CHAPTER 12
MIDDLE DESCHUTES RIVER TEMPERATURE EVALUATION

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CHAPTER 12

MIDDLE DESCHUTES RIVER TEMPERATURE EVALUATION

12.0 Introduction

This chapter presents the results of an evaluation of river temperatures for the Middle Deschutes River. Temperature profiles for peak conditions were calculated for five flow scenarios based on modeling completed by the Oregon Department of Environmental Quality (DEQ) in 2008. The results are compared and evaluated with respect to the study objectives.

12.0.1 Purpose and Objectives

Brown and Caldwell have been retained by the City of Bend (City) to develop the City's Water Supply Alternatives Project. Task 7.5 of the project is the Middle Deschutes River Temperature Evaluation, which is documented in this chapter. The purpose of this analysis is to evaluate the effects of changes in water withdrawals on temperatures in the Middle Deschutes River. To fulfill the stated purpose, the following objectives were achieved:

- Modeling files and documentation for temperature study completed by DEQ were obtained and reviewed.
- Results for two scenarios from the DEQ study were reproduced to verify model calibration and to provide a baseline for comparison.
- Three new flow scenarios were modeled to obtain moving 7-day average of the daily maximum temperatures (7DADM) for the Middle Deschutes River.
- Peak 7DADM temperature profiles for all five scenarios (two previous plus three new) were graphed for comparison. In addition, 7DADM temperatures were compared with fish rearing temperature criteria.

12.0.2 Background

DEQ is currently developing a total maximum daily load[1] (TMDL) requirement for temperature in Tumalo Creek, Whychus Creek, Middle Deschutes River, and Upper Deschutes River[2]. The middle reach of the Deschutes River generally has lower flows and higher temperatures than the upper reach, which raises both recreational and environmental concerns. DEQ recently completed a temperature study for the subject river and stream reaches (DEQ, 2008). The 2008 study evaluated temperatures for the following two flow scenarios:

1. Calibrated conditions: 2001 (equivalent to new Scenario 1-CC).
2. Conditions proposed to meet Oregon Department of Fish and Wildlife (ODFW) instream water rights (equivalent to new Scenario 2-ODFW).

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[1]The Federal Clean Water Act requires the establishment of a TMDL for pollutants when water quality standards are not met. A TMDL is based on how much pollutant a water body can receive without exceeding water quality standards.

[2]The TMDL is specified for the "Upper Deschutes River," which is defined by DEQ as the reach from Lake Billy Chinook to the headwaters. However, for the purposes of this chapter, the river reach upstream of Lake Billy Chinook will be divided into two reaches: the *Middle Deschutes River* spanning from Lake Billy Chinook to the North Canal Dam near the City of Bend, and the *Upper Deschutes River* spanning from the North Canal Dam to the headwaters. Whychus Creek and Tumalo Creek are tributaries to the Middle Deschutes River.

The City currently utilizes surface water rights on the Deschutes River for municipal water supply. It is allowed to use up to 36.1 cubic feet per second (cfs) from Tumalo Creek and Bridge Creek (GSI, May 2007). Bridge Creek is a tributary to Tumalo Creek, which is a tributary of the Deschutes River. However, due to a variety of factors including seasonal limitations, a more reliable supply is approximately 11.7 cfs (GSI, May 2007). The City collects water from source springs above upper Tumalo Creek; a portion of this water is diverted through two steel pipes into a short canal that discharges into the top of Bridge Creek, while the remaining water flows into Tumalo Creek. The City then diverts water out of Bridge Creek at an intake facility 7 miles downstream. Water that is not diverted at the City's intake facility is returned to Tumalo Creek through Bridge Creek, which flows into Tumalo Creek approximately 16 miles upstream of the confluence of Tumalo Creek and the Deschutes River.

Figure 12-1 provides a schematic that shows the connections between Tumalo Creek and Bridge Creek, as well as other major inflows and diversions along the Middle Deschutes River. Distances labeled on the figure are river/stream stations, which represent the distance in miles along the water course measured from the outlet of the water course. For example, Tumalo creek has a stream station of 0 miles at its confluence with the Deschutes River.

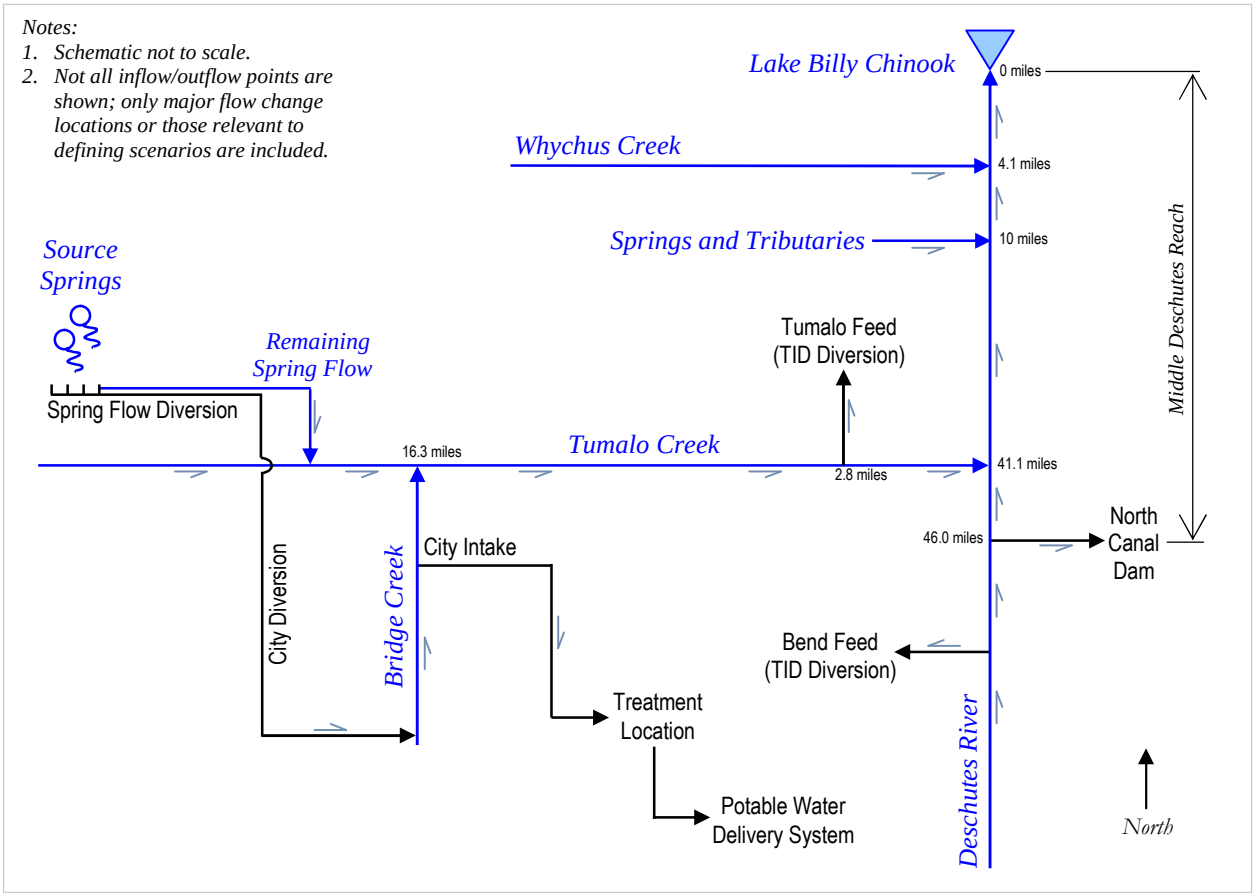

Figure 12-1. Schematic of Middle Deschutes River System and Major Diversions

Tumalo Creek flows into the Deschutes River about 4.6 miles downstream of the North Canal Dam. Therefore, inflows (and hence water withdrawals) from Tumalo Creek can influence flow rates and temperatures in the Middle Deschutes River.

