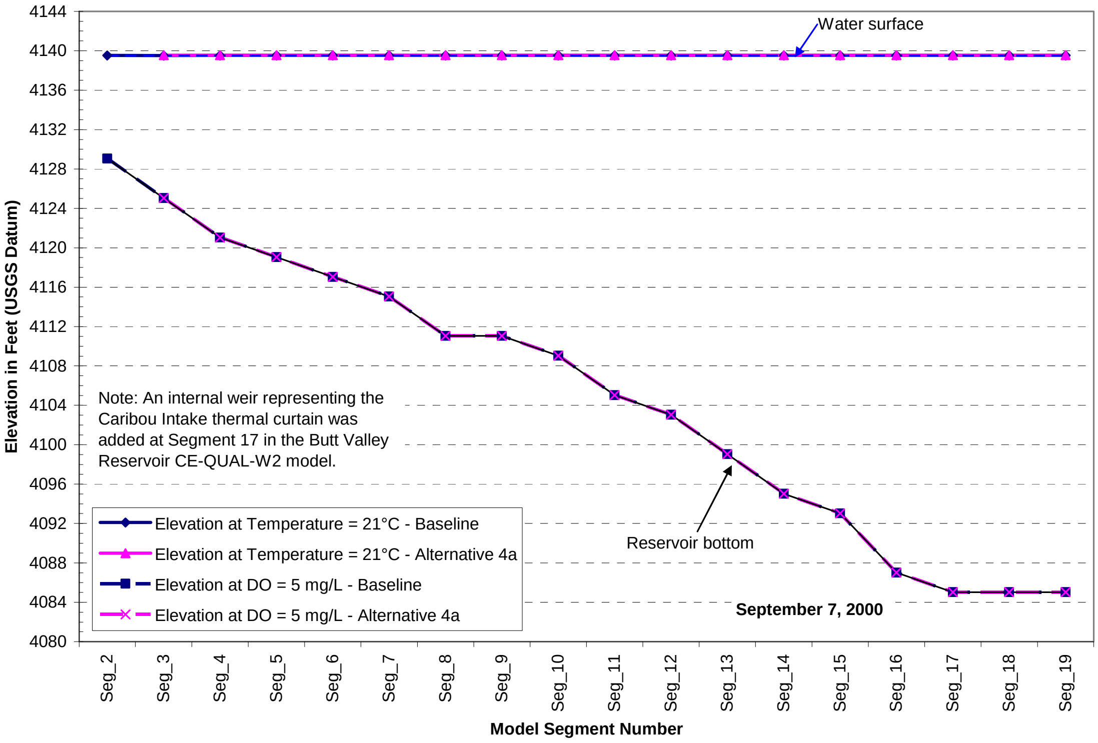
Note: An internal weir representing the Caribou Intake thermal curtain was added at Segment 17 in the Butt Valley Reservoir CE-QUAL-W2 model.

August 7, 2000

Note: An internal weir representing the Caribou Intake thermal curtain was added at Segment 17 in the Butt Valley Reservoir CE-QUAL-W2 model.

August 17, 2000

Figure 2c Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, August 2000



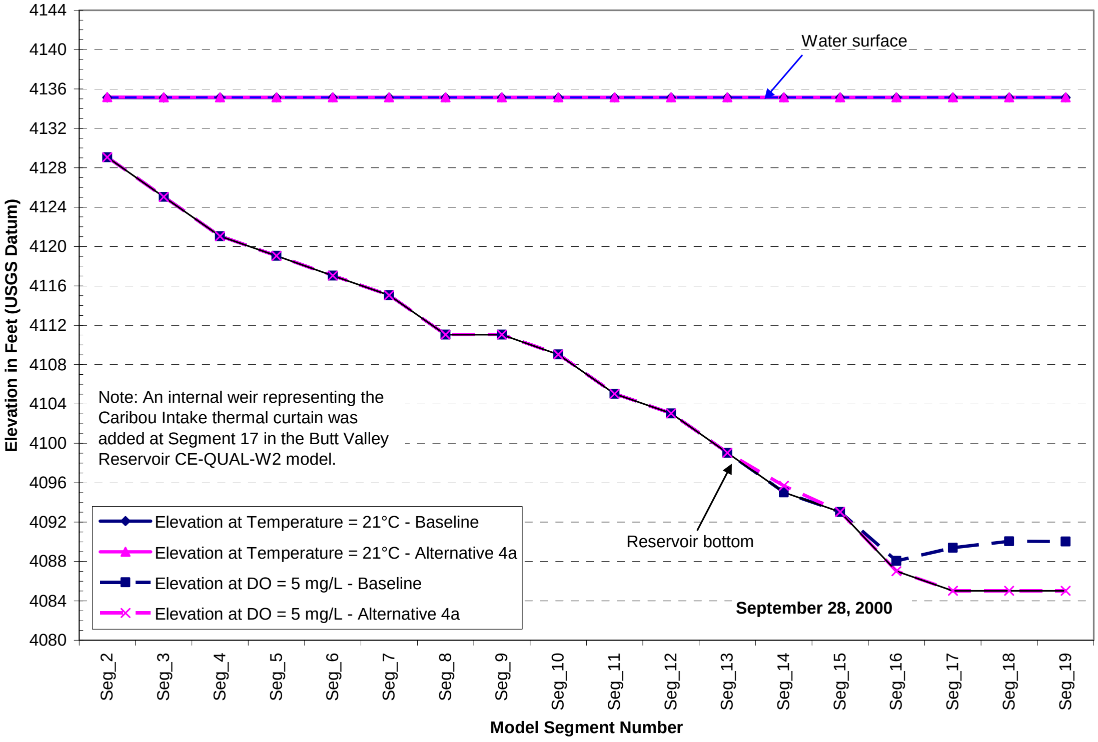
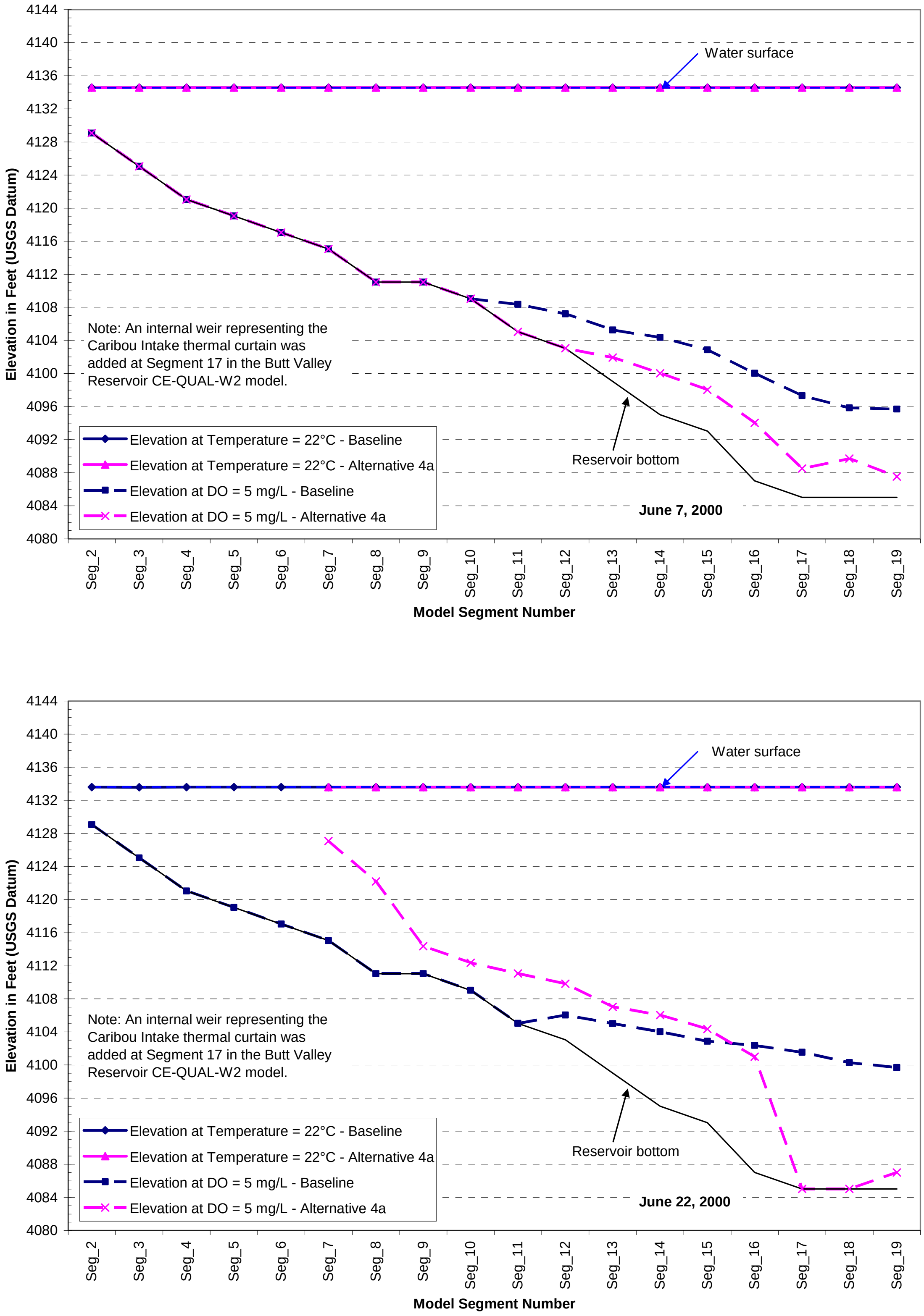


Figure 2d Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, September 2000



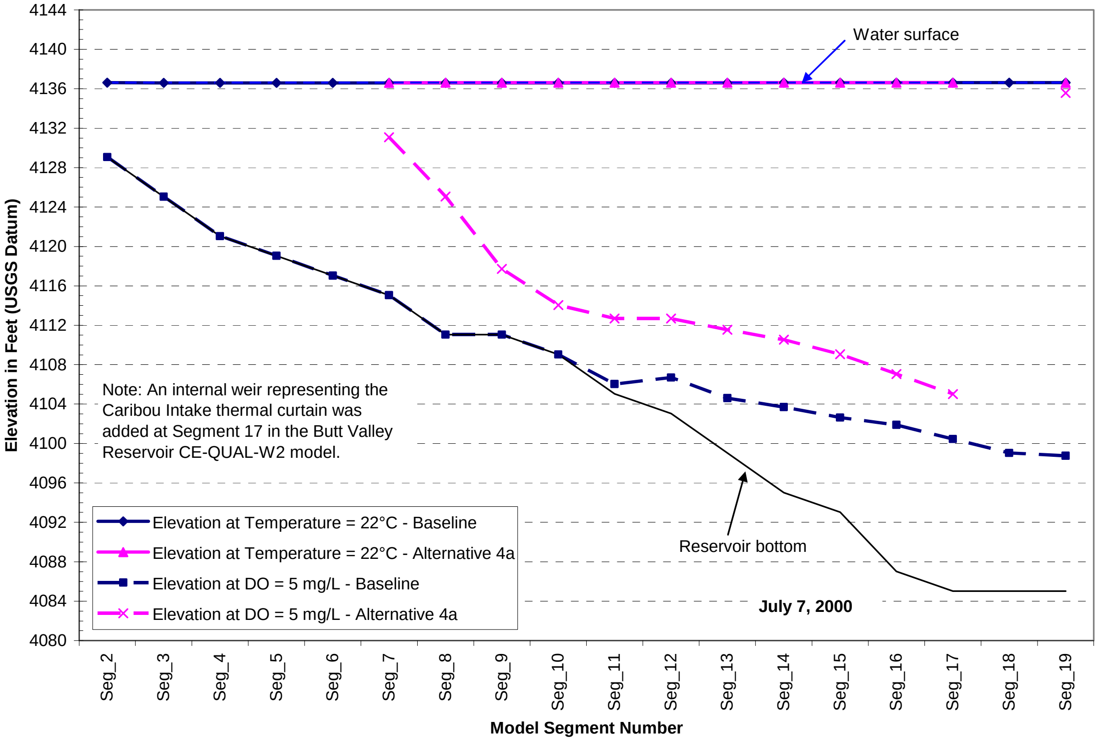
Note: An internal weir representing the Caribou Intake thermal curtain was added at Segment 17 in the Butt Valley Reservoir CE-QUAL-W2 model.

June 7, 2000

Note: An internal weir representing the Caribou Intake thermal curtain was added at Segment 17 in the Butt Valley Reservoir CE-QUAL-W2 model.

June 22, 2000

Figure 3a Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, June 2000



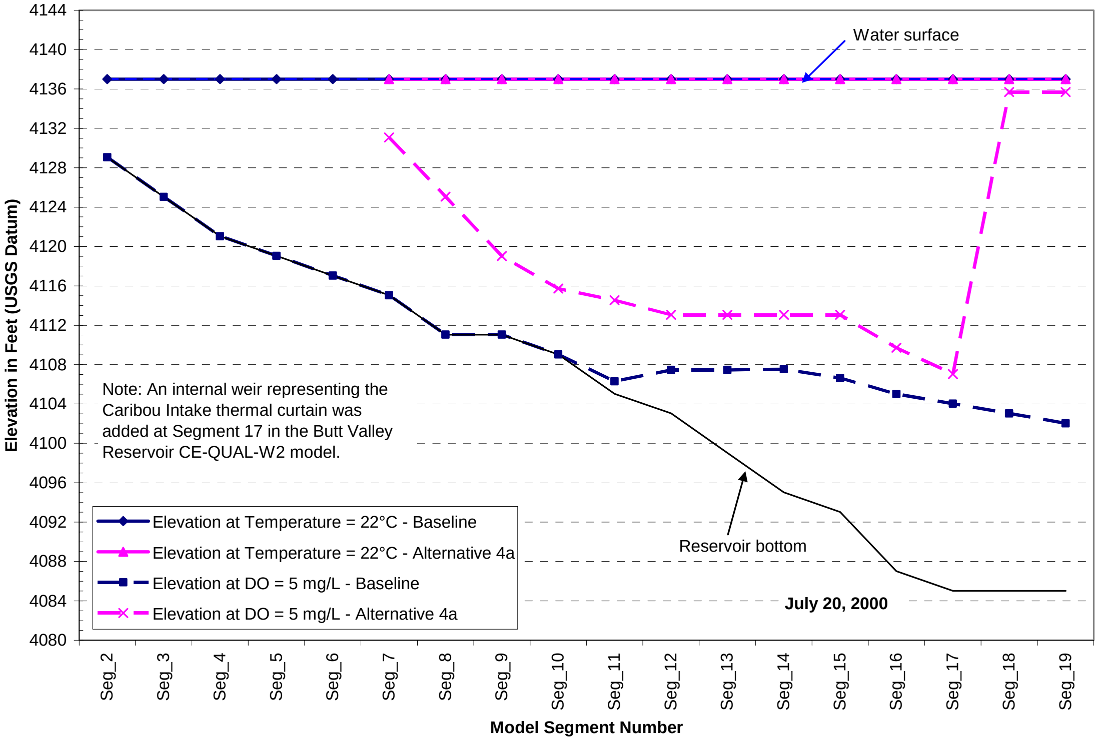
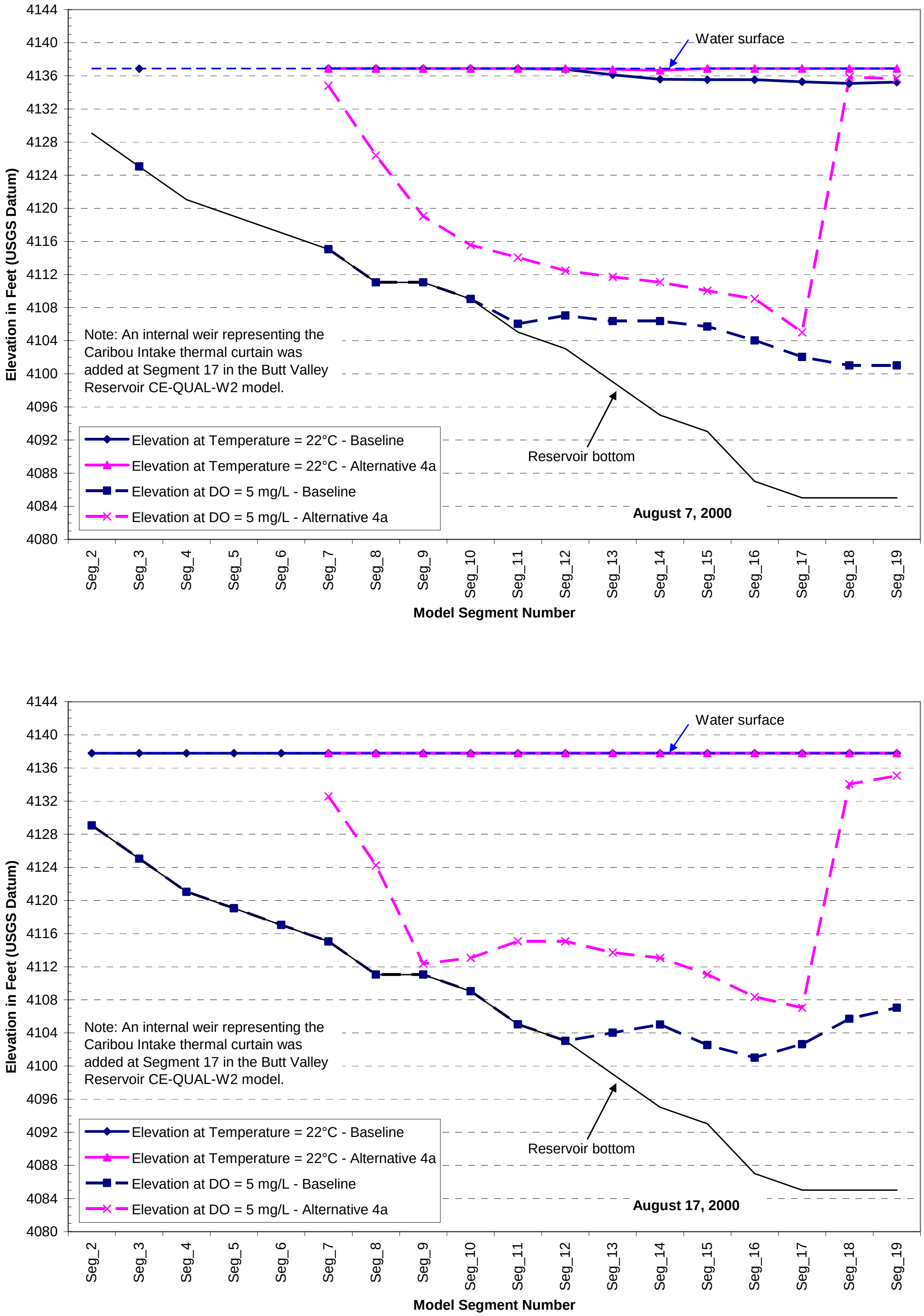


