Appendix B:
Temperature Model Scenario Report

(Revised June 2010)

THIS DOCUMENT IS SUPPLEMENTAL TO THE ROGUE RIVER BASIN TEMPERATURE TMDL (CHAPTER 2)

State of Oregon
Department of Environmental Quality

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1. INTRODUCTION

Once stream temperature models were calibrated (see **Appendix A**), several scenarios were simulated by changing one or more input parameters for each of the six calibrated models. The simulated scenarios focused largely on defined system potential vegetation and derived flow mass balances. The largest difference in temperature between current conditions and Natural Thermal Potential (NTP) model results are presented in **Table B1**. A basic sensitivity analysis was performed on selected waterbodies and parameters to assist in interpreting the uncertainty of the model predictions.

Table B1. Maximum predicted difference between current conditions and the applicable criteria and the location of the maximum difference (point of maximum impact).

Waterbody	Greatest excursion from applicable criteria (maximum 7-DADM, Δ °C)	Point of Maximum Impact (river km)
South Fork Little Butte Creek	16.5	0.95
Antelope Creek	14.1	8.3
Little Butte Creek	12.5	0.1
Elk Creek	11.0	2.5
Evans Creek	9.2	15.4
North Fork Little Butte Creek	6.4	0
Rogue River[1]	2.2	100.4
Rogue River[2]	-0.3	0

[1]Rogue River at the time of maximum excursion from the criteria (9/27/2003)
[2]Rogue River at the time of maximum river temperatures

2. SYSTEM POTENTIAL VEGETATION

System potential vegetation is essentially the mature species composition, height, and density of vegetation that would occur in the absence of human disturbances. System potential vegetation conditions were used in stream temperature modeling scenarios to quantify the impacts of nonpoint source solar radiation loads, and ultimately to develop nonpoint source load allocations for the TMDL.

The Rogue River Basin is large and consists of a variety of unique ecosystems. System potential vegetation height and density was based on EPA Level IV Ecoregions (Thorson et al. 2003), each capable of supporting different types of vegetation (**Figure B1**). Ecoregions are classified based on multiple parameters, including elevation, climate, soils, vegetative communities, geology, physiography, hydrology, land use, etc. System potential vegetation characteristics for each ecoregion were based on the following previously approved TMDLs with overlapping ecoregions: Lower and Upper Sucker Creek, Lobster Creek, Applegate Subbasin, Umpqua Basin and Bear Creek (**Table B2**) (see DEQ 1999, 2002a, 2002b, 2004, 2006, and 2007). For ecoregions that don't overlap with a previously completed TMDL area, characteristics were informed by vegetation descriptions from the Oregon Watershed Assessment Manual (1999) and average of site potential tree heights by watershed provided by Bureau of Land Management (Laurie Lindell 2008, personal communication).

The methodology for applying system potential vegetation in the temperature models was based on the following general rules:

Existing stands of trees were assigned their system potential heights and densities. Existing mature trees were left as-is, while immature tree stands were assigned the appropriate system potential (mature) heights.

Non-forested areas which are capable of supporting trees (i.e., clear cuts, fields, recently disturbed areas) were assigned the appropriate mature species composition type.

Areas that are naturally incapable of supporting trees or other shade producing vegetation were left as-is (i.e., barren steep rocky slopes, bedrock outcrops, etc.). Notably, this includes portions of the riparian area along the Rogue River in the “Wild and Scenic” reach identified by the TMDL technical committee which are currently identified as grasses and shrubs. These are areas that have not been actively managed and due to hillside slope, soil and other factors are not predicted to support forests.

Developed areas (i.e., roads, buildings, rail, dams, etc.) were assigned the appropriate mature species composition type.

Figure B1. EPA Level IV Ecoregions in the Rogue River Basin

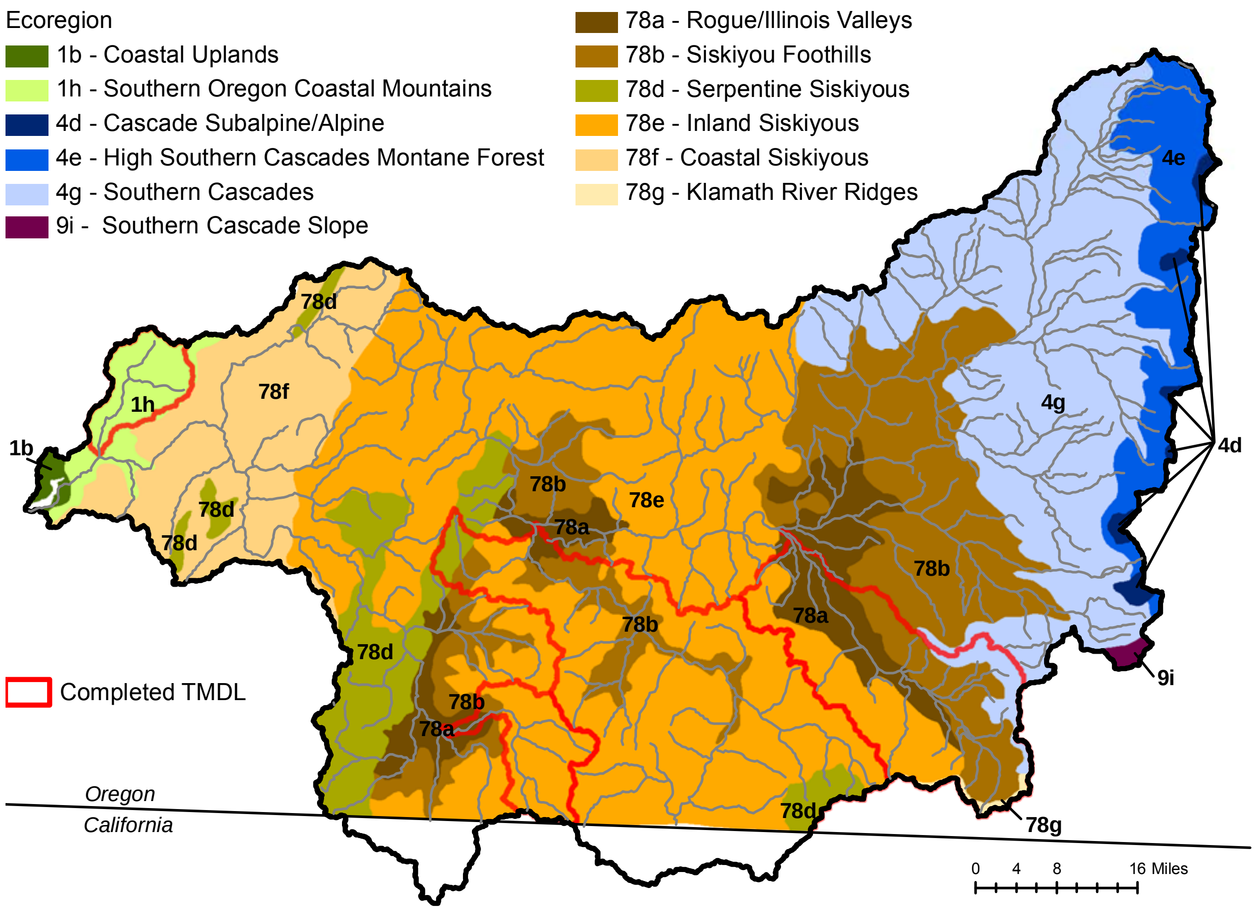


Table B2. Summary of the system potential vegetation species compositions, heights, and densities for each Level IV Ecoregion. Ecoregions 9i and 78g were not included because they represent a small portion of the basin.

Ecoregion	Vegetation Type	Examples from Oregon Watershed Assessment Manual (1999)	height (m)	density
1b	Conifer	Spruce, Hemlock	41.1	80%
	Hardwood	Alder dominant with maple	27.4	70%
	Mixed		30.5	75%
1h	Mixed	Western hemlock, western redcedar, Port-Orford cedar, grand fir, tanoak, myrtle, red alder	48.8	70%
4d	Herbaceous plants	Arrowleaf groundsel, red mountain heath	0.2	50%
4e	Conifer	True Fir, Mountain Hemlock and Lodgepole Pine	42.7	70%
	Mixed	Mountain alder and some conifers	14.9	80%
4g	Conifer	Douglas Fir, true firs and incense cedar	56.4	70%
	Hardwood	Mountain alder	14.9	80%
	Mixed		35.7	75%
78a	Conifer	Douglas Fir, Ponderosa pine	46.0	80%
	Hardwood	Red Alder, Cottonwood	28.2	70%
	Mixed		37.1	75%
78b	Conifer	Douglas-fir, incense cedar	51.8	80%
	Hardwood	Cottonwood, oak, madrone	29.3	85%
	Mixed		42.1	70%
78d	Mixed	Jeffery pine, tanoak, Doug-fir, white fir	36.0	52%
	Willows	Willows, azalea, shrubs	4.6	90%
78e	Conifer	Douglas-fir, ponderosa pine, incense cedar, white fir	53.6	80%
	Hardwood	Oak, madrone	29.3	85%
	Mixed		42.1	70%
78f	Conifer	Sitka spruce, western hemlock, Doug-fir, Port Orford cedar and Jeffery pine	57.0	70%
	Hardwood	Alder, myrtle and bigleaf maple	27.4	70%
	Mixed		42.2	70%

3. SIMULATED SCENARIOS

3.1 Rogue River

Table B3 describes the different simulation scenarios for the Rogue River. A further discussion of several of the scenarios is provided below the table.

Table B3. Simulated Scenario Definitions

“Current”	Current Calibrated Condition (see **Appendix A** for details)
“Restored Vegetation”	System Potential Vegetation (see effective shade figure, system potential vegetation table and summary of results in the main text of the TMDL document, **Chapter 2**)
“No PODs”	No points of diversion (see **Appendix A** for current representation and main text, **Chapter 2** for a summary of the results). This just includes points of diversions determined for the Rogue River mainstem and Big Butte Creek.
“No LCR”	No Lost Creek Reservoir. Flow and temperature determined through using a regression of pre dam data (see below for discussion)
“Restored Tributaries”	Tributaries flow and temperature set to estimated natural thermal potential (see below for discussion)
“No Small Dams”	Representation without the four small mainstem dams (see below for discussion and summary of results in the main text, **Chapter 2**).
“No point sources”	Point source flow set to zero (summary of results in the main text, **Chapter 2**)
“NTP”	Natural Thermal Potential: combining the inputs of system potential vegetation, natural flow (i.e. no withdrawals, no Lost Creek Reservoir), natural channel form (i.e. no small dams), no point sources and tributaries, headwater discharging natural thermal potential temperatures (summary of results in the main text, **Chapter 2**)

‘No Lost Creek Reservoir’ Scenario

In order to estimate what flow and temperature would have been in 2003 without Lost Creek Reservoir, regressions were developed using pre-dam data. USGS flow and temperature gages have been operating upstream (Rogue River below Prospect) and downstream (Rogue River near McLeod) of the reservoir site since at least 1970 (the dam was completed in 1977). Daily average flow data were used to calculate a regression (**Figure B2**). As only daily minimum and maximum temperatures were available, the linear regression used 2478 paired minimum and maximum temperature observations between 1970 and 1976 (**Figure B3**). Parsing the data and using seasonal regressions did not appear to provide better predictive capability (**Figure B4**). The regression for July – August appears to be heavily influenced by outliers. The non-parsed temperature data was used to derive the relationship for this scenario.

Figure B2. Pre-dam relationship (1970 – 1976) between flow upstream of Lost Creek Reservoir (Rogue River below Prospect) and downstream of Lost Creek Reservoir (Rogue River near Mcleod)

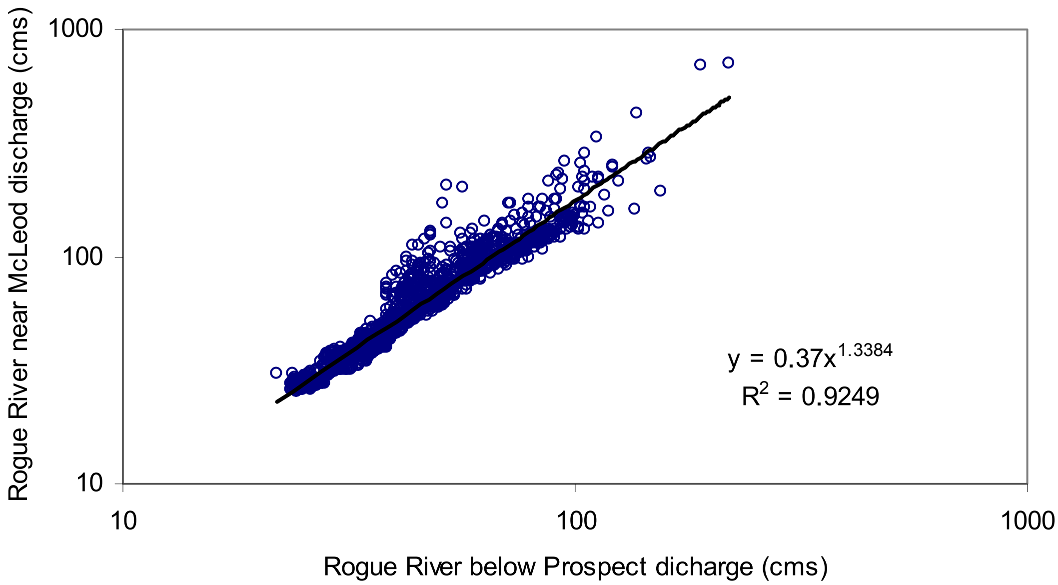


Figure B3. Pre-dam relationship (1970 – 1976) between river temperature upstream of Lost Creek Reservoir (Rogue River below Prospect) and downstream of Lost Creek Reservoir (Rogue River near Mcleod)