The DEQ 2008 report describes several temperature-influencing parameters on the Deschutes River and its tributaries. These include water withdrawals, historical channel modifications, and near-stream disturbances

of vegetation. Water withdrawals and in-stream flow rates are of particular concern in the Middle Deschutes River because, under current conditions, most of the summertime flow is diverted for irrigation before it flows past North Canal Dam. In light of temperature concerns in the Middle Deschutes River, the City has proposed to evaluate the effects of Tumalo Creek withdrawals on temperatures in the Middle Deschutes River.

12.1 Analysis

Temperature modeling for the DEQ study was performed using Heat Source, which is a spreadsheet-based computer model developed in 1996 as a Master's thesis at the Oregon State University Department of Bioresource Engineering and Civil Engineering. Heat Source is a one-dimensional model that simulates stream thermodynamics. DEQ currently supports the Heat Source methodology for stream temperature analyses and maintains the latest version of the computer program.

12.1.1 Model Setup

The Heat Source modeling files used for the 2008 DEQ study were provided to Brown and Caldwell for use in this analysis. Brown and Caldwell reviewed the Heat Source modeling files received from DEQ. The files contained sufficient temperature, terrain, vegetation, hydrologic, and meteorological data to replicate calibrated conditions from the 2008 DEQ study and to simulate new flow scenarios. No new data were collected for this analysis.

Heat Source modeling files are divided by water course, where the results from a tributary stream are used as inputs to the main stem. Consequently, models for Tumalo Creek and the Deschutes River were run separately with the results from Tumalo Creek being used as inputs for the Deschutes River. Whychus Creek is located over 40 miles downstream from the Tumalo and Deschutes confluence, and was not validated, nor modified for any of the scenarios, as it did not affect the area of interest for this study.

12.1.2 Model Calibration and Validation

According to the 2008 DEQ report, Heat Source models for Tumalo Creek and the Deschutes River were calibrated using hourly stream temperature data, thermal infrared temperature profiles and measured stream flow parameters collected during the summer of 2001. The calibrated period of simulation covered 20 days from July 19 to August 7, 2001, which was considered the critical summertime period when stream temperatures reach their yearly maximums and aquatic life is at the greatest risk of thermal impairment. The 2008 DEQ report provides additional details regarding model calibration, assumptions, and baseline input parameters.

The calibrated current conditions scenario simulated by DEQ was re-simulated for this analysis to verify that the results within the report could be replicated. In addition, this scenario provides a baseline for comparison with other flow conditions and is included as one of the five scenarios described in the next section.

The 2008 DEQ study contained another flow scenario designed to meet Oregon Department of Fish and Wildlife (ODFW) in-stream water rights. These water rights target in-stream flows of 32 cfs for Tumalo Creek downstream of the Bridge Creek confluence, 250 cfs for the Middle Deschutes River and 650 cfs for the Upper Deschutes River. The ODFW scenario from the 2008 DEQ study was reproduced for this analysis to validate the model and to provide another scenario for comparison.

12.1.3 Modeling Scenarios

Brown and Caldwell performed simulations for five flow scenarios, each targeting a different combination of flow rates in Tumalo Creek and the Middle Deschutes River. The first two scenarios were based on reproducing results from the 2008 DEQ study as described in the previous section. Three new scenarios

were developed also to evaluate a range of flows entering the Deschutes River from Tumalo Creek. The scenarios are defined as follows:

- **Scenario 1: Calibrated Conditions (1-CC).** This scenario represents flow conditions that occurred in 2001, as shown in Figure 12-2. Tumalo Creek flows increased from 32 cfs to 46 cfs along the stream reach between the Bridge Creek confluence and the Tumalo Irrigation District (TID) diversion due to springs and tributary inflows. The Bridge Creek confluence and TID diversion are located approximately 16 miles and 3 miles upstream of the Deschutes River confluence, respectively. Over the simulation period, the average Tumalo Creek flow downstream of the TID diversion of the simulation is 9.3 cfs, which becomes inflow to the Middle Deschutes River. The average flow in the Middle Deschutes River just downstream of North Canal Dam was approximately 51 cfs.

