Upper Deschutes Watershed Council

Water Quality Monitoring Program

2011 Technical Report

Instream Flow Restoration and Temperature Responses

Middle Deschutes River, Deschutes Basin, Oregon

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EXECUTIVE SUMMARY

Since 1996, the Deschutes River Conservancy (DRC) has engaged in efforts to restore summer streamflow in the middle Deschutes River and lower Tumalo Creek through a variety of techniques, including conservation, leasing, and acquisition. The DRC has identified streamflow restoration in the Deschutes River and Tumalo Creek as a priority because summer flows have historically been very low, resulting in summer water temperatures that exceed the Oregon Department of Environmental Quality (ODEQ) standard established to protect salmon and trout rearing and migration.

To evaluate the effectiveness of streamflow restoration efforts, the DRC, its funders, and other partners have been interested in tracking 1) whether specific streamflow restoration actions have reduced water temperatures in downstream reaches of the river and 2) whether reductions in temperature, if observed, can be attributed to streamflow restoration projects. Since 2008 the DRC has partnered with the Upper Deschutes Watershed Council (UDWC) to conduct temperature monitoring to investigate potential temperature changes associated with streamflow restoration projects. This ongoing monitoring effort incorporates data collected from 2001 to 2011 to address the following key questions:

1) Temperature status: What is the status of water temperatures in the middle Deschutes River relative to the state of Oregon standard?

   We found temperatures downstream of Bend to consistently rise above the state standard of 18°C / 64°F set to protect salmon and trout rearing and migration, consistent with the existing Clean Water Act Section 303(d) listing for temperature impairment along the Deschutes River. However, during July 2011, flows downstream of Tumalo Creek remained above 200 cfs for more than six days for the first time since 2001, with corresponding temperatures at or below 18°C. And, while summer temperatures at Lower Bridge Road continue to exceed the state standard, we have observed them steadily decreasing since 2001. These data suggest that higher flows resulting from streamflow restoration are producing temperatures that meet or are very close to the state standard at some sites, but that still higher flows, and additional streamflow restoration, will be required to meet the 18°C standard at the most impaired sites. Until these flows are achieved, temperature data suggest that the middle Deschutes River will continue to exceed the state temperature standard during the summer months.

2) Restoration effectiveness: Have increases in streamflow effectively reduced water temperatures?

   Restoration effectiveness analysis indicates that temperatures have changed in middle Deschutes River restoration reaches in direct response to the effects of streamflow restoration. Streamflow restoration efforts initiated in 2005 have incrementally increased flows in the middle Deschutes River. Although from 2007 to 2008 one of two restoration reaches warmed in response to streamflow restoration, since 2008 temperatures in both restoration reaches have cooled or remained constant in response to increased flows.

Increased flows in the middle Deschutes River resulting from streamflow restoration at North Canal Dam and in Tumalo Creek thus produced a net warming in one year but have resulted in net cooling or no change in July temperatures along the middle Deschutes River from one year to the next from 2008 to 2011. Direction (warming or cooling) and magnitude of the temperature response may depend in part on the relative streamflow contribution of the Deschutes at North Canal Dam and Tumalo Creek at the confluence with the Deschutes.

3) <u>Target streamflow</u>: What is the estimated streamflow needed to meet the 18°C / 64°F State of Oregon temperature standard for salmon and trout rearing and migration?

   We used data from 2001 to 2011 to evaluate this question for two locations on the middle Deschutes River: a) downstream of Tumalo Creek near the site of instream flow restoration, and b) at Lower Bridge Road 30 miles downstream of flow restoration sites.

   a) <u>Deschutes River downstream of Tumalo Creek</u>: How much instream flow do we need in the Deschutes River downstream of Tumalo Creek to reduce water temperatures to meet state standards? Based on a temperature-flow regression of data from 2001-2011, flows of 206 cfs are needed to reduce temperatures to meet the 18°C state standard in July. Temperatures recorded at similar flows support this estimate.

   b) <u>Deschutes River at Lower Bridge Road</u>: How much instream flow do we need at Lower Bridge Road to reduce water temperatures to meet state standards? The temperature-flow relationship observed at Lower Bridge Road appears to suggest temperatures continuing to cool as flows increase above 171 cfs, the highest flow for which enough data was available for analysis. However, applying this relationship to predict temperatures beyond the observed range of flows introduces substantial uncertainty.

Temperatures thus remain elevated in the middle Deschutes River, exceeding the state standard and potentially compromising rearing and migration habitat for salmon and trout, but showed substantial improvement with higher flows in July 2011. Cooling trends observed in two out of the last three years in both the Deschutes and Tumalo restoration reaches document the effects of streamflow restoration, and a stronger response observed in the Tumalo restoration reach suggests that cold Tumalo Creek flows increase the cooling effect downstream of the confluence of Tumalo Creek and the Deschutes River. Downstream of Tumalo Creek at DR 160.00, flows as low as 206 cfs result in temperatures that meet or are less than the 18°C state standard. The temperature-flow relationship for Lower Bridge Road at DR 133.50 documents temperatures cooling to the highest observed flow of 171 cfs. Until flows of 250 cfs occur over enough days to produce the minimum number of temperature observations required, the relationship between temperature and flow at this level, and the resulting temperature predicted at 250 cfs, will remain speculative. Collaboration between restoration partners to implement a flow release of 250 cfs over 16 days would provide the necessary data to predict stream temperature at this volume. Conducting studies that evaluate relationships between increased streamflow, temperature, fish population response and fish habitat use, such as the upcoming ODFW study to be implemented in summer 2012, will also contribute substantially to the ability of restoration partners to identify a flow target that maximizes the ecological benefits of streamflow restoration for fish and the middle Deschutes River ecosystem.

ACKNOWLEDGMENTS

Deschutes River Conservancy provided funding in support of research and analyses that form the basis for this report. Water quality monitoring conducted by Upper Deschutes Watershed Council is funded in large part by the Oregon Watershed Enhancement Board and the Oregon Department of Environmental Quality (ODEQ) 319 Grant Program; their generous support has been instrumental in the data collection and analysis informing this report. Monitoring by the City of Bend, ODEQ, Oregon State University (OSU), Oregon Water Resources Department (OWRD), and DRC has contributed invaluable data to this long-term effort. Many thanks to members of the Water Quality Committee and contributing partners who provided expertise, insight, and time in support of the development of the UDWC Water Quality Monitoring Program from which the data and analyses included here emerged. Special thanks to Lesley Jones who spearheaded and grew the UDWC Water Quality Monitoring Program to produce rigorous statistical analyses of the effects of streamflow restoration on temperature.

ABBREVIATIONS

<u>Organizations</u>

DRC	Deschutes River Conservancy
UDWC	Upper Deschutes Watershed Council
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
OWRD	Oregon Water Resources Department

<u>Terminology</u>

°C	Degree Celsius
°F	Degree Fahrenheit
7DMAX	Seven Day Moving Average Maximum
BACI	Before After Control Impact
df	Degrees of freedom
CI	Confidence interval
CL	Confidence level
cfs	Cubic feet per second
Ln	Natural logarithm
OAR	Oregon Administrative Rules
PBACI	Paired Before After Control Impact
QA/QC	Quality assurance / quality control
QD	Average daily flow
S	Standard distance from regression line
StDev	Standard deviation from mean
TMDL	Total Maximum Daily Load

1. Introduction

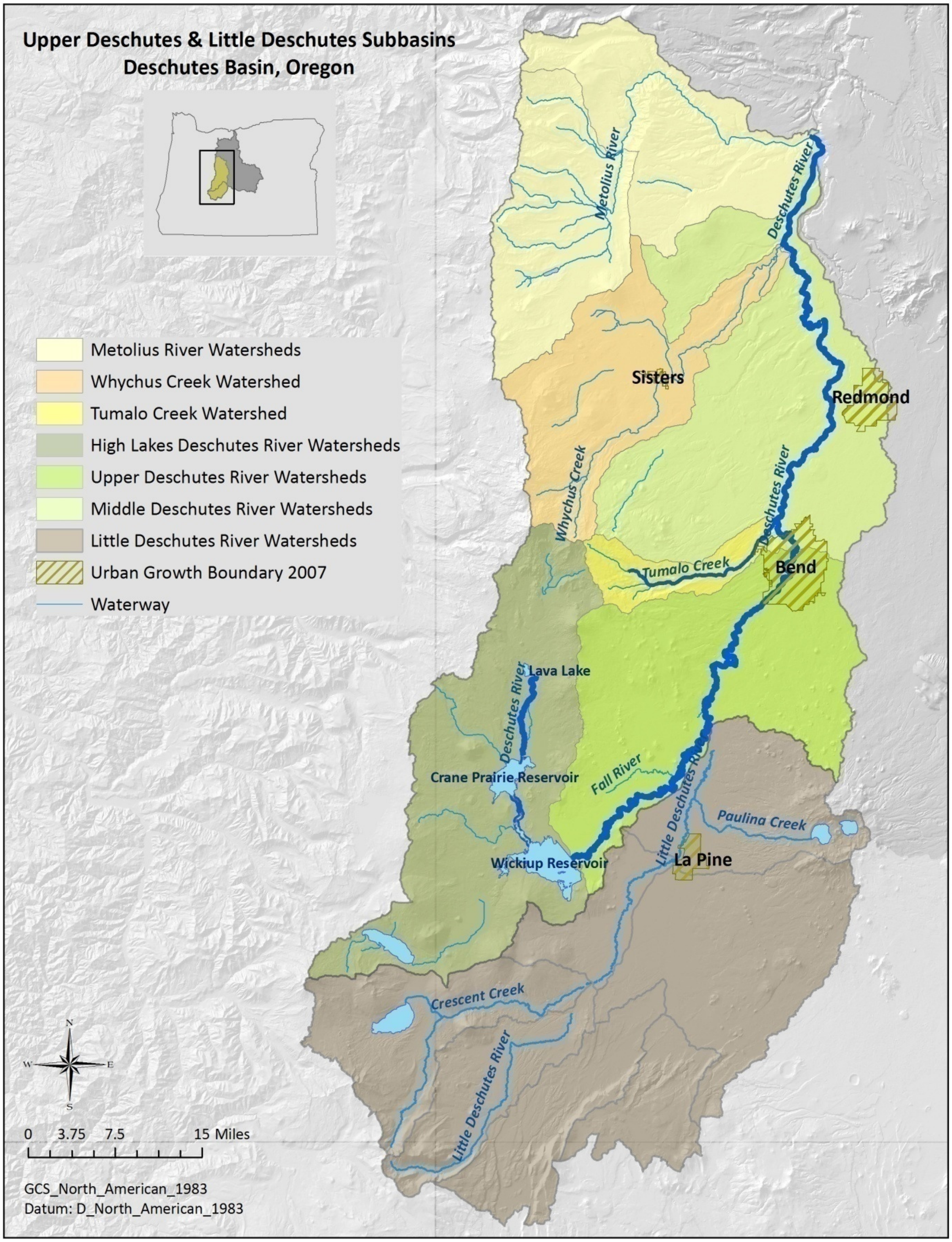
The middle Deschutes River Watershed is located within the Deschutes Basin, Oregon, and is bordered by the Metolius River, Whychus Creek, Tumalo Creek, and Upper Deschutes River watersheds (**Map 1**). The middle Deschutes River is listed as a temperature impaired waterway under Clean Water Act Section 303(d) for not meeting State of Oregon water temperature standards for salmon and trout rearing and migration (**Map 2**).

Since 1996, the Deschutes River Conservancy (DRC) has engaged in efforts to restore summer streamflow in the middle Deschutes River and lower Tumalo Creek. Through a variety of techniques, including conservation, leasing, and acquisition, the DRC has successfully negotiated more than 150 cubic feet per second (cfs) of streamflow protected in-stream for the middle Deschutes River and more than 10 cfs for Tumalo Creek. As a result, July median average daily streamflow has increased from 5 cfs in 2001 to 56 cfs in 2011 at the mouth of Tumalo Creek, and from 48 cfs in 2001 to 151 cfs in 2011 in the Deschutes River at North Canal Dam below Bend, OR (Figure 1). Combined, streamflow restoration efforts at each of these locations have contributed to a 178 cfs increase in middle Deschutes River July median average daily flows, from 53 cfs in 2001 to 231 cfs in 2011[1]. DRC has prioritized streamflow restoration in these reaches because historically low summer flows have resulted in summer water temperatures that exceed the Oregon Department of Environmental Quality standard of 18°C / 64°F established to protect salmon and trout rearing and migration.