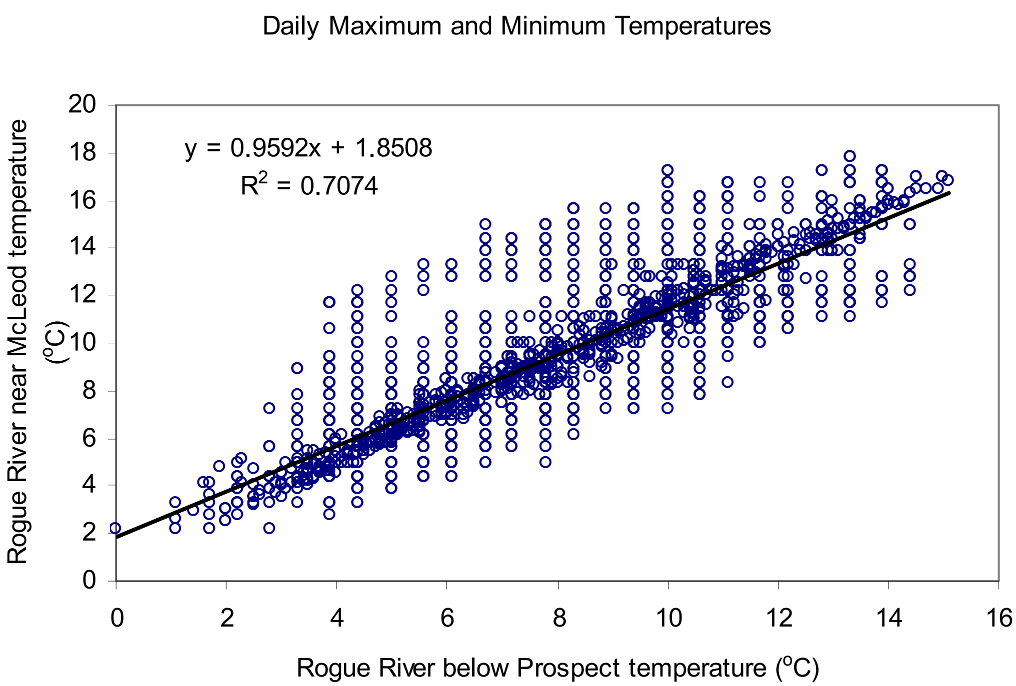
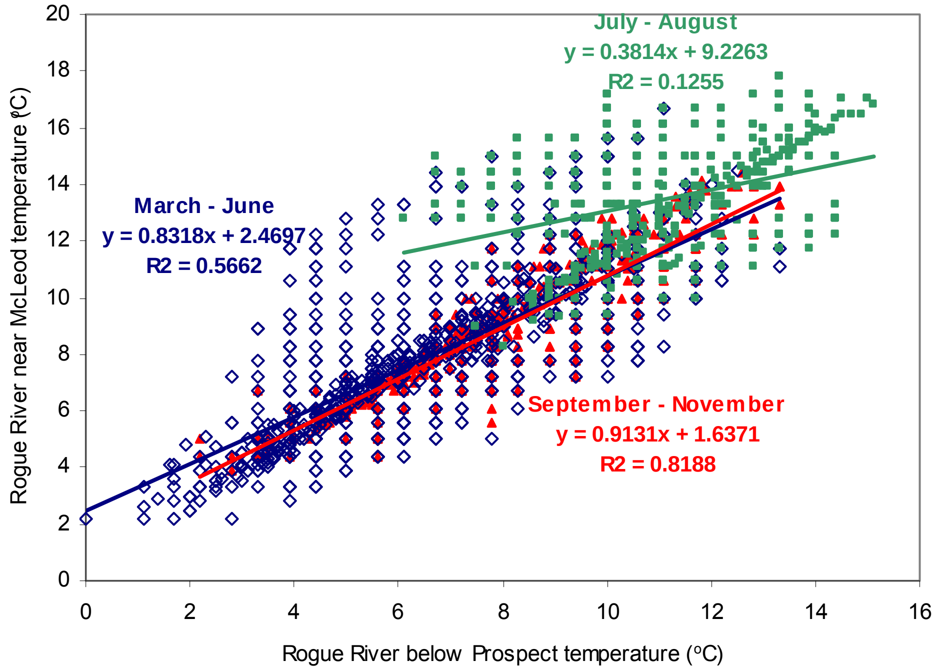


Figure B4. Pre-dam seasonal relationships by season between river temperature upstream of Lost Creek Reservoir (Rogue River below Prospect) and downstream of Lost Creek Reservoir (Rogue River near Mcleod)



Using the derived temperature and flow relationships and data from Rogue River below Prospect, daily average flow and hourly stream temperatures for Rogue River at McLeod (the model headwaters) were predicted as if there was no Lost Creek Dam for the 2003 model period (**Figure B5 & Figure B6**).

Figure B5. Comparison of measured daily average flow (2003) and predicted 'no Lost Creek Reservoir' flow at the headwaters of the model.

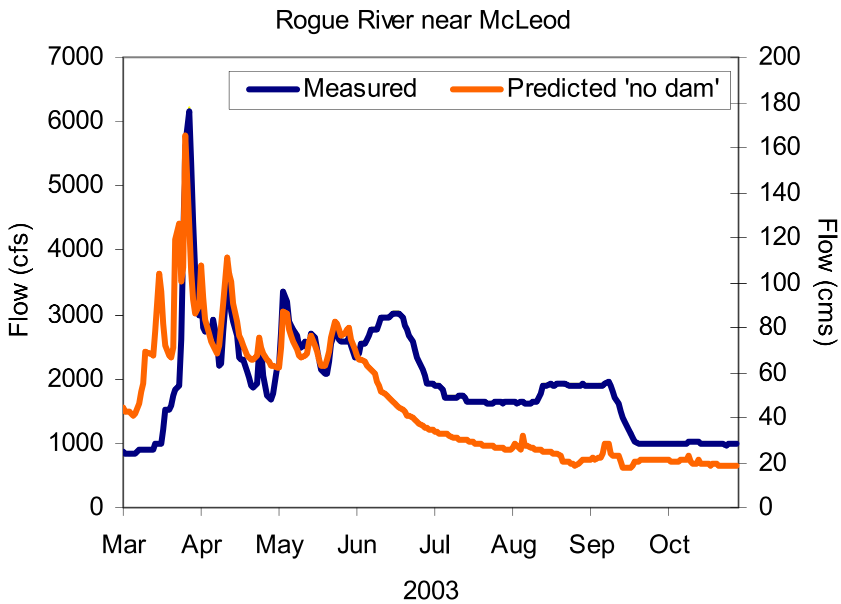
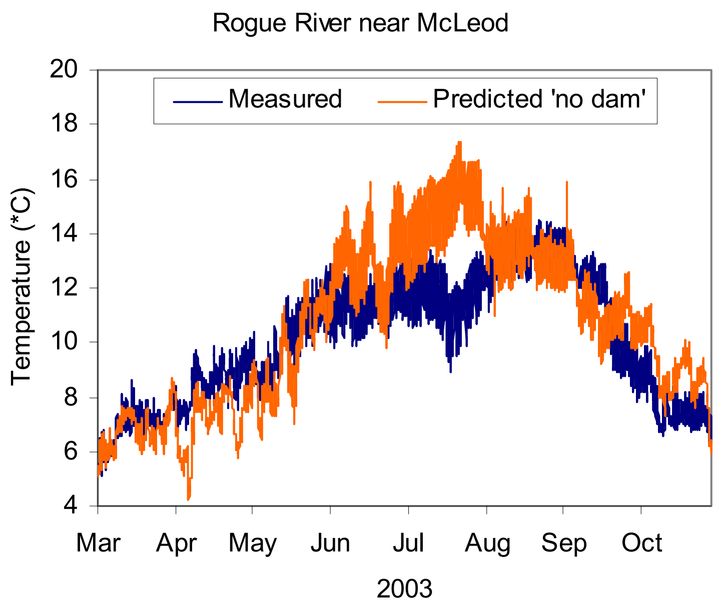
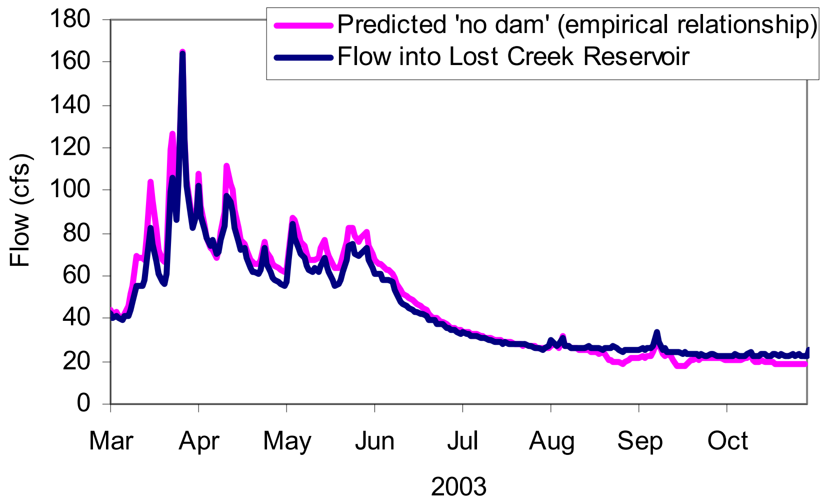


Figure B6. Comparison of current hourly stream temperatures (2003) and predicted 'no Lost Creek Reservoir' temperatures at the headwaters of the model.



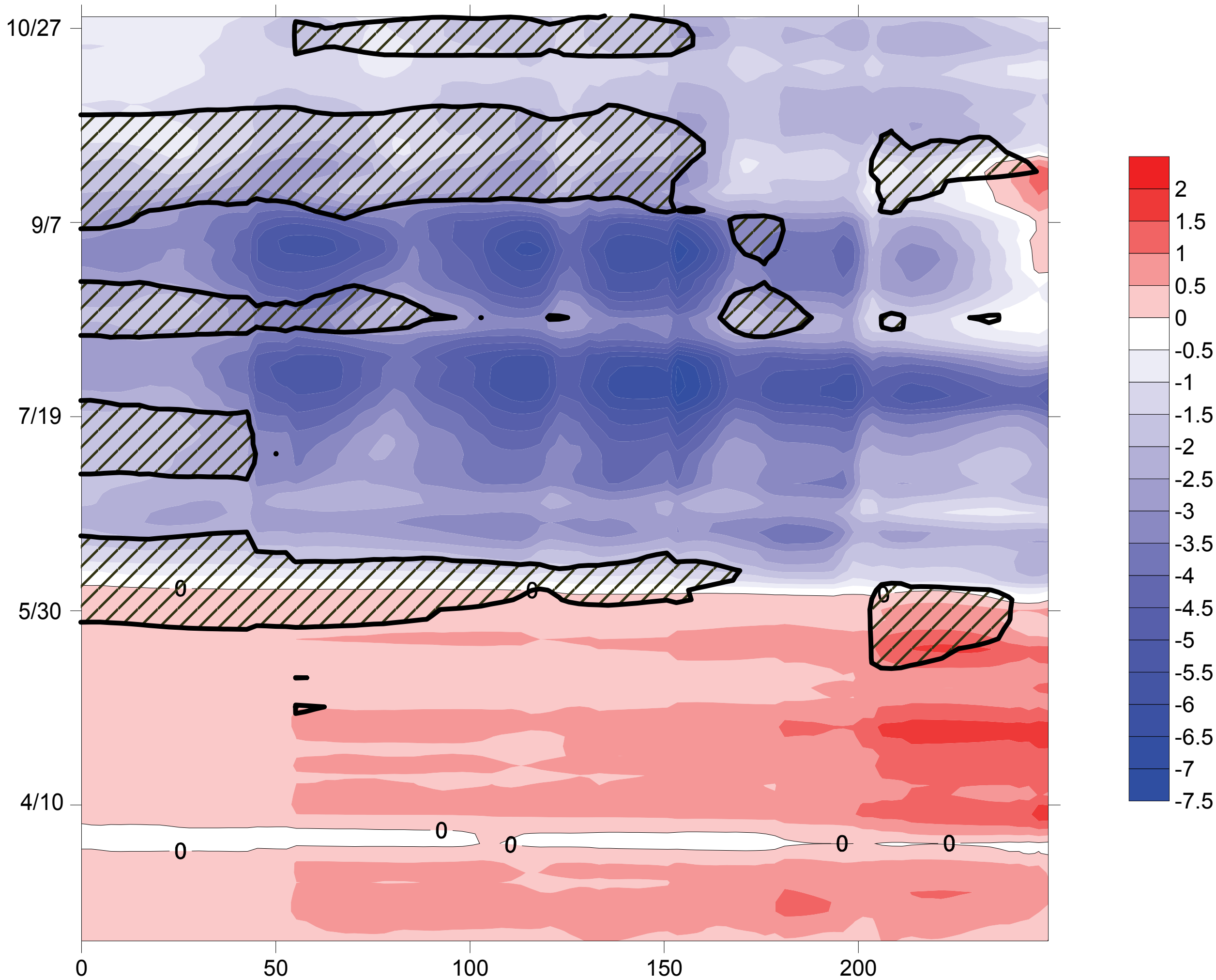
The Army Corp of Engineers provided a second data set of calculated inflows into Lost Creek Reservoir for 2003 (Michael Schneider 2008, personal communication). Both methods of deriving flows predict similar results (**Figure B7**). The regression in **Figure B2** was used for this TMDL because it uses a similar methodology that is used to derive stream temperature.