Figure 3b Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, July 2000



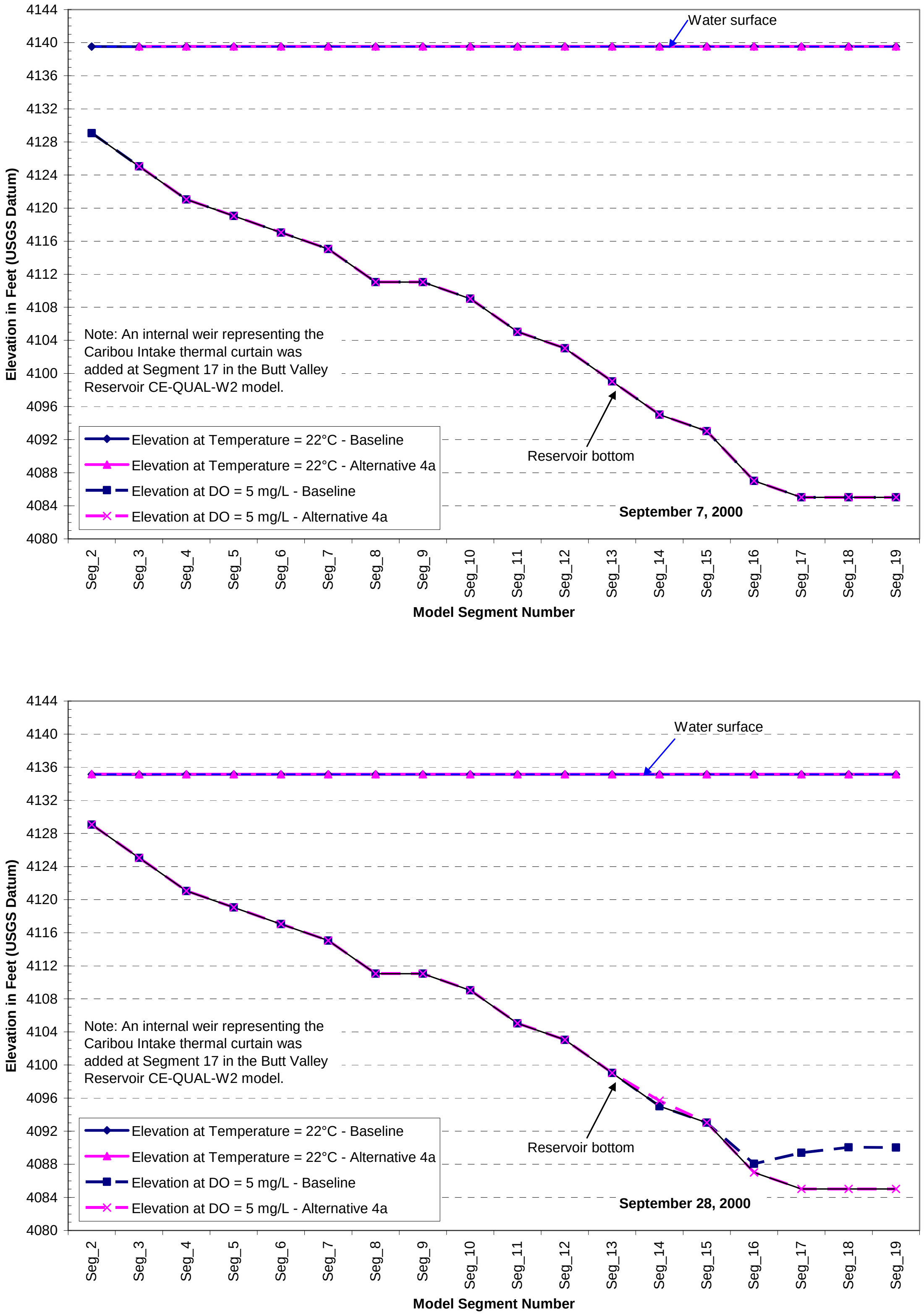
Note: An internal weir representing the Caribou Intake thermal curtain was added at Segment 17 in the Butt Valley Reservoir CE-QUAL-W2 model.

August 7, 2000

Note: An internal weir representing the Caribou Intake thermal curtain was added at Segment 17 in the Butt Valley Reservoir CE-QUAL-W2 model.

August 17, 2000

Figure 3c Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, August 2000



Note: An internal weir representing the Caribou Intake thermal curtain was added at Segment 17 in the Butt Valley Reservoir CE-QUAL-W2 model.

September 7, 2000

Note: An internal weir representing the Caribou Intake thermal curtain was added at Segment 17 in the Butt Valley Reservoir CE-QUAL-W2 model.

September 28, 2000

Figure 3d Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, September 2000

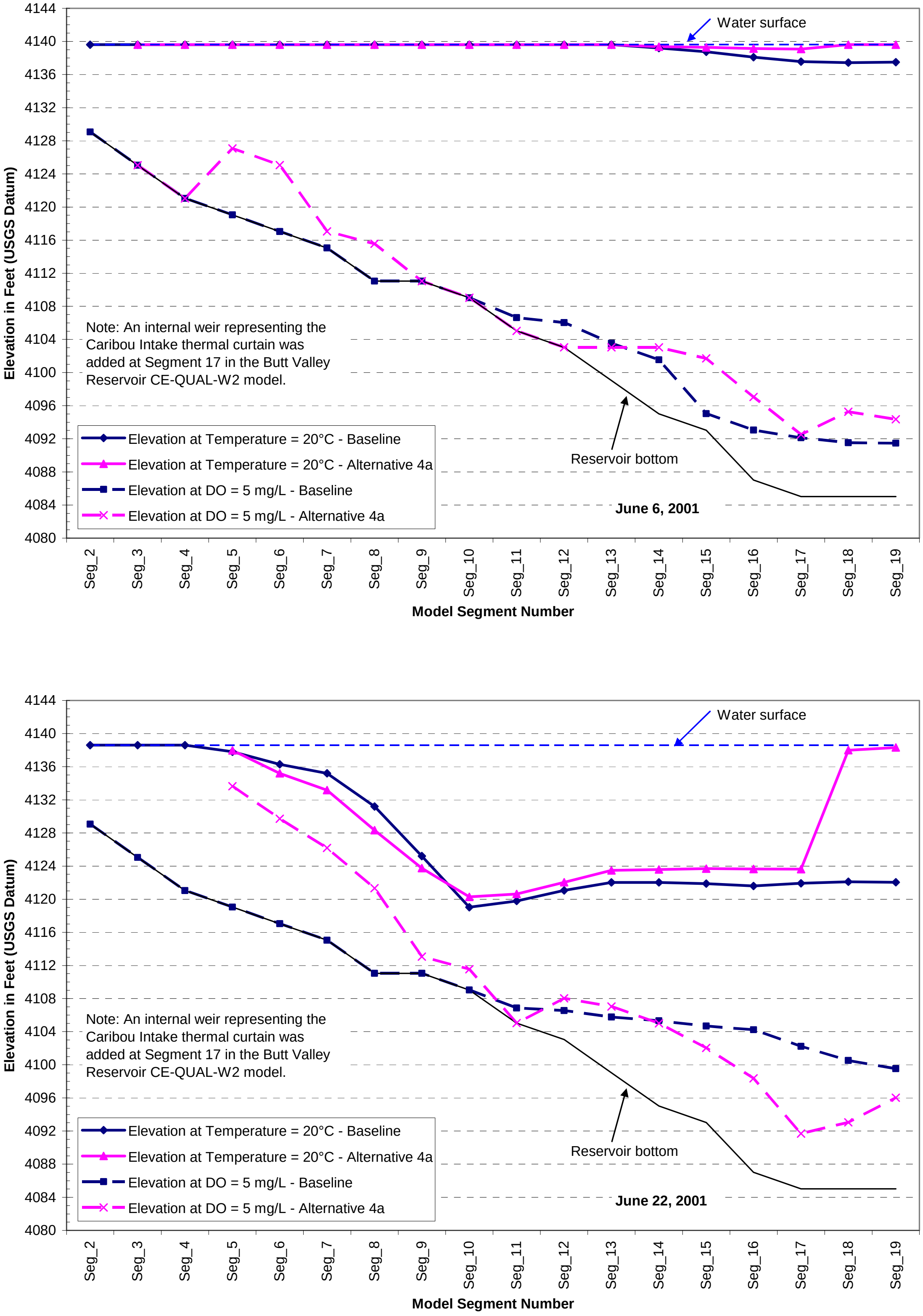
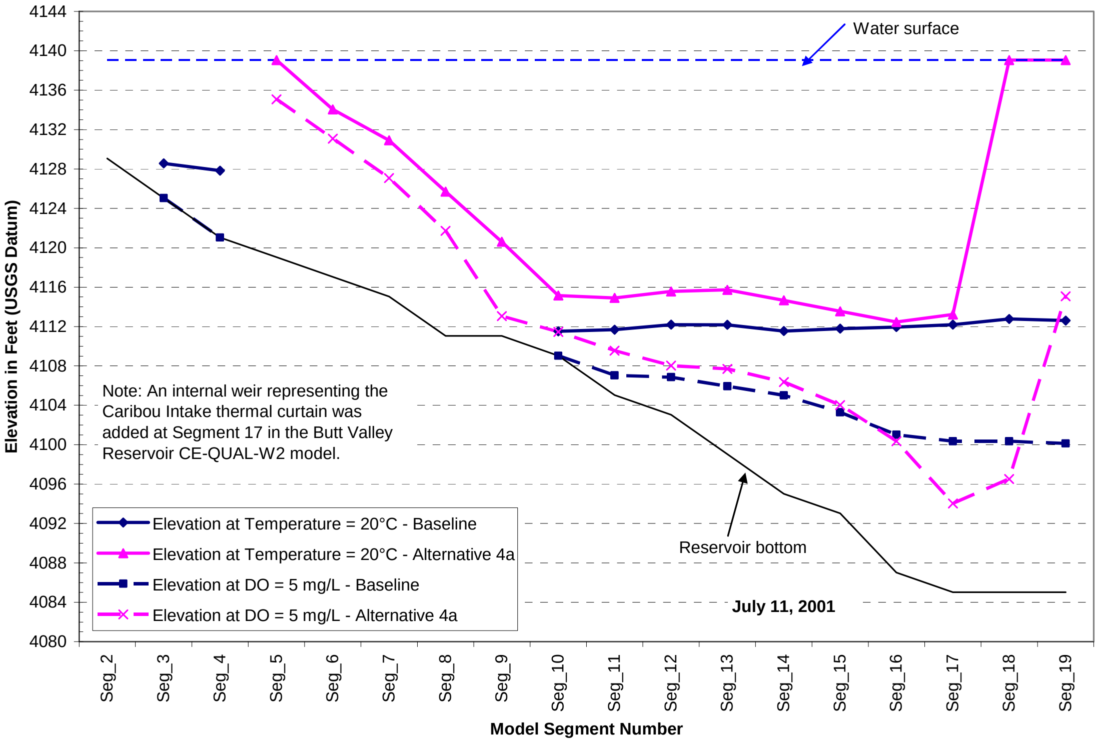


Figure 4a Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, June 2001



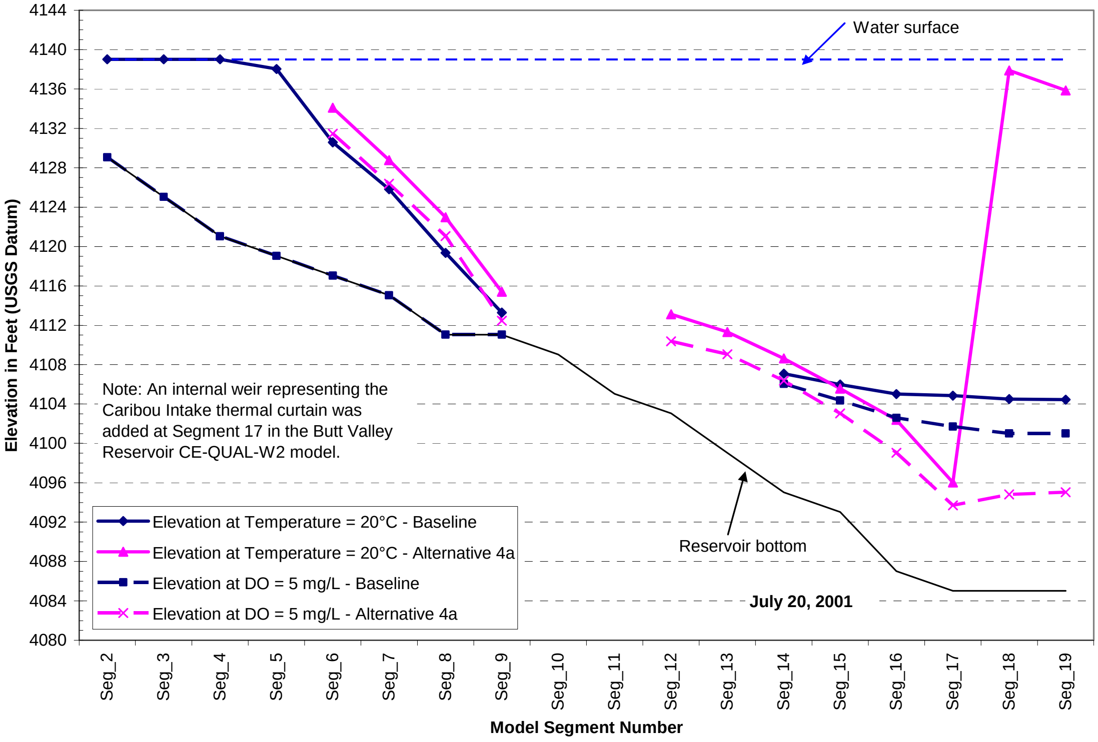
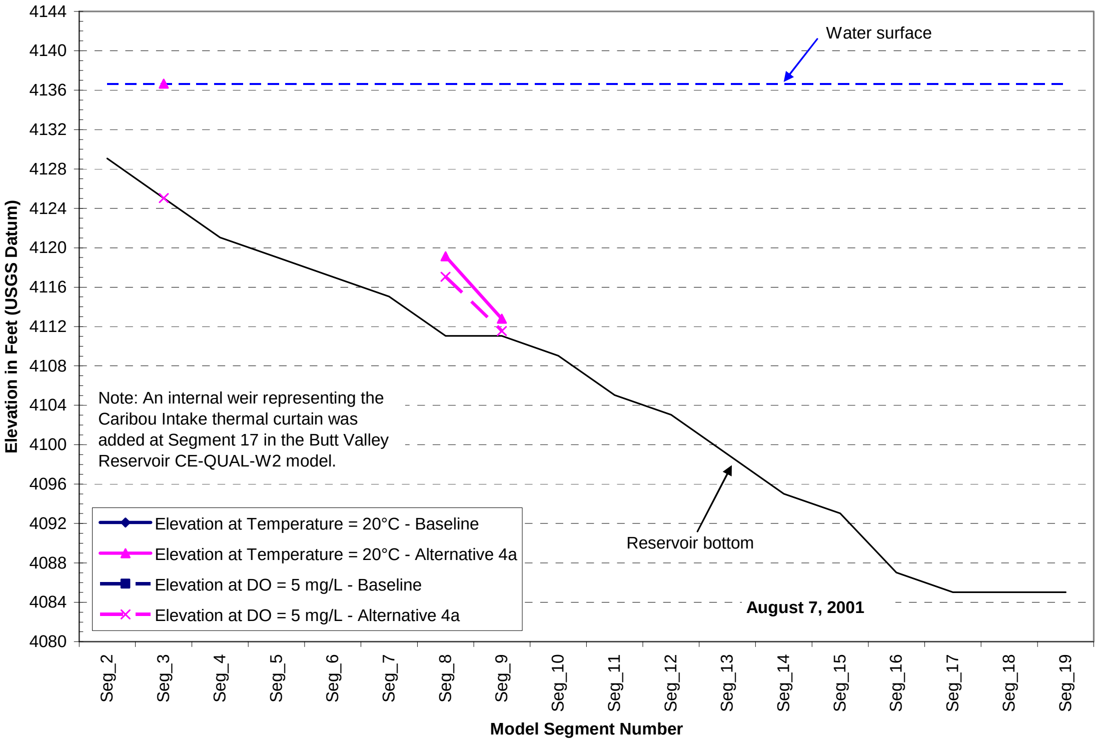