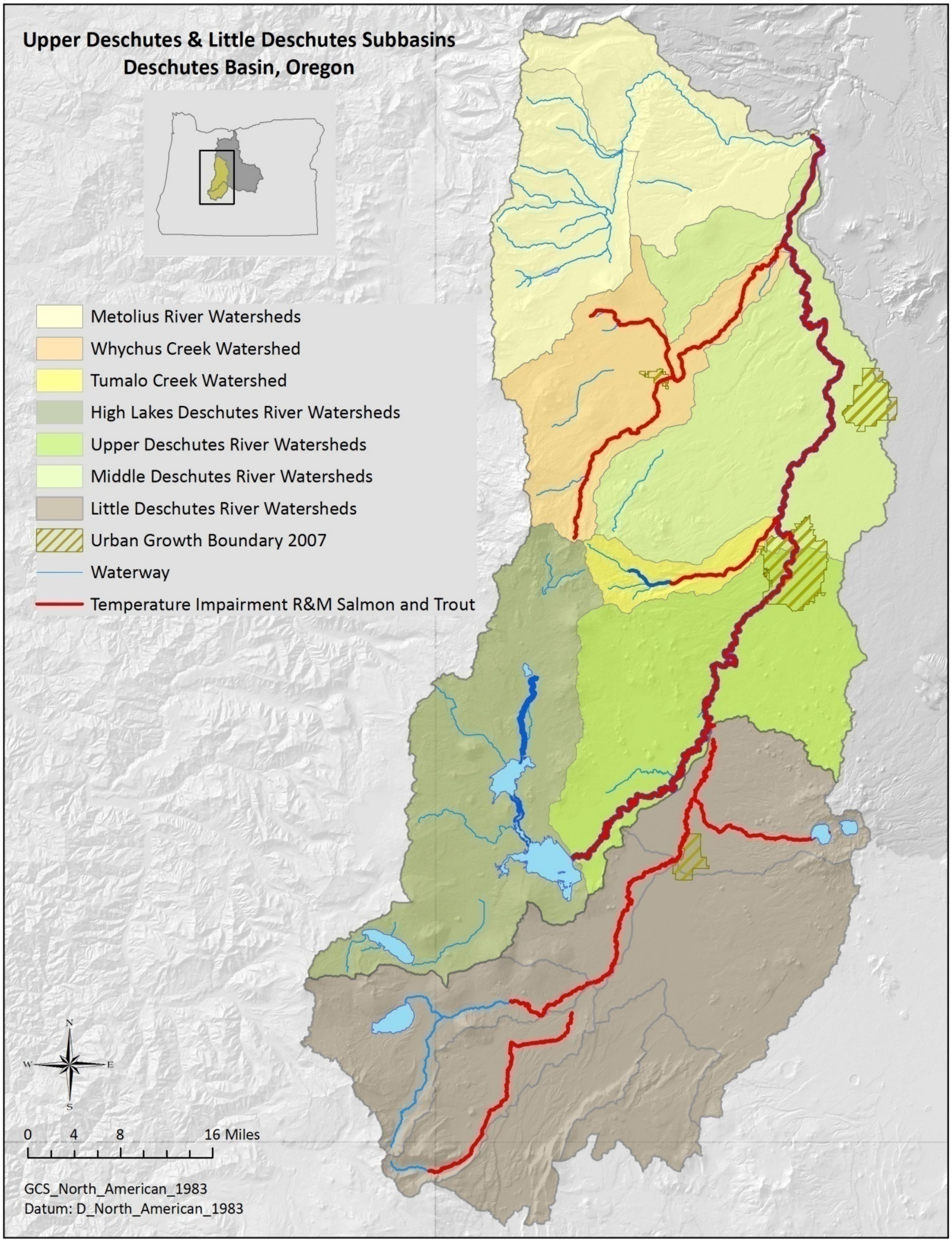
Although model predictions and substantial empirical evidence indicate that reductions in summer streamflow lead to increased water temperatures in central Oregon (ODEQ, 2004) (ODEQ, 2007) (UDWC, 2003) (UDWC, 2006), the DRC and restoration partners are interested in showing how increased flows resulting from specific restoration actions affect water temperatures in downstream reaches. Although collecting water temperature and streamflow data is straightforward, the ability to establish a correlation between small changes in temperature and small increases in streamflow that result from specific restoration actions requires accounting for inter-annual climatic variation and seasonality, which can substantially alter the relationship between streamflow and water temperature. An approach that incorporates multiple years of data and uses statistical analyses that can accommodate inter-annual environmental variability allows restoration partners to understand how streamflow restoration projects affect long-term trends in water temperature and, accordingly, to prioritize restoration actions that will most effectively reduce temperatures in the middle Deschutes River.

[1] There is not an active gage station on the Deschutes River downstream of Tumalo Creek to collect middle Deschutes River flow data. To estimate flows for the middle Deschutes River, the streamflow data collected by the Oregon Water Resources Department (OWRD) gage located on the Deschutes River below Bend (OWRD gage #14070500) is combined with the streamflow data collected by the OWRD gage located on Tumalo Creek downstream the Tumalo Irrigation District Feed Canal (OWRD gage #14073520). Therefore, middle Deschutes River streamflow data used in this Technical Report is estimated.

Map 1 Middle Deschutes River Study Area



Map 2 Salmon and Trout Rearing and Migration Section 303(d) Impaired Waterways



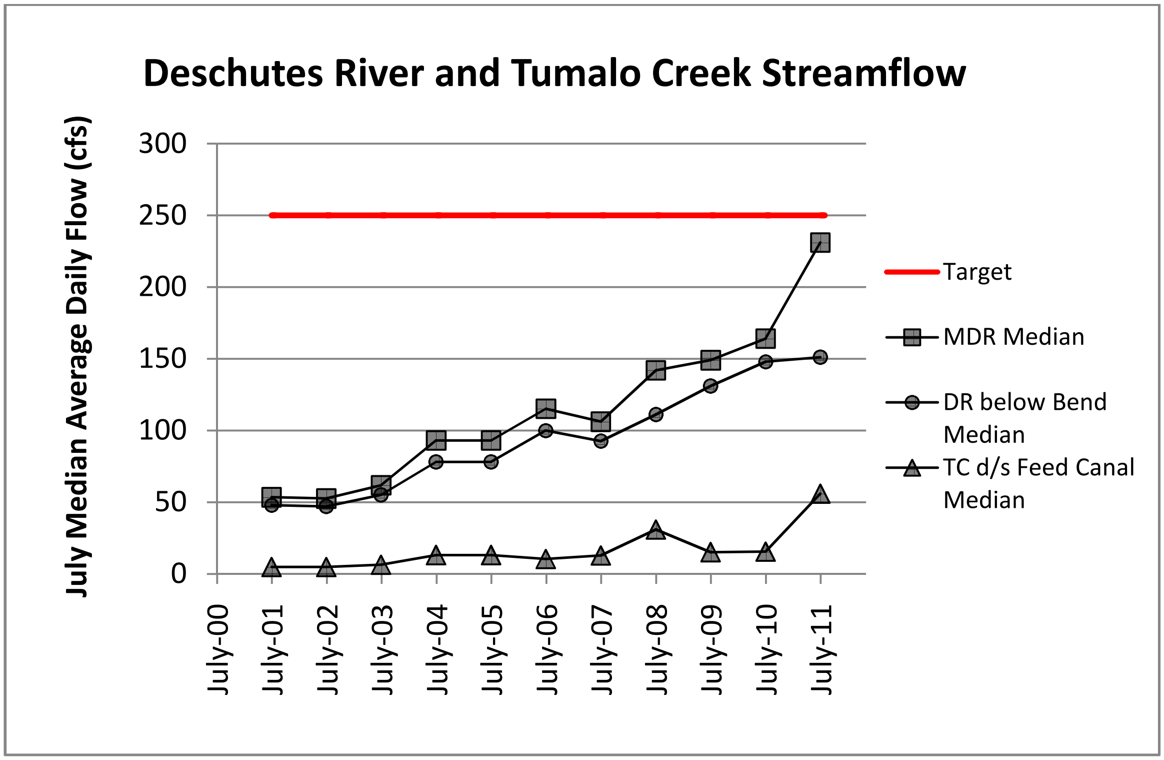


Figure 1

Middle Deschutes River streamflow represents a combination of flows passing over North Canal Dam and flows from Tumalo Creek. July median average daily streamflow has increased as a result of DRC instream flow restoration, from 5 cfs in 2001 to 56 cfs in 2011 at the mouth of Tumalo Creek, and from 48 cfs in 2001 to 151 cfs in 2011 in the Deschutes River at North Canal Dam below Bend, OR. Combined, streamflow restoration efforts at each of these locations have contributed to a 178 cfs increase in middle Deschutes River July median average daily flows, from 53 cfs in 2001 to 231 cfs in 2011 [2].

[2] There is not an active gage station on the Deschutes River downstream of Tumalo Creek to collect middle Deschutes River flow data. To estimate flows for the middle Deschutes River, the streamflow data collected by the Oregon Water Resources Department (OWRD) gage located on the Deschutes River below Bend (OWRD gage #14070500) is combined with the streamflow data collected by the OWRD gage located on Tumalo Creek downstream the Tumalo Irrigation District Feed Canal (OWRD gage #14073520). Therefore, middle Deschutes River streamflow data used in this Technical Report is estimated.

1.1. Key Questions

Since 2008 the DRC has partnered with the Upper Deschutes Watershed Council (UDWC) to conduct temperature monitoring to investigate potential temperature changes associated with streamflow restoration projects. UDWC and monitoring partners have monitored water temperature throughout the Upper Deschutes River subbasin since 2001 and have developed statistical approaches to describe relationships between streamflow and temperature. UDWC and partners conducted temperature monitoring and data analysis to address the following questions:

1) <u>Temperature status:</u> What is the status of middle Deschutes River water temperatures relative to the State of Oregon 18°C / 64°F standard?

2) <u>Restoration effectiveness:</u> Have observed increases in streamflow reduced water temperatures?

3) <u>Target streamflow:</u> What is the estimated streamflow needed to meet the State of Oregon temperature standard?

2. Methods

2.1. Data Collection

2.1.1. Water Temperature

UDWC compiled continuous water temperature data from six water temperature monitoring stations on the Deschutes River (**Table 1**; **Map 3**). Data for 2001 through 2011 were obtained from the UDWC's online water quality database (UDWC, 2011). Data is not available for all years due to equipment failure or no monitoring (**Table 2**). All temperature data used in analyses were collected by ODEQ, the City of Bend, and UDWC. UDWC operates per the *Water Quality Monitoring Program Standard Operating Procedures* (UDWC, 2008) under a State of Oregon approved Quality Assurance Project Plan (UDWC, 2008).

2.1.2. Average Daily Flow

UDWC obtained average daily streamflow (QD) data for the Deschutes River and Tumalo Creek from the Oregon Water Resources Department (OWRD) (OWRD, 2010) (**Table 1**; **Map 4**). Streamflows recorded at the two gage stations are combined to approximate the streamflow below the confluence of the Deschutes River and Tumalo Creek.[3] Some of the streamflow data used for analysis is considered provisional by OWRD. All 2008-2010 Tumalo Creek and Deschutes River data with the exception of 2009 Tumalo Creek data is considered published; 2009 Tumalo Creek data and 2011 data for both waterways is considered provisional and subject to change. Although some data is provisional, the 2001-2011 datasets are large enough that provisional data is not expected to affect the results of analyses; we further minimized possible effects of outliers by using statistical metrics that are robust to outliers.

[3] There is not an active gage station on the Deschutes River downstream of Tumalo Creek to collect middle Deschutes River flow data. To estimate flows for the middle Deschutes River, the streamflow data collected by the Oregon Water Resources Department (OWRD) gage located on the Deschutes River below Bend (OWRD gage #14070500) is combined with the streamflow data collected by the OWRD gage located on Tumalo Creek downstream the Tumalo Irrigation District Feed Canal (OWRD gage #14073520). Therefore, middle Deschutes River streamflow data used in this Technical Report is estimated.