Figure B7. Comparison of DEQ predicted flow without Lost Creek Reservoir and calculated inflows into Lost Creek Reservoir by the Army Corp.



The influence of Lost Creek Reservoir on 7-DADM temperature was further examined by subtracting the "Current" scenario temperatures from "No LCR" scenario temperatures (**Figure B8**). It appears that during most of the time when the Rogue River temperature exceeds the applicable criteria, operation of Lost Creek Reservoir is resulting in cooler river temperatures. This includes the period during the summer when river temperatures are expected to the warmest. However, it also appears that the operation of Lost Creek Reservoir is contributing to temperature exceedances of the applicable criteria during a portion of the spring and fall.

Figure B8. Comparison of current conditions (2003) to the "'No Lost Creek Reservoir' scenario (current – 'No Lost Creek Reservoir') in space and time. The areas shaded red represent times and places when the model predicts that operations of Lost Creek Reservoir are contributing to warmer temperatures and areas shaded blue when resulting in cooler temperatures. The areas designated with a hash pattern are when the model predicts that the current condition temperature exceeds the applicable criteria (Figure B14)



"Restored Tributaries" Scenario

In order to provide a better estimate of natural thermal potential, estimates of natural flow and temperature inputs to the Rogue River from the tributaries were derived using a variety of different methods shown in **Table B4**. Although the Big Butte Creek confluence is approximately 2 km upstream of the model headwaters (USGS gage near McLeod), the calculated amount of withdrawals from the creek was added as a tributary just downstream of the model headwaters.

Table B4. Summary of adjustments made to tributaries for the representation of natural conditions.

Tributary	Derived natural temperature and flow methodology
Big Butte Creek adjustment	Flow equal to the amount of withdrawals presented in the calibration section. Temperature equal to NTP headwaters condition
Elk Creek	Used TMDL model based on 2001 data (this report) to develop a temperature regression between current and NTP daily average temperatures and residuals. Applied these relationships to 2003 model input when model input exceeded 17 °C; otherwise used 2003 inputs. Applied the average increase in flow at the mouth predicted by the 2001 Elk Creek model under NTP conditions (0.08 cms) to the 2003 input into the Rogue River model from May to October (assumed irrigation season) (**Appendix A**).
Trail Creek	No temperature or flow model available. Decreased May through September temperatures by 2 °C from 2003 inputs based on professional judgment. Used the same flow relationship with Elk Creek as the based model.
Little Butte Creek	Used same methodology as Elk Creek (see above) using a temperature model based on 2001 data (this report). Average flow increase is 1.32 cms.
Bear Creek	TMDL previously completed using a temperature model based on data from 8/3/1999 (DEQ 2007). Applied the difference at the mouth between the daily maximum temperature under current conditions and under NTP (4.5 °C) to hourly data after May 1. Applied the flow difference from Bear Creek model (1.9 cms) to 2003 flow inputs after May 1. Did not adjust flows or temperature prior to May 1.
Derived flow (d/s of Bear Creek)	Did not adjust flow or temperature from 2003 inputs
Evans Creek	Used TMDL model based on 2003 data (this report) predictions for NTP and natural flow for available period (July – August). Used the same method as Elk Creek for other times.
Applegate River	TMDL previously completed (DEQ 2003). Used the same methodology as Bear Creek for temperature. TMDL did not consider flow in computing NTP. Flow is based on 80th exceedance pertcentile estimated natural flow from Oregon Water Resources Department (2002). The monthly estimates from June – October were linearly interpolated. The minimum flow occurs in September at 1.30 cms.
Derived Flow (at Foster Creek)	Applied the difference between current and NTP daily average temperatures at the mouth of Evans Creek (2.8 °C) to 2003 temperature inputs after May 1. No adjustment was made to flows.
Illinois River	Applied the difference between the current and NTP daily maximum temperatures from the Applegate model (2.3 °C). No adjustment was made to flows.
Lobster Creek	TMDL previously completed using a temperature model based on data from 7/22/1999. Used the same methodology as Bear Creek (a computed 0.9 °C adjustment). No adjustment was made to flows.

"No Low-Head Dams" Scenario

There is a series of low-head dams on the mainstem Rogue River within the model reach. These dams have limited storage capabilities but change the hydrodynamics of the river and therefore temperature.

Given the limitation of the model, these dams could not be physically represented. Hence, they were represented using a 'hydraulically similar' reach by increasing the roughness coefficient until the thermal pattern in the downstream reach was reproduced. The effect of these dams was removed in this scenario by reducing the roughness coefficient for these reaches to the immediate upstream value.

Scenario Results

The flows predicted in the different scenarios are presented graphically in **Figure B9**. The flow predicted in the NTP scenario was corroborated via comparison with a second set of natural flow exceedance percentages estimated by Oregon Water Resources Department (WRD) (2002) (**Figure B11**). Direct comparison is difficult because WRD's natural flow estimates are by month for two different flow year types. The mean 2003 August flow at the Rogue River below Prospect gage (which is upstream of Lost Creek Reservoir) corresponds to the 88% exceedance flow. The comparison between model results and WRD estimates of natural flow does not appear to warrant revision to the NTP methodology. The results of the scenarios are presented graphically in **Figure B911 & Figure B12**.

Figure B9. Longitudinal profiles of predicted flows for scenarios which considered flow alterations.

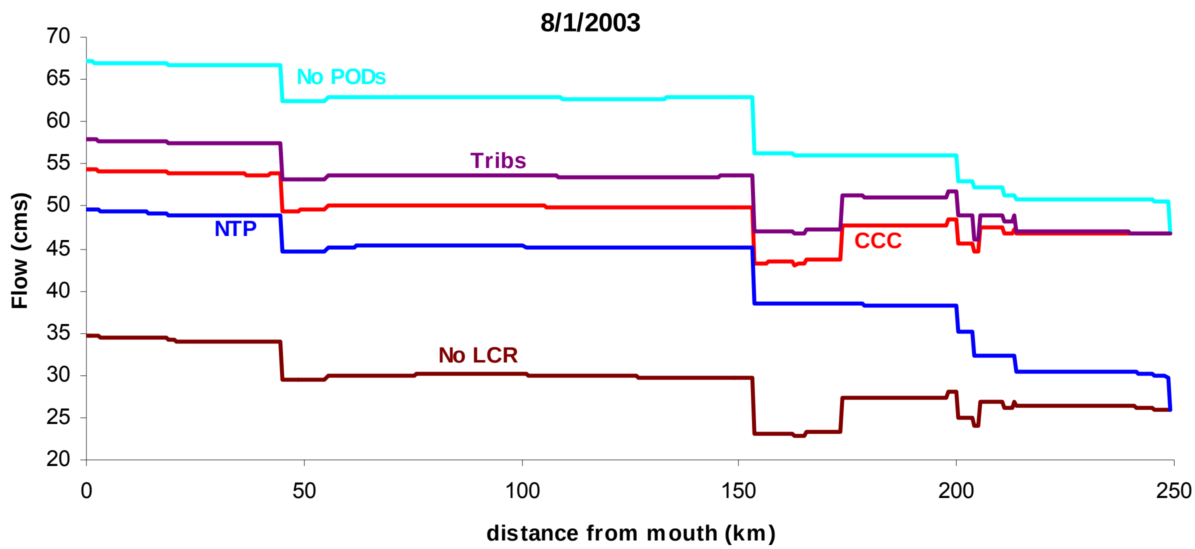


Figure B10. Comparison of NTP model flow for the Rogue River flow near at the mouth with estimated natural flows (OWRD 2002). The estimated natural flows (pink and blue lines) represent the 50% and 80% exceedance stream flow.

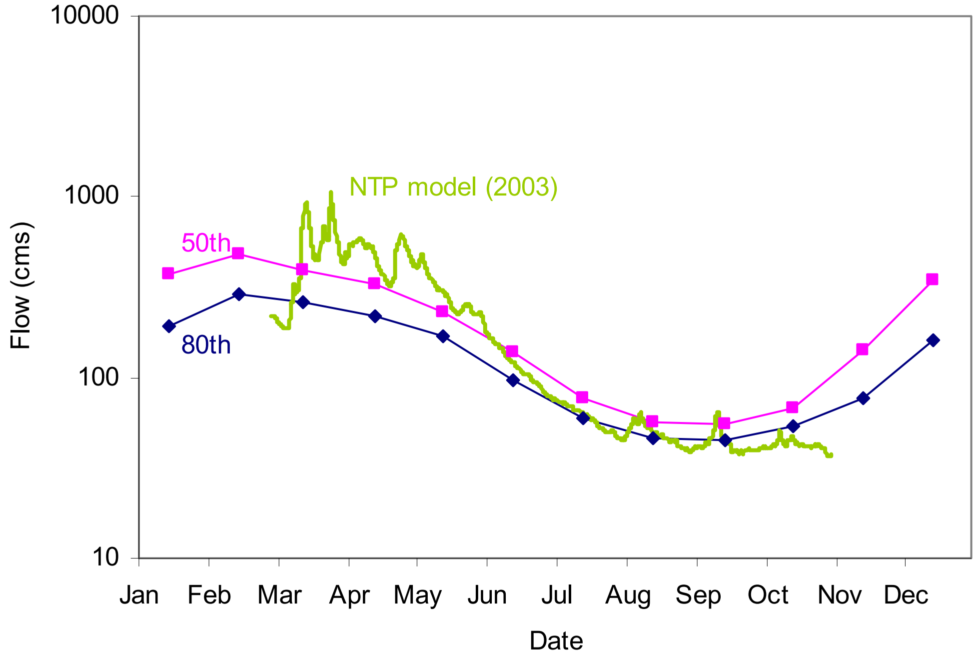


Figure B11. Predictions of Rogue River scenarios based on the July and August median 7 day average of the daily maximum (7-DADM) temperatures. The point source scenario is not shown because it is nearly indistinguishable from 'current' at the scale below.

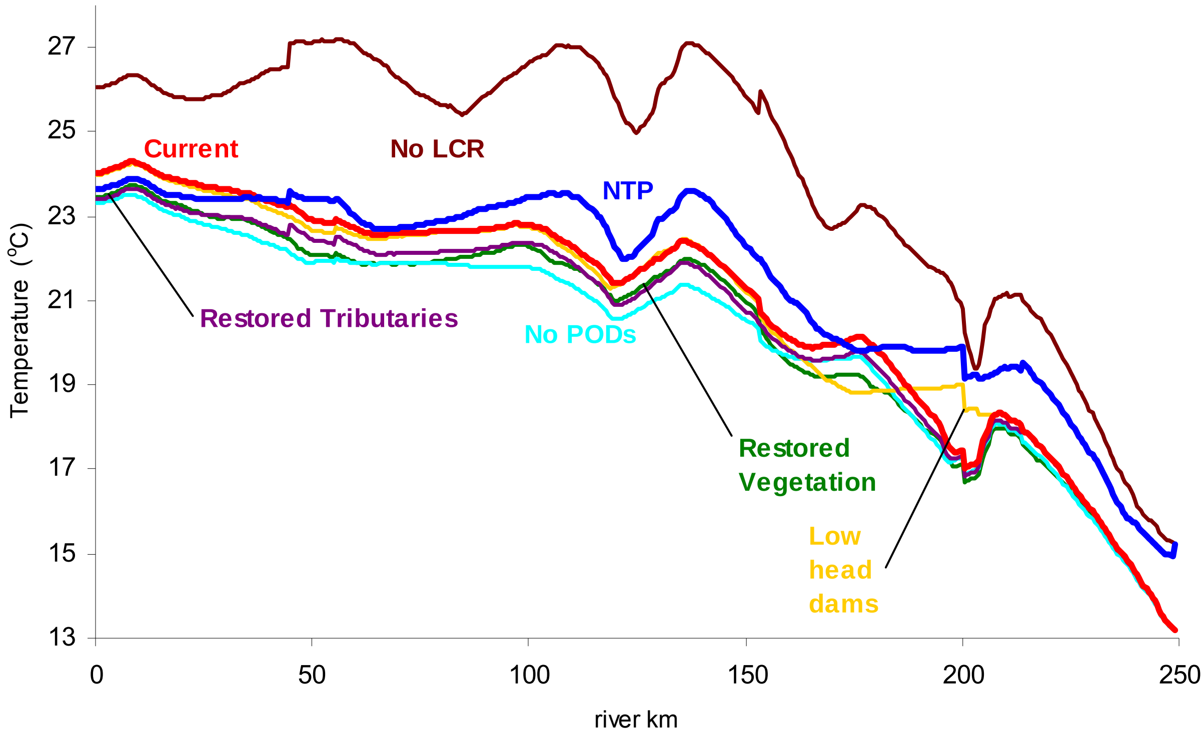
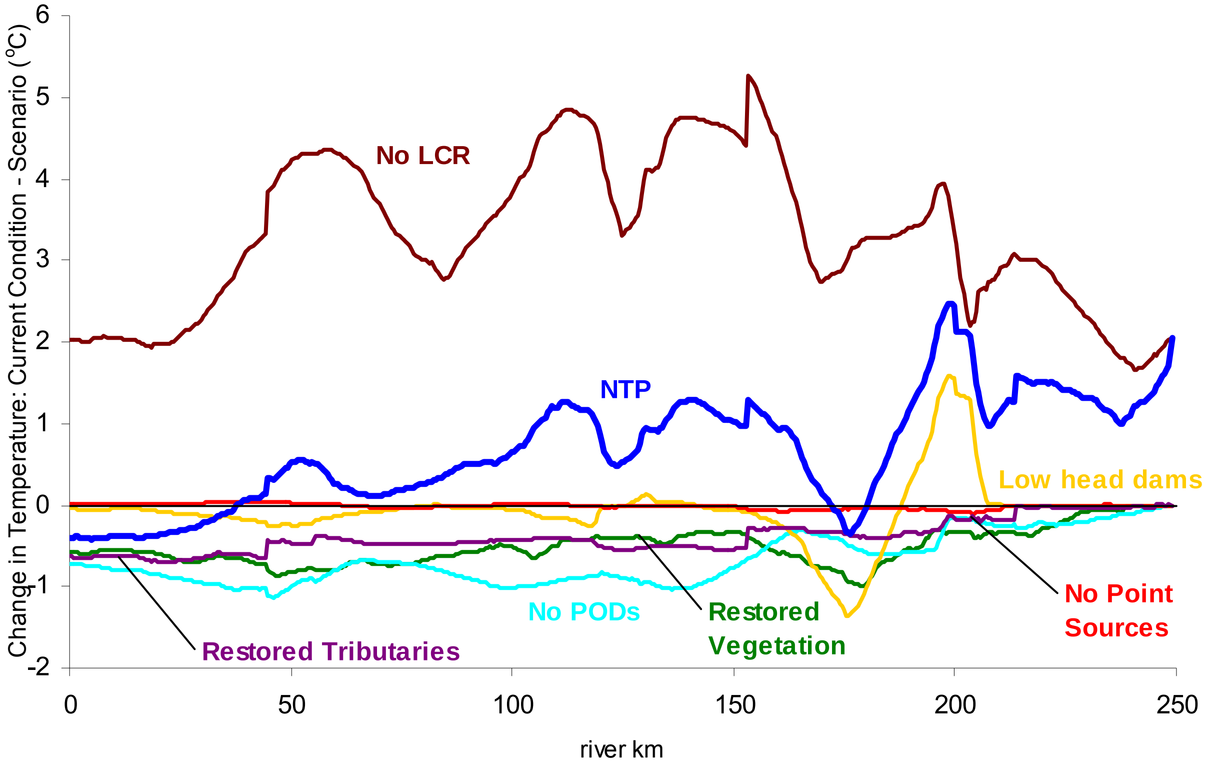