Figure 4b Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, July 2001



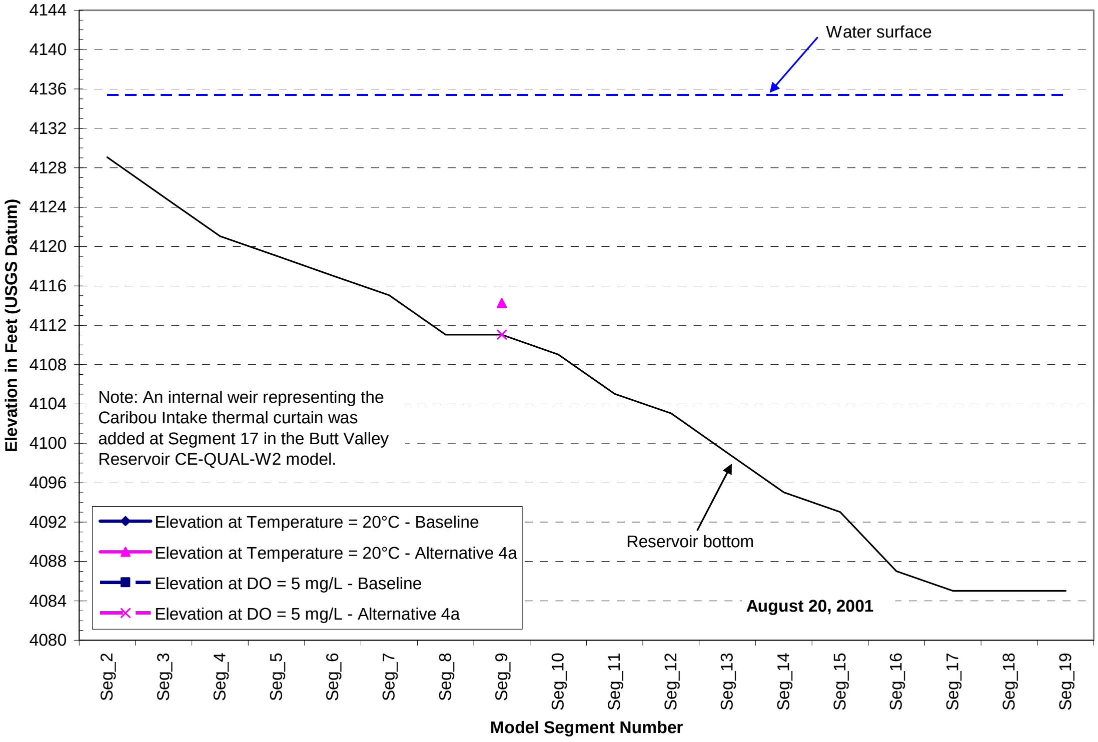
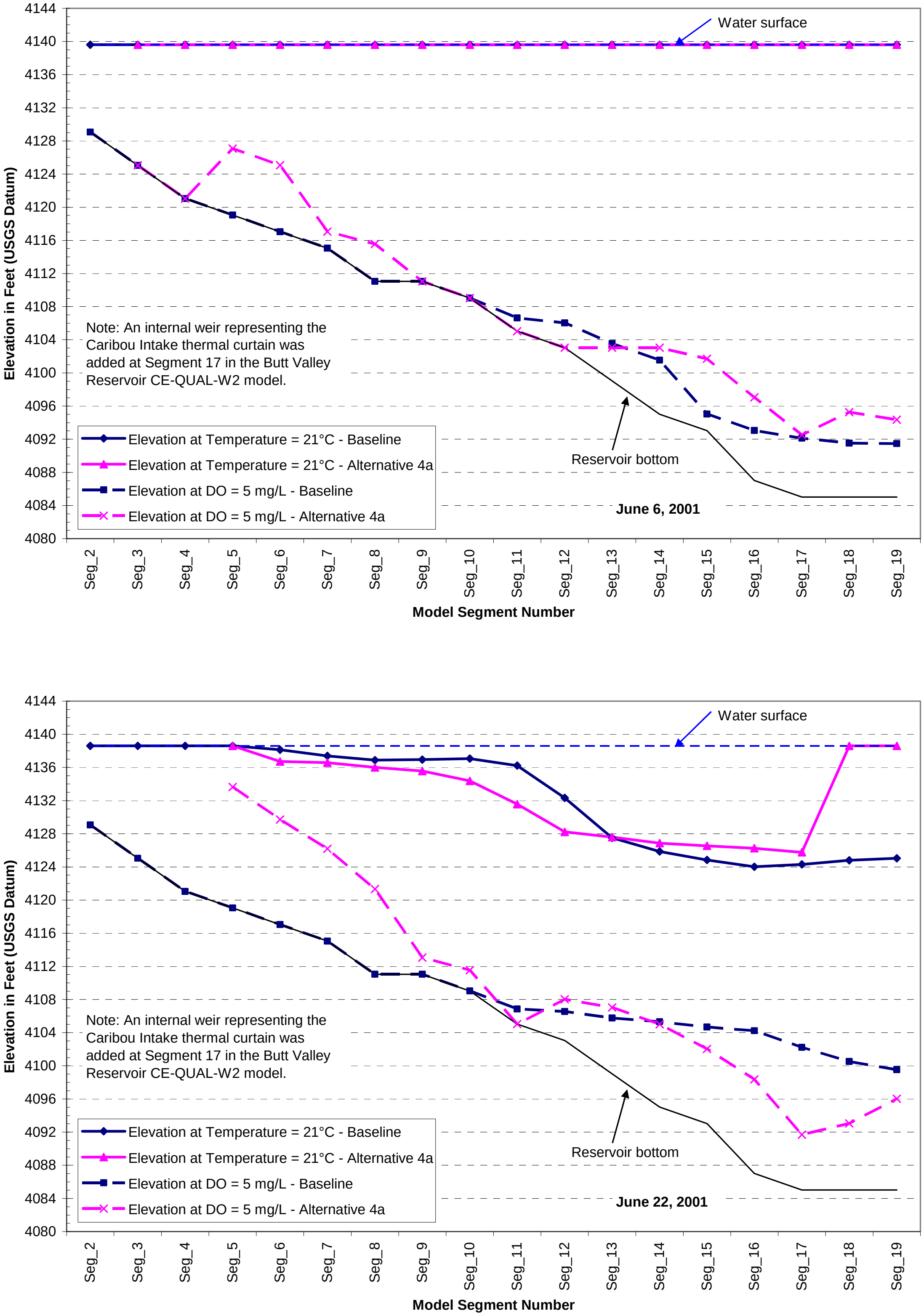


Figure 4c Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 20°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, August 2001



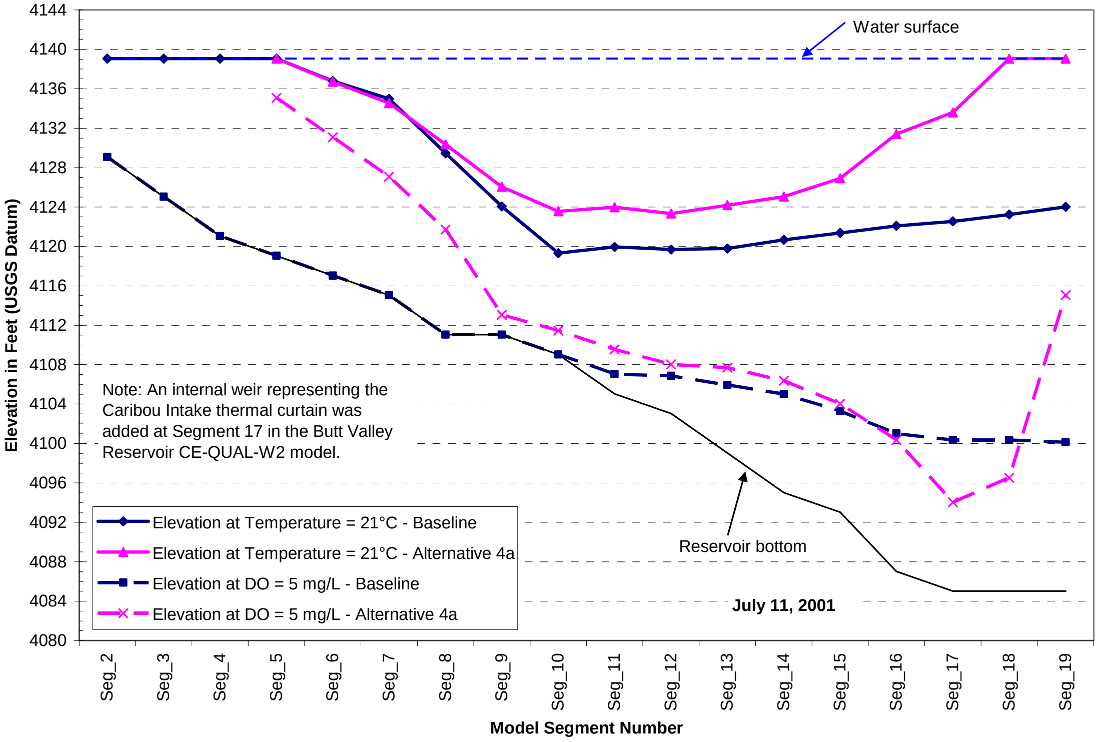
Note: An internal weir representing the Caribou Intake thermal curtain was added at Segment 17 in the Butt Valley Reservoir CE-QUAL-W2 model.

June 6, 2001

Note: An internal weir representing the Caribou Intake thermal curtain was added at Segment 17 in the Butt Valley Reservoir CE-QUAL-W2 model.

June 22, 2001

Figure 5a Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, June 2001



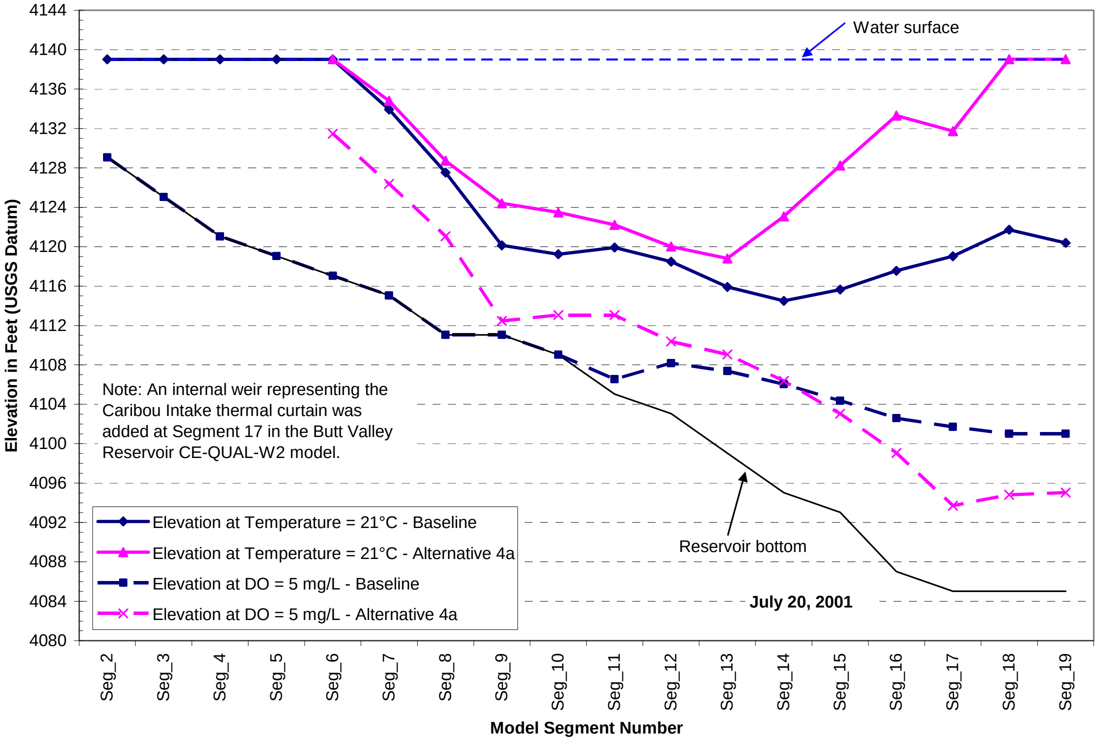


Figure 5b Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, July 2001

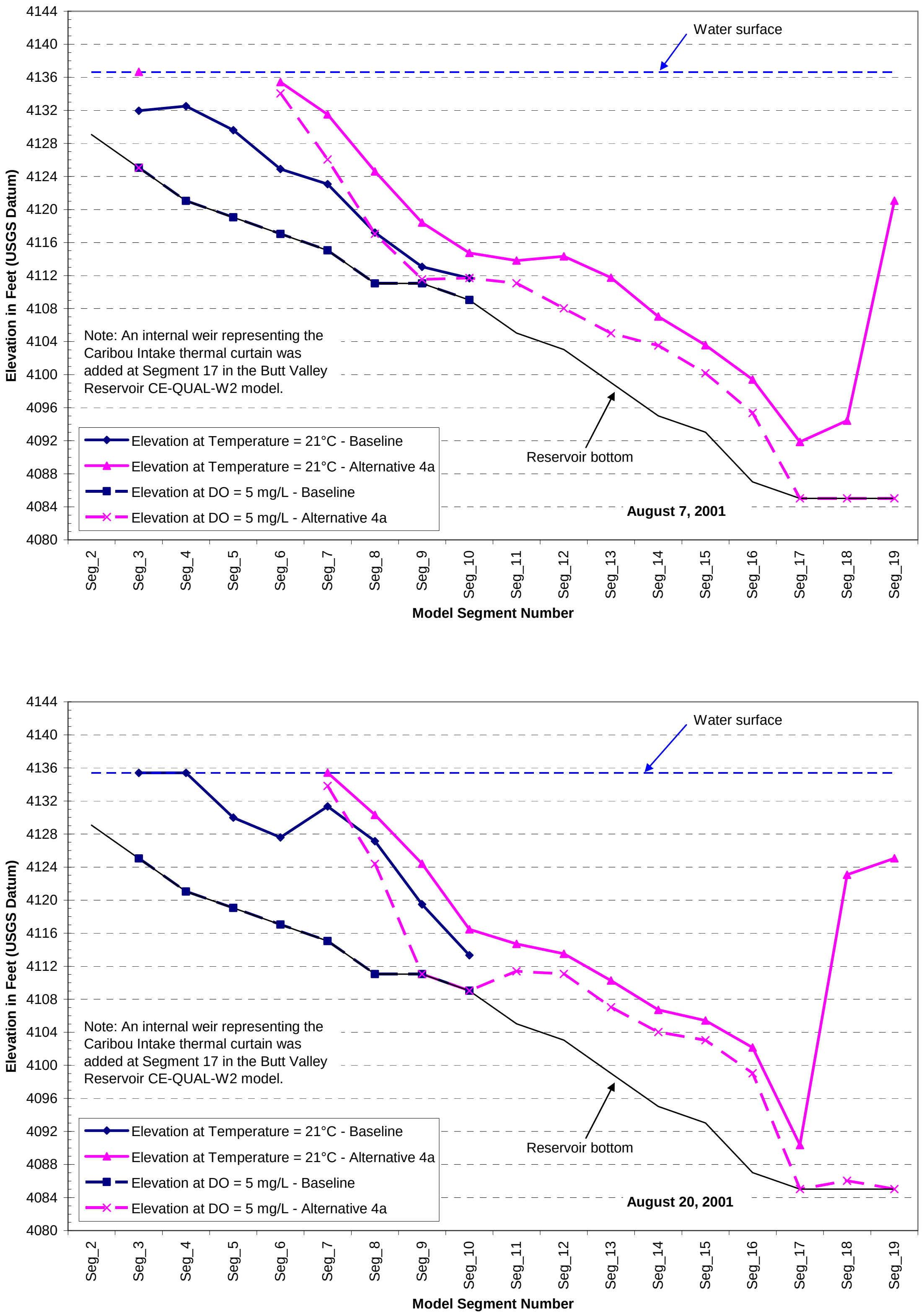
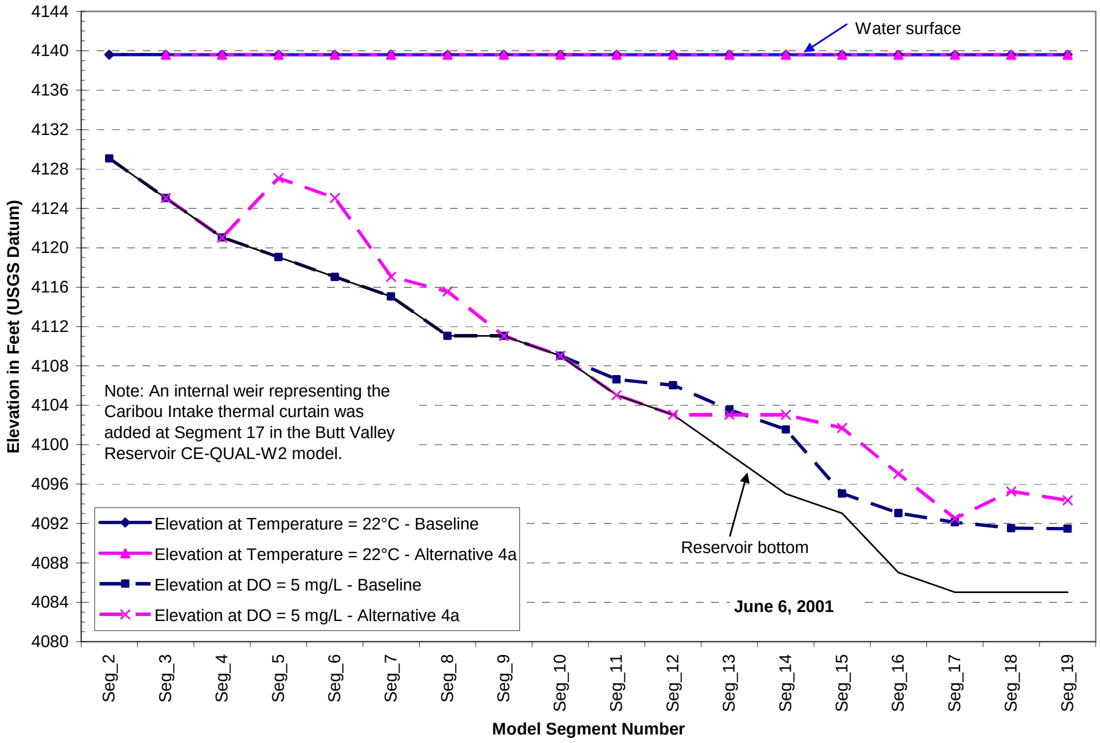