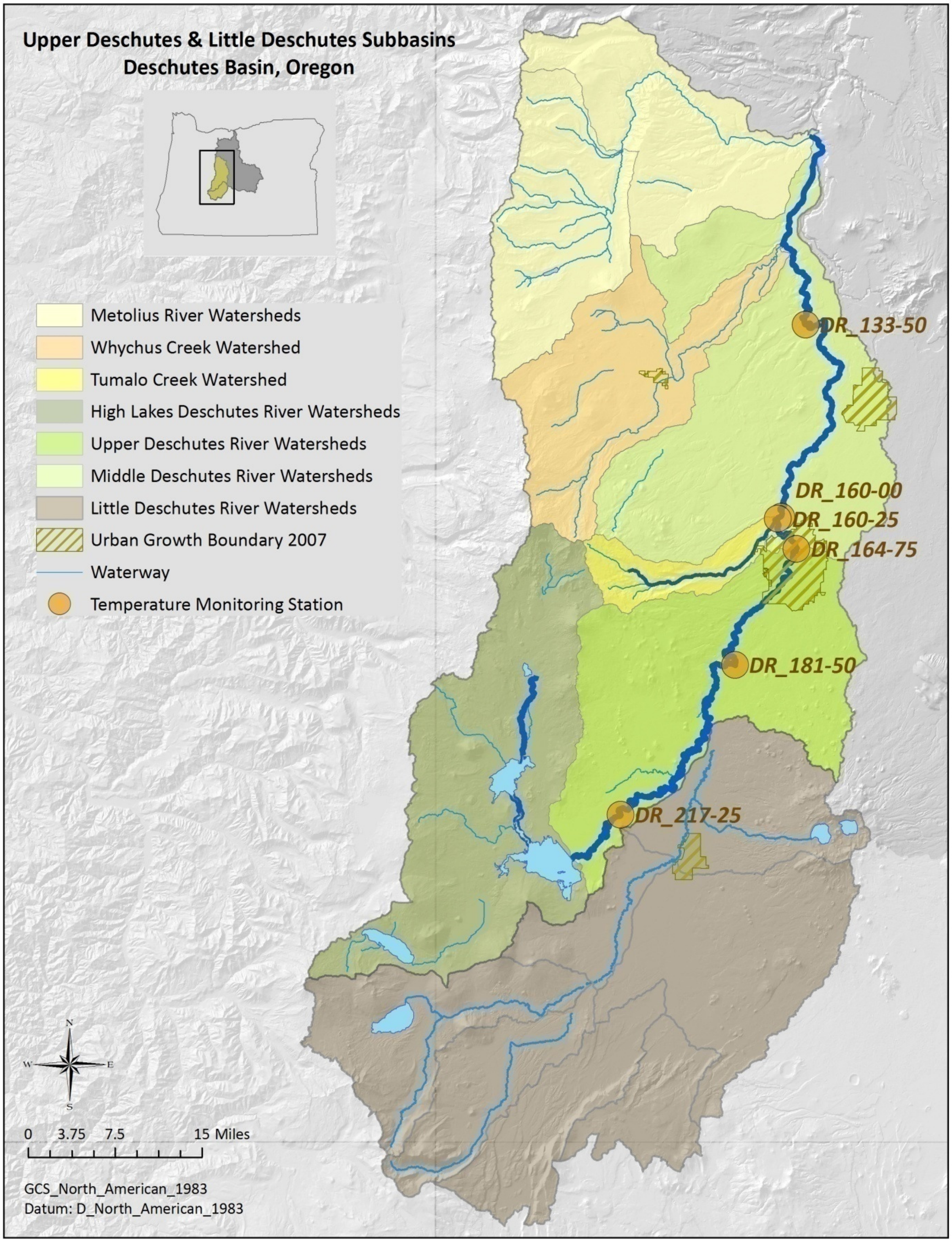
Table 1 Middle Deschutes River Flow and Temperature Monitoring Stations

Station ID	Waterway	Description	Latitude	Longitude	Elev. (ft)
OWRD gage #14073520	Tumalo Creek	d/s of Tumalo Feed Canal	44.08944	-121.36667	3550
OWRD gage #14070500	Deschutes River	d/s of North Canal Dam, Bend	44.08280	-121.30690	3495
DR 217.25	Deschutes River	Pringle Falls	43.74075	-121.60672	4250
DR 181.50	Deschutes River	Benham Falls	43.93080	-121.41107	4140
DR 164.75	Deschutes River	u/s of Riverhouse Hotel	44.07733	-121.30592	3540
DR 160.25	Deschutes River	u/s of Tumalo Creek	44.11501	-121.33904	3240
DR 160.00	Deschutes River	d/s of Tumalo Creek	44.11767	-121.33326	3210
DR 133.50	Deschutes River	Lower Bridge	44.35970	-121.29378	2520

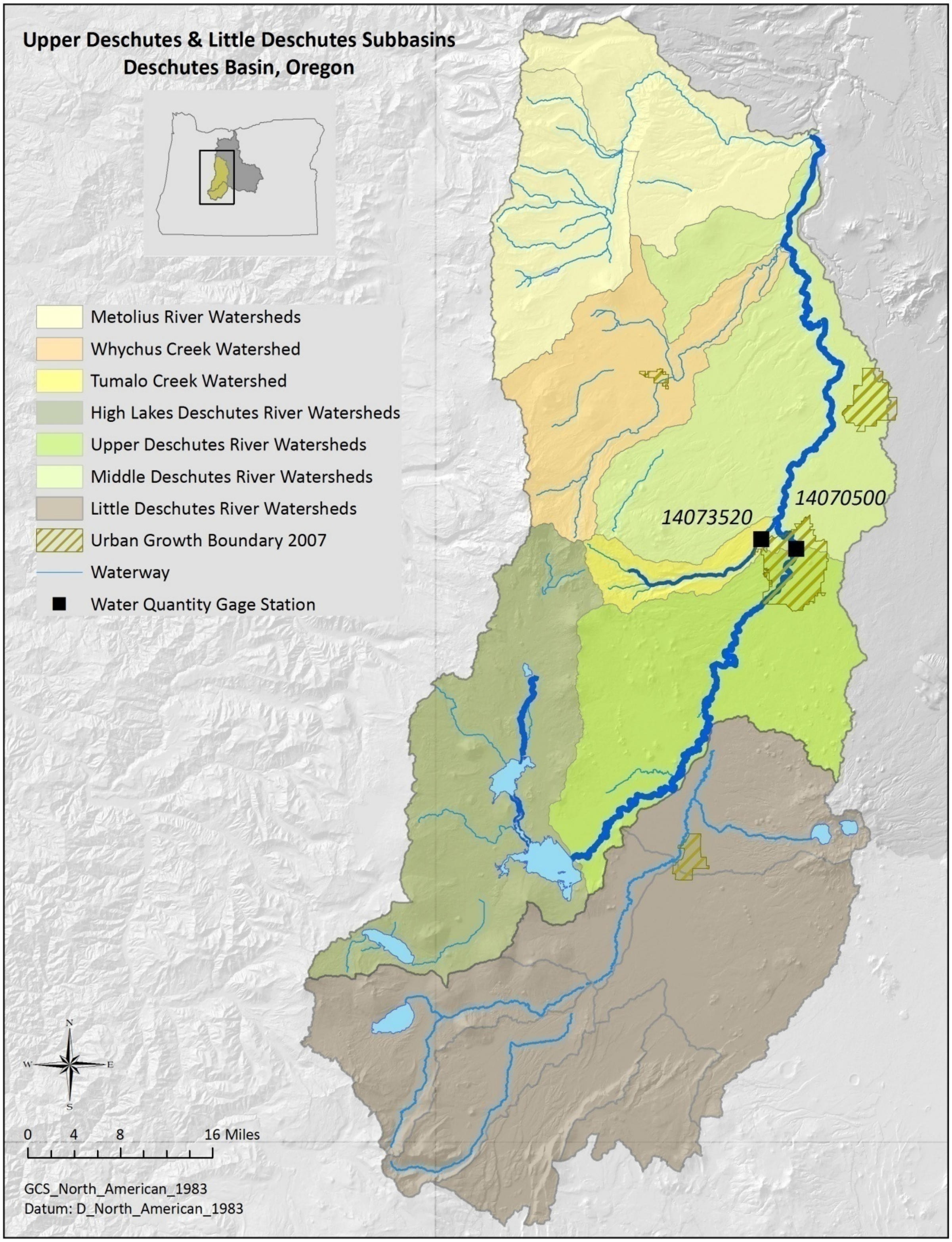
Table 2 Summary of Available July Temperature Data

Station ID	Waterway	Description	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
DR 217.25	Deschutes River	Pringle Falls		X	X	X	X	X	X	-	X	X	X
DR 181.50	Deschutes River	Benham Falls			X		X	X	X	X	X	X	X
DR 164.75	Deschutes River	u/s Riverhouse Hotel				X	X		-	X	X	X	X
DR 160.25	Deschutes River	u/s Tumalo Creek		X	X	X	X		-	X	X	X	X
DR 160.00	Deschutes River	d/s Tumalo Boulder Field					X	X	X	X	X	X	X
DR 133.50	Deschutes River	Lower Bridge	X	X		X	X	X	X	X	-	X	X
X	Data available for analysis												
-	Limited data available for analyses												

Map 3 Temperature Monitoring Stations used in Analyses



Map 4 Streamflow Gaging Stations used in Analyses



2.2. Data Analysis

2.2.1. Temperature Status

The seven day moving average maximum (7DMAX) temperature is the statistic used by the State of Oregon to evaluate stream temperatures and is calculated using the Hydrostat Simple spreadsheet available online from ODEQ (ODEQ, 2010). The current State of Oregon water temperature standard that applies to the Deschutes River above the Pelton Round Butte Dam complex specifies that the 7DMAX shall not exceed 18°C / 64°F to protect salmon and trout rearing and migration (OAR 340-041-0028) (ODEQ, 2010). We compared July 7DMAX temperatures for 2001-2011 to the state standard of 18°C / 64°F to evaluate whether temperatures in the middle Deschutes River meet the state standard for salmonid rearing and migration.

2.2.2. Restoration Effectiveness

We selected five Deschutes River monitoring stations to establish trends in temperature associated with ongoing streamflow restoration (**Map 5**). Using these stations as reach boundaries, we designated a reference reach and two restoration reaches. The reference reach (DR 217.25 to DR 181.50) serves as an experimental control. No streamflow restoration has occurred in this reach, and flows are regulated and therefore are consistent year to year. The Deschutes restoration reach (DR 164.75 to DR 160.25) demonstrates the effect of restored streamflow at North Canal Dam (NCD) by examining changes in temperature in the Deschutes River downstream of the NCD diversion and upstream of Tumalo Creek (**Map 6**). This reach is *not* expected to be influenced by restored streamflow in Tumalo Creek. The Tumalo restoration reach (DR 160.25 to DR 160.00) shows the combined effects of restored streamflow at North Canal Dam and in Tumalo Creek by quantifying changes in temperature in the Deschutes River immediately downstream of Tumalo Creek.

To control for natural variability in streamflow, climate (e.g. precipitation, solar radiation, air temperature, etc.) and other environmental factors that influence inter-annual differences in temperature we used a paired Before After Control Impact (BACI) design that compares pre- (Before) and post- (After) restoration changes between years within a reference (Control) reach to changes between years within a restoration (Impact) reach (Smith, 2002; NIST, 2010). By accounting for inter-annual environmental variability this analysis allows differences in temperature observed between reference and restoration reaches to be attributed to the effects of streamflow restoration. Because additional streamflow was restored in each year of the analysis, for each pair of consecutive years for which data are available the preceding year represents the BACI “Before” year and the subsequent year represents the BACI “After” year. To calculate BACI differences we subtracted subsequent year from preceding year temperatures for each station (e.g. DR 217.25_{2005} - DR 217.25_{2007}) then subtracted the downstream from the upstream difference for each reach (e.g. Δ DR $217.25_{2005\text{-}2007}$ – Δ DR $181.50_{2005\text{-}2007}$). We compared the mean BACI difference of changes between years in the reference reach to the same difference in the two restoration reaches for all years for which enough July data was available for analysis, including 2005/2007, 2007/2008, 2009/2010, and 2010/2011 for the Tumalo restoration reach, and 2008/2009, 2009/2010, and 2010/2011 for the Deschutes restoration reach. We restricted data included in the analysis to one month of the year, July, and included temperature data from at least seven of the same July calendar dates for each year, to reduce the effect of inter-annual seasonal variation in the analysis (Helsel & Hirsch, 1991). Temperature data were available for only six days in July 2008, thus 2007/2008 and 2008/2009 comparisons include six instead of seven July dates. July data were used because July represents the hottest month for water temperatures in the Deschutes River (UDWC, 2003) (UDWC, 2006). For each year included in the analysis, mean BACI differences were calculated from the July daily median temperature, a statistic which reflects small changes in temperature more precisely than the daily mean or daily maximum temperature, and at a finer temporal scale than the seven day moving average maximum (7DMAX) temperature.