Figure B12. Predictions of Rogue River scenarios based on the difference between 'current' and scenario median July-August 7-DADM temperatures.



Comparison to Water Quality Standard

The water quality standard for temperature is discussed in detail in Chapter 2. The standard has two criteria and both vary in time and space: the biologically based criteria and Natural Thermal Potential (NTP). Which ever calculated temperature is greater is the applicable criterion. Some simple longitudinal comparisons are presented in **Chapter 2**. Below, are some additional comparisons of time series (**Figure B13**) and in space and time (**Figure B14 & Figure B15**).

Figure B13. Comparison of 'current', natural thermal potential (NTP) and the biologically based criteria (grey line) at four locations in the Rogue River using the 7-DADM.

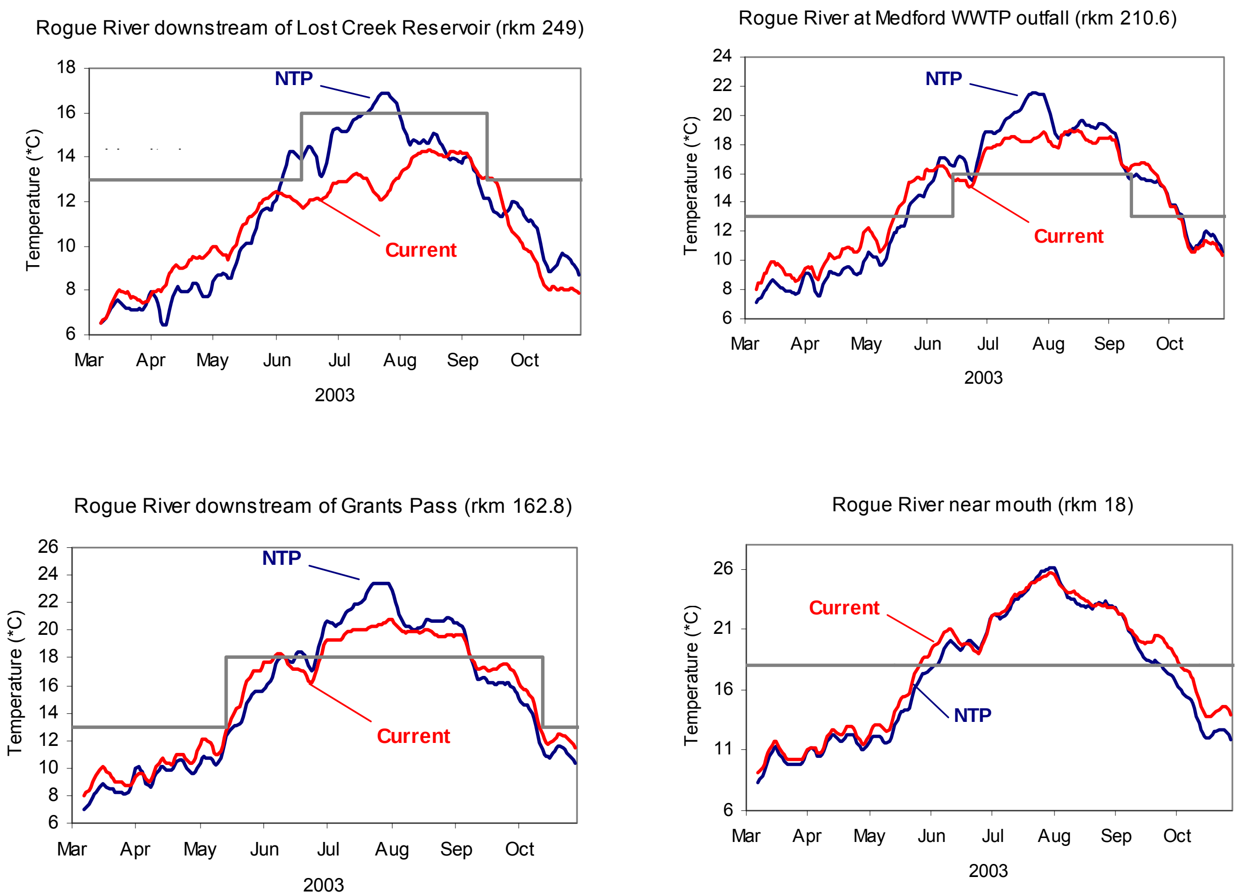


Figure B14. Applicable criteria determination in space and time for 2003. The thick black line designates application of the biologically based criteria instead of NTP.

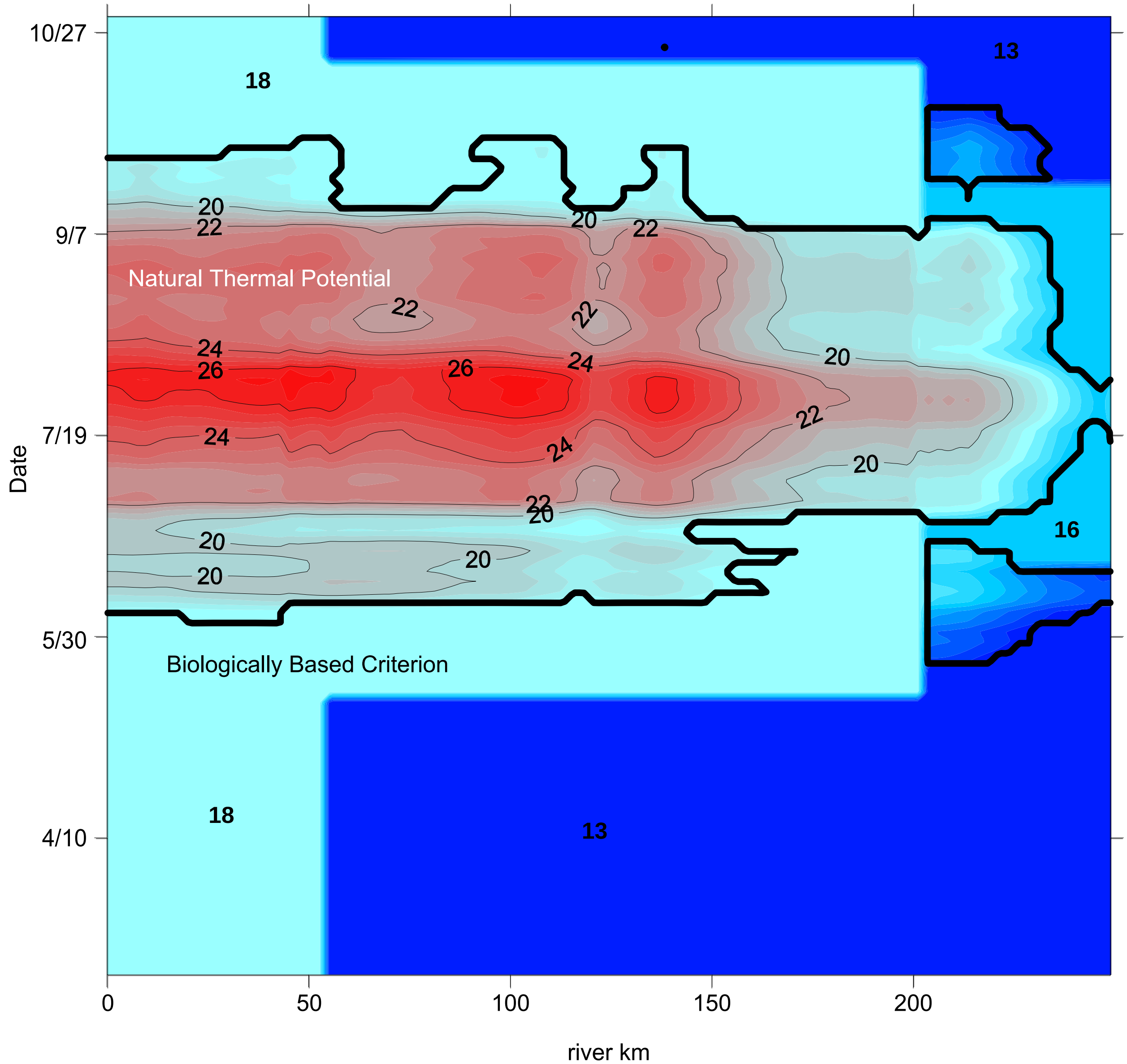
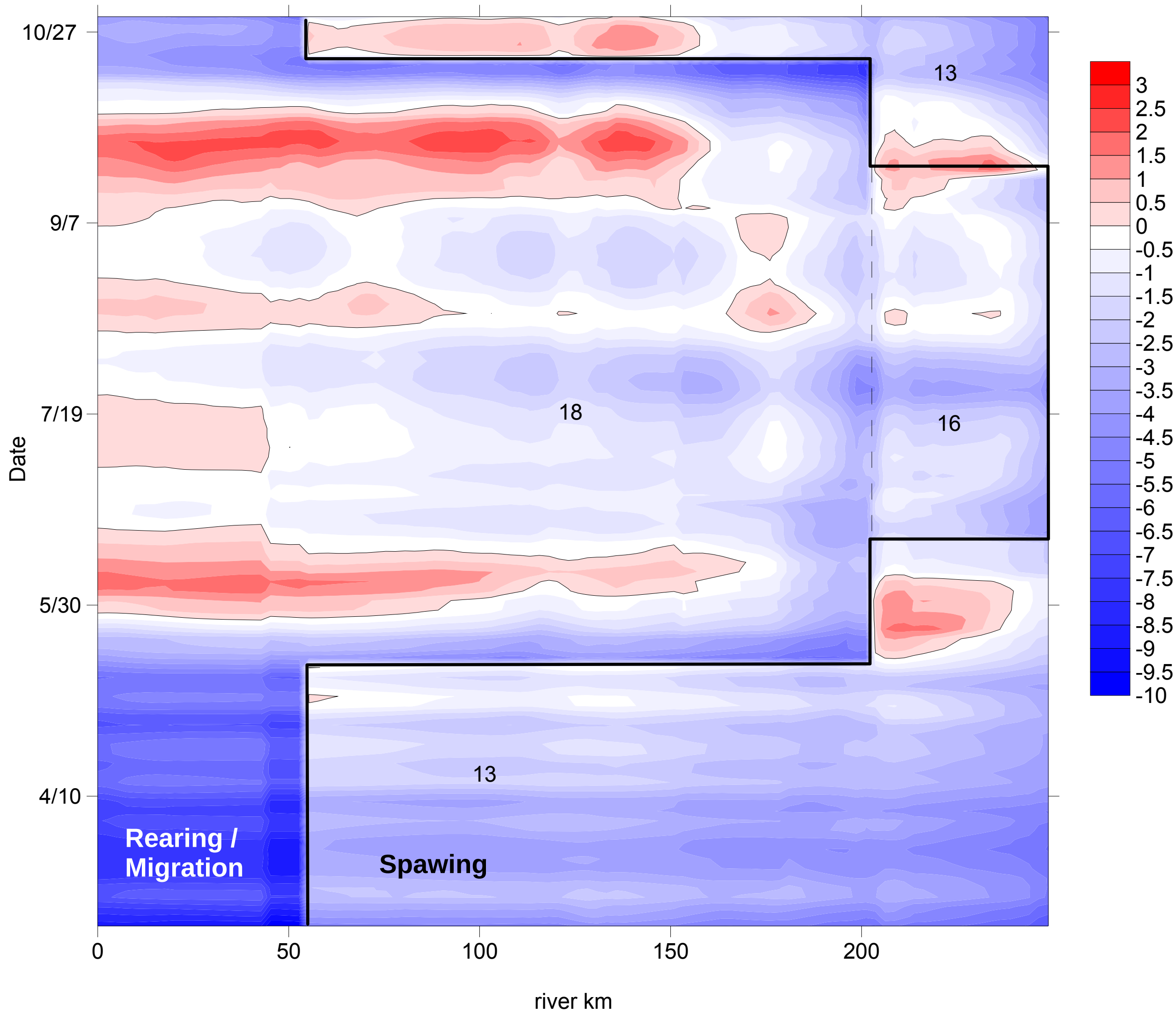


Figure B15 Comparison of current conditions (2003) to the applicable criteria (current – applicable criteria) in space and time. The areas shaded red represent times and places when the observed temperature is greater than the applicable water quality standard. The numbers within the chart refer to the biologically based criteria (°C).