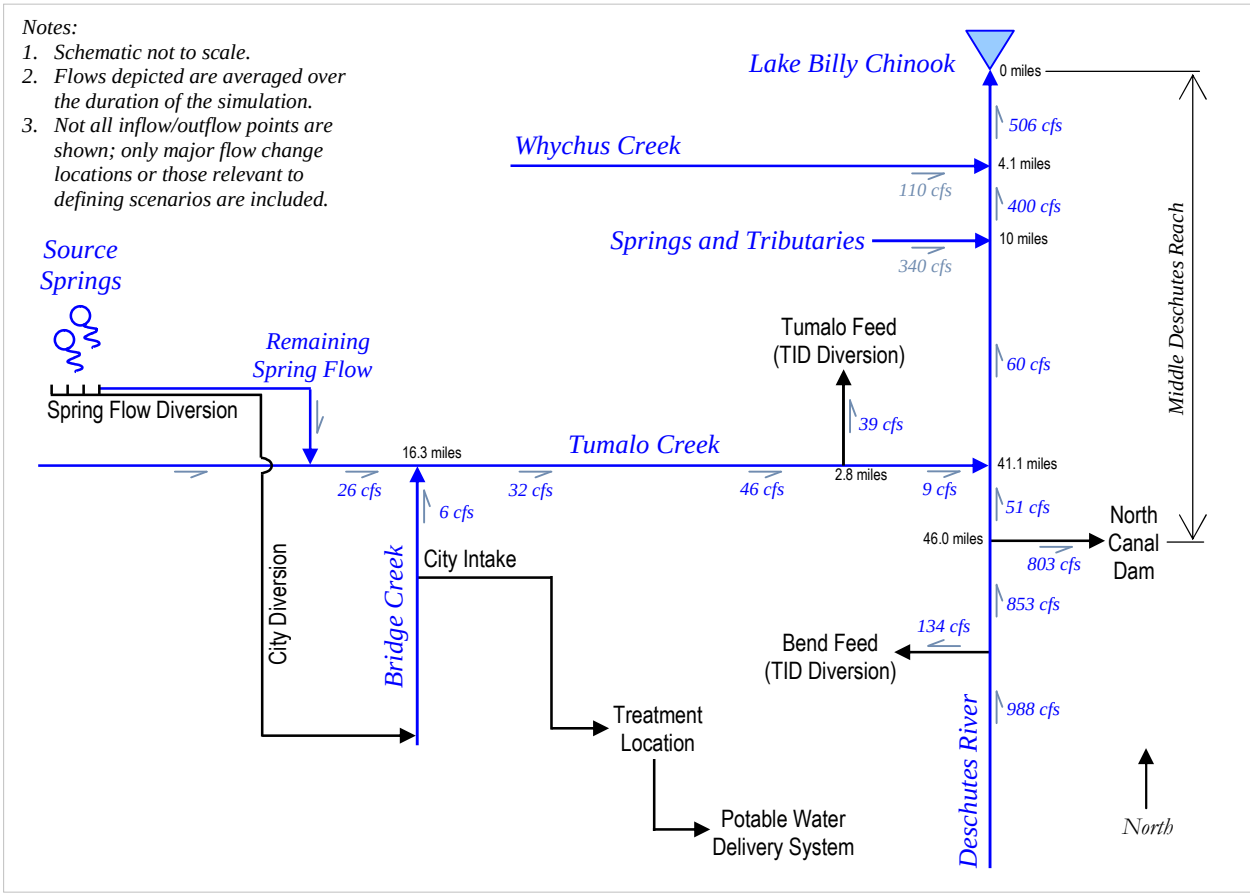

Figure 12-2. Schematic of Middle Deschutes River System and Major Inflows/Outflows for Scenario 1

- **Scenario 2: ODFW (2-ODFW).** For this scenario, changes were made to flow rates in the 1-CC scenario such that Tumalo Creek and the Middle Deschutes River would maintain target flow rates[3] based on ODFW instream water rights, as shown in Figure 12-3. The instream water rights for Tumalo Creek and the Middle Deschutes River are 32 cfs and 250 cfs, respectively.

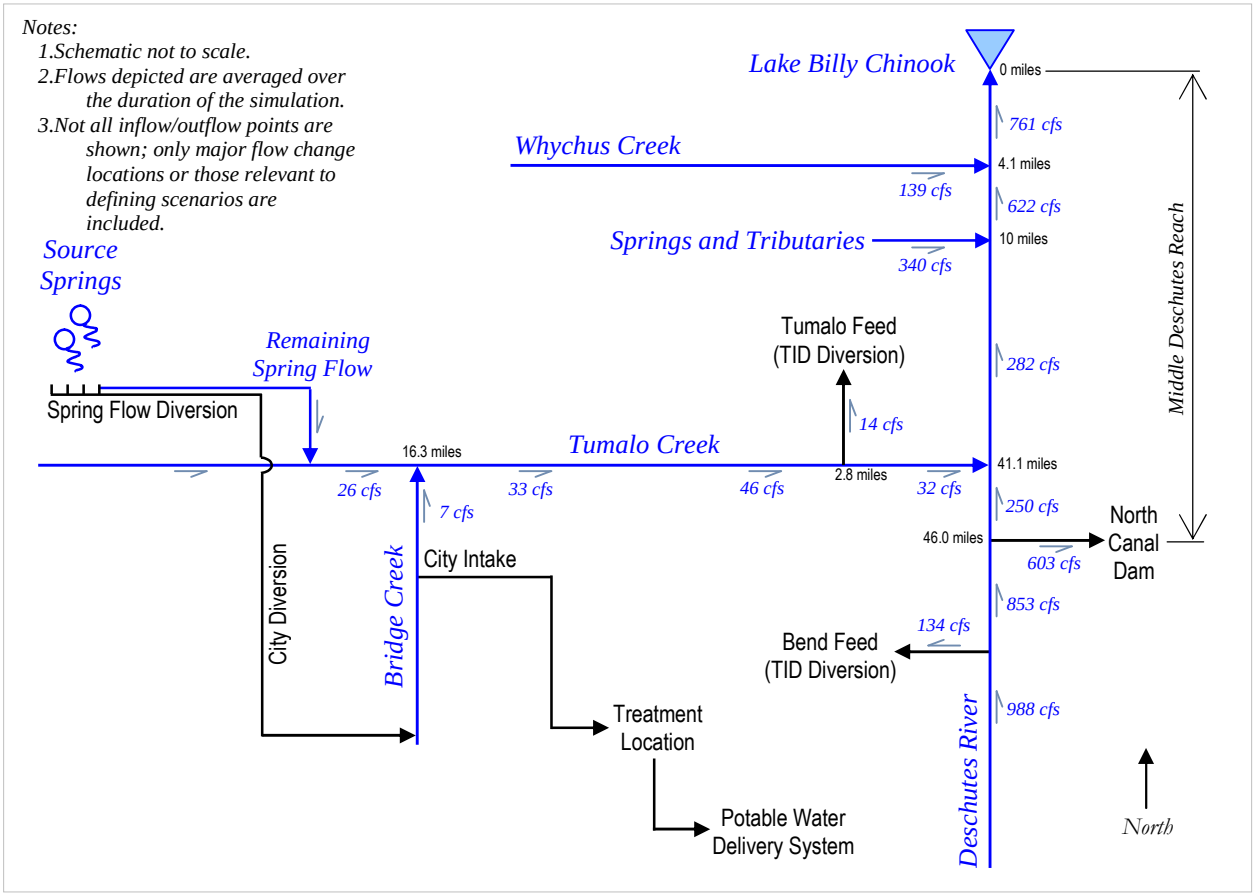

Figure 12-3. Schematic of Middle Deschutes River System and Major Inflows/Outflows for Scenario 2

[3]The phrase target flow rate refers to the desired flow rate around which flow management scenarios are developed. For Tumalo Creek the flow rate of interest is the rate that discharges into the Deschutes River. For the Middle Deschutes River, the flow rate of interest is discharge passing North Canal Dam.

- **Scenario 3: Tumalo Creek High (3-TCH).** The target flow rate for the Middle Deschutes River was changed to 130 cfs for Scenarios 3, 4 and 5, which is a moderate flow rate relative to the 1-CC and 2-ODFW scenarios. Figure 12-4 shows a schematic for Scenario 3. The Tumalo Creek target flow rate for this scenario was set at flow rate of 32 cfs, which matches the one specified in the 2-ODFW scenario to meet instream water rights.

