# Upper Deschutes and Little Deschutes Subbasins TMDLs

## Context for Reviewing Watershed Sciences Temperature Modeling Reports

### Overview and Scope

The Oregon Department of Environmental Quality (DEQ) contracted with Watershed Sciences, Inc. to conduct some of the preliminary temperature modeling analyses in the Upper Deschutes, Little Deschutes and Crooked River Subbasins. This work was done under two different contracts (2007-2008 and 2008-2011) and was designed to support TMDL development by DEQ at a later date. This work was funded by the U.S. Environmental Protection Agency.

Heat Source is the computer model DEQ uses to simulate stream thermodynamics and hydrology. Under the first contract, Watershed Sciences calibrated Heat Source temperature models for Tumalo Creek, Whychus Creek, and Deschutes River between Wickiup Reservoir and Lake Billy Chinook. Under the second contract, Watershed Sciences did additional modeling on Metolius River, Little Deschutes River, Crescent Creek, Deschutes River above Wickiup Reservoir and a number of streams in the Crooked River Subbasins. Under these contracts, Watershed Sciences wrote a series of reports providing background material on the data used in the Heat Source models and on model calibration.

DEQ began work on TMDL development in the Upper Deschutes and Little Deschutes Subbasins in 2011, with the expectation of completing these TMDLs by the end of 2012. During TMDL development, it is possible that some of the calibration and flow modeling results presented in this Watershed Sciences reports may be modified. The existing models may be revised to incorporate more site-specific input gathered from local stakeholders during the advisory committee process and/or public review. DEQ is not working on TMDLs in the Crooked River subbasins at this time so the information provided in the Watershed Sciences reports for the streams in this area are very preliminary in nature at this time.

***The attached report describes the data used in the modeling done under the second contract.*** Compilation of this data was identified as “Task 2” in the contract with Watershed Sciences. Until completion of the TMDLs, this document provides useful information about the data used in these models.

### Model Limitations

The temperature modeling effort undertaken in the Upper and Little Deschutes Subbasins provides some very interesting and meaningful results. However, it is worth identifying up-front some of the specific limitations of the models and the appropriate scale in which to interpret the results. Stream temperature dynamics are complex and analytical methods have limitations.

- <u>Heat Source simulations are only valid for the simulation time period</u> (which corresponds to the time period that ground level data was collected). Watershed Sciences calibrated the Heat Source models in the Upper and Little Deschutes Subbasins based on conditions in summer 2000 or summer 2001. It would not be appropriate to use these models to simulate stream temperature in another year without re-calibrating the model with input data from that other year.


State of Oregon
**Department of Environmental Quality**

**Water Quality**
**Eastern Region**
**Bend Office**
475 NE Bellevue, Suite 110
Bend, OR 97701
Phone: (541) 388-6146
(866) 863-6668
Fax: (541) 388-8283
Contact: Bonnie Lamb

*www.oregon.gov/DEQ*


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By: Bonnie lamb

Simulating other seasons or years introduces un-measurable uncertainty via a combination of climate, flow, and boundary condition assumptions. In addition, the existing flows in portions of Tumalo Creek and Whychus Creek were quite small (i.e. less than 10 cfs). Small flows equate to temperatures that are extra sensitive to climate and effective shade. Certain features such as vegetation growth or changes in flow can be simulated for the same time period, assuming that all other calibration inputs remain unchanged.

- Heat Source is not a groundwater model. The model has simulation inputs for groundwater and hyporheic exchange and attempts to include them in the heat flux, but Heat Source does not model far-field groundwater processes. Complex and wide-scale water table processes are not accounted for.

  Heat Source only includes groundwater contributions to surface water that were measured during the simulation time period. Alder Springs was the only spring where flows were measured during field data collection. Other springs were identified in the thermal infrared imagery and a flow mass balance was derived for those areas. The contain estimated flows and temperatures of springs that were observed in the TIR data. The uncertainty associated with such inputs is not directly quantifiable and therefore should not be used for simulating different spring flow scenarios.

- Heat Source results are only as good as the field data. Measured temperatures, flows, velocities, widths, effective shade, substrate, and other data are used as model validation. When these data types are sparse or absent, the user is required to make assumptions regarding channel morphology and hydrology. These assumptions introduce uncertainty and increase the model error. For some reaches there was limited field data due to lack of access. Verifying model accuracy in these reaches is difficult and is a source of uncertainty.

# Deschutes Basin TMDL Modeling - Task 2

## Data Summary & Digitization of Streams, Banks, and Riparian Corridor

Contract No. 046-09 Final Report February 4, 2009

*Prepared for,*

Oregon Department of Environmental Quality
475 NE Bellevue Dr., Suite 110
Bend, OR 97701