3.2 Little Butte and North Fork Little Butte Creek

The Heat Source model was used to predict the influence of various factors on stream temperature (**Table B5 and Figure B16 & Figure B17**). As seen in **Figure B17**, the model predicts that at some portions of the stream, nearer the mouth, NTP is the applicable criterion, while closer to the headwaters, the biologically-based criterion applies.

Table B5. Simulated Scenario Definitions

“Current”	Current Calibrated Condition (see Appendix A for details)
“Restored Vegetation”	System Potential Vegetation (see effective shade figure, system potential vegetation table Band summary of results in the main text of the TMDL document, **Chapter 2**). Left wetlands and lava flows near the headwaters as-is.
“Flow 1”	No points of diversion or ditch inputs (see **Appendix A** for current representation and main text, **Chapter 2** for a summary of the results)
“Flow 2”	Scenario “Flow 1” without Fish Lake reservoir. Natural flows were estimated by predicting spring flow into Fish Lake. This was done by subtracting lake outflow from the change in storage and inflow from Cascade Canal (trans-basin transfer via shallow groundwater), averaging over July and August. This method predicts a natural flow of 0.51 cms (18 cfs). Stream temperature at Fish Lake outfall was assumed to be the same as spring temperatures (8 °C) because the lake is entirely fed by springs. This is likely a conservative estimate because some heating would have occurred between the springs inlet and the current lake outlet.
“Hyporheic”	Hyporheic flow percentage was increased based on estimates from Tetra Tech (2008) presented in **Appendix C**
“NTP”	Natural Thermal Potential: combining the inputs of system potential vegetation, natural flow (ie Flow 2), natural hyporheic flow and results from Antelope Creek NTP and South Fork NTP (summary of results in the main text, **Chapter 2**). No other adjustments were made to tributary inputs.

Figure B16. Longitudinal profiles of predicted flows for scenarios which considered flow alterations on Little Butte / North Fork Little Butte Creek for 8/1/2001.

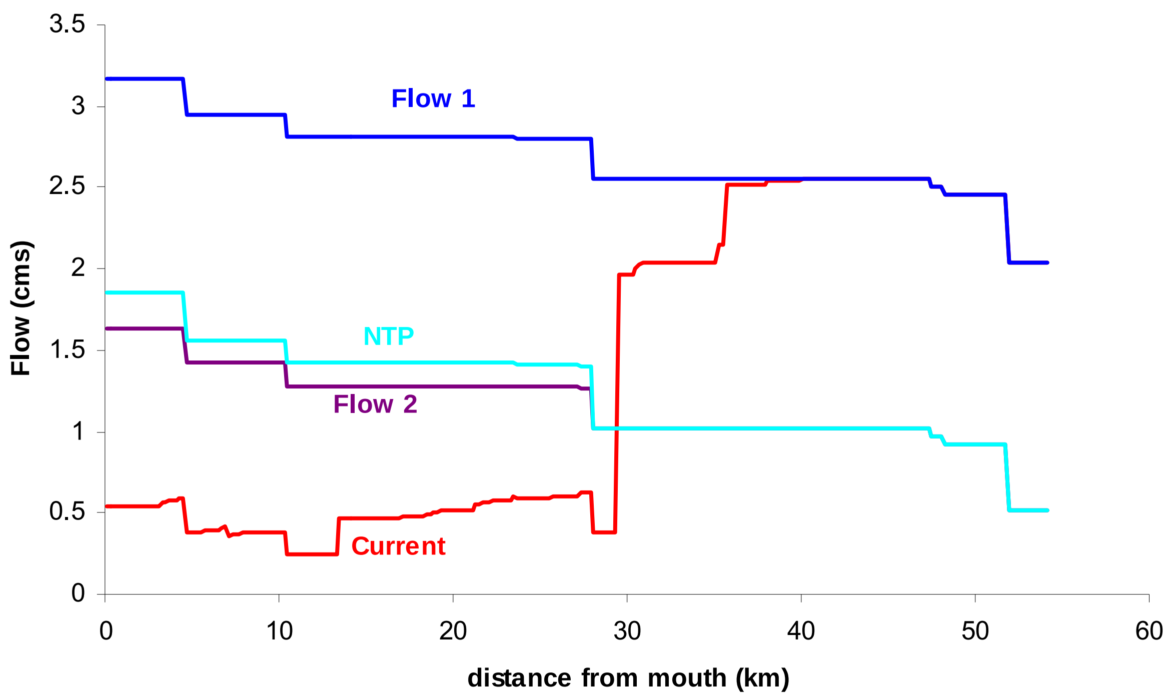
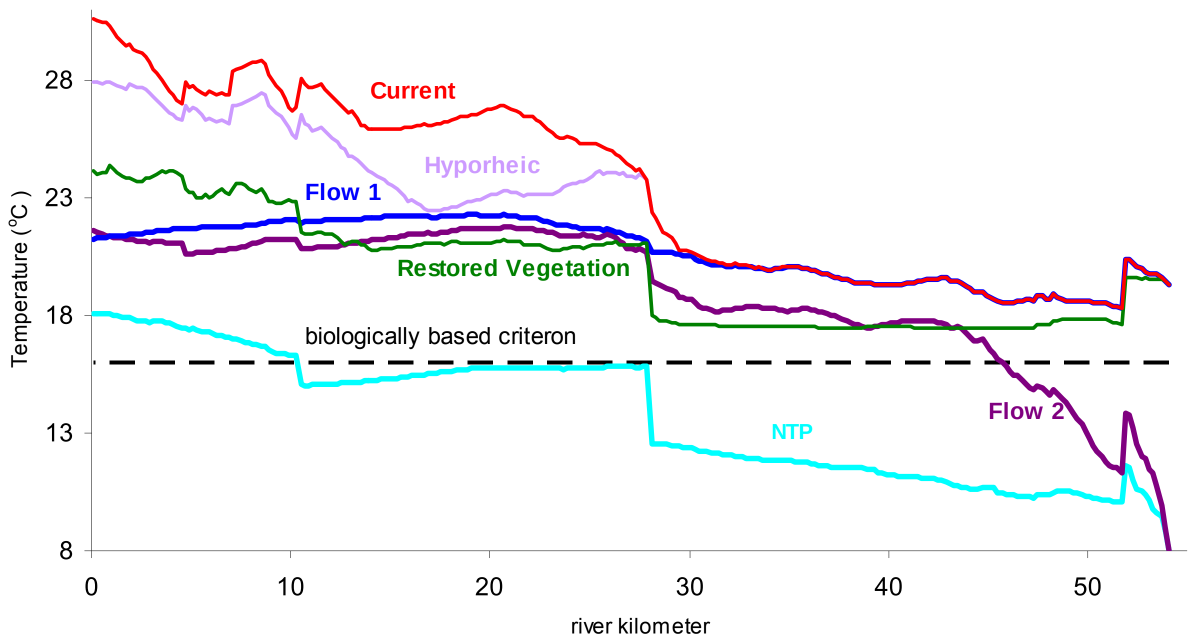


Figure B17. Predictions of Little Butte / North Fork Little Butte Creek scenarios based on the maximum 7-DADM, July and August, 2003.



3.3 South Fork Little Butte Creek

The Heat Source model was used to predict the influence of various factors on stream temperature (**Table B6, Figure B18 & Figure B19**). The model predicts that at some portions of the stream, nearer the mouth, NTP is the applicable criterion while closer to the headwaters, the biologically-based criterion applies.

Table B6. Simulated Scenario Definitions

"Current"	Current Calibrated Condition (**see Appendix A** for details)
"Restored Vegetation"	System Potential Vegetation (see effective shade figure, system potential vegetation table Band summary of results in the main text of the TMDL document, **Chapter 2**). Left wetlands and lava flows near the headwaters as-is.
"Flow"	No points of diversion or ditch inputs (see **Appendix A** for current representation and main text, Chapter 2 for a summary of the results)
"Hyporheic"	Hyporheic flow percentage was increased based on estimates from Tetra Tech (2008) presented in **Appendix C**.
"NTP"	Natural Thermal Potential: combining the inputs of system potential vegetation, natural stream flow, and natural hyporheic flow (summary of results in the main text, **Chapter 2**). No other adjustments were made to tributary inputs.

Figure B18. Longitudinal profiles of predicted flows for scenarios which considered flow alterations on South Fork Little Butte Creek for 8/1/2003.

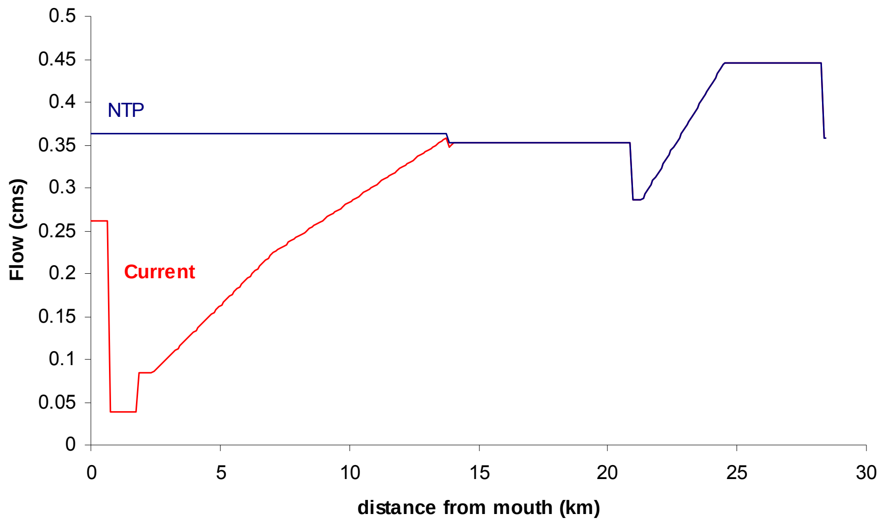
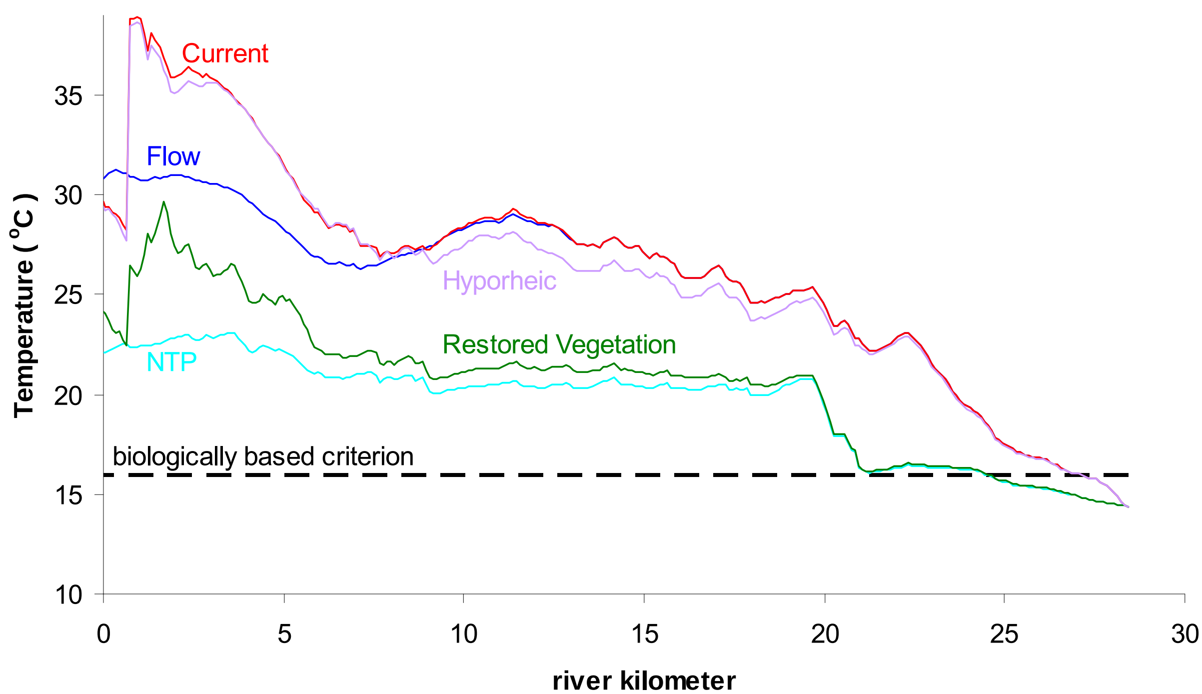


Figure B19. Predictions for South Fork Little Butte Creek scenarios based on the maximum 7-DADM, July and August, 2003.