Figure 5c Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 21°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, August 2001



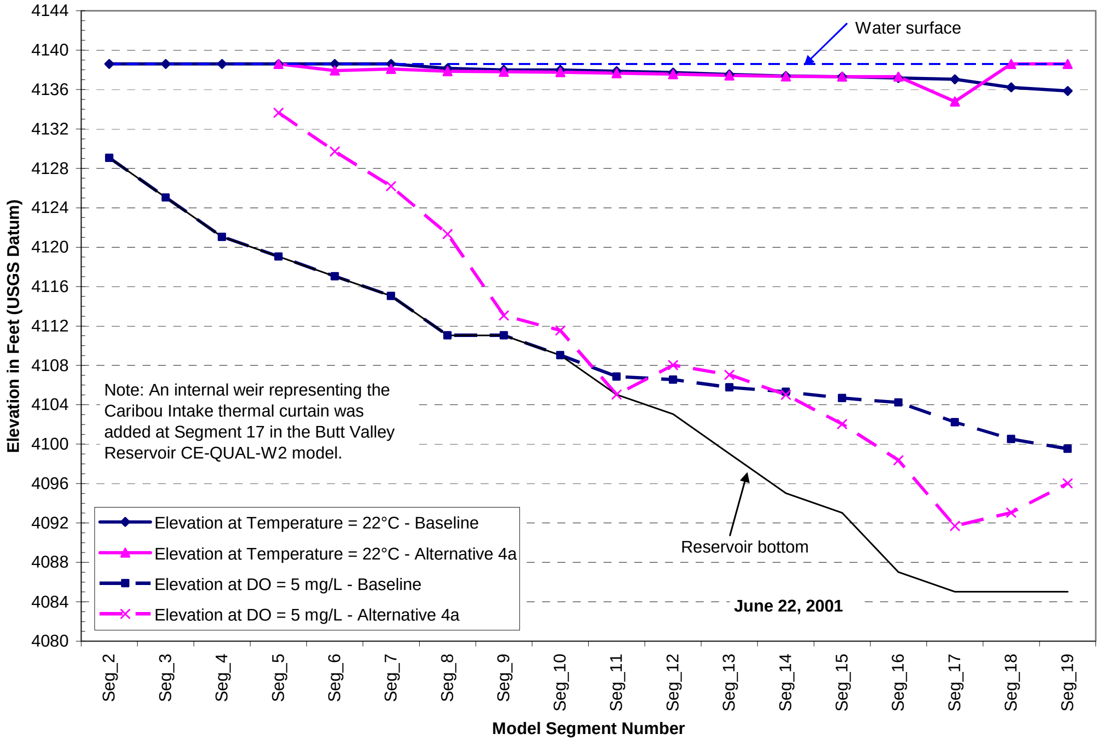


Figure 6a Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, June 2001

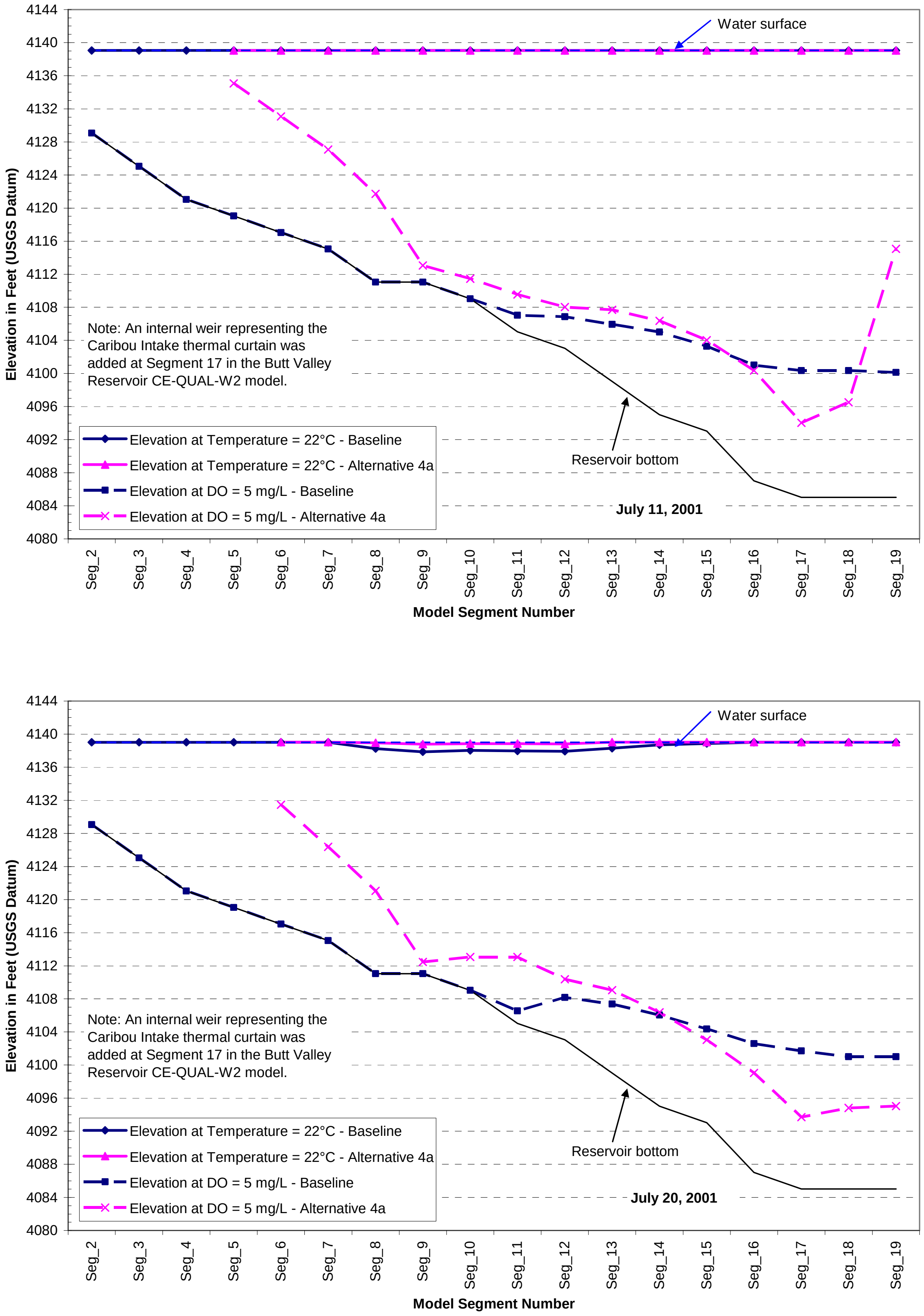
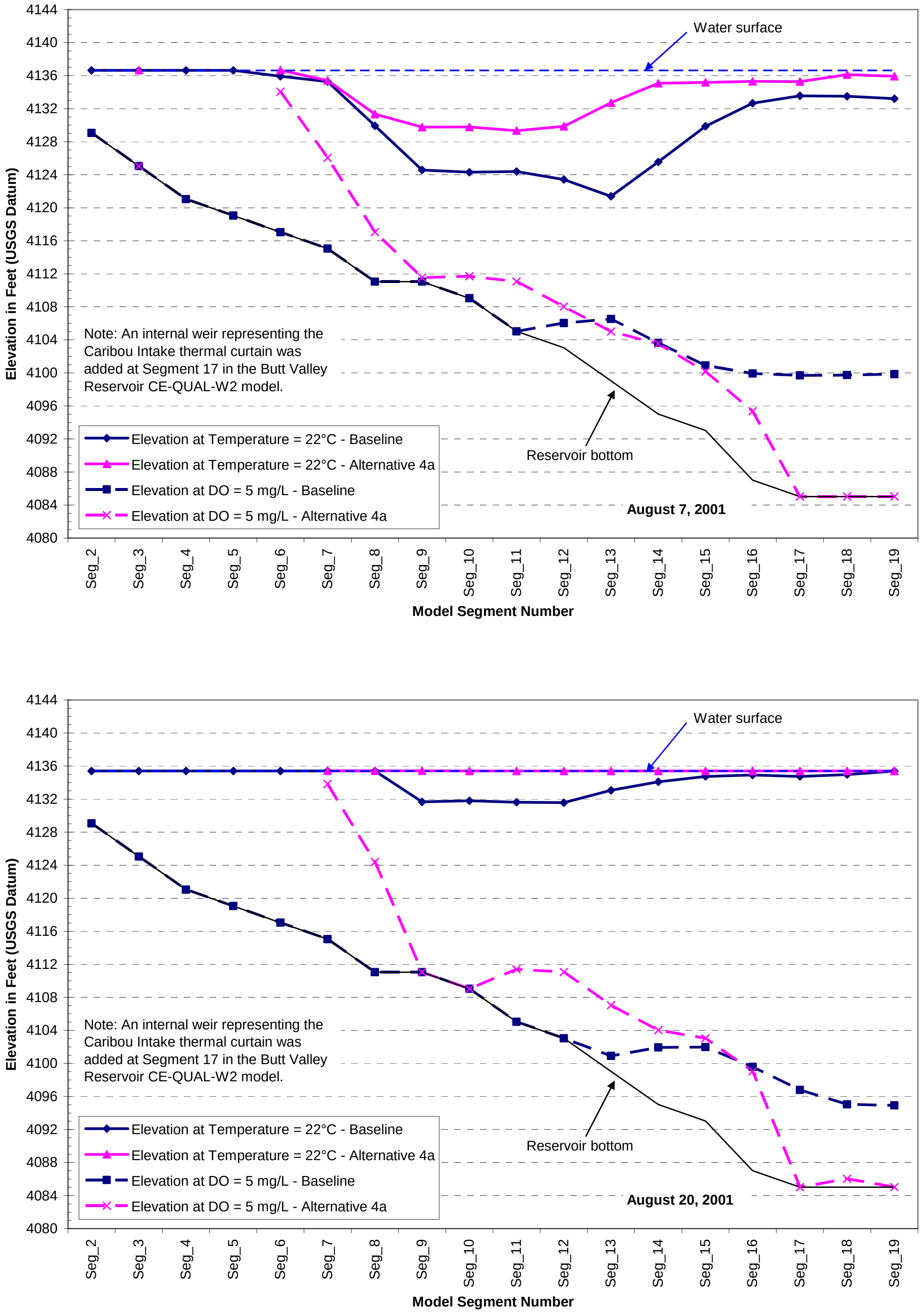


Figure 6b Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, July 2001



Note: An internal weir representing the Caribou Intake thermal curtain was added at Segment 17 in the Butt Valley Reservoir CE-QUAL-W2 model.

August 7, 2001

Note: An internal weir representing the Caribou Intake thermal curtain was added at Segment 17 in the Butt Valley Reservoir CE-QUAL-W2 model.

August 20, 2001

Figure 6c Comparison of Simulated Butt Valley Reservoir Elevation Range of the Water Layer Having Temperature ≤ 22°C and DO ≥ 5 mg/L by Model Segment between Baseline Condition and Alternative 4a, August 2001

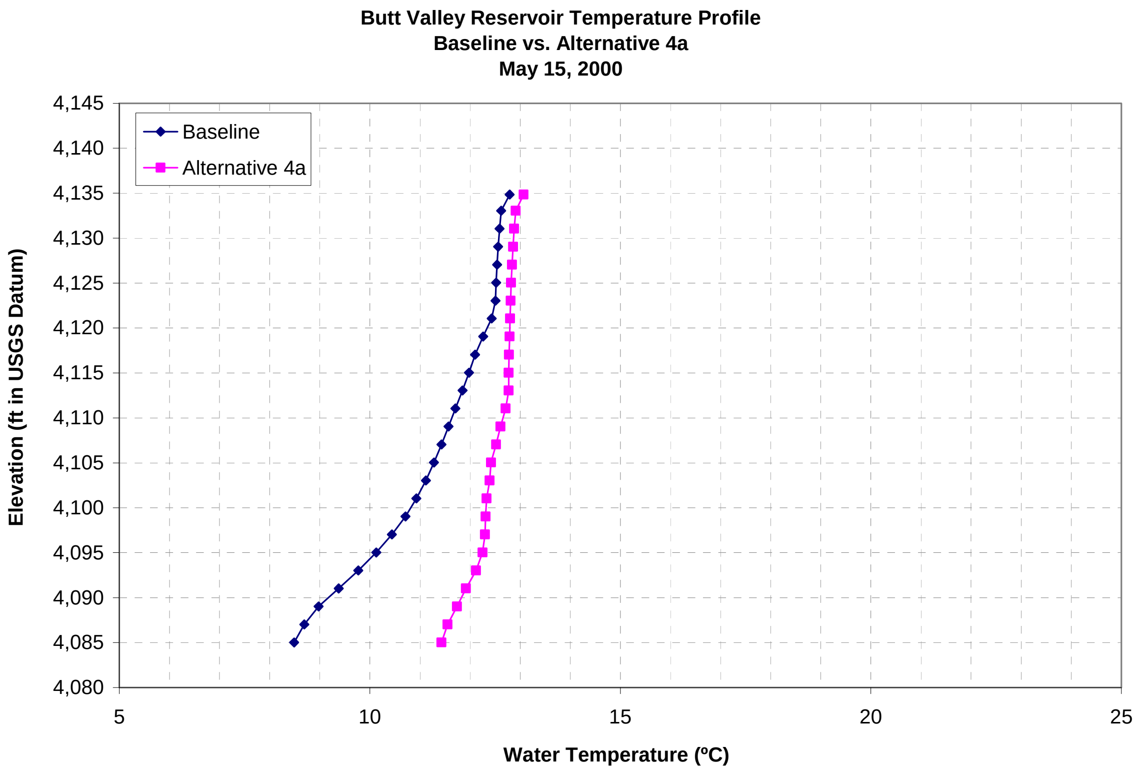
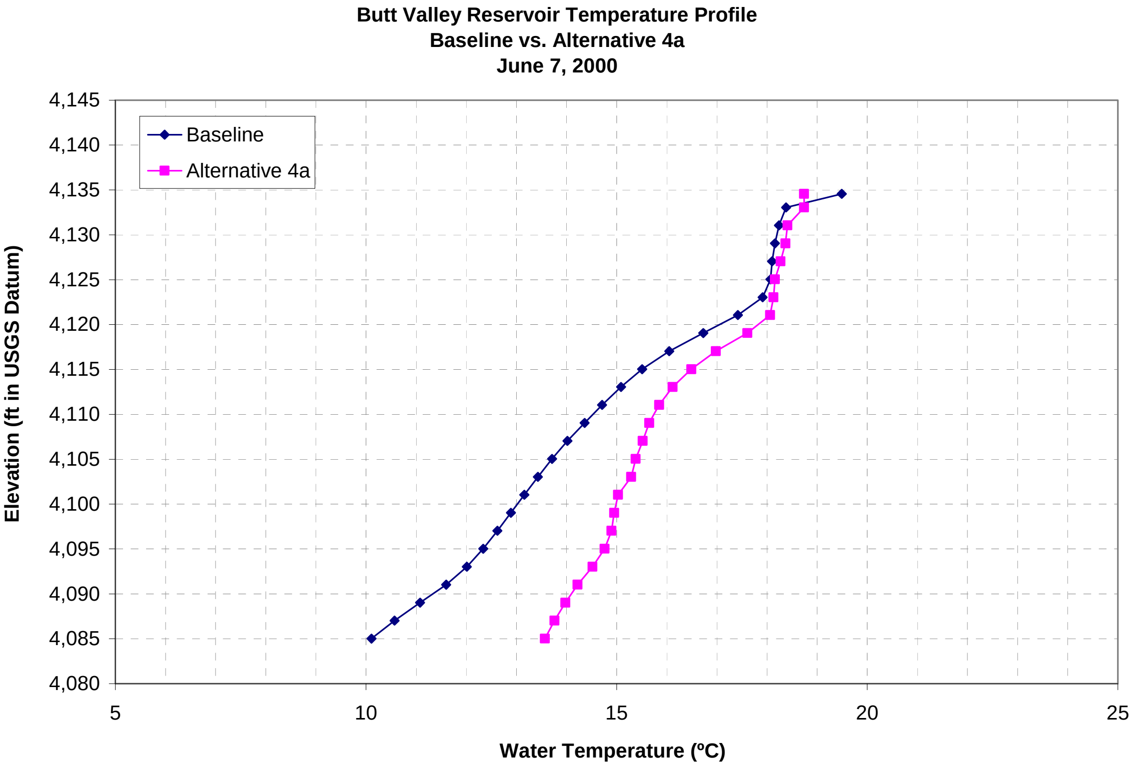