Analyses were conducted using R open source statistical software (R Core Development Team 2007). We used normality plots and the Shapiro-Wilks test to establish normal distribution of data. Where data were normally distributed we used a Student's t-test to identify 1) whether temperature changes observed between years in restoration reaches were significantly different than changes observed between years in reference reaches, and 2) in which direction these changes occurred (warming or cooling) relative to the reference reach (Helsel & Hirsch, 1991) . For reaches where data were non-normal we used an exact permutation test (Hothorn and Hornik 2006) to compare the restoration reach and reference reach means. An exact permutation test for paired samples compares the observed statistic, the difference of means from two experimental groups, to the expected statistic under a permutation distribution created by randomly resampling from all possible permutations of the data from treatment and control groups. Here the observed statistic is the difference of the restoration and reference reach means. For this analysis we identified a Confidence Level of 90% and a corresponding α-value of 0.10. For each restoration reach- reference reach pair and for each combination of data years we evaluated the following four hypotheses:

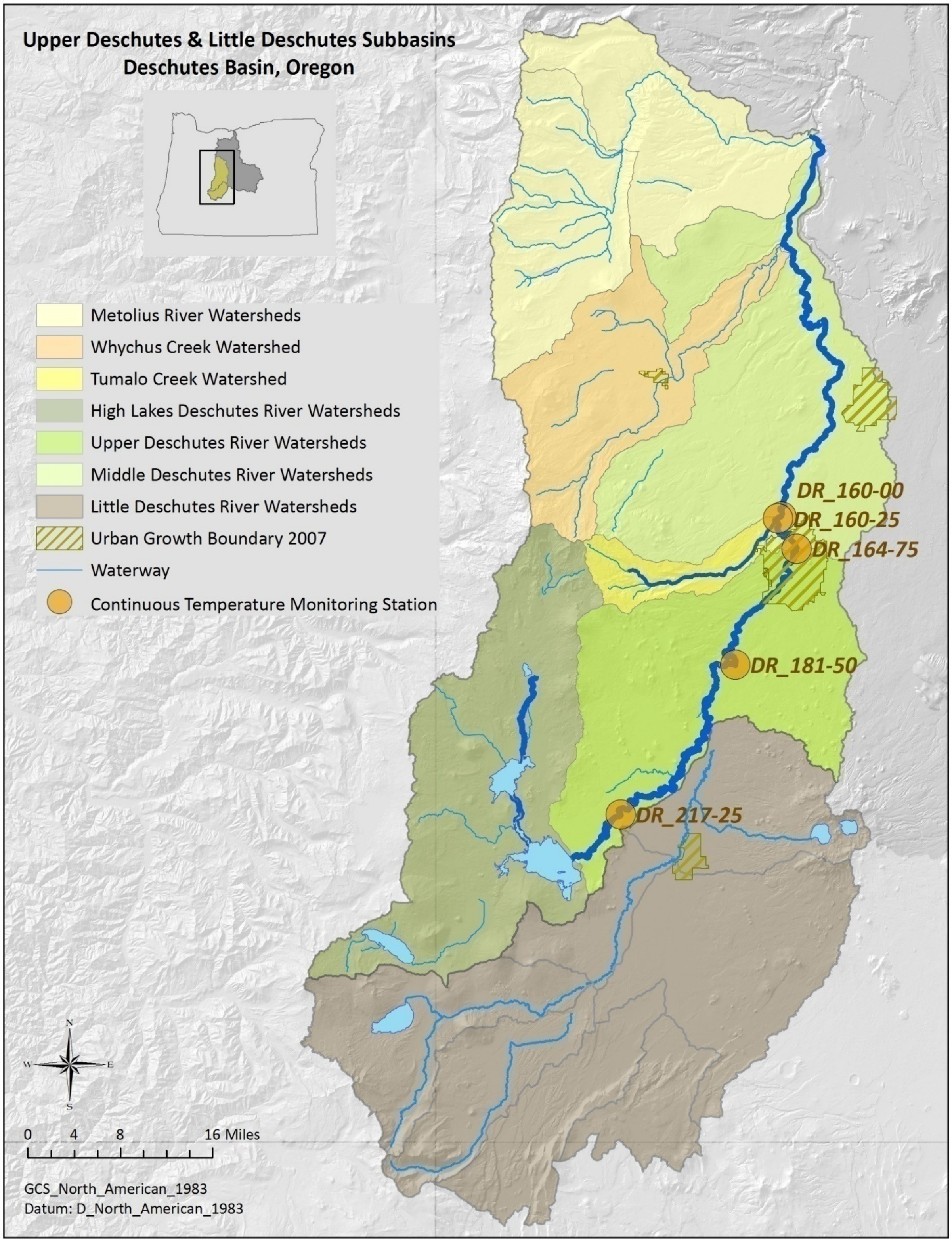
1) H_0: There is no difference between the mean for the restoration reach and the mean for the reference reach.

2) H_1: The mean for the restoration reach and the mean for the reference reach are statistically different.

3) H_2: The mean for the restoration reach is significantly less than the mean for the reference reach; the restoration reach has cooled relative to the reference reach

4) H_3: The mean for the restoration reach is significantly greater than the mean for the reference reach; the restoration reach has warmed relative to the reference reach.

Map 5 Continuous Temperature Monitoring Stations used in Restoration Effectiveness Analysis



Map 6 Deschutes and Tumalo Restoration Reaches used in Restoration Effectiveness Analysis

2.2.3.Target Streamflow

The DRC streamflow restoration efforts aim to meet the State of Oregon instream flow target of 250 cfs in order to improve water temperatures to support sustainable anadromous and resident fish populations. In 1990, ODFW initiated the process to establish an instream water right by applying to the OWRD for certified instream water rights for the Deschutes River, Deschutes Basin, Oregon (OWRD, 2010). The pending application for an instream water right for the Deschutes River describes a streamflow restoration target of 250 cfs from North Canal Dam (river mile 165) to Round Butte Reservoir (river mile 119). This target is lower than the flow requested by ODFW, and represents the *minimum* streamflow required to support fish populations.

To determine the volume of streamflow required to reduce water temperatures in the middle Deschutes River to meet the 18°C/64°F state standard, we analyzed the relationship between flow and temperature for two locations on the middle Deschutes: a) downstream of Tumalo Creek near the site of streamflow restoration (DR 160.00), and b) at Lower Bridge Road 30 miles downstream of flow restoration (DR 133.50) (**Map 7**). Temperature data from DR 160.00 represent the combined effects of restored streamflow at North Canal Dam and in Tumalo Creek; data from DR 133.50 represent the historically worst temperature conditions on the creek, and thus the location that is both most critically in need of and also stands to benefit the most from streamflow restoration. As in our restoration effectiveness analysis, we restricted data included in the analysis to one month of the year to reduce the effect of inter-annual seasonal variation in the analysis (Helsel & Hirsch, 1991) and identified July as the hottest month for water temperatures in the Deschutes River (UDWC, 2003) (UDWC, 2006). For DR 160.00 downstream of Tumalo Creek, we analyzed July 7DMAX temperature and average daily flow data for 2005-2011; for DR 133.50 at Lower Bridge Road we analyzed July temperature and flow data for 2001-2011. Only flow values associated with at least ten 7DMAX temperature observations were included in the analysis to make the resulting relationship as representative as possible of typical conditions

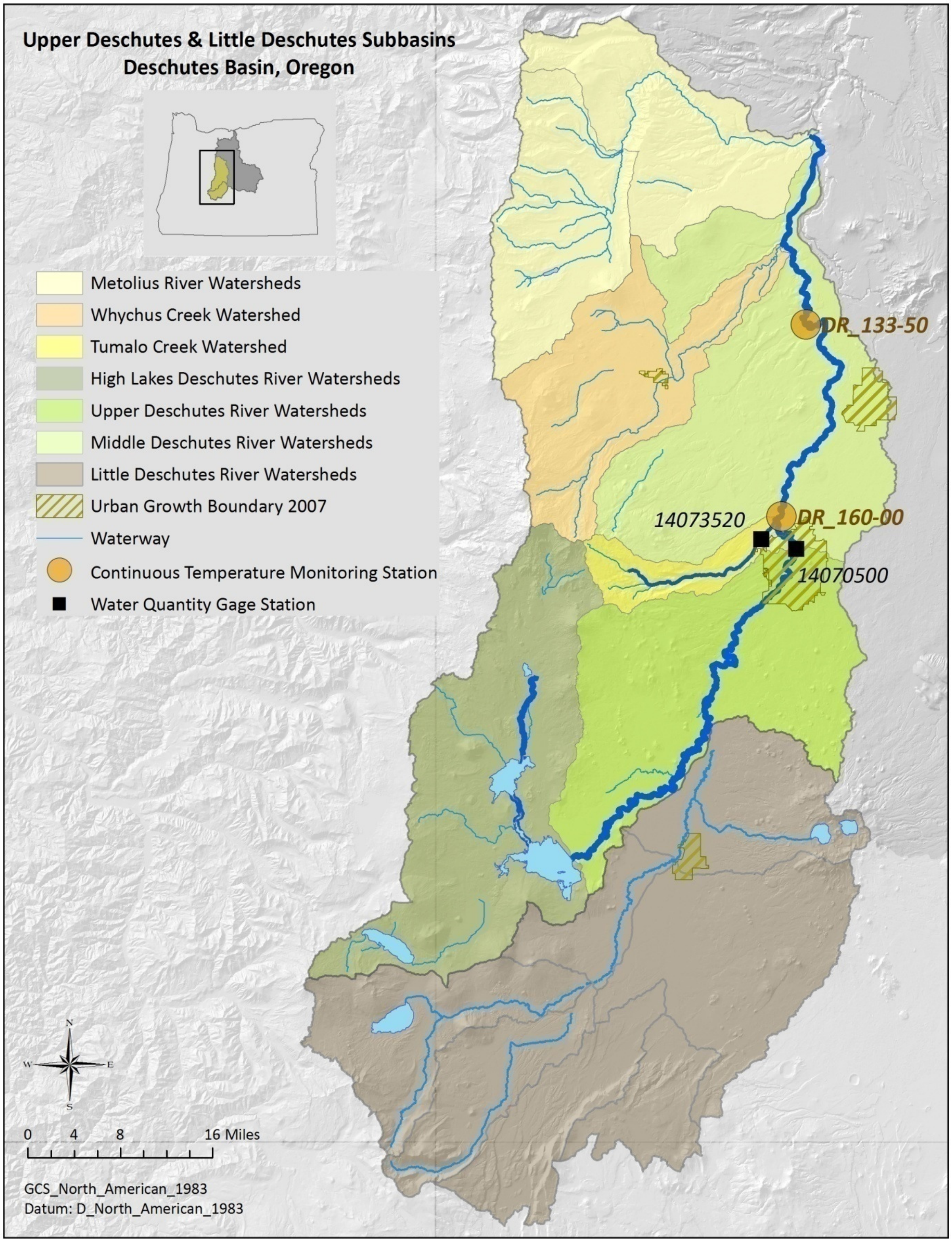
To describe the relationship between flow and temperature at the two locations we performed a regression of temperature and flow data. The resulting equations accurately represent the relationship between flow and temperature only for the specific locations, within the evaluated time period, and within the range of flows observed. We paired 7DMAX temperature with the corresponding natural log of the average daily flow (LnQD) for each July day included in the analysis, then ranked flow data and assigned associated temperatures from all July days to each flow value, excluding flows with fewer than ten corresponding temperature records ($n < 10$), to calculate the mean of all 2001-2011 July 7DMAX temperatures observed at each flow level. We plotted flows versus mean temperature and fitted a regression trendline that best described the data by adding polynomial terms to the corresponding regression equation. We evaluated S and R^2 values to assess the fit of the regression model to the temperature-flow data. S is the standard error and represents the standard distance (°C) that mean 7DMAX temperature values fall from the regression line. A better fit between the regression line and the data results in a lower S value. R^2 represents the proportion of the variation in mean 7DMAX temperatures that is explained by streamflow (Ln QD). As the fit of the regression to the data improves, the R^2 value increases toward a maximum 100%. Using the regression equation for each location, we calculated the predicted temperature and 95% confidence interval for all flows within the observed range (**Appendix A**). We calculated the 95% confidence interval (CI) as:

$$Y \pm Y^{(Z_{1-\alpha/2}\, S(x) / \sqrt{N})}$$

$$\text{where } Z_{1-\alpha/2} = Z_{1-0.05/2} = Z_{0.475} = 1.9 \text{ (NIST 2011)}$$

We compared the resulting 2001-2011 temperature-flow regressions and predicted temperatures at given flows for each site to 2001-2010 regressions (UDWC, 2011) and to Heat Source model scenarios for the same locations on the Deschutes River (Watershed Sciences and MaxDepth Aquatics 2007).