3.4 Antelope Creek

The Heat Source model was used to predict the influence of various factors on stream temperature (**Table B7, Figure B20 & Figure B21**). The model predicts that, along most of the analyzed portion, NTP is greater than the biologically based criterion of 16°C. In those portions, NTP is the applicable criterion.

Table B7. Simulated Scenario Definitions

"Current"	Current Calibrated Condition (see **Appendix A** for details)
"Restored Vegetation"	System Potential Vegetation (see effective shade figure, system potential vegetation table Band summary of results in the main text of the TMDL document, **Chapter 2**).
"Flow"	No points of diversion (see **Appendix A** for current representation and main text, **Chapter 2** for a summary of the results)
"NTP"	Natural Thermal Potential: combining the inputs of system potential vegetation and natural flow. Model headwater temperature was decreased because temperatures exceeded the biologically based criteria and there is evidence of upstream riparian disturbance. The headwater temperature was set to measurements from South Fork Little Butte Creek (upstream of Beaver Dam Creek), an adjacent watershed, at a point minimum upstream disturbance. No other adjustments were made to tributary inputs.

Figure B20. Longitudinal profiles of predicted flows for scenarios which considered flow alterations on Antelope Creek for 8/1/2001.

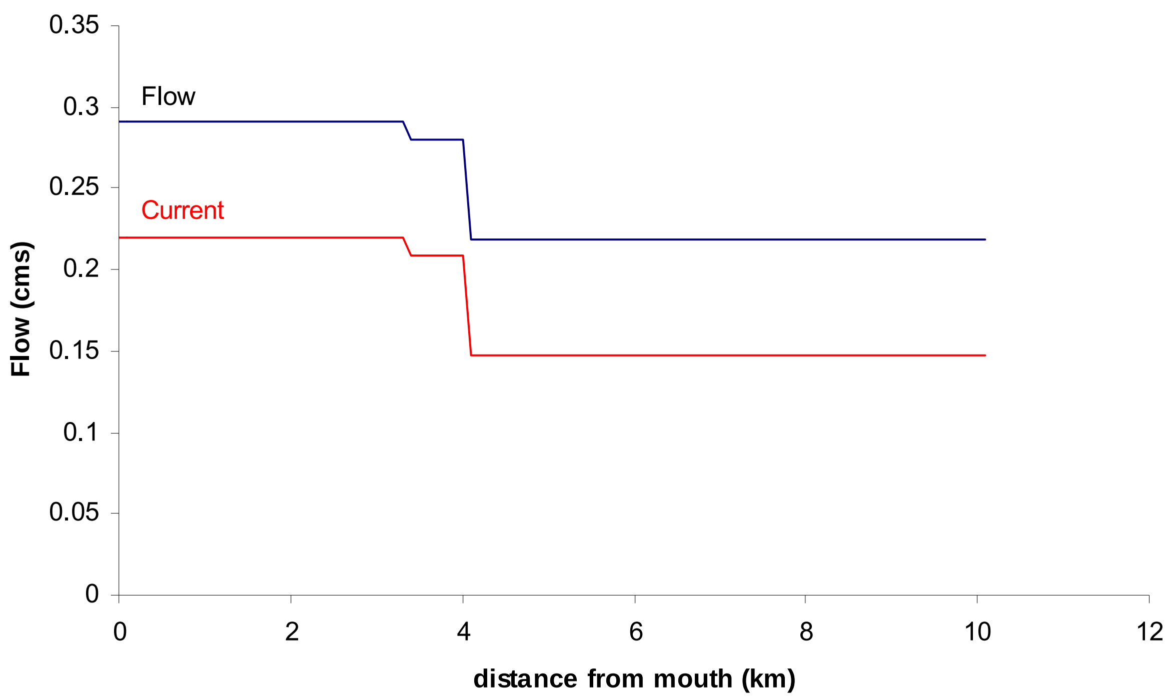
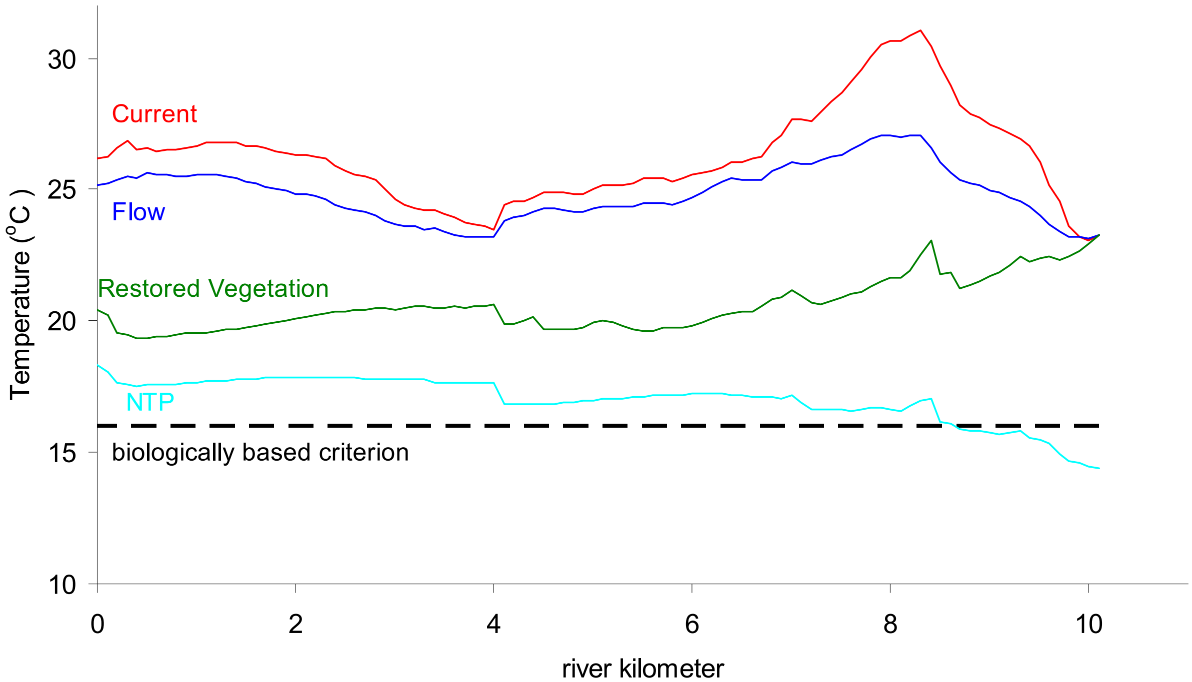


Figure B21. Simulated maximum 7-DADM, July and August, 2003 for Antelope Creek scenarios.



3.5 Elk Creek

The Heat Source model was used to predict the influence of various factors on stream temperature (**Table B8; Figure B22 & Figure B23**). The model predicts that NTP is the applicable criterion along the entire modeled reach.

Table B8. Simulated Scenario Definitions

"Current"	Current Calibrated Condition (see **Appendix A** for details)
"Restored Vegetation"	System Potential Vegetation (see effective shade figure, system potential vegetation table and summary of results in the main text of the TMDL document, **Chapter 2**).
"Flow"	No points of diversion (see **Appendix A** for current representation and main text, **Chapter 2** for a summary of the results)
"NTP"	Natural Thermal Potential: combining the inputs of system potential vegetation and natural flow. Model headwater temperature was decreased because temperatures exceeded the biologically base criteria and there is evidence of upstream riparian disturbance. Headwater temperature was set to measurements from an upstream site with minimum disturbance (Elk Creek at Al Serena Buzzard Mine). For more discussion of the influence of headwater temperature assumptions, see sensitivity analysis below. No other adjustments were made to tributary inputs.

Figure B22. Longitudinal profiles of predicted flows for scenarios which considered flow alterations on Elk Creek for 8/1/2001.

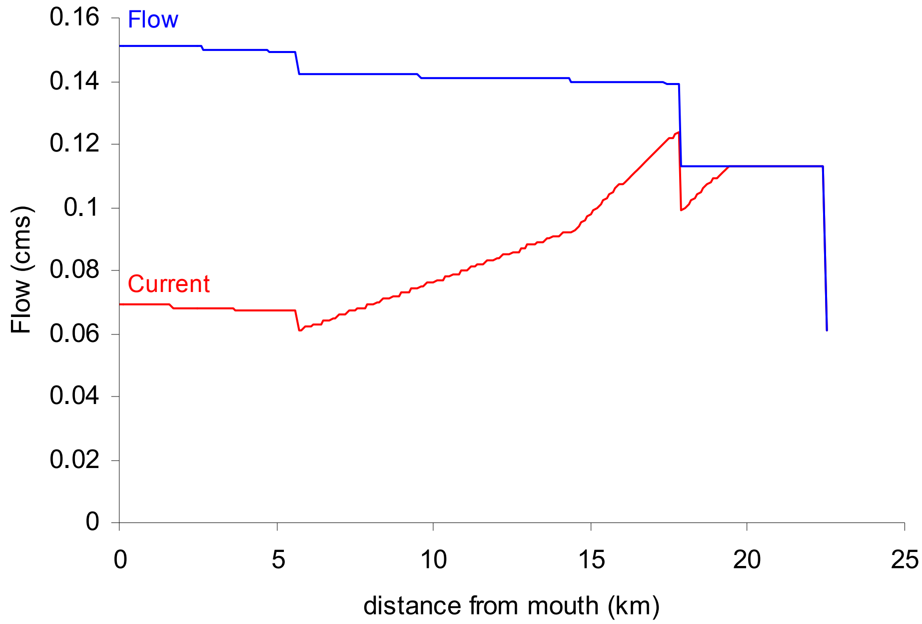
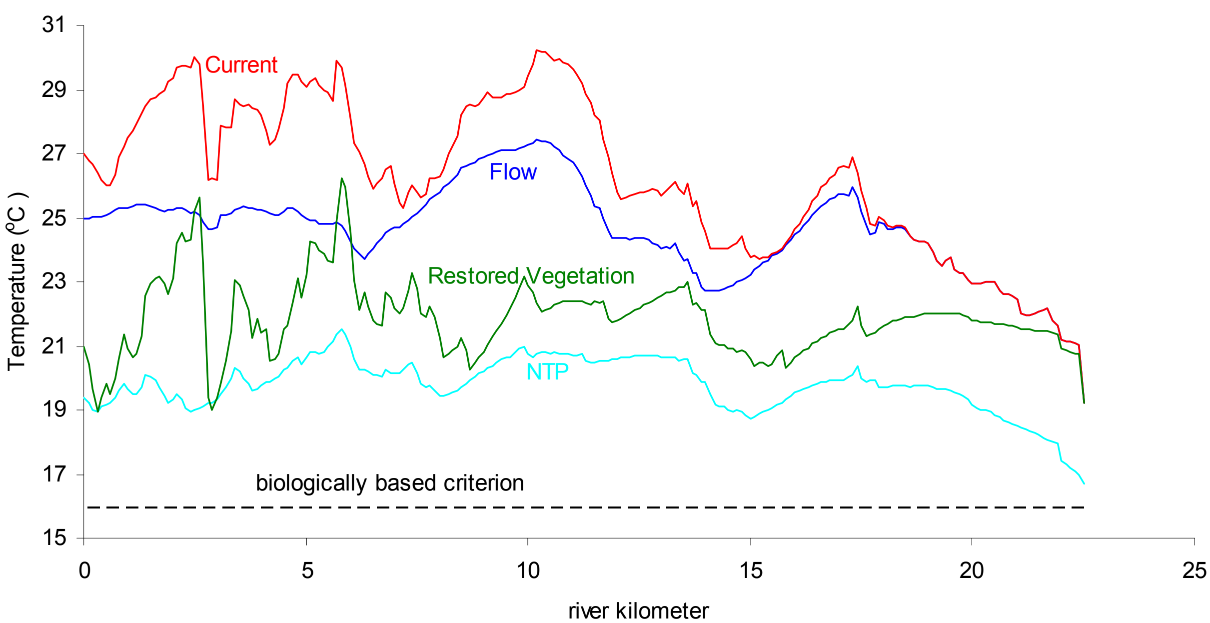


Figure B23. Predictions for Elk Creek scenarios based on the maximum 7-DADM, July and August, 2003.



3.6 Evans Creek and West Fork Evans Creek

The Heat Source model was used to predict the influence of various factors on stream temperature (**Table B9; Figure B24 & Figure B25**). The model predicts that at some portions of the stream, nearer the mouth, NTP is the applicable criterion while closer to the headwaters, the biologically-based criterion applies.

Table B9. Simulated Scenario Definitions

"Current"	Current Calibrated Condition (see **Appendix A** for details)
"Restored Vegetation"	System Potential Vegetation (see effective shade figure, system potential vegetation table and summary of results in the main text of the TMDL document, **Chapter 2**).
"Flow"	No points of diversion (see **Appendix A** for current representation and main text, **Chapter 2** for a summary of the results)
"NTP"	Natural Thermal Potential: combining the inputs of system potential vegetation and natural flow. No other adjustments were made to tributary or headwater inputs.

Figure B24. Longitudinal profiles of predicted flows for scenarios which considered flow alterations on Evans Creek for 8/1/2003.