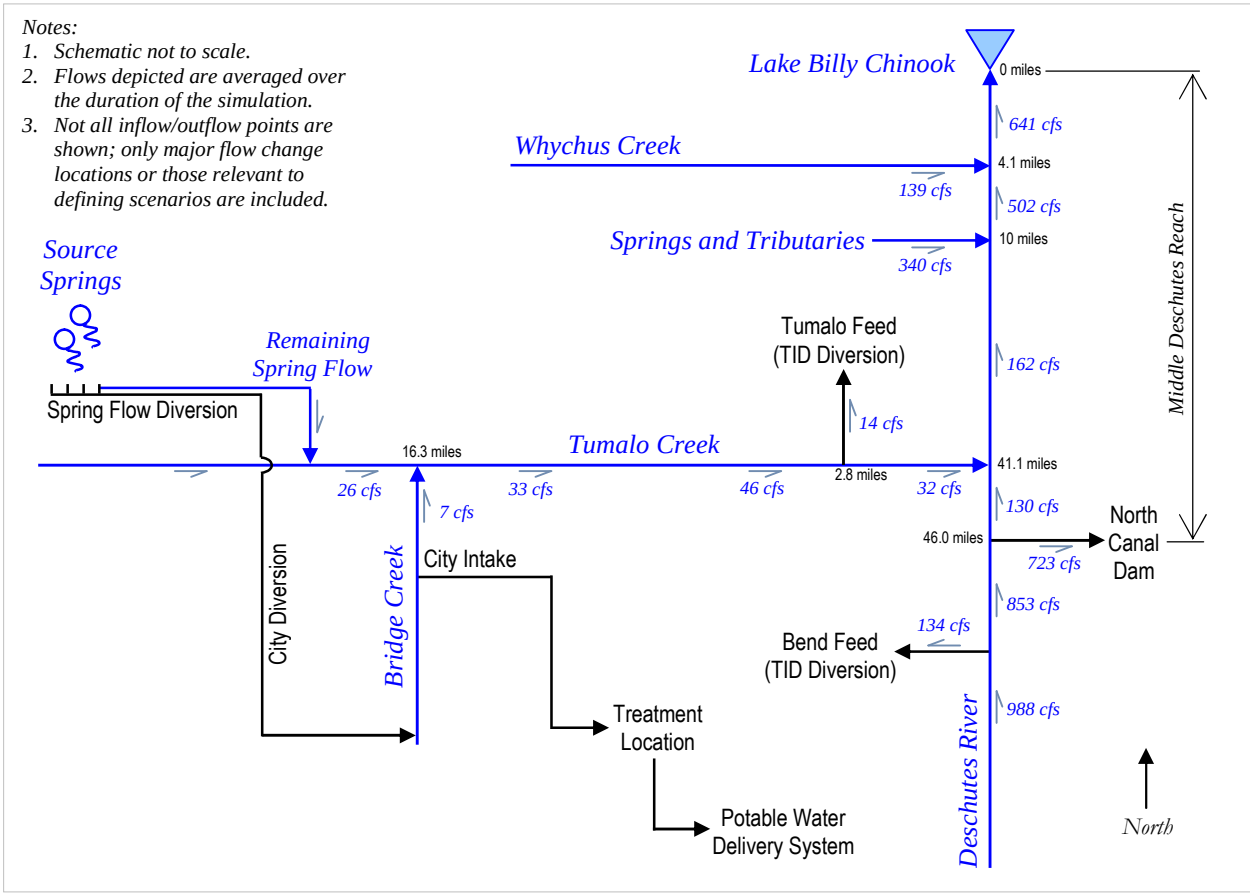

Figure 12-4. Schematic of Middle Deschutes River System and Major Inflows/Outflows for Scenario 3

- **Scenario 4: Tumalo Creek Medium (4-TCM).** For Scenario 4, the target flow rate for the Deschutes River downstream of North Canal Dam was kept at 130 cfs, but the Tumalo Creek target flow rate was reduced to 20 cfs, as shown in Figure 12-5. A target flow rate of 20 cfs in Tumalo Creek corresponds to flow goals specified by the Deschutes River Conservancy as an outcome of the Tumalo Feed Canal piping project.

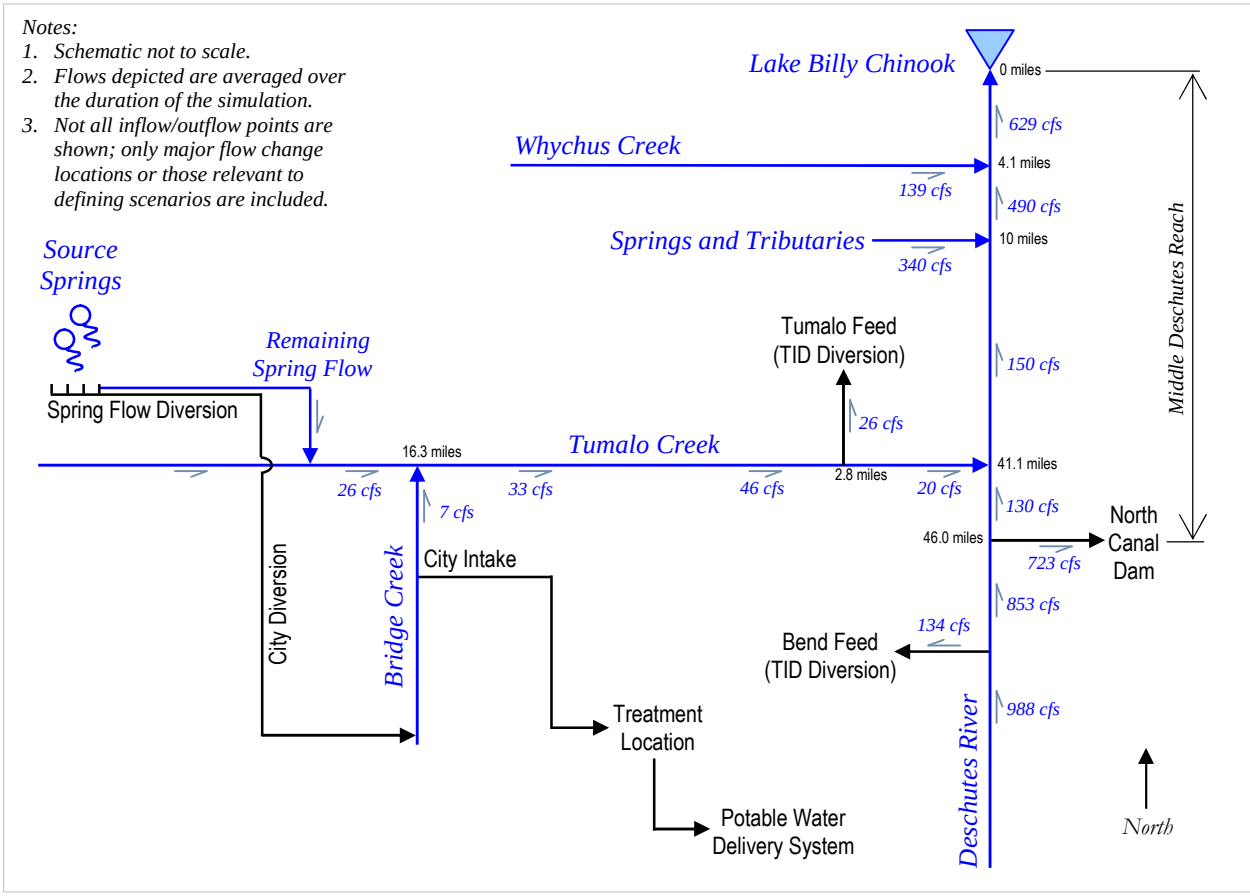

Figure 12-5. Schematic of Middle Deschutes River System and Major Inflows/Outflows for Scenario 4

- **Scenario 5: Tumalo Creek Low (5-TCL).** For Scenario 5, the Tumalo Creek target flow rate was further reduced to 10 cfs, which approximates existing conditions for Tumalo Creek, as shown in Figure 12-6. This flow rate is also approximately equal to the flow rate from Tumalo Creek in Scenario 1. Although existing conditions for Tumalo Creek are typically slightly lower than 10 cfs, this estimate takes into account other factors such as water leasing and in-stream water rights. The target flow rate for the Middle Deschutes River was kept at 130 cfs. These conditions are thought to most closely represent current summertime flow conditions.