Map 7 Temperature Monitoring and Streamflow Gaging Stations used in Target Streamflow Analysis



3. Results

3.1. Temperature Status

Seven-day moving average maximum (7DMAX) temperatures exceeded the 18˚C state standard for steelhead and salmon rearing and migration at four monitoring locations in 2011 (**Figure 2**), supporting the existing State of Oregon Section 303(d) listing of the middle Deschutes River for temperature impairment. Temperatures in the reference reach (DR 217.25 to DR 181.50), where no streamflow restoration is occurring, exceeded the state standard in 2002, 2004, 2005, and 2009, and approached 18°C / 64°F during July, the hottest month for water temperatures, for all other years evaluated. Temperatures in the Deschutes restoration reach (DR 164.65 to DR 160.25), the Tumalo restoration reach (DR 160.25 – DR 160.00), and at Lower Bridge Road (DR 133.50) exceeded the state standard in every year for which data is available for analysis. However, during July 2011, when flows at DR 160.00 downstream of Tumalo Creek remained above 200 cfs for most of the month, 7DMAX temperatures were consistently lower than 18°C. Although mean 7DMAX temperatures at Lower Bridge Road continue to exceed the state temperature standard, summer temperatures have steadily decreased since 2001 (**Figure 3**).

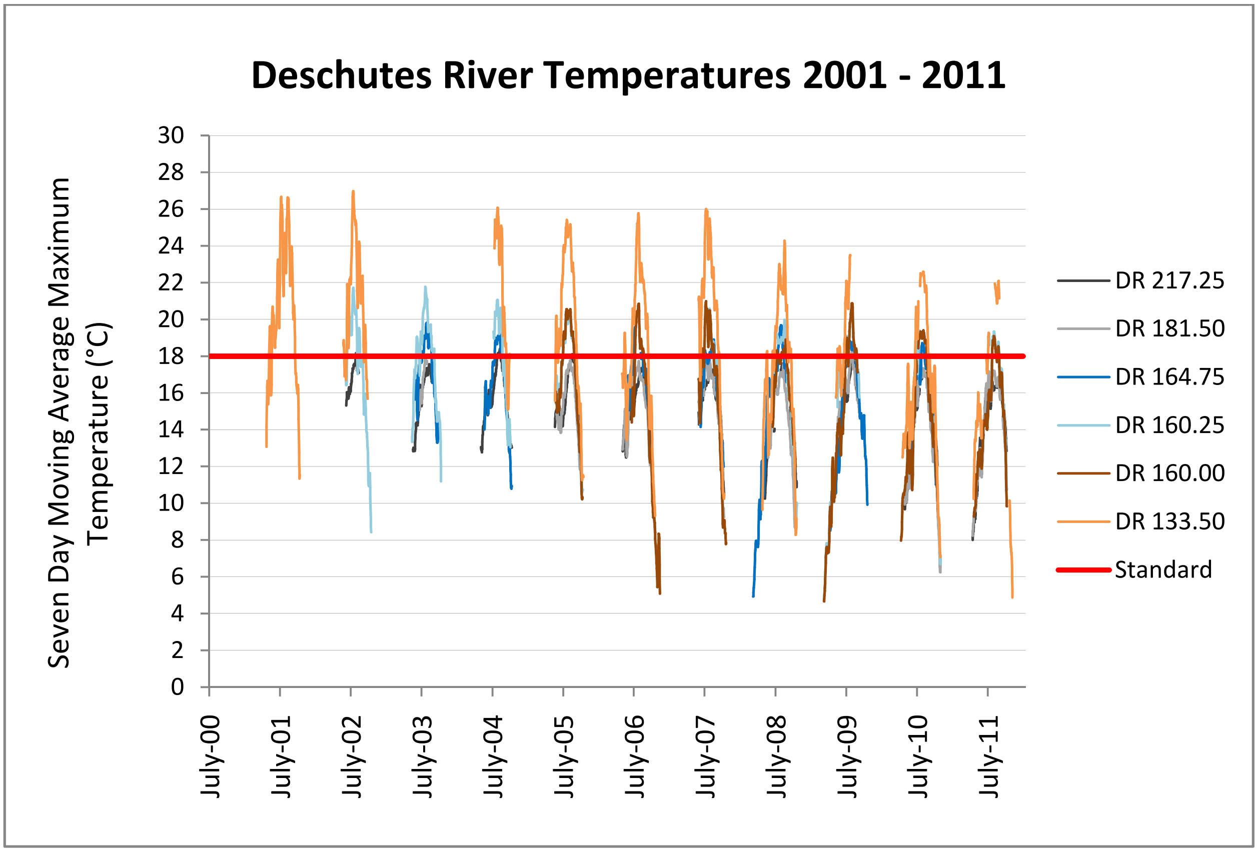


Figure 2

Temperatures at 6 stations along the Deschutes River between 2001 and 2011 exceeded the State of Oregon temperature standard established to protect salmon and trout rearing and migration (solid red line) at all sites and in most years.

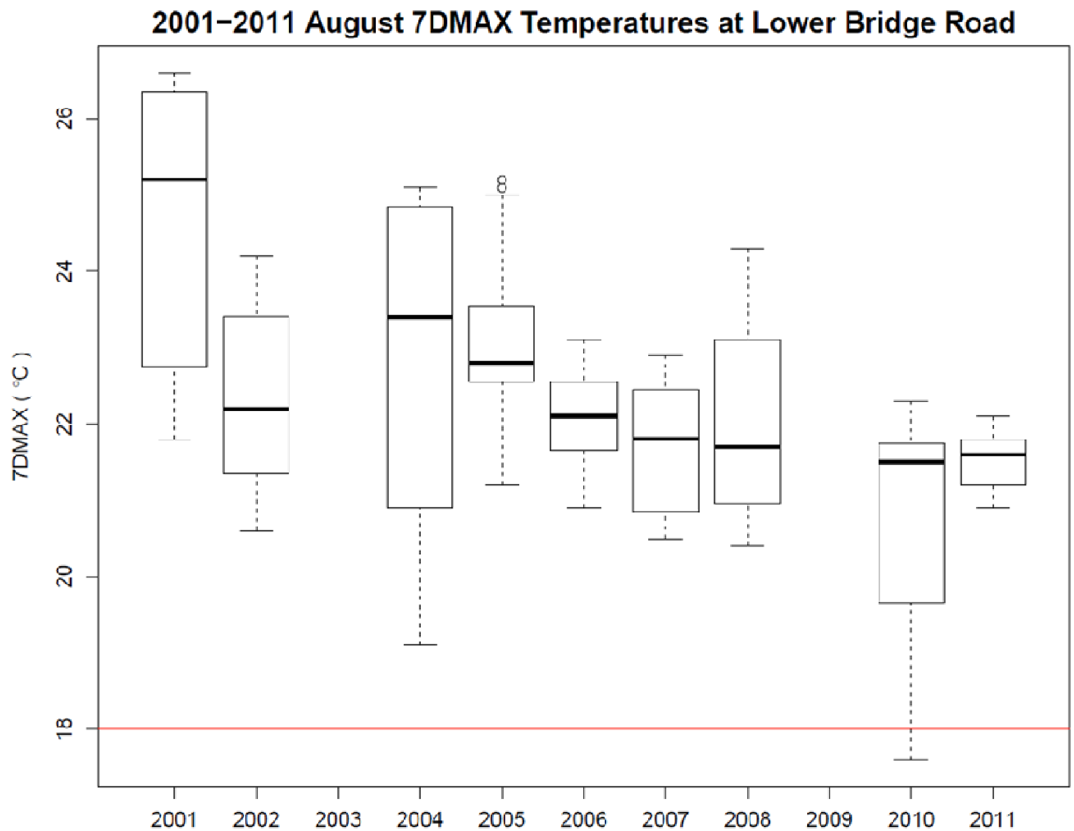


Figure 3

August mean 7DMAX temperatures at Lower Bridge Rd (DR 133.50), the most impaired site for which temperature data are available, have steadily decreased since 2001. We present data for August instead of July because more data are available for August for the years of interest, however August data equivalently represent summer conditions characterized by high temperatures and low flows.

3.2. Streamflow Restoration Effectiveness

Temperatures recorded at the two upstream reference reach stations and the three downstream restoration reach stations from 2005 to 2011 varied among stations and years (**Figure 3**). Normal plots and Shapiro-Wilks tests of 2010/2011 BACI differences in mean July daily median temperatures established that reference reach and Deschutes restoration reach data were normally distributed, while distribution of Tumalo reference reach data was non-normal. Accordingly, we used student's t-tests to statistically compare the Deschutes and reference reaches, and permutation tests to compare the Tumalo and reference reaches. Data for all three reaches for all previous years were normally distributed ($\alpha = 0.90$). Temperature data were available only for the last six days of July 2008, therefore sample sizes for 2007-2008 and 2008-2009 comparisons represent BACI differences six instead of seven July dates.

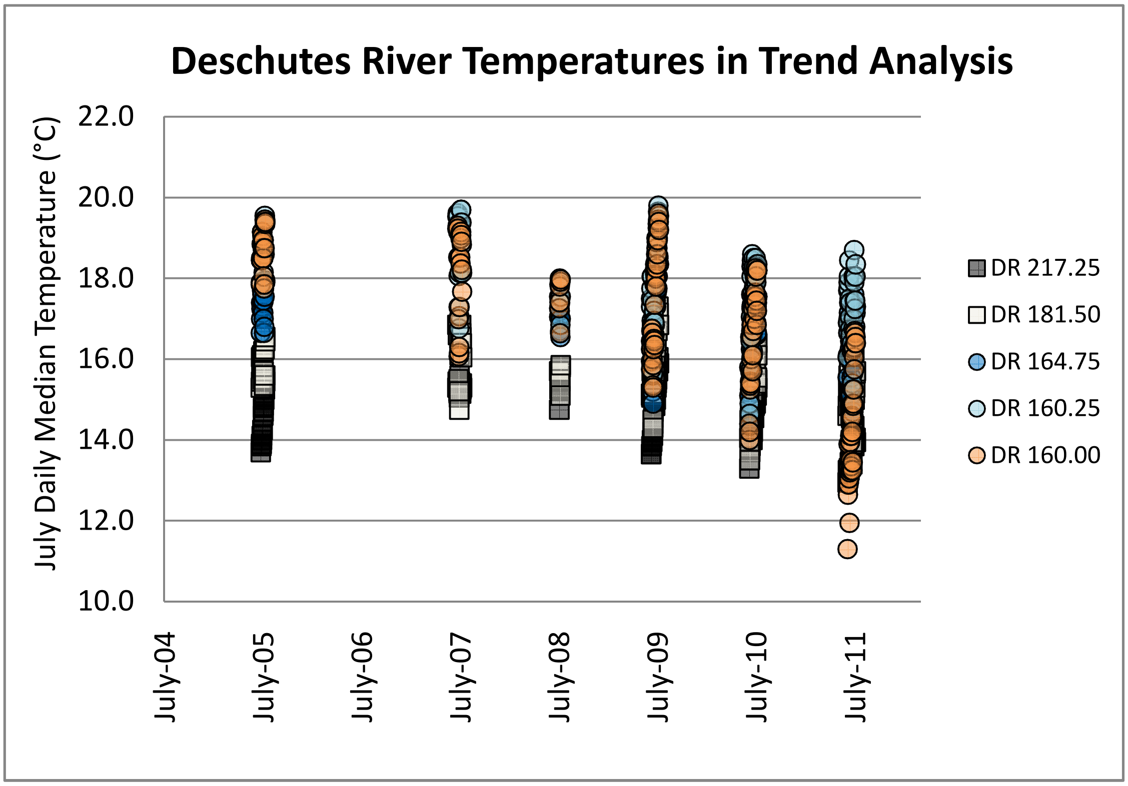


Figure 4

Deschutes River July temperatures varied among stations and years. A paired BACI analysis using only July data allows for the identification of trends in temperature that are associated with instream flow restoration and controls for the effects of seasonal and inter-annual environmental variability.