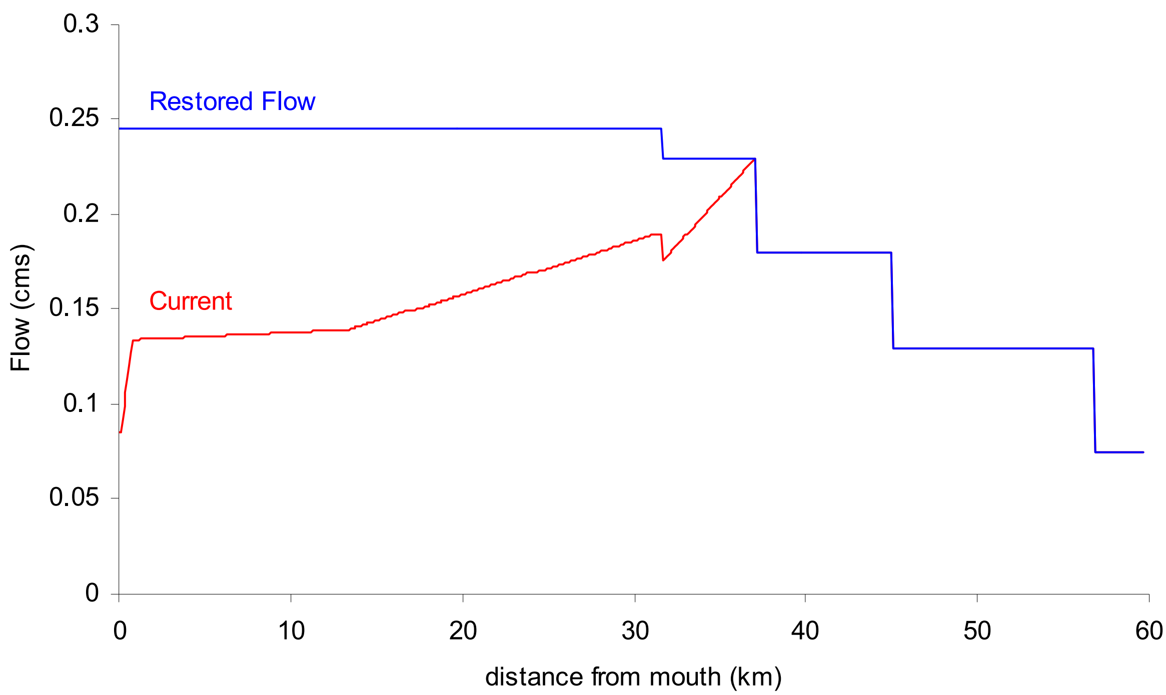
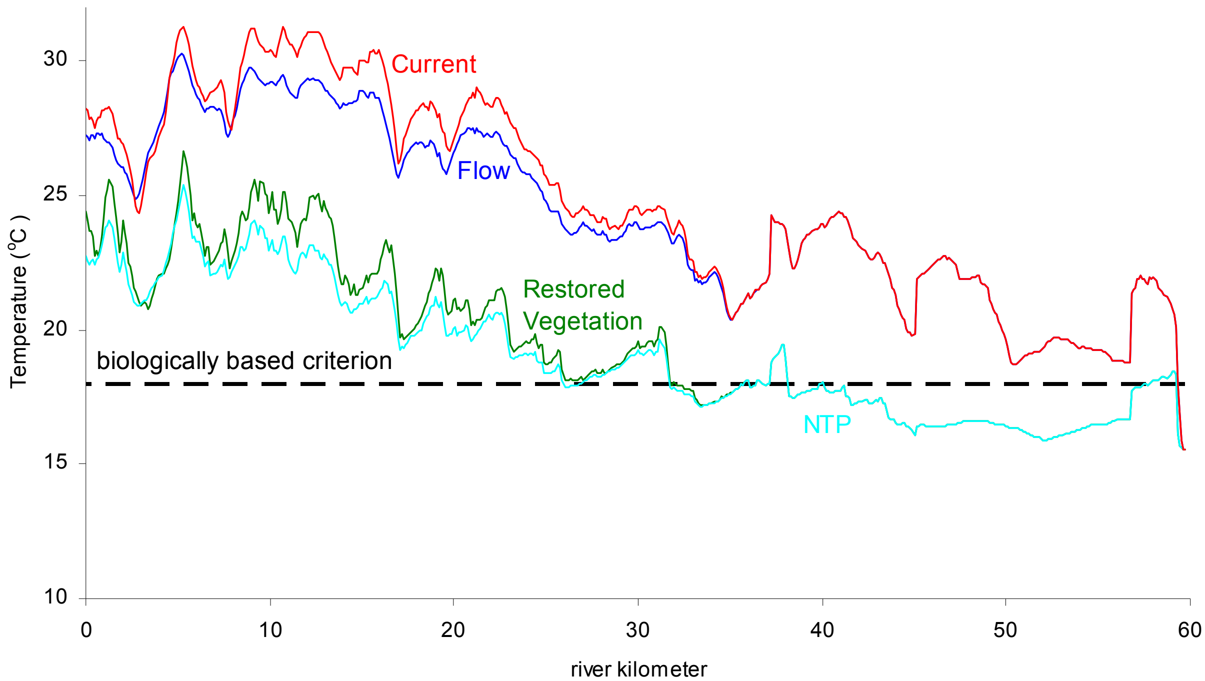


Figure B25. Predictions for Evans Creek/West Fork Evans Creek scenarios based on the maximum 7-DADM, July and August, 2003. The 'Flow' line is hidden behind the 'Current' line upstream of river km 35. Likewise, 'Restored Vegetation' is hidden behind 'NTP'.



4. SENSITIVITY ANALYSIS

The sensitivity of the Rogue River and Elk Creek model results was tested by varying individual parameters (**Figure B26 -- Figure B30**). The following different scenarios were suggested by the Rogue River TMDL technical committee.

Figure B26. Sensitivity of the maximum 7-DADM of Rogue River NTP temperatures to various headwater temperatures.

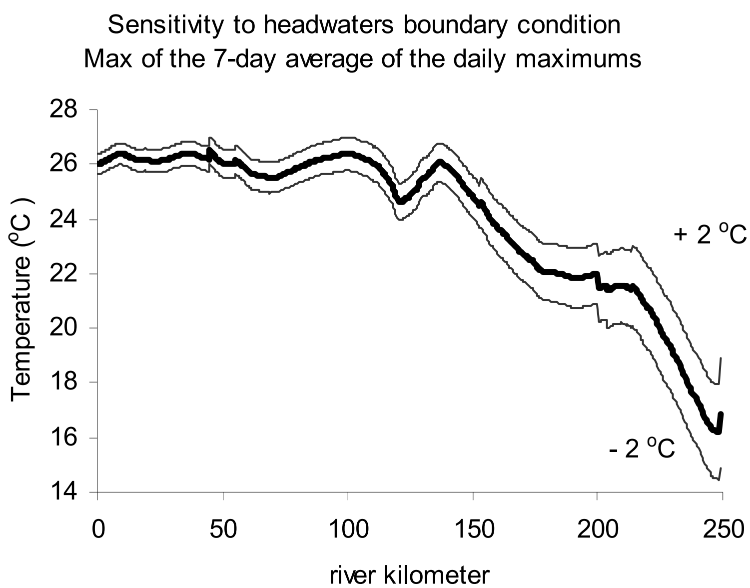


Figure B27. Sensitivity of the maximum 7-DADM of Rogue River NTP temperatures to various tributary temperatures.

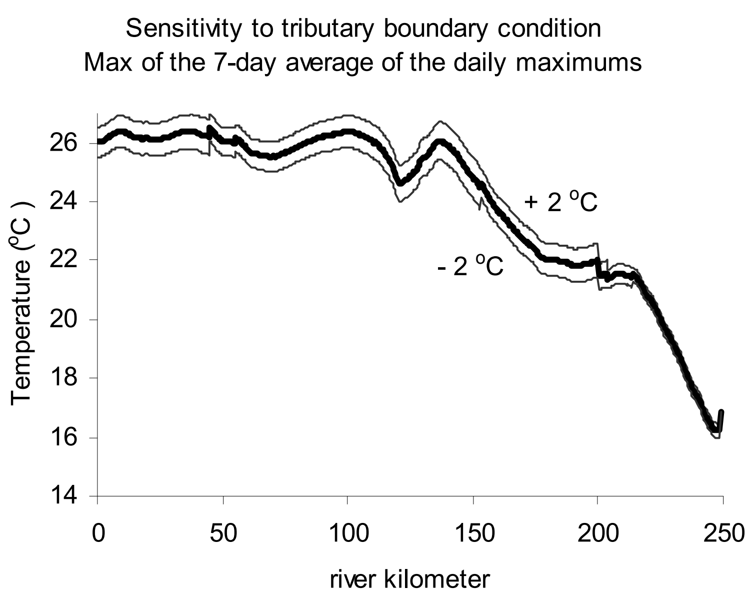
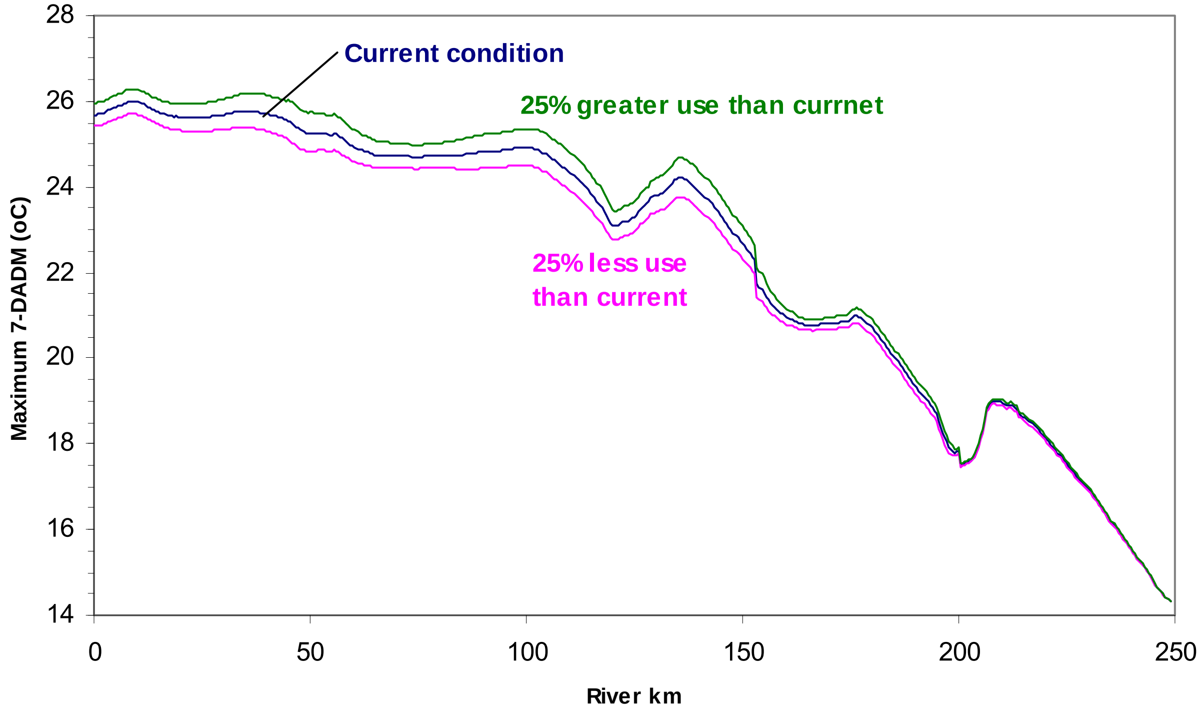
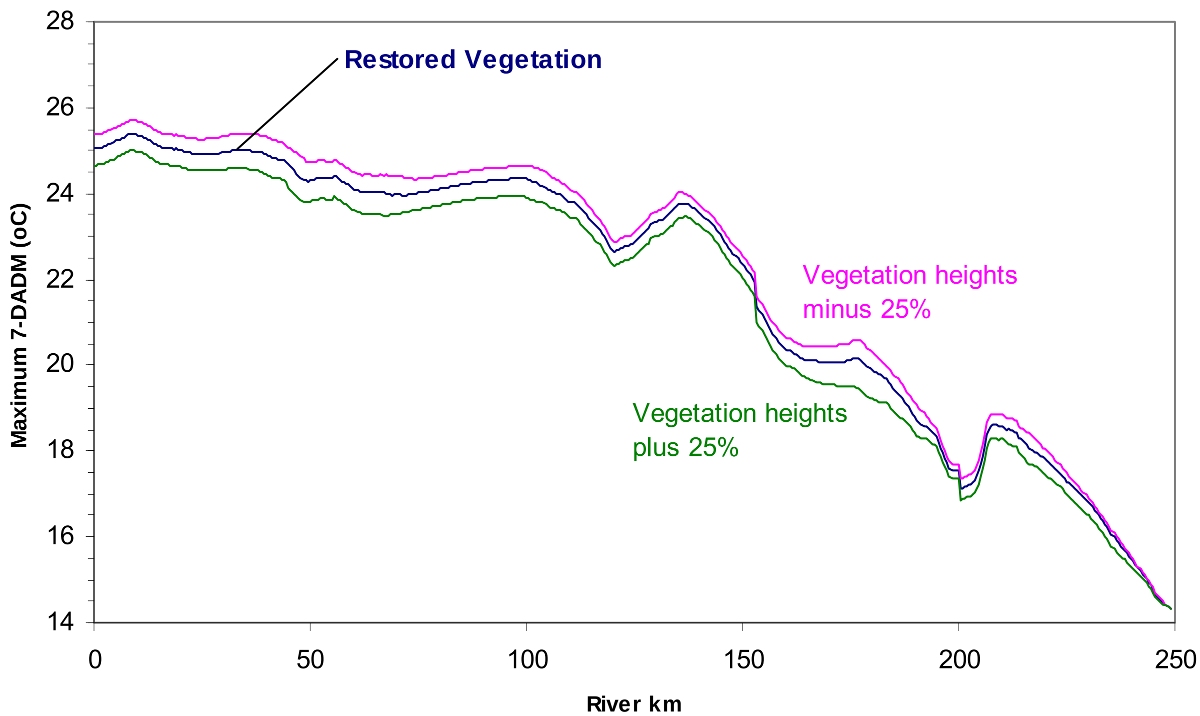


Figure B28. Sensitivity of the maximum 7-DADM of Rogue River current condition temperatures to various amounts of withdrawals.