Figure 7a Comparison of Simulated Water Temperature Profiles near Caribou #1 Intake (Model Segment 17) between Alternatives May 2000



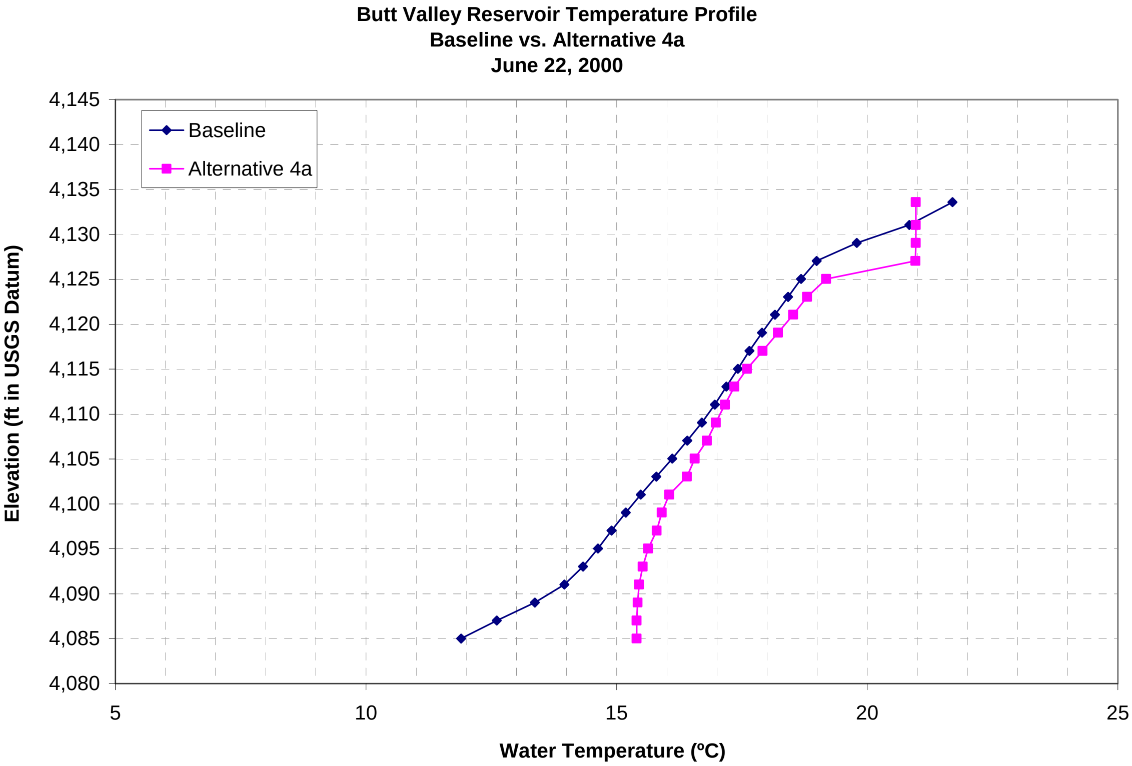
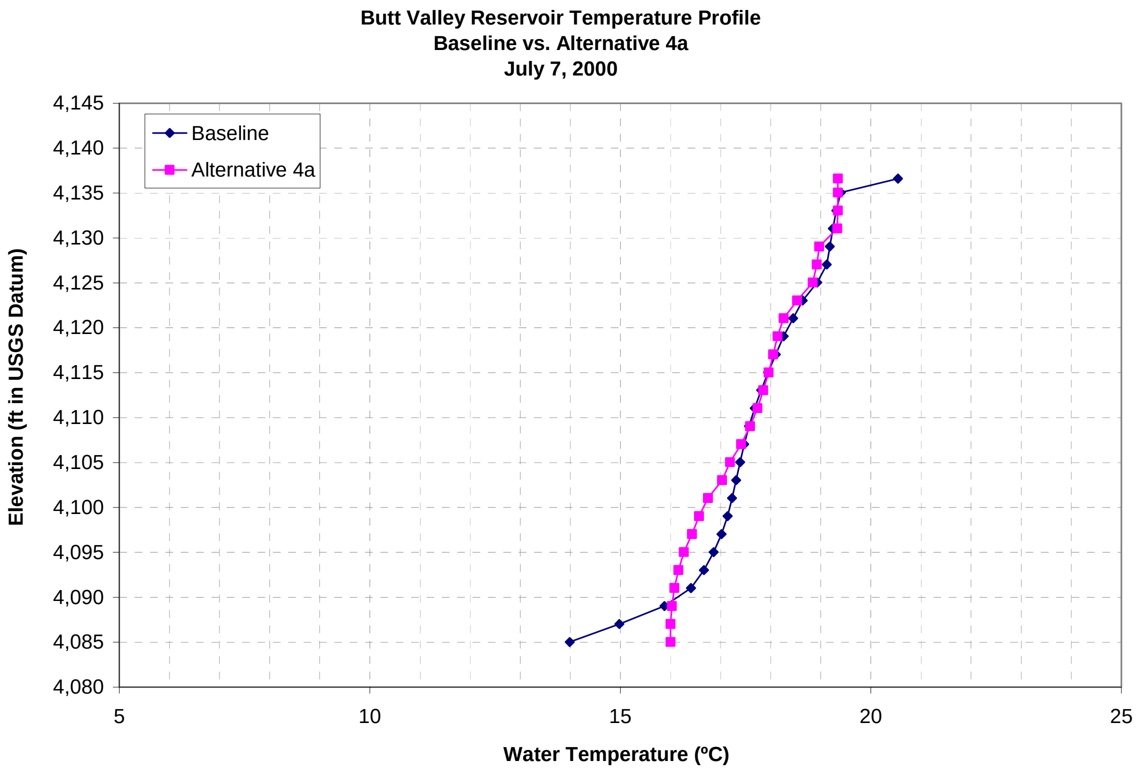


Figure 7b Comparison of Simulated Water Temperature Profiles near Caribou #1 Intake (Model Segment 17) between Alternatives June 2000



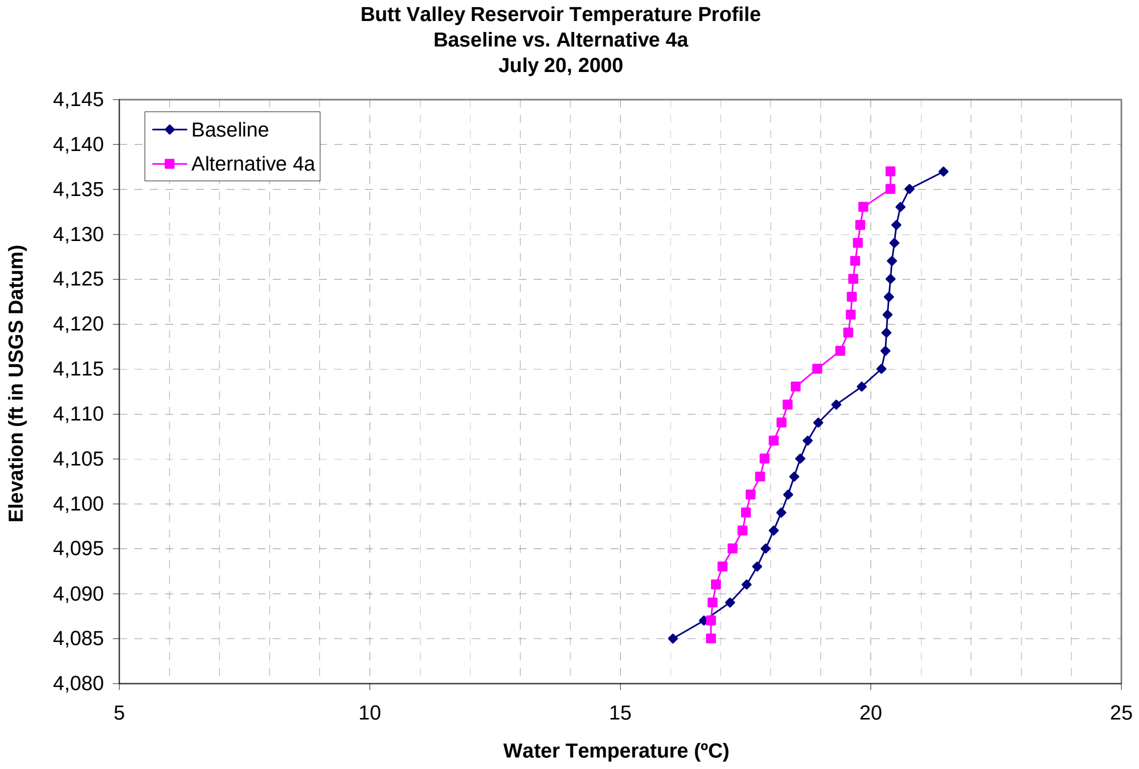
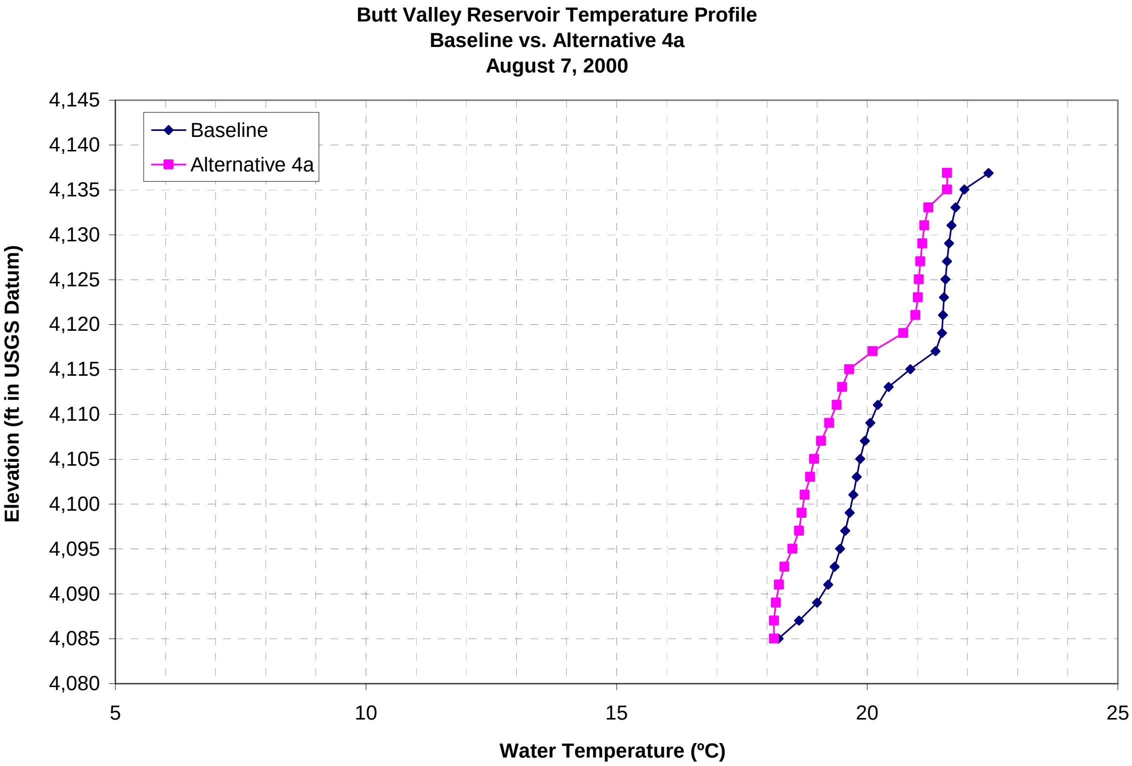


Figure 7c Comparison of Simulated Water Temperature Profiles near Caribou #1 Intake (Model Segment 17) between Alternatives July 2000



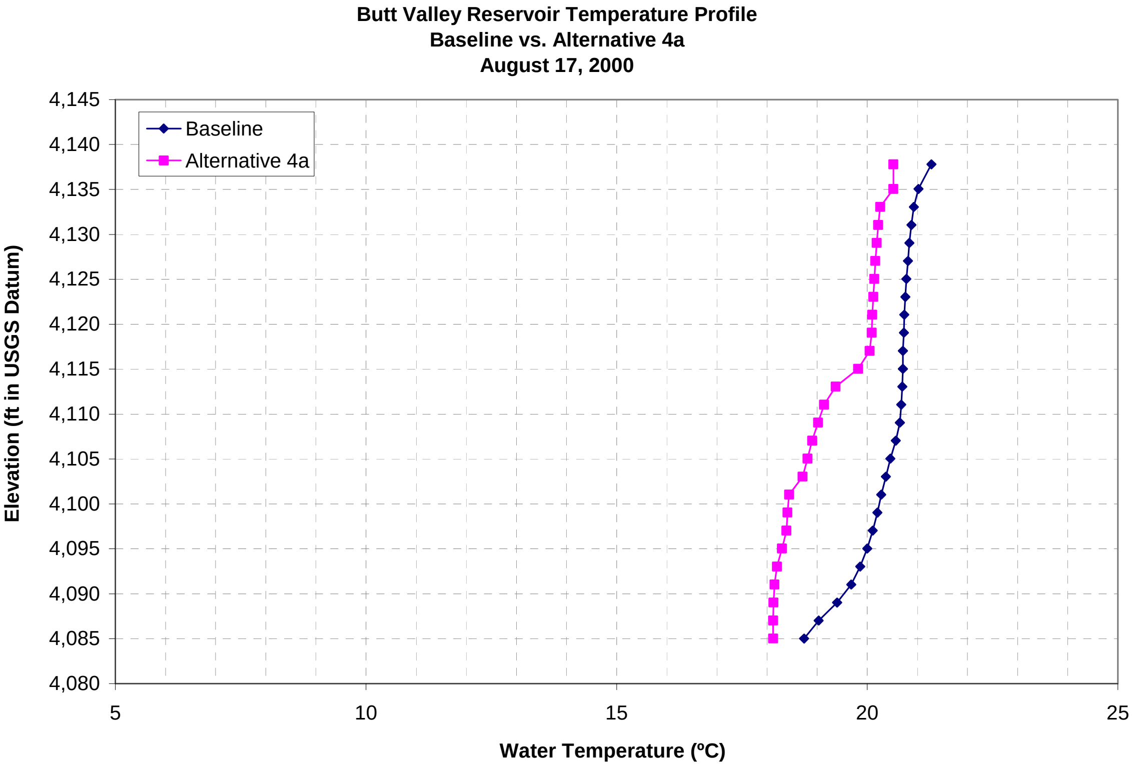
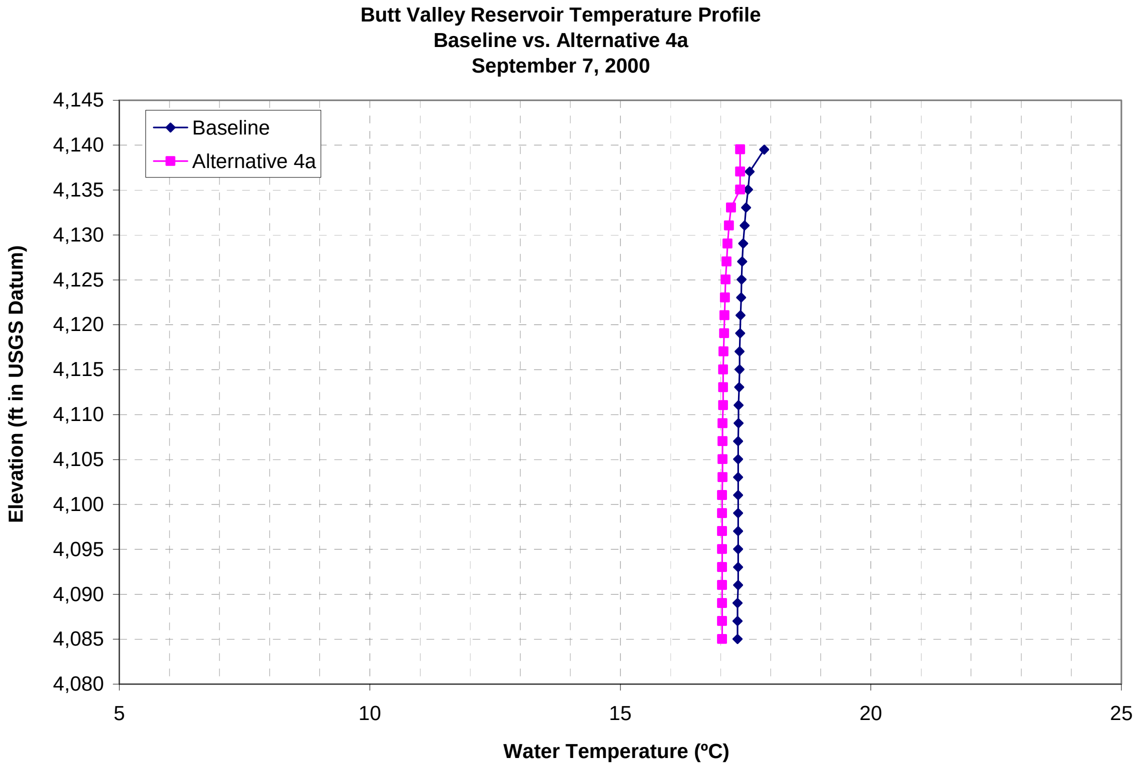
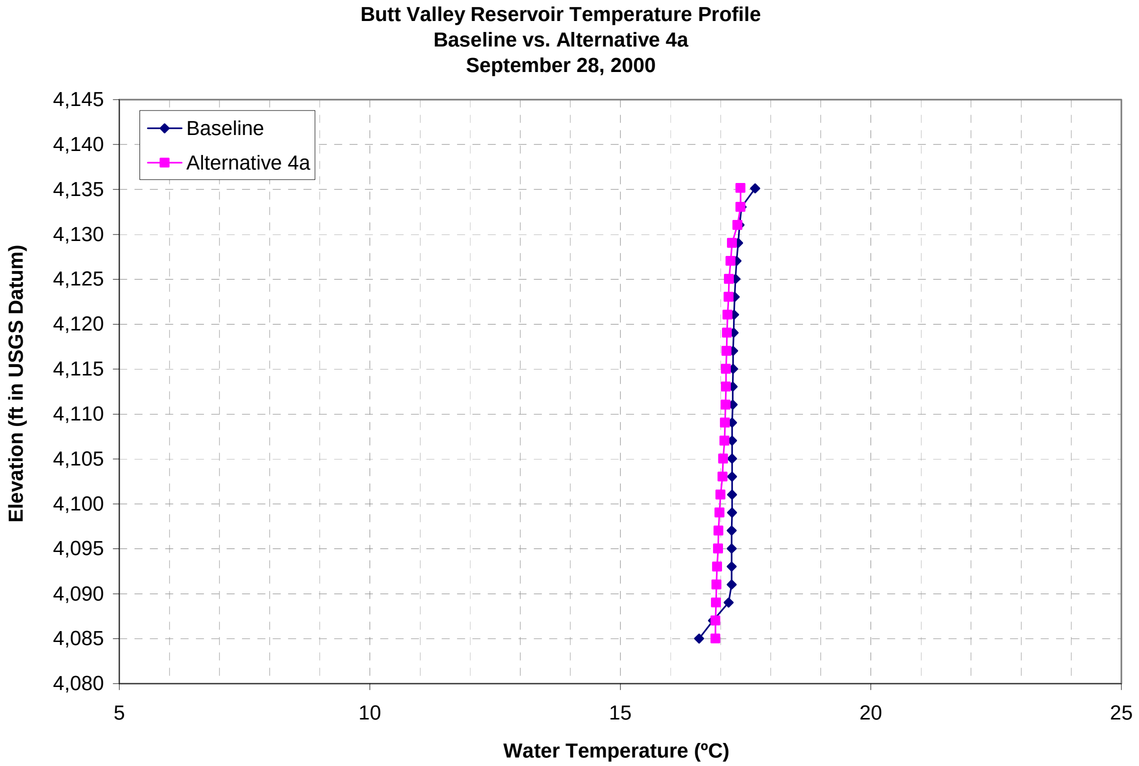