The BACI difference of mean July daily median temperatures in the Tumalo restoration reach from 2005 to 2007 was not significantly different than this difference for the reference reach (p=0.40), indicating that changes in temperature in the two reaches from 2005 to 2007 were similar, with no detectable response to stream flow restoration in the Tumalo reach (**Table 3**). The Tumalo-reference reach paired BACI (PBACI) difference, the difference of the BACI differences for the two reaches, approximates zero with a 90% confidence interval overlapping zero, illustrating the marginal difference between the two means (**Figure 4**). The BACI difference of mean July daily median temperatures in the Tumalo restoration reach from 2007/2008 was significantly greater than this difference for the reference reach (p=0.00), indicating the Tumalo reach warmed significantly relative to the reference reach from 2007 to 2008, a difference which can be directly attributed to the effects of stream flow restoration. The resulting 2007/2008 Tumalo-reference reach PBACI difference is negative, with a negative 90% confidence interval, providing support for warming in the Tumalo reach from 2007 to 2008. The BACI difference for the Tumalo reach was significantly less than that for the reference reach for 2008/2009 (p=0.01) and 2010/2011 (p=0.00), indicating a cooling trend in response to stream flow restoration. PBACI differences for these years were positive, substantiating the cooling response. Although not significant (p=0.47), the Tumalo BACI difference was also less than the reference reach difference for 2009/2010, and the Tumalo-reference reach PBACI difference positive, indicating minimal cooling in the Tumalo reach relative to the reference reach.

The BACI difference of mean July daily median temperatures in the Deschutes reach for 2008/2009 was significantly less than this difference for the reference reach (p=0.06), indicating that July temperatures in this reach also cooled from 2008 to 2009 relative to July temperatures in the reference reach in response to stream flow restoration (**Table 3**). The 2008/2009 Deschutes-reference reach PBACI difference was positive, providing support for cooling in the Deschutes reach (**Figure 4**). From 2009 to 2010 the BACI difference for the Deschutes reach was not significantly different than the BACI difference for the reference reach (p=0.96) and the PBACI difference for the two reaches approximated zero, indicating that changes in temperature were similar in restoration and reference reaches, with no detectable response in the Deschutes reach to any additional flow restoration that occurred over this interval. As in the Tumalo reach, the BACI difference for the Deschutes reach from 2010 to 2011 was significantly less than this difference for the reference reach (p=0.01), with a positive PBACI difference, indicating that the Deschutes reach also cooled from 2010 to 2011 relative to temperatures in the reference reach, in direct response to stream flow restoration.

Table 3 BACI differences and standard deviations of July daily median temperatures for the reference reach and the Deschutes and Tumalo restoration reaches between data years. Values that are less than the reference reach mean indicate a cooling trend from one data year to the next; values that are greater than the reference reach mean indicate a warming trend between data years. Asterisks indicate a significant difference between the specified restoration reach and the reference reach.

	2005-2007	2007-2008	2008-2009	2009-2010	2010-2011
Reference reach	**-0.4 ± 0.99**	**-1.0 ± 0.36**	**1.0 ± 0.46**	**0.18 ± 1.04**	**0.73 ± 1.17**
Deschutes reach	-	-	0.5 ± 0.21*	0.05 ± 0.33	-0.04 ± 0.33*
Tumalo reach	-0.6 ± 0.27	0.5 ± 0.71*	-0.1 ± 0.65*	-0.59 ± 0.60	-1.81 ± 1.32*

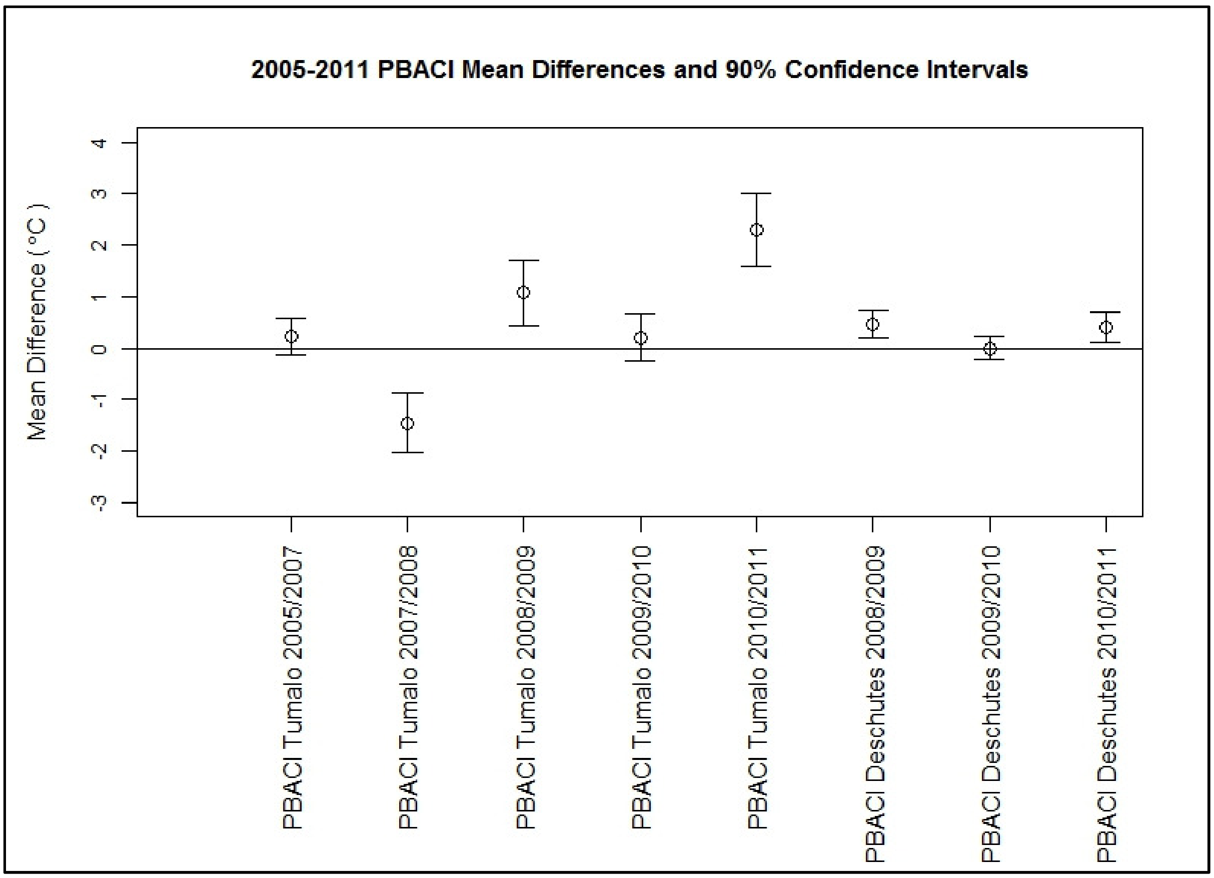


Figure 5

Paired BACI (PBACI) differences, the difference of BACI differences for a restoration reach and the reference reach, illustrate temperature responses to streamflow in restoration reaches. PBACI values approximating zero indicate no temperature response to streamflow restoration; PBACI values greater than zero represent a cooling temperature response to streamflow restoration, while values less than zero demonstrate a warming response. PBACI differences for the Tumalo and reference reach for 2005/2007 and 2009/2010, and for the Deschutes and reference reach for 2009/2010, indicate no response to streamflow restoration in restoration reaches over these intervals. PBACI differences for both restoration-reference reach pairs for 2008/2009 and 2010/2011 indicate a cooling response. The negative Tumalo-reference reach PBACI difference for 2007/2008 flags a warming response.

Streamflow volume and temperature in the middle Deschutes River are influenced by flows from two sources: upper Deschutes streamflow passing over North Canal Dam, and flows from Tumalo Creek (**Figure 1**). These two locations are also the source of instream flow restoration. Streamflow passing over North Canal Dam is consistently above the state temperature standard of 18°C/64°F in July (UDWC, 2006) (ODEQ, 2004). Temperatures in Tumalo Creek have been recorded at temperatures both above and below the state standard depending on flows (UDWC, 2006). The Deschutes restoration reach (DR 164.00 – 160.25) is above the confluence of Tumalo Creek and the Deschutes River, thus we do not expect increases in Tumalo Creek flows to influence temperature trends in this reach. The Tumalo restoration reach (DR 160.25 – DR 160.00) extends from immediately above the confluence with the Deschutes to just below the confluence, therefore we anticipate increases in streamflow in both the upper Deschutes at North Canal Dam and from Tumalo Creek to affect temperatures in this reach.

Increases in streamflow in the middle Deschutes each year from 2007 to 2011 resulted in a cooling response (2008-2009, 2010-2011) or no response (2009-2010) in the Deschutes restoration reach but did not result in a warming response in this reach in any year of the study as suggested in previous reports. Responses in the Tumalo reach to streamflow restoration in the middle Deschutes and in Tumalo Creek tracked trends in the Deschutes restoration reach from 2008 to 2011, but were more extreme than those observed in the Deschutes reach, possibly reflecting the additional cooling influence of colder Tumalo Creek flows. Increases in streamflow from both the upper Deschutes and Tumalo Creek resulted in temperatures warming in the Tumalo restoration reach from 2007 to 2008 relative to the reference reach.

3.3. Target Streamflow

A regression of July temperature and streamflow data from the middle Deschutes River downstream of Tumalo Creek (DR 160.00) and at Lower Bridge Road (DR 133.50) from 2001 – 2011 describes temperature-flow relationships for observed flows and estimates target flows needed to achieve the 18°C/64°F state temperature standard at these sites. July 7DMAX temperatures from 2001 to 2011 for the middle Deschutes River downstream of Tumalo Creek (DR 160.00) ranged from 14.8°C to 21.0°C (**Figure 5**). July 7DMAX temperatures for the middle Deschutes at Lower Bridge Road (DR 133.50) ranged from 17.9°C to 27.0 °C. July streamflows ranged from 46.4 to 447.0 cfs (**Figure 6**)[4]. Flows with ten or more associated temperature records included in target analysis ranged from 78 cfs to 207 cfs for DR 160.00 and from 47 to 171 cfs for DR 133.50. Temperature estimates for each site are valid within the range of flows included in target analysis and from which regression equations were derived.

[4] There is not an active gage station on the Deschutes River downstream of Tumalo Creek to collect middle Deschutes River flow data. To estimate flows for the middle Deschutes River, the streamflow data collected by the Oregon Water Resources Department (OWRD) gage located on the Deschutes River below Bend (OWRD gage #14070500) is combined with the streamflow data collected by the OWRD gage located on Tumalo Creek downstream the Tumalo Irrigation District Feed Canal (OWRD gage #14073520). Therefore, middle Deschutes River streamflow data used in this Technical Report is estimated.

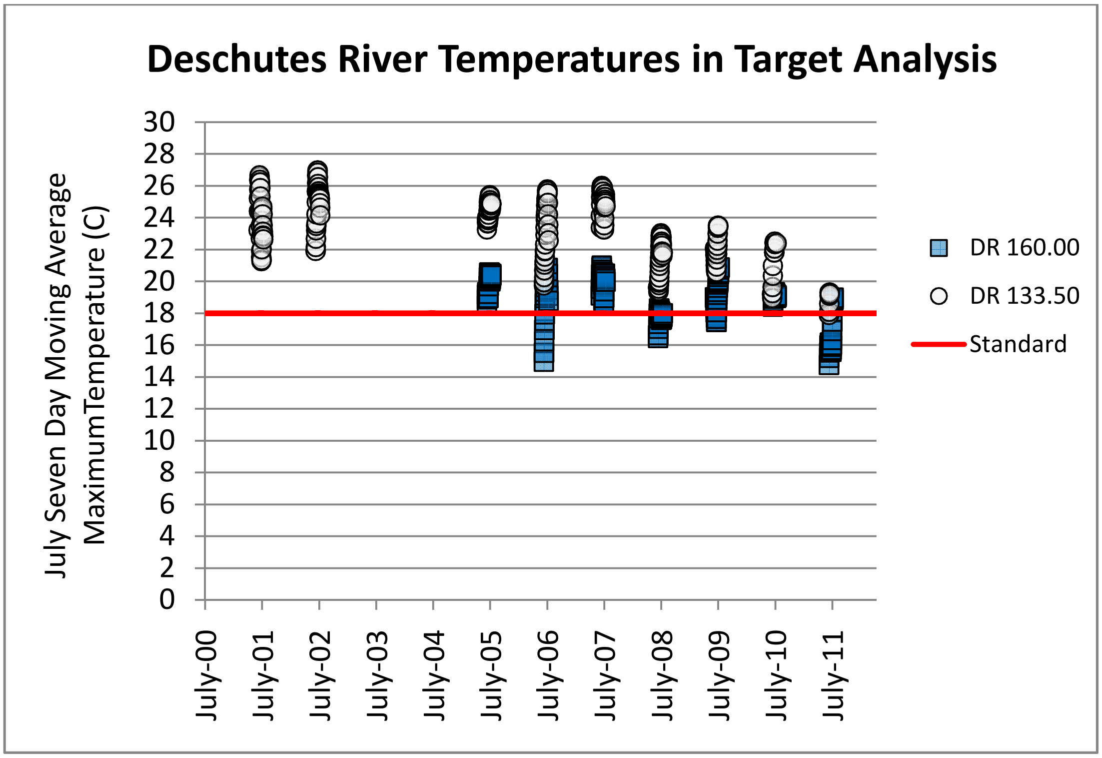


Figure 6

Middle Deschutes River July 7DMAX temperatures used in streamflow target analysis range from 15.0°C to 21.0°C downstream of Tumalo Creek (DR 160.00; dark squares) and from 17.9°C to 27.0°C at Lower Bridge Road (DR 133.50; light circles).