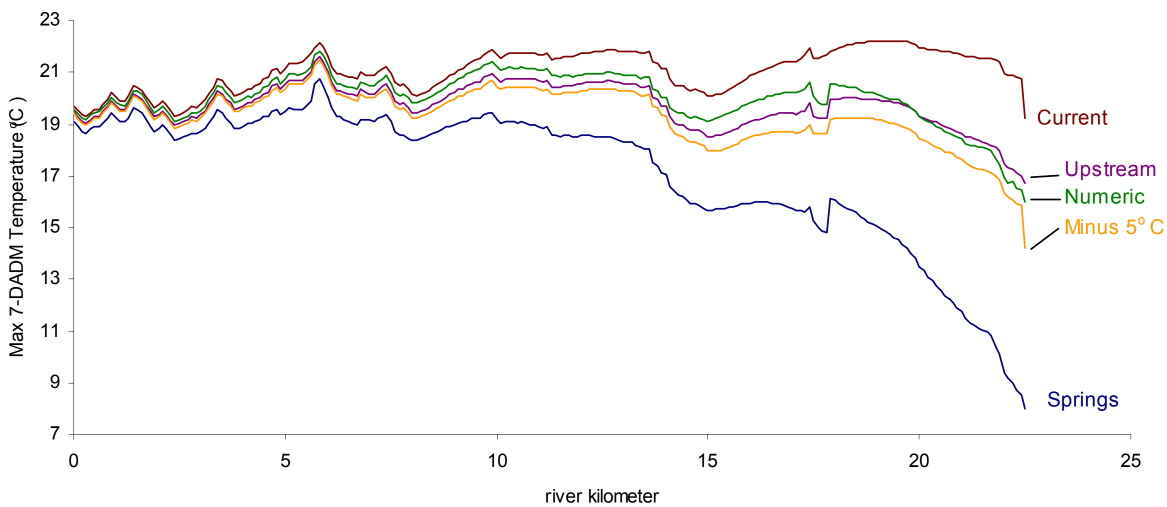
Note: The resulting flow at the mouth varied by ±3.2 cms (110 cfs).

Figure B29. Sensitivity of the maximum 7-DADM of Rogue River 'restored vegetation' temperatures to various vegetation heights.



The Elk Creek model boundary conditions were changed to reflect a range of upstream temperatures (**Figure B30**). All sensitivity scenarios were based on the NTP scenario while varying tributary and headwater temperatures. "Current" refers to setting the boundary condition temperatures set at current temperatures. "Upstream" refers to setting the boundary condition temperature to temperatures observed at a site upstream of the model reach with a less disturbed riparian area (Elk Creek at Al Serena Buzzard Mine). "Numeric" refers to setting current temperatures as the boundary condition, however the scenario caps the maximum boundary condition temperature at 16 °C, the biologically based criteria. "Minus 5 °C" scenarios used boundary condition temperatures that were derived by subtracting 5 °C from current. "Springs" refers to setting boundary condition temperatures to 8 °C, equivalent to temperatures of springs in the basin. Although the upstream temperatures of the scenarios varied by 11 °C, the downstream temperatures converged to a smaller range.

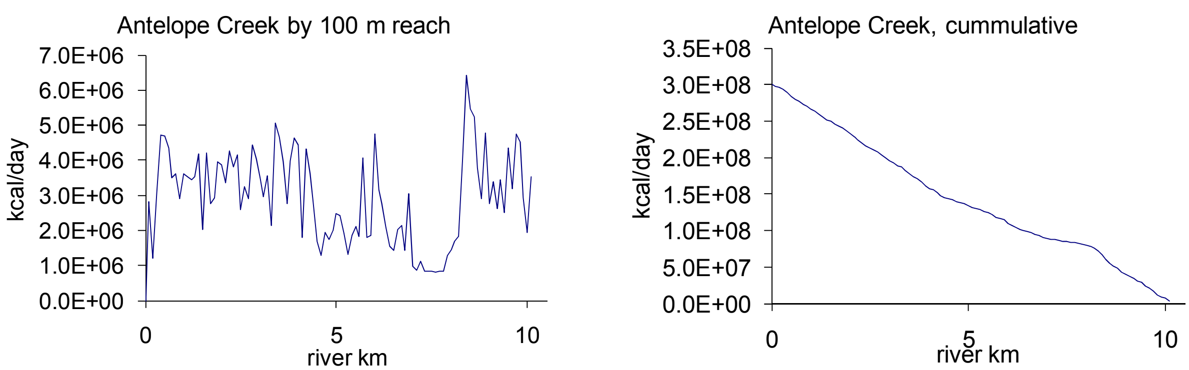
Figure B30. Sensitivity of Elk Creek NTP to variations in headwater and tributary temperatures.

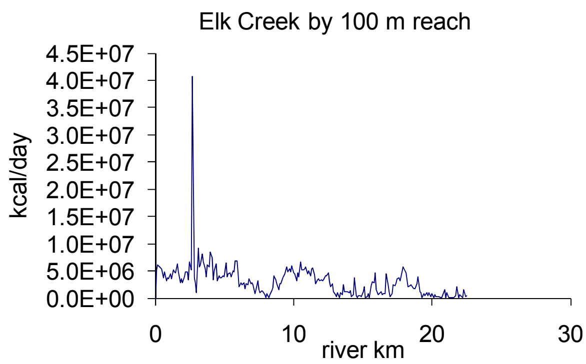


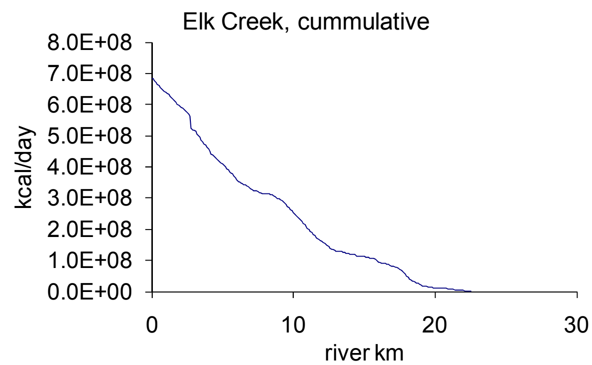
5. EXCESS SOLAR LOADS IN MODELED REACHES

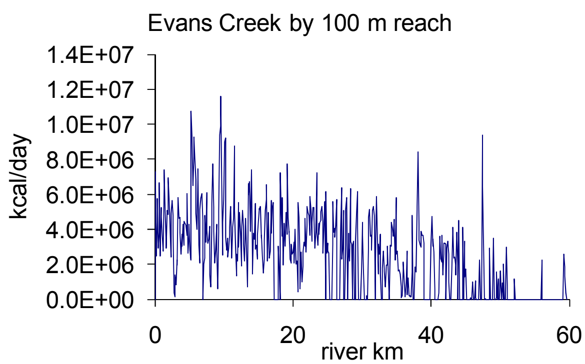
Excess solar load (time-series and cumulative) is shown in **Figure B31** for all of the impaired reaches.

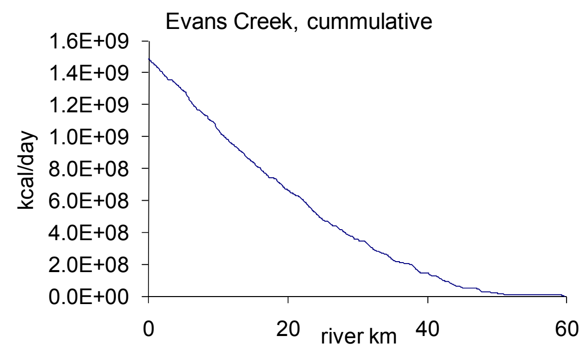
Figure B31. Excess solar load for all of the impaired reaches.

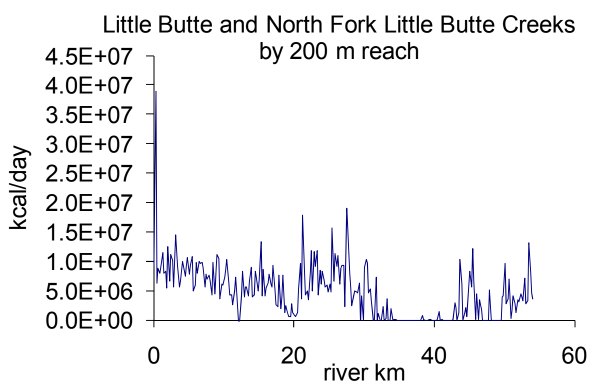


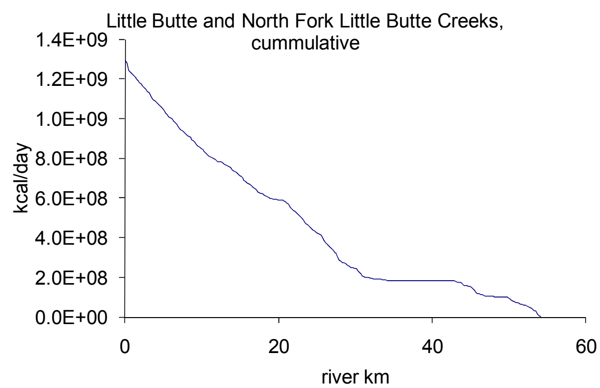

Elk Creek by 100 m reach
kcal/day
river km

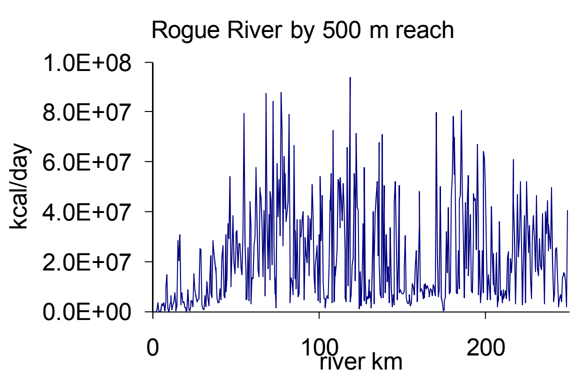

Elk Creek, cummulative
kcal/day
river km

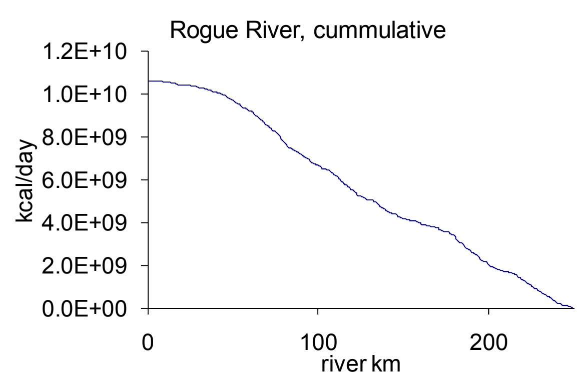

Evans Creek by 100 m reach
kcal/day
river km

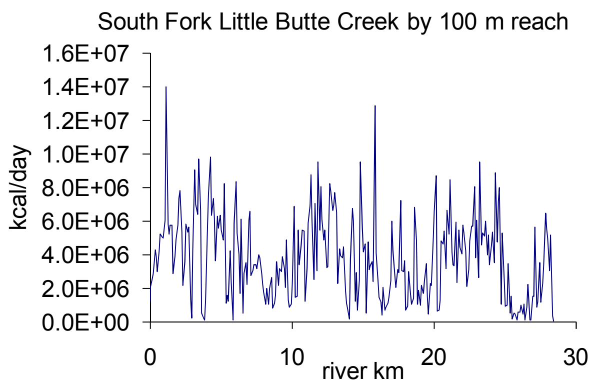

Evans Creek, cummulative
kcal/day
river km

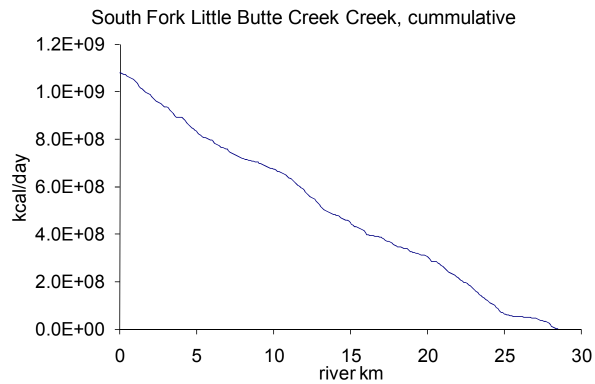

Little Butte and North Fork Little Butte Creeks
by 200 m reach
kcal/day
river km


Little Butte and North Fork Little Butte Creeks,
cummulative
kcal/day
river km


Rogue River by 500 m reach
kcal/day
river km


Rogue River, cummulative
kcal/day
river km





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