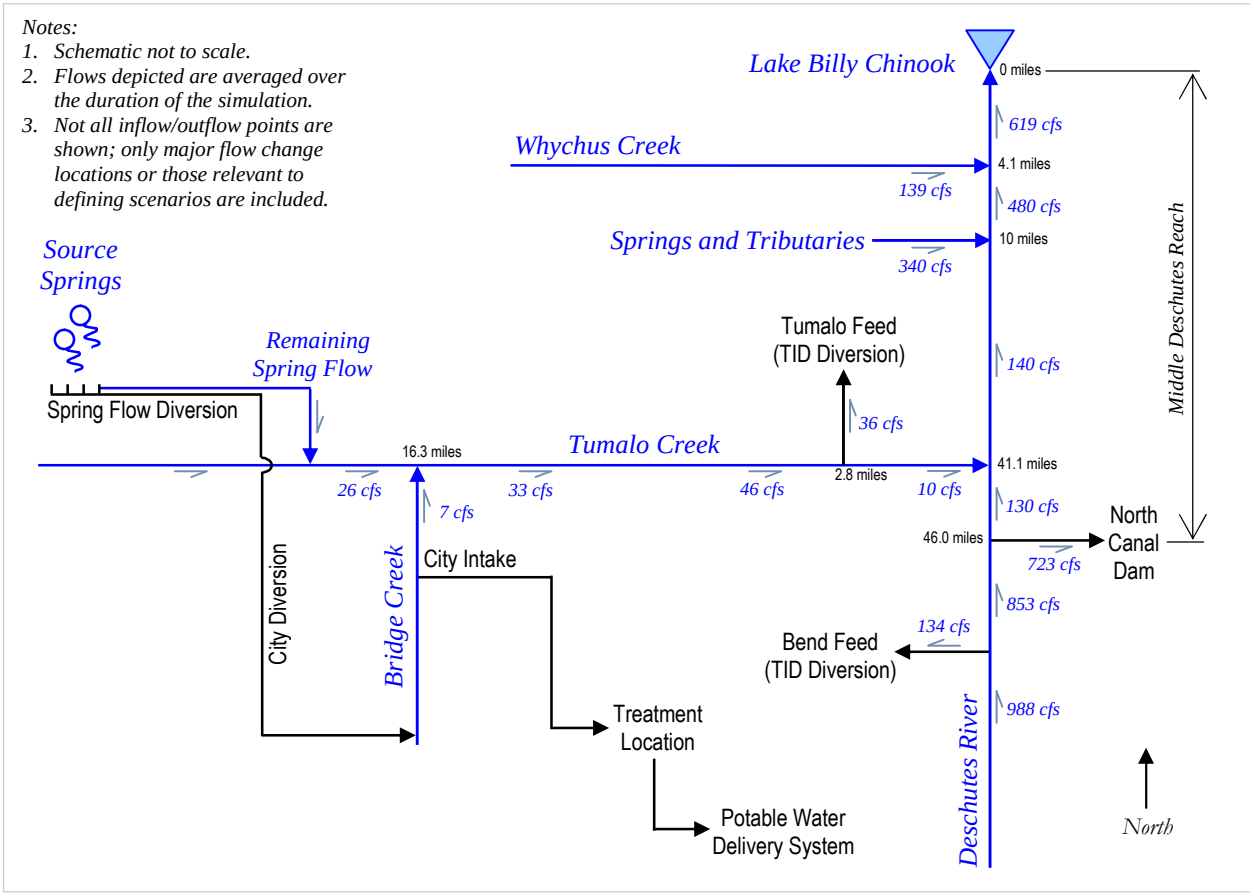

Figure 12-6. Schematic of Middle Deschutes River System and Major Inflows/Outflows for Scenario 5

To maintain target flow rates in Tumalo Creek and at the upstream end of the Middle Deschutes River, inflows and outflows had to be adjusted at the following three locations:

- **Bridge Creek Confluence at Tumalo Creek (Tumalo Creek Mile 16.3).** The confluence of Bridge Creek and Tumalo Creek is approximately 16 miles upstream of the confluence of Tumalo Creek and Deschutes River. Bridge Creek inflows are adjusted to represent changes in withdrawal rates by the City. Adjustments to withdrawal rates on Bridge Creek were used to alter Tumalo Creek flows between the Bridge Creek confluence and the TID diversion.
- **TID Diversion (Tumalo Creek Mile 2.8).** TID diverts water from Tumalo Creek approximately 3 miles upstream of the Deschutes River confluence. Diversion rates at this location are adjusted to change flows in the lowest reach of Tumalo Creek and determines the inflow rates to the Deschutes River.
- **North Canal Dam Diversion (Deschutes River Mile 46.0).** This location represents the total diversions at North Canal Dam, which is approximately 46 miles upstream of Lake Billy Chinook. Diversion rates at this location affect flow rates into the upstream end of the Middle Deschutes River reach.

A summary of flow conditions for all five scenarios is presented in Table 12- 1.

Table 12- 1. Summary of Flow Conditions for Modeling Scenarios

Flow location[1]	Description	Average[2] flows by scenario, cfs				
		1-CC	2-ODFW	3-TCH	4-TCM	5-TCL
Tumalo Creek	Tumalo Creek flow rate downstream of Bridge Creek confluence	N/A	32	32	20	10
Tumalo Creek Mile 16.3	Bridge Creek inflow to Tumalo Creek	6.0	6.7	6.7	6.7	6.7
Tumalo Creek Mile 2.8	Diversion flow to TID Canal	38.5	14.1	14.1	26.1	36.1
Tumalo Creek Outlet	Tumalo Creek flow into Deschutes River	9.3	32	32	20	10
Middle Deschutes River	Deschutes River below North Canal Dam	51	250	130	130	130
Deschutes River Mile 46.0	Diversion flow at North Canal Dam	802	603	723	723	723

[1] See Figure 12-1 for locations A, B, and C.

[2] Flows averaged over time for the 20-day simulation period.