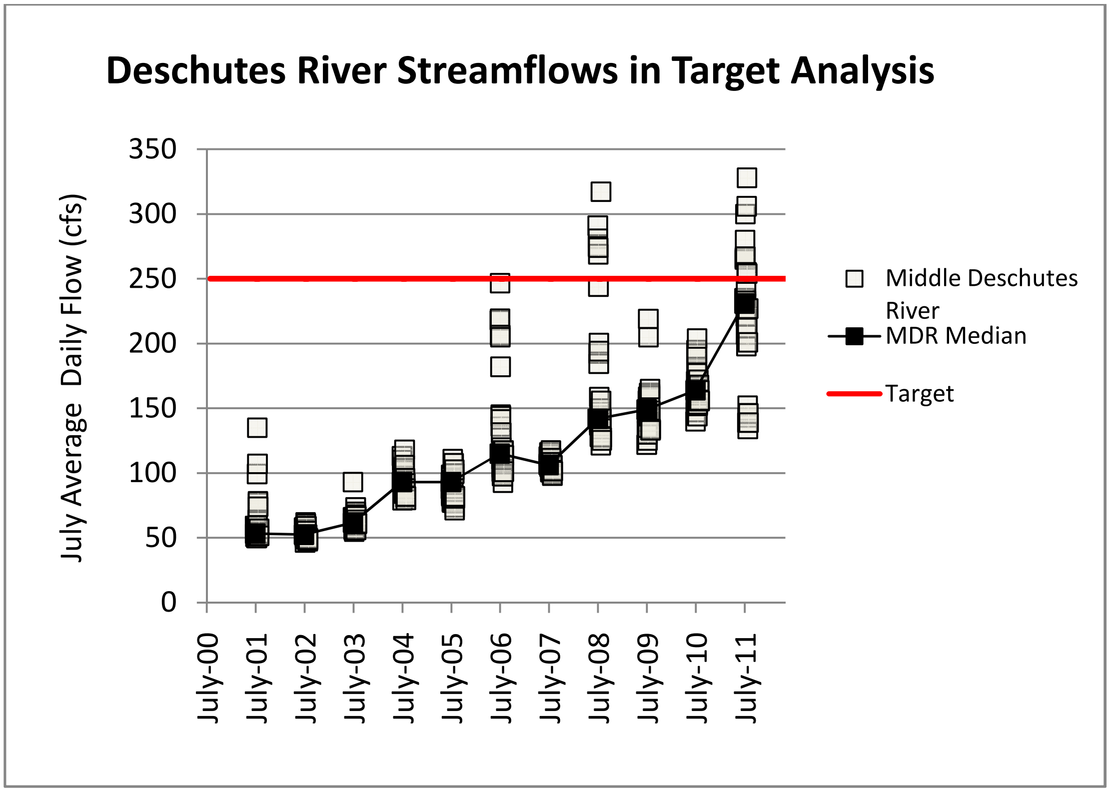


Figure 7

July streamflows from 2001 to 2011 ranged from 46.4 to 447.0 cfs[5]. Flows with ten or greater associated temperature observations eligible for target analysis ranged from 48 cfs to 200.3 cfs.

A quadratic regression model produced the best fit to temperature-flow data for both DR 160.00 and DR 133.50 sites (**Table 4)**. S-values for the quadratic model were lower than those for the cubic model for both sites, with an R^2 value only 1% higher for DR 160.00 and equivalent R^2 values for DR 133.50.The minimum flow estimated to result in 18°C (± 3.2°C) stream temperature at DR 160.00 is 206 cfs (5.3 LnQD), as calculated from the quadratic equation for the regression of 2001-2011 temperature and flow data from this location (**Figure 7**; **Appendix A**). This result is consistent with the Heat Source model, which predicts that temperatures will continue to cool as flows increase, with a 250 cfs model input resulting in an estimated 17 °C 7DMAX in the Deschutes River downstream of Tumalo Creek during the hottest time of year (Watershed Sciences; MaxDepth Aquatics, Inc., 2007).

[5] There is not an active gage station on the Deschutes River downstream of Tumalo Creek to collect middle Deschutes River flow data. To estimate flows for the middle Deschutes River, the streamflow data collected by the Oregon Water Resources Department (OWRD) gage located on the Deschutes River below Bend (OWRD gage #14070500) is combined with the streamflow data collected by the OWRD gage located on Tumalo Creek downstream the Tumalo Irrigation District Feed Canal (OWRD gage #14073520). Therefore, middle Deschutes River streamflow data used in this Technical Report is estimated.

Table 4 A quadratic equation provided the best fit to the regression of 2001-2011 temperature-flow data, with the lowest S and highest R^2 values, for both sites. Temperatures calculated using the corresponding equation are expected to be the most accurate of the three regression models.

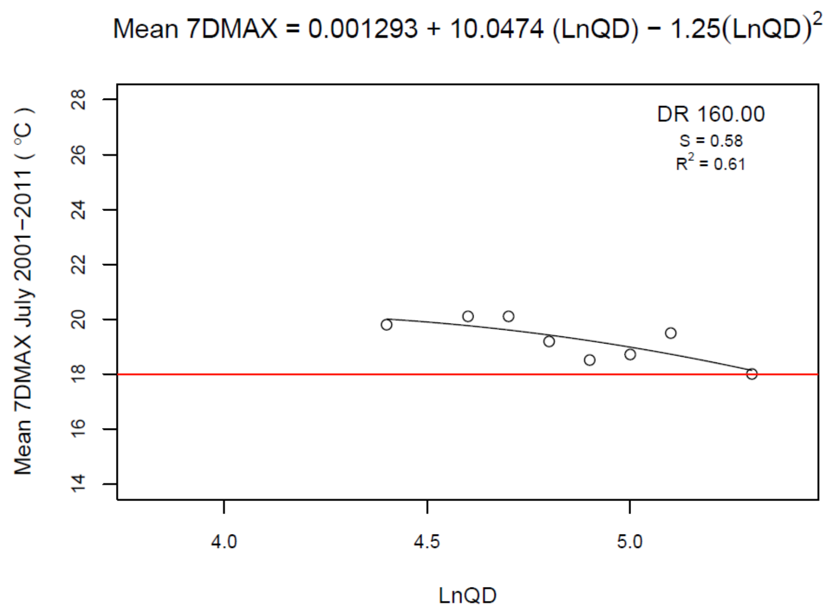
Regression	Equation	df	S	R^2
	DR 160.00 (n=8)			
Linear	29.3138 - 2.0776(LnQD)	6	0.54	0.59
Quadratic	**0.001293 + 10.0474(LnQD) - 1.25(LnQD)^2**	**5**	**0.58**	**0.61**
Cubic	-413.427 + 266.919(LnQD) - 54.331(LnQD)^2 + 3.648(LnQD)^3	4	0.64	0.62
	DR 133.50 (n=9)			
Linear	35.6958 - 2.6319(LnQD)	7	0.94	0.62
Quadratic	**-51.366 + 36.564(LnQD)-04.373(LnQD)^2**	**6**	**0.72**	**0.81**
Cubic	-167.657 + 114.430(LnQD) - 21.665(LnQD)^2 + 1.274(LnQD)^3	5	0.79	0.81

The 206 cfs flow estimated to meet the 18° C state temperature standard is substantially higher than predicted by the 2001-2010 model estimate of 18° C ± 2.0°C at 130 cfs reported in 2010. Several factors contribute to this difference. Temperature data from 2009, a year in which temperatures were on average higher for a given flow than in other years included in the analysis, were omitted from 2010 analyses for three flow levels (4.9 – 5.1), and 2010 data were additionally omitted for 5.0 LnQD, resulting in lower mean temperature values and consequently in a regression equation which predicted similarly low temperatures at corresponding flow levels. These missing observations accounted for a substantial proportion of the values included in the analysis of 2001-2011 data. The addition of a new temperature-flow data point given the requisite number of temperature observations at 5.3 LnQD in the 2001-2011 regression, with a mean temperature value lower than that for any flow level in any year of the analysis, also substantially altered both the fit of the regression trendline to the data points as well as the accuracy of the quadratic versus cubic regression equation in describing the temperature-flow relationship. Together, the low mean of 7DMAX temperatures recorded at 5.3 LnQD representing actual flows from 192-207 cfs across five years of data, and the corresponding regression equation predicting 18.0°C at this flow, provide strong support for approximately 206 cfs resulting in temperatures that meet or approach the 18.0°C state standard and biological requirement for resident salmonids. It is worth noting that, although higher than previously reported flow estimates, 206 cfs is an achievable flow well within the existing target.

The estimated July 7DMAX temperature at DR 133.50 for the highest flow with enough temperature observations to be included in analysis is 21°C ± 4.2°C at 171 cfs, slightly lower than the 2005-2010 estimate of 21.6°C ± 4.6°C for the same location (**Appendix A**). The temperature-flow relationship for Lower Bridge Road describes temperatures remaining relatively constant within a degree of 25°C from 47 to 95 cfs then gradually decreasing to the lowest estimated temperature of 21°C±4.2°C at 171 cfs (**Figure 7**). Although flows recorded for July 2011 ranged from 134 cfs to 447 cfs (4.9-6.1 LnQD), 7DMAX temperatures were only available for 6 days in July 2011, corresponding to 5.5 and 5.6 LnQd, historically high flows for which the number of temperature observations available are not yet sufficient to be included in regression analysis. Thus, no July 2011 7DMAX temperatures were included in the DR 133.50 regression analysis. Only one mean 7DMAX temperature value included in the 2005-2011 regression changed from the 2005-2010 analysis, due to the inclusion of 2010 data for one flow level where it had been omitted from previous analyses. When calculated using temperature means to two decimal places, the resulting cubic equation was very similar to that reported for the 2005-2010 analysis (UDWC, 2011). The Heat Source model estimates a 7DMAX temperature of approximately 19 °C at the present target flow of 250 cfs for the middle Deschutes River at Lower Bridge Road (Watershed Sciences; MaxDepth Aquatics, Inc., 2007).[6] Because temperature estimates calculated from regression equations are valid only within the range of flows included in the analysis and 250 cfs falls outside of the range of available data used to develop this relationship, given available data we are unable to support or refute the Heat Source estimate.

[6] Heat Source model uses seven day moving average maximum temperatures (a daily statistic) while the regression model in this Technical Report uses the mean seven day moving average maximum temperature for July (a monthly statistic), hence direct comparison of results is difficult.

a)



b)

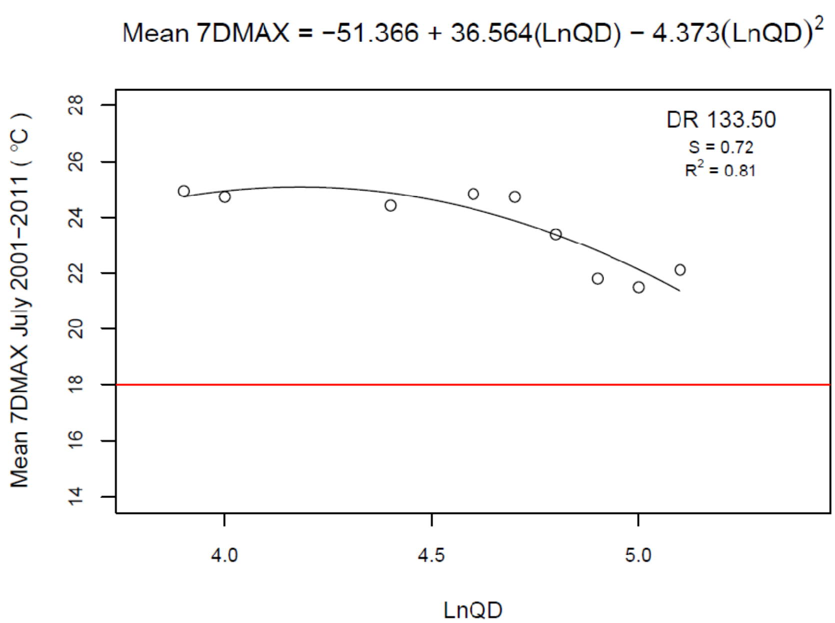


Figure 8

Regression models fitted to temperature-flow data describe the relationship between temperature and flow observed during July 2001-2001 at a) DR 160.00, the Deschutes River immediately downstream of Tumalo Creek, and b) DR 133.50, Lower Bridge Road. Corresponding regression equations can be used to calculate temperature at a given flow within the range of flows included in analysis.