Figure 7d Comparison of Simulated Water Temperature Profiles near Caribou #1 Intake (Model Segment 17) between Alternatives August 2000



Butt Valley Reservoir Temperature Profile
Baseline vs. Alternative 4a
September 7, 2000



Butt Valley Reservoir Temperature Profile
Baseline vs. Alternative 4a
September 28, 2000

Figure 7e Comparison of Simulated Water Temperature Profiles near Caribou #1 Intake (Model Segment 17) between Alternatives September 2000

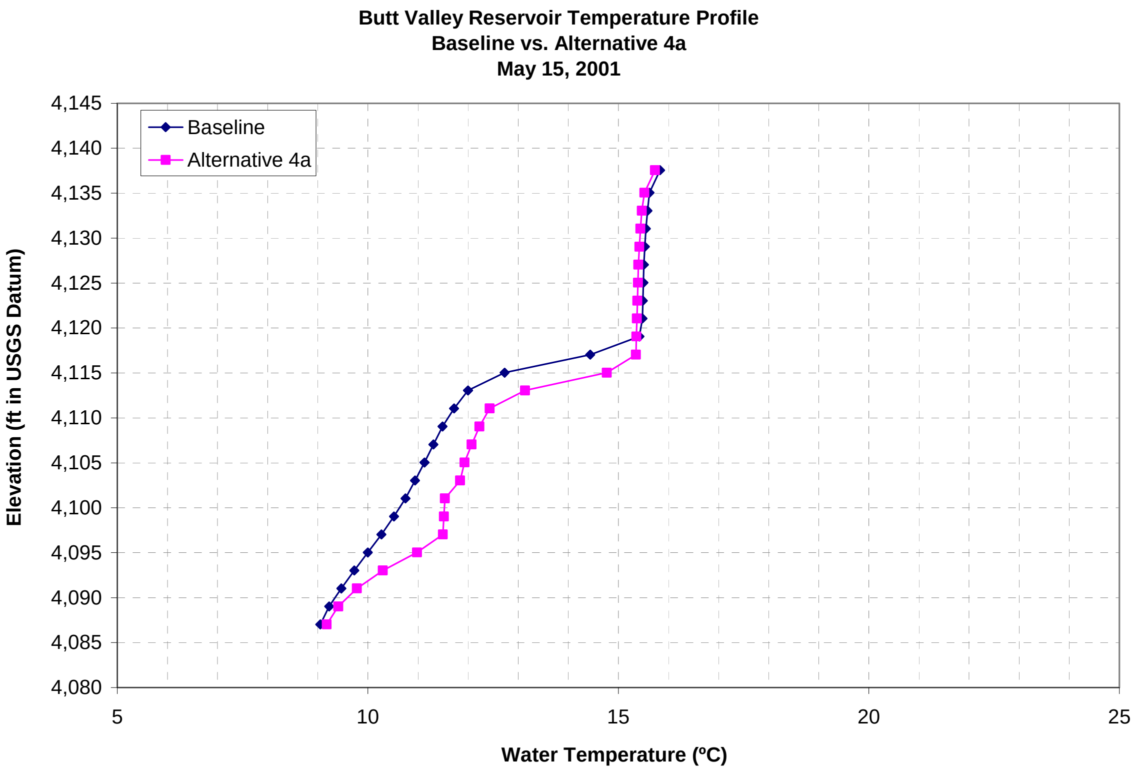
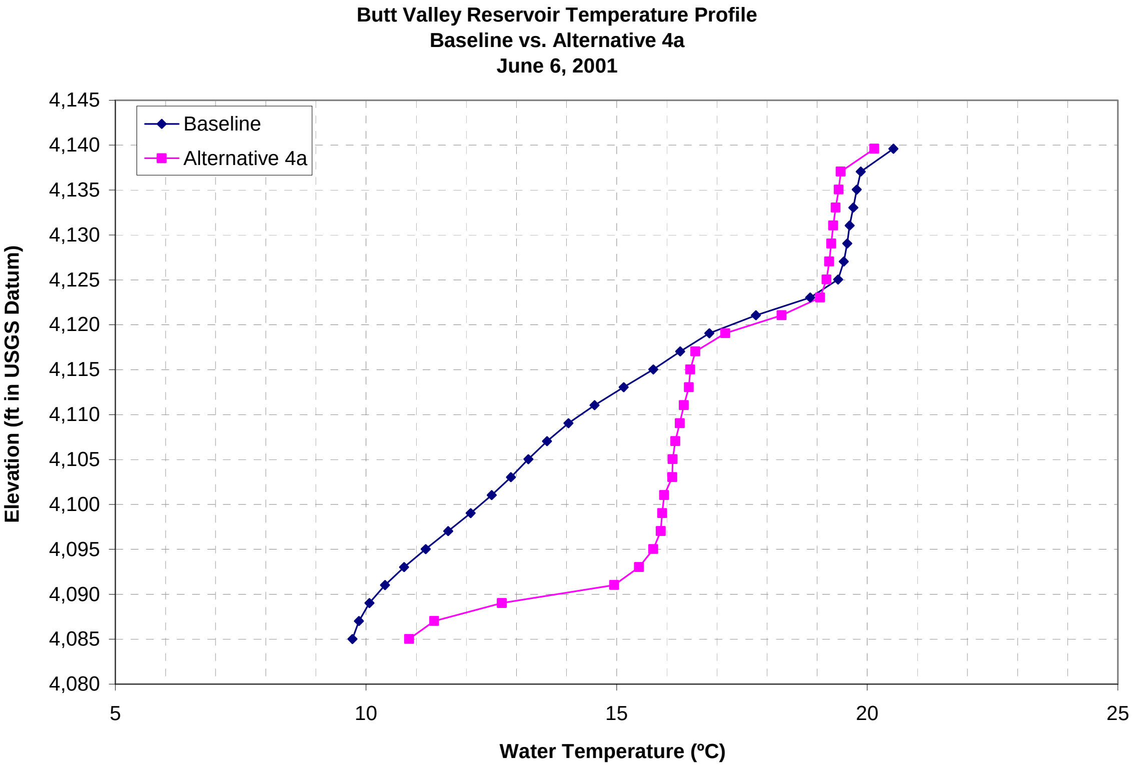


Figure 8a Comparison of Simulated Water Temperature Profiles near Caribou #1 Intake (Model Segment 17) between Alternatives May 2001



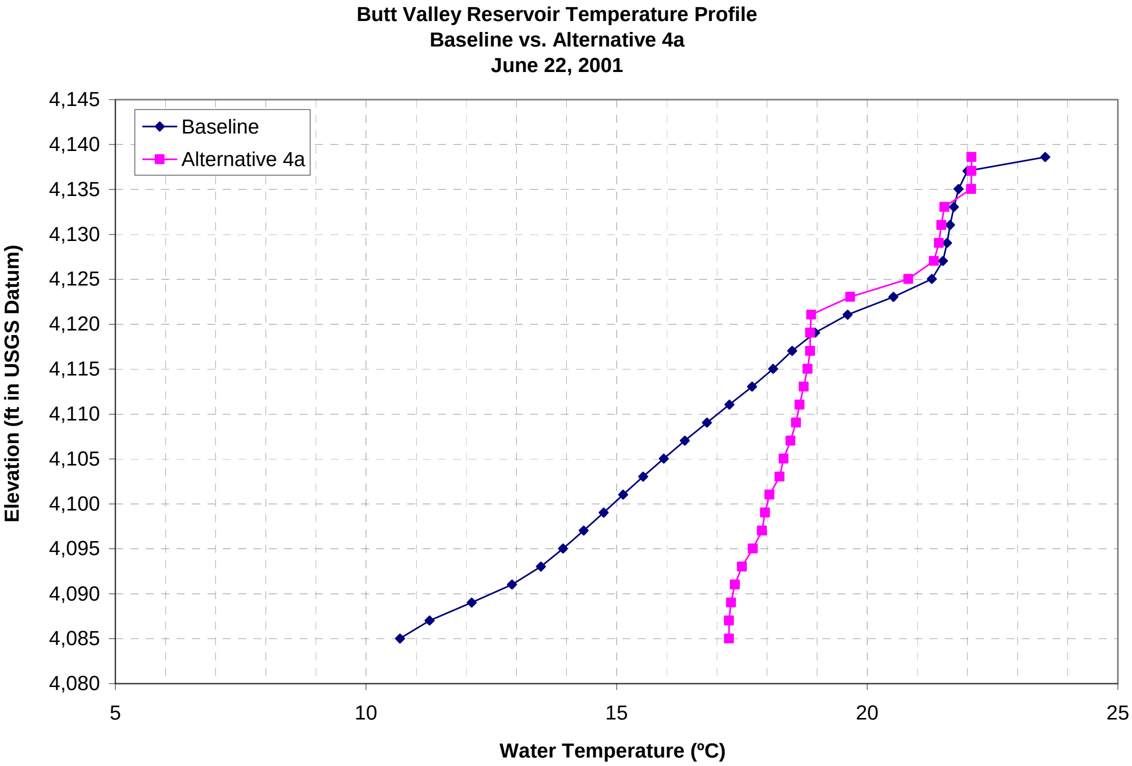
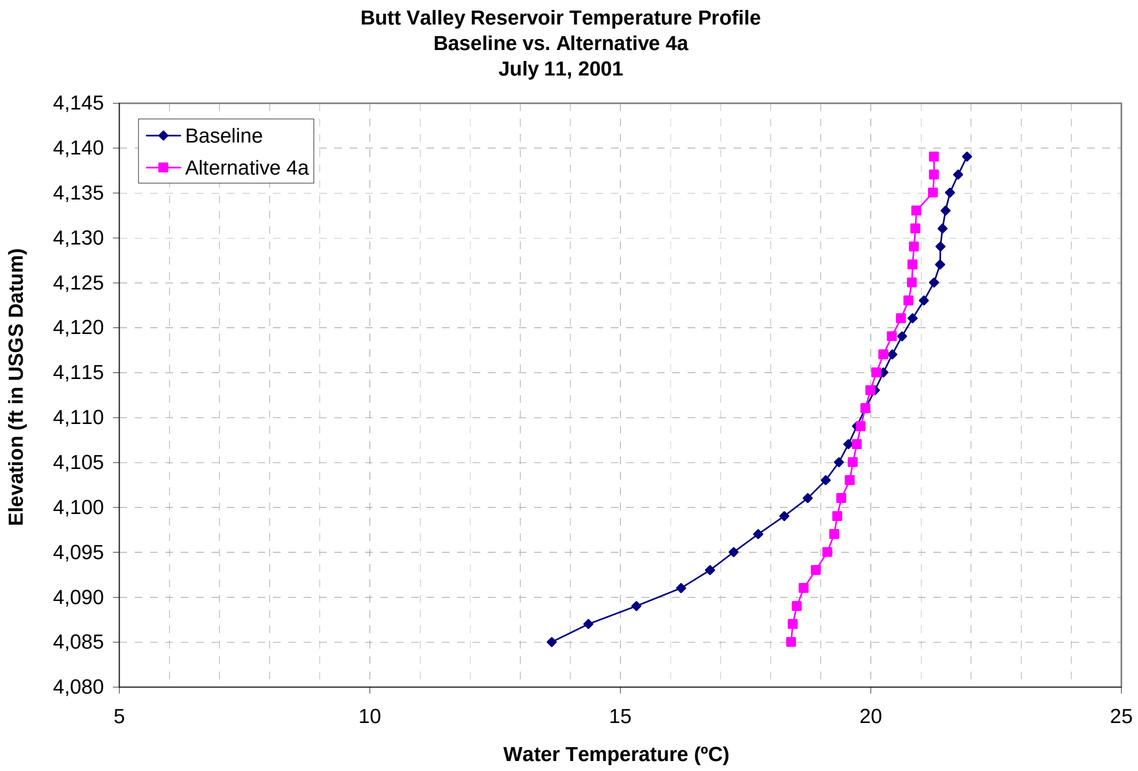


Figure 8b Comparison of Simulated Water Temperature Profiles near Caribou #1 Intake (Model Segment 17) between Alternatives
June 2001