12.2 Results and Discussion

Stream temperatures vary by time; i.e., temporally, as well as spatially along water course. Stream temperatures were first examined over time to identify the day at which temperatures were highest. The peak day was not always the same day for all points along the water course. Therefore, one specific point had to be selected to examine temperature variations over time. For this analysis, the first model node[4] located on the Deschutes River downstream of the Tumalo Creek confluence was selected (river mile 26). Figure 12-7 shows simulated hourly stream temperatures at this location for all five scenarios.

[4]The Heat Source provides only time series output at pre-specified nodes that are built into the model input. The basic structure of the model, including node locations, was not changed for this analysis. Therefore, hourly temperature data could be output only at existing model nodes.

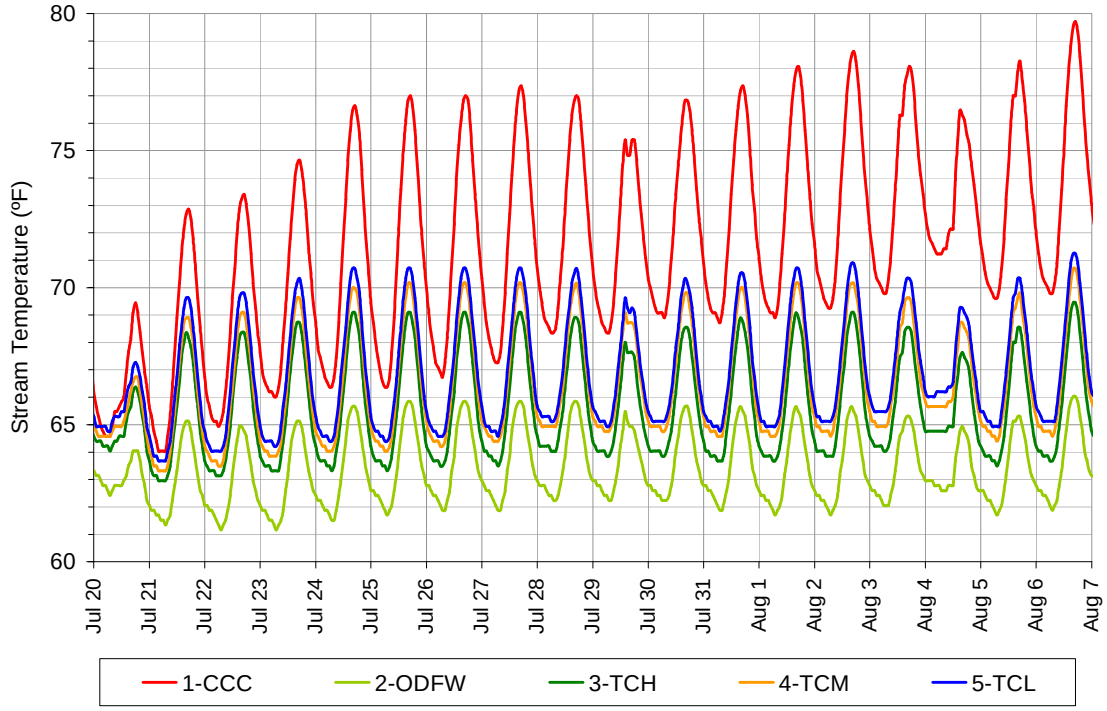

Figure 12-7. River temperatures at Mile 26 of the Middle Deschutes River over the simulation period (July 19 through August 7)

Inspection of the temperature results in Figure 12-7 finds that August 6 is the day with the highest daily maximum temperatures. Therefore, flow and temperature results for August 6 were used for further evaluation. Profile plots for all five scenarios (1-CC, 2-ODFW, 3-TCH, 4-TCM, and 5-TCL) were generated for Tumalo Creek and the Middle Deschutes River using the simulation results from August 6. Figure 12-8 and 12-9 show flow profile plots for Tumalo Creek and Middle Deschutes River, respectively. Figure 12-10 and 12-11 show 7DADM temperature profile plots for Tumalo Creek and Middle Deschutes River, respectively. Subsequent discussion of simulation results is based on conditions for August 6.

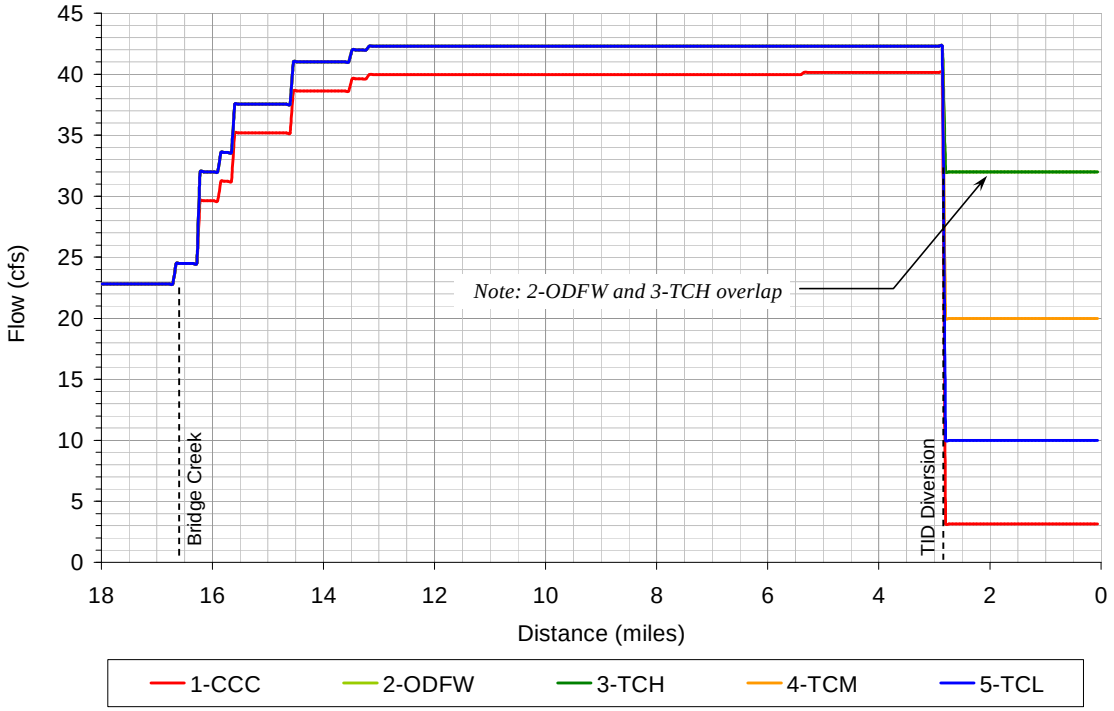

Figure 12-8. Flow profiles for Tumalo Creek (occurring on August 6)