4. Discussion

4.1. Temperature Status

Temperatures exceeded the state temperature standard of 18°C / 64°F at four monitoring locations between DR 164. 75 and DR 133.50 in 2011, confirming the temperature impaired status of the middle Deschutes River under Clean Water Act Section 303(d). However, during July 2011, when flows downstream of Tumalo Creek remained above 200 cfs for most of the month, 7DMAX temperatures were consistently lower than 18°C. And, while summer temperatures at Lower Bridge Road continue to exceed the state standard, we have observed them steadily decreasing since 2001. These data suggest that higher flows resulting from streamflow restoration are producing temperatures that meet or are very close to the state standard at some sites, but that still higher flows, and additional streamflow restoration, will be required to meet the 18°C standard at the most impaired sites. Until these flows are achieved, temperature data suggest that the middle Deschutes River will continue to exceed the state temperature standard during the summer months.

4.2. Restoration Effectiveness

Significantly different changes in temperature in the two restoration reaches of the middle Deschutes River relative to the reference reach from 2008 to 2009 and from 2010 to 2011 indicate that increased flows from streamflow restoration resulted in cooler downstream temperatures in these years. The greater difference in changes in temperature in the Tumalo reach relative to the reference reach over both intervals suggests a stronger cooling effect downstream of the cooler flow contribution of Tumalo Creek. Streamflow restoration projects that strategically increase flows in Tumalo Creek in proportion to the flow contribution of the upper Deschutes at North Canal Dam may be an effective approach to maximize reductions in temperature in the middle Deschutes downstream of Tumalo Creek.

4.3. Target Streamflow

The observed temperature-flow relationship does not allow us to predict whether the 250 cfs streamflow restoration target will produce the requisite 18°C in the middle Deschutes River at Lower Bridge Rd (**Table 5**). The maximum average daily flow with the minimum number of associated temperature records required for analysis observed between 2001 and 2011 was 171 cfs. 250 cfs falls outside of the range of available data used to develop this relationship. Applying the temperature-flow relationship to predict temperatures beyond the observed range of flows introduces substantial uncertainty. Working with restoration partners and particularly irrigation districts to plan flow releases of 250 cfs over a minimum period of sixteen days to allow the minimum number of temperature records required for analysis would provide the data necessary to develop a temperature-flow relationship that could predict with 95% certainty the temperature expected at the target flow of 250 cfs.

Temperatures immediately downstream of Tumalo Creek at DR 160.00 met or approached the state standard at flows between 192 and 207 cfs, the highest flow available for analysis (**Appendix A**).

Although this relationship neither supports nor contradicts the 250 cfs streamflow restoration target, temperature records from 2006-2011 provide a growing body of evidence for flows around 200 cfs and higher resulting in temperatures of approximately 18°C or below.

The observed temperature-flow relationships reflect flow regimes in the upper Deschutes at North Canal Dam and in Tumalo Creek and the ratio of flows from each source over the eleven-year period during which data were collected. Streamflow restoration that results in long-term changes to the ratio of flows from each source may also alter downstream temperature-flow relationships. New data on fish response to increased flows and fish habitat use, to be collected by ODFW from summer 2012 to 2013, will contribute to the ability of restoration partners to discern how flow level affects habitat availability and use in which locations, and refine streamflow targets accordingly to maximize ecological benefits.

Table 5 Summary of Flow Scenarios and Temperature Status for the Middle Deschutes River at DR 160.00 immediately downstream of Tumalo Creek, and at DR 133.50 at Lower Bridge Road.

QD (cfs)	DR 160.00	DR 133.50
≤ 171	standard not met	standard not met
< 206	standard not met	data unavailable
206-207	standard met	data unavailable
> 207	data unavailable	data unavailable

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APPENDIX A Estimated temperatures at given flows

Deschutes River downstream of Tumalo Creek (DR 160.00)

Flow (cfs)	Mean Temp (7DMAX)	CI (±)	Flow (cfs)	Mean Temp (7DMAX)	CI (±)	Flow (cfs)	Mean Temp (7DMAX)	CI (±)
78	20.0	3.3	**133**	19.2	3.3	**188**	18.3	3.2
79	20.0	3.3	**134**	19.2	3.3	**189**	18.3	3.2
80	20.0	3.3	**135**	19.2	3.3	**190**	18.3	3.2
81	20.0	3.3	**136**	19.2	3.3	**191**	18.3	3.2
82	20.0	3.3	**137**	19.2	3.3	**192**	18.3	3.2
83	20.0	3.3	**138**	19.2	3.2	**193**	18.3	3.2
84	20.0	3.3	**139**	19.1	3.2	**194**	18.2	3.2
85	20.0	3.3	**140**	19.1	3.2	**195**	18.2	3.2
86	20.0	3.3	**141**	19.1	3.2	**196**	18.2	3.2
87	19.9	3.3	**142**	19.1	3.2	**197**	18.2	3.2
88	19.9	3.3	**143**	19.1	3.2	**198**	18.2	3.2
89	19.9	3.3	**144**	19.1	3.2	**199**	18.2	3.2
90	19.9	3.3	**145**	19.0	3.2	**200**	18.1	3.2
91	19.9	3.3	**146**	19.0	3.2	**201**	18.1	3.2
92	19.9	3.3	**147**	19.0	3.2	**202**	18.1	3.2
93	19.9	3.3	**148**	19.0	3.2	**203**	18.1	3.2
94	19.8	3.3	**149**	19.0	3.2	**204**	18.1	3.2
95	19.8	3.3	**150**	19.0	3.2	**205**	18.1	3.2
96	19.8	3.3	**151**	18.9	3.2	**206**	18.0	3.2
97	19.8	3.3	**152**	18.9	3.2	**207**	18.0	3.2
98	19.8	3.3	**153**	18.9	3.2			
99	19.8	3.3	**154**	18.9	3.2			
100	19.8	3.3	**155**	18.9	3.2			
101	19.7	3.3	**156**	18.9	3.2			
102	19.7	3.3	**157**	18.8	3.2			
103	19.7	3.3	**158**	18.8	3.2			
104	19.7	3.3	**159**	18.8	3.2			
105	19.7	3.3	**160**	18.8	3.2			
106	19.7	3.3	**161**	18.8	3.2			
107	19.7	3.3	**162**	18.8	3.2			
108	19.6	3.3	**163**	18.7	3.2			
109	19.6	3.3	**164**	18.7	3.2			
110	19.6	3.3	**165**	18.7	3.2			
111	19.6	3.3	**166**	18.7	3.2			
112	19.6	3.3	**167**	18.7	3.2			
113	19.6	3.3	**168**	18.7	3.2			
114	19.5	3.3	**169**	18.6	3.2			
115	19.5	3.3	**170**	18.6	3.2			
116	19.5	3.3	**171**	18.6	3.2			
117	19.5	3.3	**172**	18.6	3.2			
118	19.5	3.3	**173**	18.6	3.2			
119	19.5	3.3	**174**	18.6	3.2			
120	19.5	3.3	**175**	18.6	3.2			
121	19.4	3.3	**176**	18.5	3.2			
122	19.4	3.3	**177**	18.5	3.2			
123	19.4	3.3	**178**	18.5	3.2			
124	19.4	3.3	**179**	18.5	3.2			
125	19.4	3.3	**180**	18.5	3.2			
126	19.4	3.3	**181**	18.5	3.2			
127	19.3	3.3	**182**	18.4	3.2			
128	19.3	3.3	**183**	18.4	3.2			
129	19.3	3.3	**184**	18.4	3.2			
130	19.3	3.3	**185**	18.4	3.2			
131	19.3	3.3	**186**	18.4	3.2			
132	19.3	3.3	**187**	18.4	3.2			

Deschutes River at Lower Bridge Road (DR 133.50)

Flow (cfs)	Mean Temp (7DMAX)	CI (±)	Flow (cfs)	Mean Temp (7DMAX)	CI (±)	Flow (cfs)	Mean Temp (7DMAX)	CI (±)
47	24.6	4.5	**102**	24.2	4.5	**157**	21.7	4.3
48	24.6	4.5	**103**	24.2	4.5	**158**	21.7	4.2
49	24.7	4.5	**104**	24.1	4.5	**159**	21.6	4.2
50	24.7	4.5	**105**	24.1	4.5	**160**	21.6	4.2
51	24.8	4.5	**106**	24.0	4.5	**161**	21.5	4.2
52	24.8	4.5	**107**	24.0	4.5	**162**	21.5	4.2
53	24.9	4.5	**108**	24.0	4.5	**163**	21.4	4.2
54	24.9	4.5	**109**	23.9	4.5	**164**	21.4	4.2
55	24.9	4.5	**110**	23.9	4.4	**165**	21.3	4.2
56	25.0	4.5	**111**	23.8	4.4	**166**	21.3	4.2
57	25.0	4.5	**112**	23.8	4.4	**167**	21.2	4.2
58	25.0	4.5	**113**	23.8	4.4	**168**	21.2	4.2
59	25.0	4.5	**114**	23.7	4.4	**169**	21.1	4.2
60	25.0	4.5	**115**	23.7	4.4	**170**	21.1	4.2
61	25.0	4.5	**116**	23.6	4.4	**171**	21.0	4.2
62	25.1	4.6	**117**	23.6	4.4			
63	25.1	4.6	**118**	23.5	4.4			
64	25.1	4.6	**119**	23.5	4.4			
65	25.1	4.6	**120**	23.5	4.4			
66	25.1	4.6	**121**	23.4	4.4			
67	25.1	4.6	**122**	23.4	4.4			
68	25.1	4.6	**123**	23.3	4.4			
69	25.1	4.6	**124**	23.3	4.4			
70	25.0	4.5	**125**	23.2	4.4			
71	25.0	4.5	**126**	23.2	4.4			
72	25.0	4.5	**127**	23.1	4.4			
73	25.0	4.5	**128**	23.1	4.4			
74	25.0	4.5	**129**	23.0	4.4			
75	25.0	4.5	**130**	23.0	4.4			
76	25.0	4.5	**131**	23.0	4.4			
77	24.9	4.5	**132**	22.9	4.4			
78	24.9	4.5	**133**	22.9	4.4			
79	24.9	4.5	**134**	22.8	4.4			
80	24.9	4.5	**135**	22.8	4.4			
81	24.9	4.5	**136**	22.7	4.3			
82	24.8	4.5	**137**	22.7	4.3			
83	24.8	4.5	**138**	22.6	4.3			
84	24.8	4.5	**139**	22.6	4.3			
85	24.8	4.5	**140**	22.5	4.3			
86	24.7	4.5	**141**	22.5	4.3			
87	24.7	4.5	**142**	22.4	4.3			
88	24.7	4.5	**143**	22.4	4.3			
89	24.6	4.5	**144**	22.3	4.3			
90	24.6	4.5	**145**	22.3	4.3			
91	24.6	4.5	**146**	22.2	4.3			
92	24.6	4.5	**147**	22.2	4.3			
93	24.5	4.5	**148**	22.1	4.3			
94	24.5	4.5	**149**	22.1	4.3			
95	24.5	4.5	**150**	22.1	4.3			
96	24.4	4.5	**151**	22.0	4.3			
97	24.4	4.5	**152**	22.0	4.3			
98	24.3	4.5	**153**	21.9	4.3			
99	24.3	4.5	**154**	21.9	4.3			
100	24.3	4.5	**155**	21.8	4.3			
101	24.2	4.5	**156**	21.8	4.3			