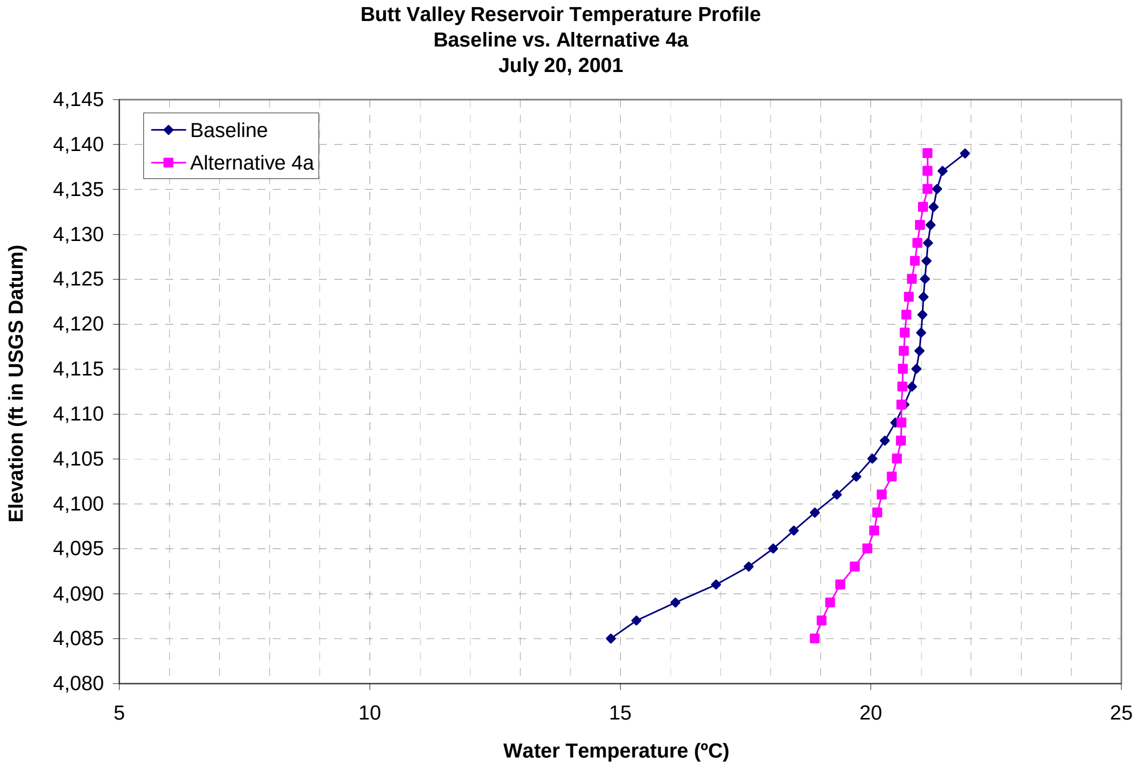
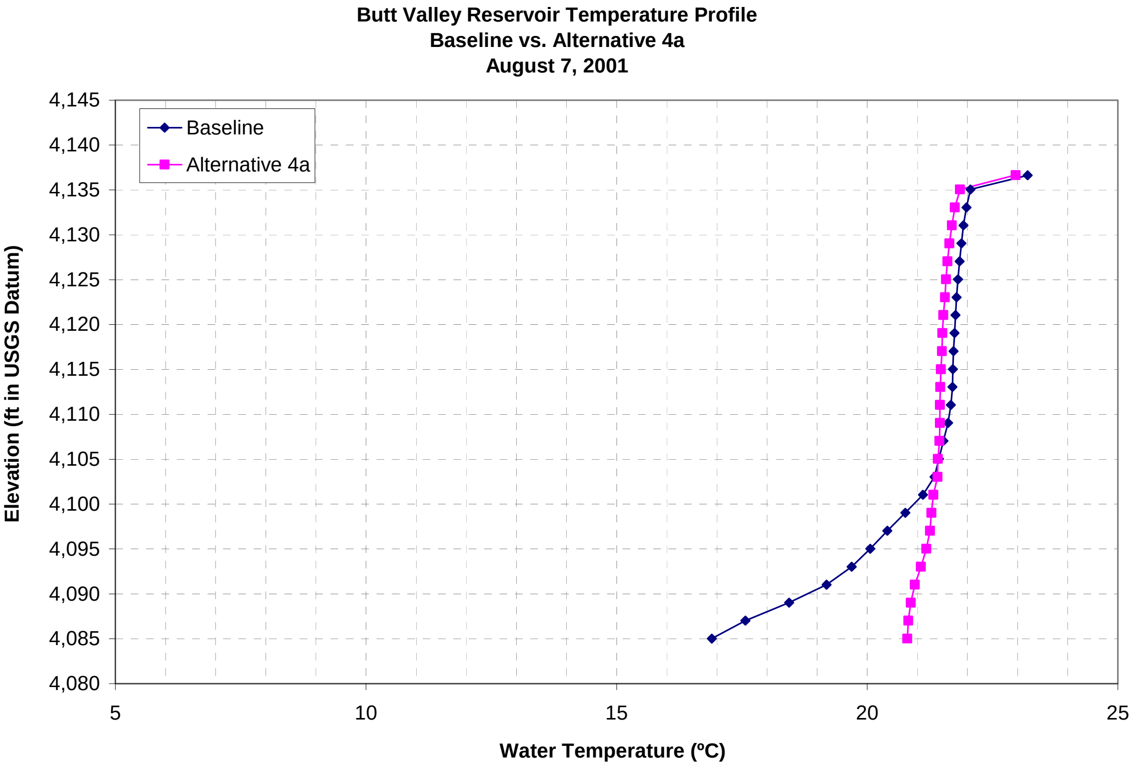


Figure 8c Comparison of Simulated Water Temperature Profiles near Caribou #1 Intake (Model Segment 17) between Alternatives July 2001



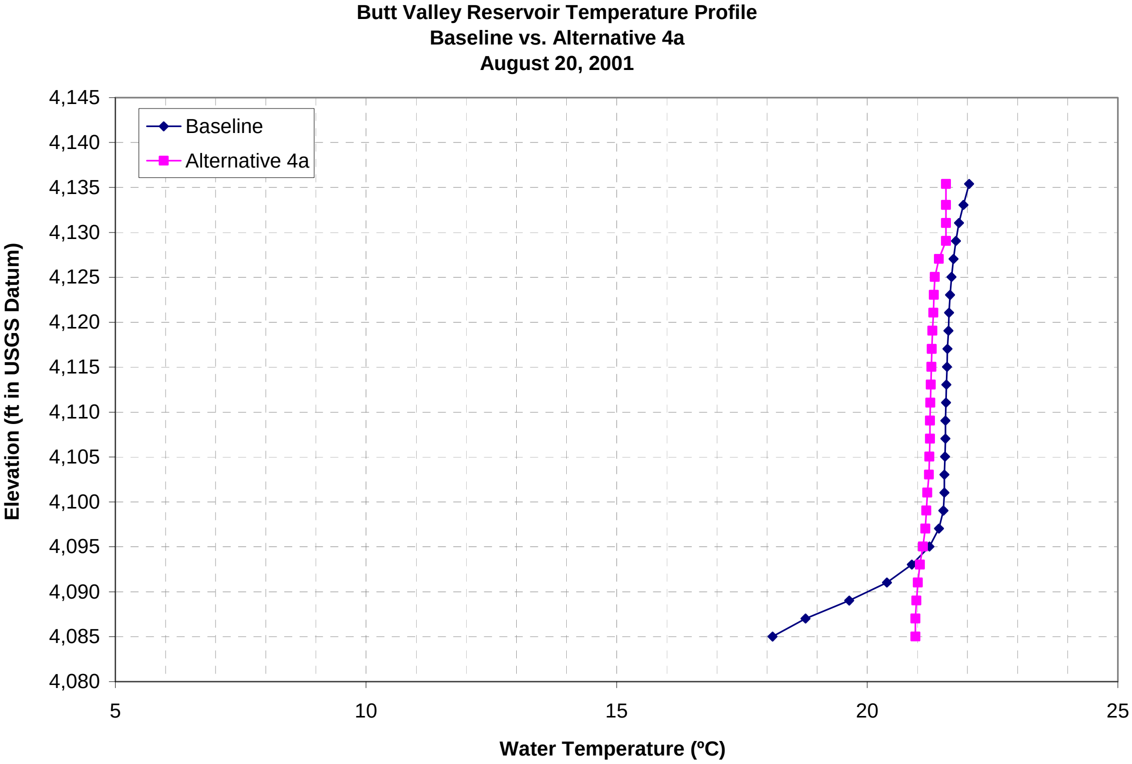


Figure 8d Comparison of Simulated Water Temperature Profiles near Caribou #1 Intake (Model Segment 17) between Alternatives August 2001

Appendix E

Documentation of Programmed Linkage of NFFR Reservoir and Stream Water Temperature Models

and

Quality Assurance/Quality Control Procedures

PROGRAMMED LINKAGE OF NFFR RESERVOIR AND STREAM WATER TEMPERATURE MODELS
AND
QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

Following is a list of models that were used in the Level 3 analysis for mean daily water temperature profiles along the NFFR:

- Lake Almanor: MITEMP as modified by Stetson
- Butt Valley Reservoir: Newly developed CE-QUAL-W2 by Stetson
- Belden Reservoir: Complete mixing method
- Rock Creek Reservoir: SNTEMP as modified by Stetson
- Cresta Reservoir and Poe Reservoir: Complete mixing method
- Five bypass reaches: SNTEMP for each reach.

Figure 1 shows all the models that were used in Level 3 to analyze mean daily water temperature profiles along the NFFR and how these models were related. For example, outflow and temperature at Canyon Dam derived from output of the Lake Almanor MITEMP model was input to the Seneca Reach SNTEMP model. Outflow and temperature at Butt Valley PH derived from output of the Lake Almanor MITEMP model was input to the Butt Valley Reservoir CE-QUAL-W2 model. The outflows and temperatures at Caribou #1 and #2 PHs derived from output of the Butt Valley Reservoir CE-QUAL-W2 model and outflow and temperature derived from output of the Seneca Reach SNTEMP model were completely mixed in Belden Reservoir. The complete mixing method of analysis was performed outside of the modeling work. The mixed water temperature in Belden Reservoir defined the discharge water temperature at Belden PH and was input to the Rock Creek Reservoir SNTEMP model. The mixed water temperature in Belden Reservoir also defined the Belden Dam release water temperature and was input to the Belden Reach SNTEMP model. Water temperature profiles along the Rock Creek, Cresta, and Poe Reaches were computed using the SNTEMP models for these reaches. Water temperature calculations for Cresta and Poe Reservoirs were conducted using the complete mixing method of analysis which was also performed outside of the modeling work.

The analysis of water temperature profiles along the NFFR involved three types of models: MITEMP, CE-QUAL-W2, and SNTEMP. Each of these models requires a particular input file format and has a particular output format. Because of the complexity of model input format requirements, the length of the analysis period, the large numbers of alternatives, several exceedance levels, and multiple water temperature models, a large amount of work is required to complete the simulation runs of different water temperature reduction alternatives.

To facilitate the scenario modeling analysis, batch files and pre/post-processing files that automatically link all the models were programmed using scripting languages including MS-DOS Batch Files, MS-DOS QBasic, Matlab, and AutoIt3. Using these batch files and pre/post-processing files in the scenario analyses avoided potential mistakes or errors that could arise from manually dealing with many different input and output files for many different simulation scenarios. Specifically, the automated procedures were as follows:

1. (1) Create Lake Almanor MITEMP model input files from the 19-year hydrology and meteorology data using Matlab;
2. (2) Run Lake Almanor MITEMP models using Batch file;
3. (3) Create Butt Valley Reservoir CE-QUAL-W2 model input files from Lake Almanor MITEMP model outputs using Matlab;
4. (4) Run Butt Valley Reservoir CE-QUAL-W2 models using Batch files/AutoIt3 scripts;
5. (5) Compute exceedence statistics of Caribou PH discharge water temperatures from Butt Valley Reservoir CE-QUAL-W2 model outputs using Matlab;
6. (6) Compute exceedence statistics of Canyon Dam release water temperatures from Lake Almanor MITEMP model outputs using Matlab;
7. (7) Create stream SNTEMP model input files from the computed exceedence statistics using Matlab;
8. (8) Run stream SNTEMP models using Batch files/QBasic/AutoIt3 scripts.
9. (9) Plot longitudinal temperature profiles along the five bypass reaches of NFFR from SNTEMP outputs using Excel.

1. QUALITY ASSURANCE AND QUALITY CONTROL PROCESSES

Prior to using the automatic procedures in scenario simulation runs, careful quality assurance/quality control (QA/QC) processes were taken to ensure that the above procedures were properly conducted and coding of scripts for automatic linkage of models were correctly programmed. These QA/QC processes included development of systematic diagrams of all procedures and associated data input and output file names; careful examination of the various models' inputs and outputs for several selected years by comparing manual treatment and automatic testing; internal independent review of the procedures and the models' inputs and outputs; and careful examination of the reasonability of model results for the baseline scenario by comparing the simulated baseline results to the historical data. The following describes the QA/QC processes for each of the above automated procedures.

1) Create Lake Almanor MITEMP model input files from the 19-year hydrology and meteorology data using Matlab

The creation of MITEMP input files require three types of source files: (1) an Excel spreadsheet file containing meteorology data (including air temperature, solar radiation, relative humidity, wind speed, and cloud cover) for the simulation period of March 1 to September 31 for each of the 19 analysis years (1984 – 2002); (2) Excel spreadsheet files containing the Baseline flow data and the re-operated flow data for each of the alternatives; (3) Lake Almanor MITEMP model input files received from PG&E for each of the three different bathymetry configurations at the Prattville Intake, serving as templates. The three different bathymetry configurations included: a) existing conditions; b) thermal curtain at the Prattville Intake with the submerged levees near the Intake in place; and c) thermal curtain at the Prattville Intake with the submerged levees removed. The data contained in these files were examined to be error free.

For the three types of data sources, scripts were written using Matlab to (1) extract meteorology data from the Excel spreadsheet file and write to text files in the format required by MITEMP for each of the 19 analysis years; (2) extract flow data from the Excel spreadsheet files corresponding to the alternatives and write to text files in the format required by MITEMP for each of the 19 analysis years; and (3) create Lake Almanor MITEMP input files by updating the corresponding template input files with corresponding meteorology text files and flow text files. This step in the automation is to create the correct input data format/input files for the Lake Almanor MITEMP model. Comparison of the data between the source files and the created MITEMP input files for different years indicated that the scripts worked as desired.

2) Run Lake Almanor MITEMP models using Batch file

The Lake Almanor MITEMP model has three different executables that apply to the three different bathymetric configurations at the Prattville Intake: (a) existing conditions (no curtain, with levee); (b) with curtain, with levee; (c) with curtain, without levee. These executables initially had the same name “MITEMP.EXE” and were identified by the folder name provided by PG&E. To avoid confusion and potential misusage, these executables were renamed as follows: (1) baseline: “mitemp_new_LOW.exe”; (2) with curtain, with levee: “CT_WL.exe”; and (3) with curtain, without levee: “CT_WOL.exe”.

A Batch file was created for running each of the alternatives for the 19 analysis years. The Batch file calls the corresponding executable to run the MITEMP model and displays the executable name and folder name on-screen to allow the user to verify that the correct executable and input files are being used for the given alternative. Quality assurance was done in this step by conducting manual model runs for several selected years and comparing the model outputs with the outputs from the automatic runs. Examination indicated that the outputs from the manual model runs were exactly the same as those using Batch files.

3) Create Butt Valley Reservoir CE-QUAL-W2 model input files from Lake Almanor MITEMP model outputs using Matlab

The Butt Valley Reservoir CE-QUAL-W2 model requires the following 7 input files in addition to other fixed input files: 1) meteorology file; 2) Butt Valley PH inflow; 3) Butt Valley PH inflow temperature; 4) Butt Creek inflow; 5) Butt Creek inflow temperature; 6) Caribou #1 PH discharge; and 7) Caribou #2 PH discharge. Three different types of source files are needed: (1) the Excel file containing meteorology data, (2) the Lake Almanor MITEMP output file OUTEMP.dat for extracting the Butt Valley PH discharge rate and water temperature, and (3) Baseline flow data of Butt Valley Reservoir extracted from the Butt Valley MITEMP model provided by PG&E.

Matlab scripts were written to extract data from source files, re-operate Caribou PH discharges for each of the alternatives, and then write these data to the 7 corresponding input files of the Butt Valley Reservoir CE-QUAL-W2 model. For the inflow rates through Butt Valley PH and the outflow rates through Caribou PHs, the automated results were compared with manually computed results for several selected years. This comparison verified that the automation scripts worked as intended. For the remaining files, only was data format changed from source files to target files. Comparison between the source files and the target files was performed for several selected files. This comparison verified that the scripts worked as intended.

4) Run Butt Valley Reservoir CE-QUAL-W2 models using Batch files/AutoIt3 scripts

This step in the automation uses commands to call the executables to run the CE-QUAL-W2 models for the 19 years of analysis for all alternatives. No data manipulation was involved in programming the scripts. The scripts were checked by trial runs; the model would not run if the script had any error. It was important in this step to make sure that the CE-QUAL-W2 control files were used correctly, as there were two sets of control files for the CE-QUAL-W2 models: one set applied to the alternatives that have a curtain near the Caribou Intakes and the other set applied to the alternatives that do not have curtain. Potential mistakes were avoided by placing the desired set of control files inside each alternative folder.

5) Compute exceedence statistics of Caribou PH discharge water temperatures from Butt Valley Reservoir CE-QUAL-W2 model outputs using Matlab;

This step involved data format change only, including reading data from the output text files of the Butt Valley Reservoir CE-QUAL-W2 model for the 19 years of analysis for each of the alternatives and writing them to Excel files, as well as writing statistical formulae for the Excel files to compute the exceedence levels for the Caribou PH discharge water temperatures. Comparison between selected source files and target files indicated that the code worked as intended.

6) Compute exceedence statistics of Canyon Dam release water temperatures from Lake Almanor MITEMP model outputs using Matlab

This step involved data format change only, including reading data from the output text files of the Lake Almanor MITEMP model for the 19 years of analysis for each of the alternatives and writing them to Excel files, as well as writing statistical formulae for the Excel files to compute the exceedence levels for the Canyon Dam release water temperatures. These files contain flow rate and water temperature data of Canyon Dam release and Caribou PHs discharges. Comparison between selected source files and target files indicated that the code worked as intended.

7) Create stream SNTEMP model input files from the computed exceedence statistics using Matlab

This step read the computed statistics of flow rate and water temperature from Excel files and wrote the data to text files in the format required by the SNTEMP models. These text files contain flow rate and temperature statistics of Canyon Dam release and Caribou PHs discharges. Comparison between selected source files and target files indicated that the code worked as intended.