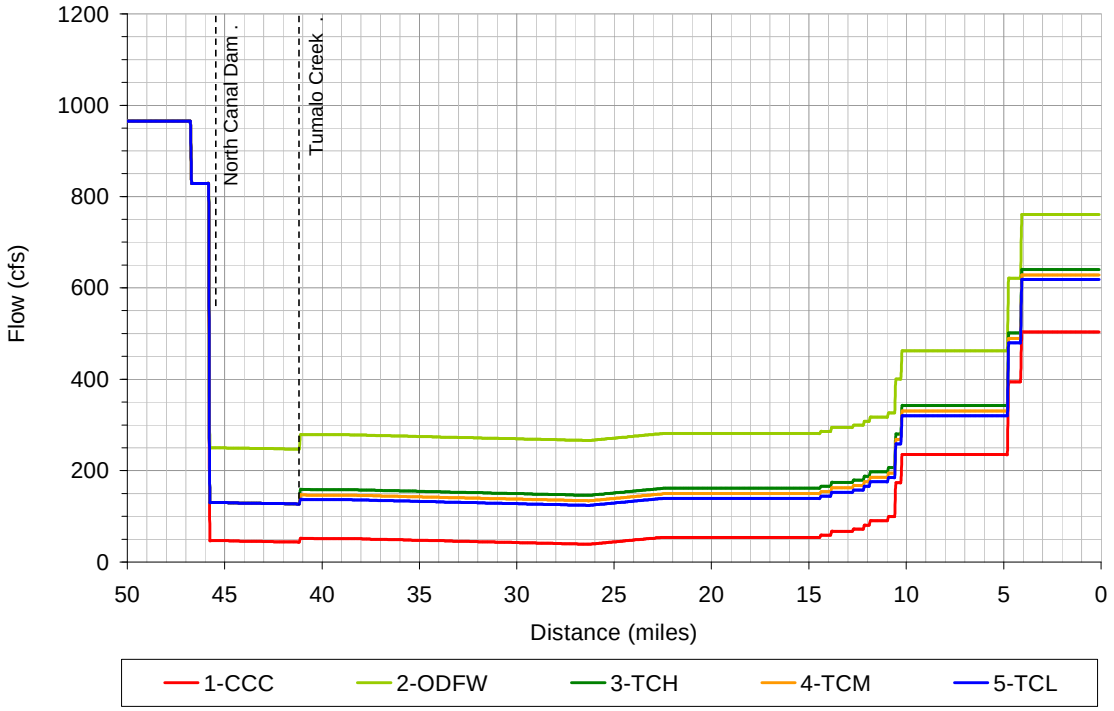

Figure 12-9. Flow profiles for the Middle Deschutes River (occurring on August 6)

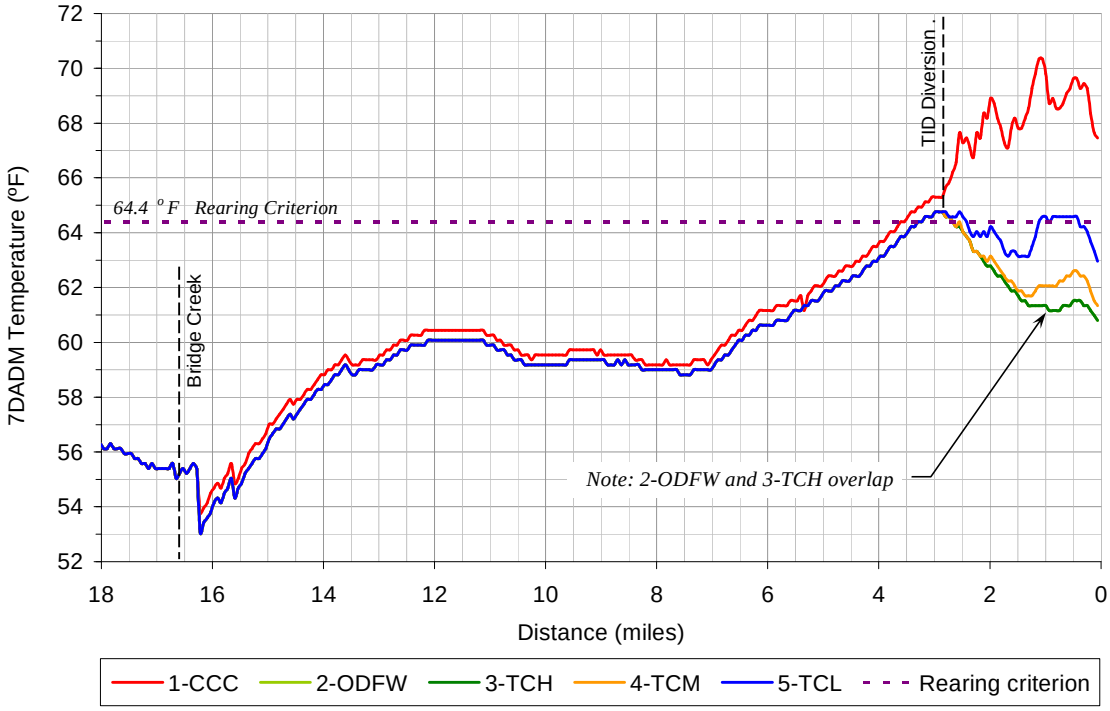

Figure 12-10. 7DADM temperature profiles for Tumalo Creek (occurring on August 6)

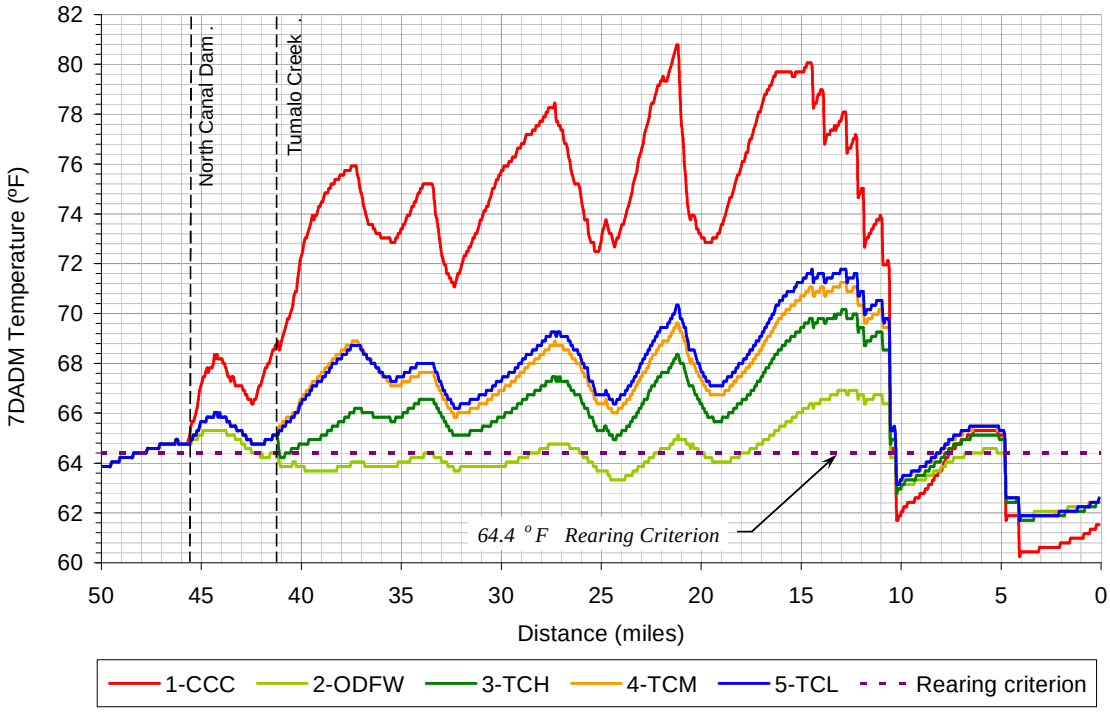

Figure 12-11. Peak 7DADM temperature profiles for the Middle Deschutes River (occurring on August 6)