8) Run stream SNTEMP models using Batch files/QBasic/AutoIt3 scripts

This step was complicated. It involved: (1) extracting flow rate and water temperature data from upstream reach model output; (2) calculating total inflow to a forebay and mixed water temperature in the forebay; (3) calculating balanced powerhouse discharge and required dam release from the forebay and creating the powerhouse discharge Q/T file; (4) reading the tributary flow rate and water temperature data for each reach; (5) creating SNTEMP hydrology data file from data of mixed forebay water temperature, dam release rate, and flow rates and water temperatures from tributaries; and (6) copying all SNTEMP input files to the desired folder and running SNTEMP models in Batch mode.

All the above steps were verified by checking the hydrology data files from the Seneca Reach to Poe Reach.

9) Plot longitudinal temperature profiles along the five bypass reaches of NFFR from SNTEMP outputs using Excel.

This step involved importing the SNTEMP output text files into Excel and plotting the results. Visual inspection was performed to make sure the data were plotted correctly.

To assist in the above QA/QC processes, systematic diagrams of all above procedures and associated data input and output file names were developed to ensure that all data were well organized. Figure 2 shows the file management structure for the linked water temperature models. The run procedures for the linked models described in the next section follow the file management structure shown in Figure 2.

2. PROGRAM INSTALLATION AND RUN PROCEDURES OF LINKED LAKE ALMANOR MITEMP, BUTT VALLEY RESERVOIR CE-QUAL-W2, AND STREAM SNTEMP MODELS

Program Installation

The automated process was developed on the Windows XP platform. To run the process, the user simply copies the entire CD to hard disk drive in the root folder and follows the model run steps. The MITEMP model, CE-QUAL-W2 model, SNTEMP model, and QBasic are DOS-version programs that do not require installation. These DOS programs are already included in the data CD. Several additional software packages need to be installed on the target computer: Compaq Array Viewer v1.6, Matlab v7.0, MS Excel v2003, and AutoIt v3.2.

Run Procedures

1) Lake Almanor MITEMP Model

a. Run MITEMP model: Go to folder "C:\NFFR2125\LA2BV\LA\"; Double click the batch file to run the corresponding alternative with different exceedance levels (e.g., double click "BSLINE.bat" will run baseline alternative for all of the 0%, 10%, 25%, 50%, 75% and 90% exceedance levels).

   Note: Each batch file calls corresponding executable located in folder ".\EXE\".

b. Extract model output: Go to folder "\MATLAB\LA_MITEMP\"; Double click "matlab.mat" to launch Matlab; In Matlab, run "PRV_QT.m".

   Note: This step extracts Q/T and creates corresponding Excel files containing Q and T.
   Q source: \NFFR2125\LA2BV\LA\%alternative%\FLOW\PRV_Q.xls
   T source: \NFFR2125\LA2BV\LA\%alternative%\STETSON\%year%\OUTTMP.DAT
   Q&T Target: \NFFR2125\LA2BV\LA\PRV_OUT\PRV_QT_%alternative%.xls
   Purpose: To be used to create Butt Valley Reservoir CE-QUAL-W2 model input files

2) Butt Valley Reservoir W2 Model

c. Create W2 input files: In Matlab, go to folder \NFFR2125\LA2BV\MATLAB\BV_W2\; Run W2.m.

   Note: This step creates the seven W2 input files for each year for a total of 19 years for a given alternative.

Source files:

\NFFR2125\LA2BV\LA\PRV_OUT\PRV_QT_%alternative%.xls
\NFFR2125\LA2BV\BV\Template\BV_QT.xls
\NFFR2125\LA2BV\WEATHER\Yearly Weather Data Updated.xls

Target files:

\NFFR2125\LA2BV\BV\%alternative%\%year%*.NPT

d. Copy shared files: Go to folder \NFFR2125\LA2BV\BV\; Double click "W2_pre_click.bat" to copy shared files to the corresponding alternative folders

e. Run W2 model: Go to folder \NFFR2125\LA2BV\BV\%alternative%\; Double click "W2 Batch_Check Files.BAT" to pre-check W2 input files; Double click "W2 Batch Run.BAT" to run W2 models for all 19 years.

3) North Folk Feather River SNTEMP Model

Create SNTEMP input files for the upstream end of Seneca Reach (Canyon Dam release)

f. Copy LA MITEMP model output files to a dedicated folder: Go to folder \NFFR2125\LA_BV_to_SNTMP1BT\LA_OUT\; Double click corresponding batch file (e.g. "BSLINE_LA_OUT_Click.bat") to copy all files at once.

Note: This step copies the model output files to a folder that contains only the output files.
Source files: \NFFR2125\LA2BV\LA\%alternative%\STETSON\%year%\outtmp.dat
Target files:
\NFFR2125\LA_BV_to_SNTMP1BT\LA_OUT\%alternative%\%year%\outtmp.dat

g. Create Canyon Dam release Q&T excel files with statistics: In Matlab, go to folder \NFFR2125\LA_BV_to_SNTMP1BT\MATLAB\; Run "Canyon_QT_WRAP.m";

Source files: \NFFR2125\LA_BV_to_SNTMP1BT\LA_OUT\%alternative%\%year%\outtmp.dat
Target files:
\NFFR2125\LA_BV_to_SNTMP1BT\SNTMP_IN\SN_JUNSEP\CAYN_QT_%alternative%_JUNSEP.xls

h. Create Canyon Dam release Q&T text files for SNTEMP model: Follow the step above, run "CD_DAT.m";

Source file:
\NFFR2125\LA_BV_to_SNTMP1BT\SNTMP_IN\SN_JUNSEP\CAYN_QT_%alternative%_JUNSEP.xls
Target file: \NFFR2125\LA_BV_to_SNTMP1BT\SNTMP_IN\SN_JUNSEP\CD_%alternative%.DAT

i. Copy text files to SNTEMP model folder: Follow the step above, copy all CD_%alternative%.DAT to \NFFR2125\SNTMP1BT\SNJUNSEP\BLO_CAYN\Seneca\

Create SNTEMP input files for the downstream end of Seneca Reach (Caribou Powerhouse releases)

j. Copy BV W2 model output files to a dedicated folder: Go to folder \NFFR2125\LA_BV_to_SNTMP1BT\BV_OUT\; Double click corresponding batch file (e.g. "BSLINE_BV_OUT_Click.bat").

   Note: This step copies the model output files to a folder that contains only the output files.
   Source files: \NFFR2125\LA2BV\LA\%alternative%\STETSON\%year%\outtmp.dat
   Target files:
   \NFFR2125\LA_BV_to_SNTMP1BT\LA_OUT\%alternative%\%year%\outtmp.dat

k. Create Caribou Powerhouse releases Q&T excel files with statistics: In Matlab, go to folder \NFFR2125\LA_BV_to_SNTMP1BT\MATLAB\; Run "Caribou_QT_WRAP.m";

   Source files:
   \NFFR2125\LA_BV_to_SNTMP1BT\BV_OUT\%alternative%\%year%\outtmp.dat
   Target files:
   \NFFR2125\LA_BV_to_SNTMP1BT\SNTMP_IN\SN_JUNSEP\CARB_QT_%alternative%_JUNSEP.xls

l. Create Caribou Powerhouse release Q&T text files for SNTEMP model: Follow the step above, run "CARB_DAT.m";

   Source file:
   \NFFR2125\LA_BV_to_SNTMP1BT\SNTMP_IN\SN_JUNSEP\CARB_QT_%alternative%_JUNSEP.xls
   Target file: \NFFR2125\LA_BV_to_SNTMP1BT\SNTMP_IN\SN_JUNSEP\CARB_%alternative%.DAT

m. Copy text files to SNTEMP model folder: Follw the step above, copy all CARB_%alternative%.DAT to \NFFR2125\SNTMP1BT\SNJUNSEP\BLO_CAYN\Belden\

Run SNTEMP models and plot model output

n. Run SNTEMP model: Go to folder \NFFR2125\SNTMP1BT\SNJUNSEP\BLO_CAYN\; Double click "1button_1_Loop_Click.bat" to run all alternatives and all exceedance levels for all reaches from Seneca Reach to Poe Reach.

o. Update model output to excel file: Double click to open "new_btwnAlt.xls"; Locate the corresponding datasheet of the alternative; Right click data area of the datasheet, and click "Refresh Data" on the context menu; Check corresponding plots for graphic results of the SNTEMP model run.

p. Repeat the above step for the Excel file "new_btwnExceedance.xls".

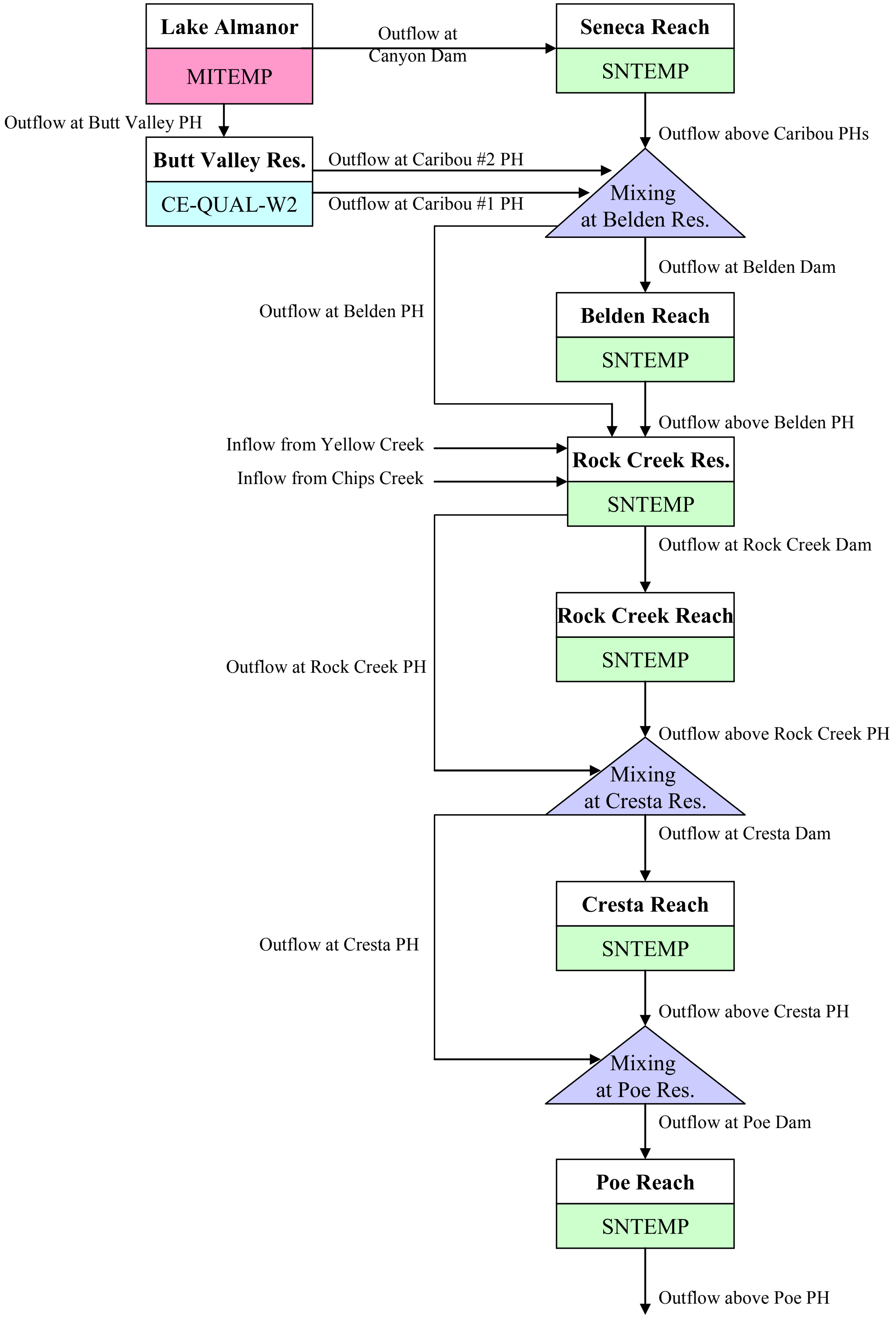
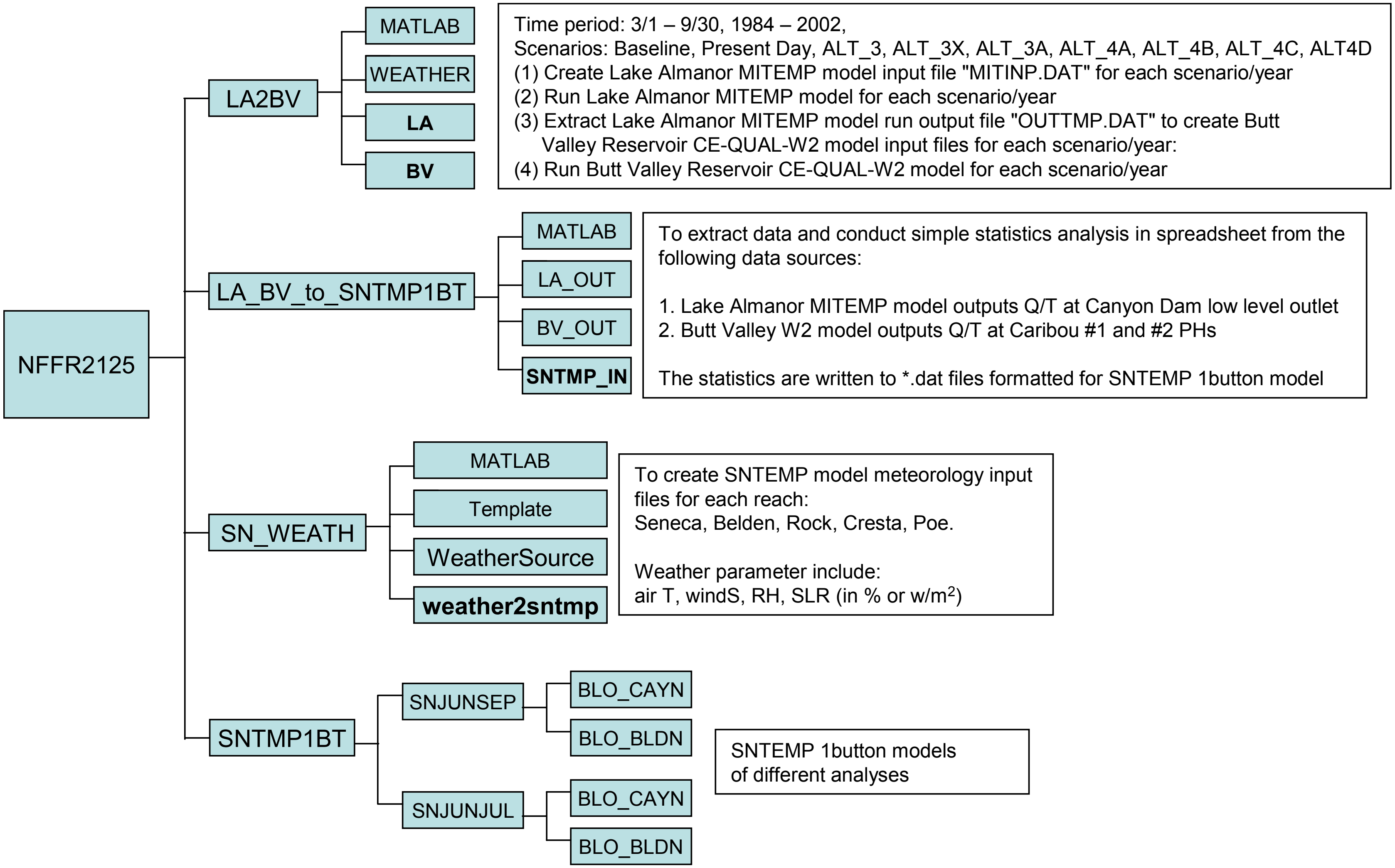


Figure 1 NFFR Water Temperature Models and Model Relationships



Time period: 3/1 – 9/30, 1984 – 2002,
Scenarios: Baseline, Present Day, ALT_3, ALT_3X, ALT_3A, ALT_4A, ALT_4B, ALT_4C, ALT4D
(1) Create Lake Almanor MITEMP model input file "MITINP.DAT" for each scenario/year
(2) Run Lake Almanor MITEMP model for each scenario/year
(3) Extract Lake Almanor MITEMP model run output file "OUTTMP.DAT" to create Butt Valley Reservoir CE-QUAL-W2 model input files for each scenario/year:
(4) Run Butt Valley Reservoir CE-QUAL-W2 model for each scenario/year

To extract data and conduct simple statistics analysis in spreadsheet from the following data sources:

1. Lake Almanor MITEMP model outputs Q/T at Canyon Dam low level outlet
2. Butt Valley W2 model outputs Q/T at Caribou #1 and #2 PHs

The statistics are written to *.dat files formatted for SNTEMP 1button model

To create SNTEMP model meteorology input files for each reach:
Seneca, Belden, Rock, Cresta, Poe.

Weather parameter include:
air T, windS, RH, SLR (in % or w/m^2)

SNTEMP 1button models
of different analyses

Figure 2 File Management Structure for the Linked Water Temperature Models