7DADM is calculated as a moving average of daily maximum temperatures over 7 consecutive days. The 7DADM metric is recommended by the U.S. Environmental Protection Agency (USEPA) for developing stream temperature criteria for water quality standards in the Northwest (USEPA, 2003), and DEQ has adopted this metric for use in developing stream temperature criteria.

The 2008 DEQ report specifies a rearing and migration criterion for fish habitat of 18 degrees Celsius, which is equivalent to 64.4 degrees Fahrenheit (F). This criterion was added to Figure 12-10 and 12-11 for comparison with the temperature profiles. The temperature profiles in Figure 12-11 indicate that flow conditions for the 2-ODFW scenario are the closest to achieving the rearing and migration criterion for the Middle Deschutes River. This is expected because flows in Tumalo Creek and the Middle Deschutes River are highest for 2-ODFW.

Using 2-ODFW as a baseline, the relative effects of flow decreases can be examined. Simulation results for the 2-ODFW scenario indicate that 7DADM temperatures in the Middle Deschutes River range between 61.9 degrees F and 66.9 degrees F, and are less than the rearing criterion along approximately 68 percent of the river reach (~30 miles). The average daily maximum temperature in the Middle Deschutes River for the 2-ODFW scenario is 64.3 degrees F, which is slightly lower than the rearing criterion. A summary of simulated temperature results for all five scenarios is presented in Table 12-2.

Table 12-2. Summary of simulated 7DADM temperatures in the Middle Deschutes River (August 6)

Parameter	1-CC	2-ODFW	3-TCH	4-TCM	5-TCL
Highest 7DADM temperature[1] degrees F	80.8	66.9	70.2	71.2	71.8
Lowest 7DADM temperature[2] degrees F	60.3	61.9	61.7	61.7	61.7
Average 7DADM maximum temperature[3] degrees F	71.6	64.3	65.8	66.7	67.0
Average increase[4] from 2-ODFW degrees F	7.4	--	1.6	2.5	2.7
Percentage of river reach below 64.4 degrees F	17	68	17	15	15

[1] Highest 7DADM temperature at any single location along the Middle Deschutes River.
[2] Lowest 7DADM temperature at any single location along the Middle Deschutes River.
[3] 7DADM temperatures averaged spatially over the length of the Middle Deschutes River reach (used for comparison).
[4] Increase in 7DADM temperatures when compared with the 2-ODFW scenario; averaged spatially over the length of the Middle Deschutes River.

The greatest difference in temperatures is found between scenarios 2-ODFW and 1-CC, where daily maximum temperatures in the Middle Deschutes River increased by an average of 7.4 degrees F. This increase is caused by substantially less flow in both Tumalo Creek and the Middle Deschutes River.

Average daily maximum temperatures in the Middle Deschutes River increase by an average of 1.6 degrees F when flow passing the North Canal Dam is decreased from 250 cfs to 130 cfs, which is the only flow change between scenarios 2-ODFW and 3-TCH.

When holding the flow rate at the upstream end of the Middle Deschutes River constant at 130 cfs, decreases in Tumalo Creek inflows from 32 cfs to 20 cfs to 10 cfs cause the average daily maximum temperature in the Middle Deschutes River to increase from 65.8 degrees F to 66.7 degrees F to 67.0 degrees F, which equates to incremental increases of 0.9 degrees F and 0.3 degrees F (see results for 3-TCH, 4-TCM and 5-TCL).

12.3 Conclusions and Recommendations

The Heat Source temperature models provided by DEQ provided a basis for analyzing flow management alternatives for Tumalo Creek and evaluating impacts to stream temperatures in the Middle Deschutes River. Results from the previous study were reproduced to validate the models and to provide baseline conditions from which new flow scenarios could be simulated and compared. In addition, three new flow scenarios were developed to evaluate changes in Tumalo Creek inflows to the Middle Deschutes River.

The flow scenario representing calibrated conditions (1-CC) produced the highest stream temperatures in the Middle Deschutes River. Modifications to flow conditions for the other four scenarios produced markedly lower temperatures. The greatest decreases can be seen when comparing scenarios 1-CC and 2-ODFW. As expected, the ODFW scenario is most optimal to fish. Scenarios 3-TCH, 4-TCM and 5-TCL also produced lower temperatures, but in general terms, the decrease was only about two-thirds that of scenario 2-ODFW. Variations in stream temperature between scenarios 3-TCH, 4-TCM and 5-TCL were relatively small when compared to the decreases from 1-CC.

Comparing all five scenarios, it can be shown that increasing flow in Tumalo Creek decreases temperatures in the Middle Deschutes River. In the same manner, increases in flow passing North Canal Dam decreases temperatures in the Middle Deschutes River. The relative impacts between Tumalo Creek inflows and water passing North Canal Dam were not evaluated explicitly. However, 7DADM temperature graphs indicate that Tumalo Creek inflows generally have lower temperatures than water passing North Canal Dam.

The following are recommendations for further study:

- Additional flow scenarios could be analyzed to evaluate the relative impacts of Tumalo Creek inflows versus water passing North Canal Dam. To accomplish this, a range of Tumalo Creek inflows would be simulated for each of several different Deschutes River flows. Flow rates would be based on applicable ranges of withdrawals. Incremental decreases in stream temperature caused by Tumalo Creek inflows would be weighed against the incremental benefits of maintaining higher flows in the Deschutes River.
- Additional flow management alternatives could be evaluated for Tumalo Creek. Temperatures in Tumalo Creek are affected by the location at which flows are added or removed. For the analysis in this chapter, Tumalo Creek flows reaching the Deschutes River were increased by decreasing TID diversions.
- The impacts of return flows at other locations along the Deschutes River should be evaluated. As noted in Figure 12-6, significant temperature swings occur at several points along the river. If these swings are associated with return flows, then there may be an opportunity to identify ways to influence the impacts of these flows.
- Input data and assumptions from the original Heat Source analysis completed for the 2008 DEQ study could be examined in more detail. For example, sensitivity analyses could be conducted to evaluate input parameters that have a high level of uncertainty.
- The levels of uncertainty associated with the temperature results should be evaluated statistically.

12.4 References

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