State of Oregon
Department of Environmental Quality

*Prepared by,*

Watershed Sciences, Inc.
529 SW Third Avenue, Suite 300
Portland, OR 97204

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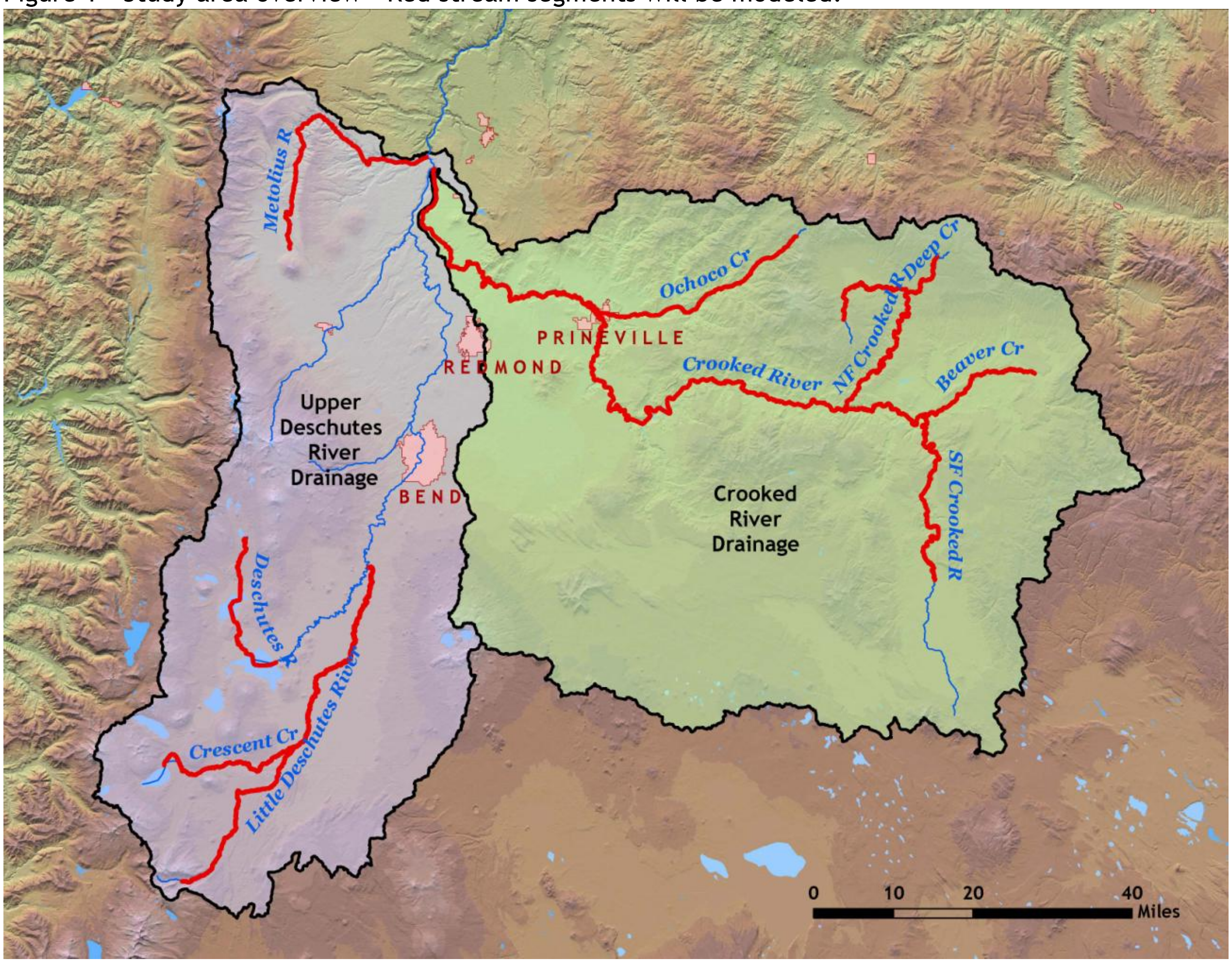
## Introduction and Scope

The Oregon Department of Environmental Quality has contracted Watershed Sciences to simulate stream temperature on 10 streams in the Upper Deschutes and Crooked River drainages in support of Total Maximum Daily Load (TMDL) development. Figure 1 shows the study area, the river drainages, and the stream reaches being simulated for this project.

The Upper Deschutes River drainage is composed of two fourth field HUCs; 17070301 and 17070302. The Crooked River drainage is composed of three fourth field HUCs; 17070303, 17070304, and 17070305. Field data was collected in the Upper Deschutes River drainage during the summer of 2001 and in the Crooked River drainage during the summer of 2005. This report summarizes the existing data and presents the TTools sampling results for each of the two drainages.

Figure 1 – Study area overview – Red stream segments will be modeled.



## Section 1 - Summary of Existing Data

The Oregon Department of Environmental Quality provided data that they collected for stream temperature TMDL development in the Upper Deschutes River drainage (2001 season) and the Crooked River drainage (2005 season). The ground level data include flow, temperature, channel, habitat, and effective shade measurements. Remote sensing data includes thermal infrared (TIR) stream temperature data, which consists of both thermal and true color imagery (Watershed Sciences 2002 & 2006). The USGS collected LiDAR in a portion of the study area during 2003 (USGS 2003). This section summarizes the locations where the data was collected and presents summary statistics. All of the data presented here will be incorporated into stream temperature modeling using the Heat Source model, version 8.x.

Under a previous contract with Oregon DEQ, Watershed Sciences simulated temperature on the Deschutes River between Wickiup and Lake Billy Chinook, Tumalo Creek, and Whychus Creek. Remote sensing and ground level data is available for those stream reaches as well, but is not presented within this report. For more information on those streams, refer to the document entitled *Deschutes River, Whychus Creek, and Tumalo Creek Temperature Modeling* (Watershed Sciences, 2007).

### Stream Flow

Flow data from both instantaneous field measurements and daily gage records will be used to set up and calibrate the hydraulics of each Heat Source model. Figure 2 shows the locations where flow data is available for the simulation time period. Table 1 and Table 2 on the following pages summarize the instantaneous data available for each of the drainages.

Figure 2 – Flow measurement sites (includes both instantaneous and gages).

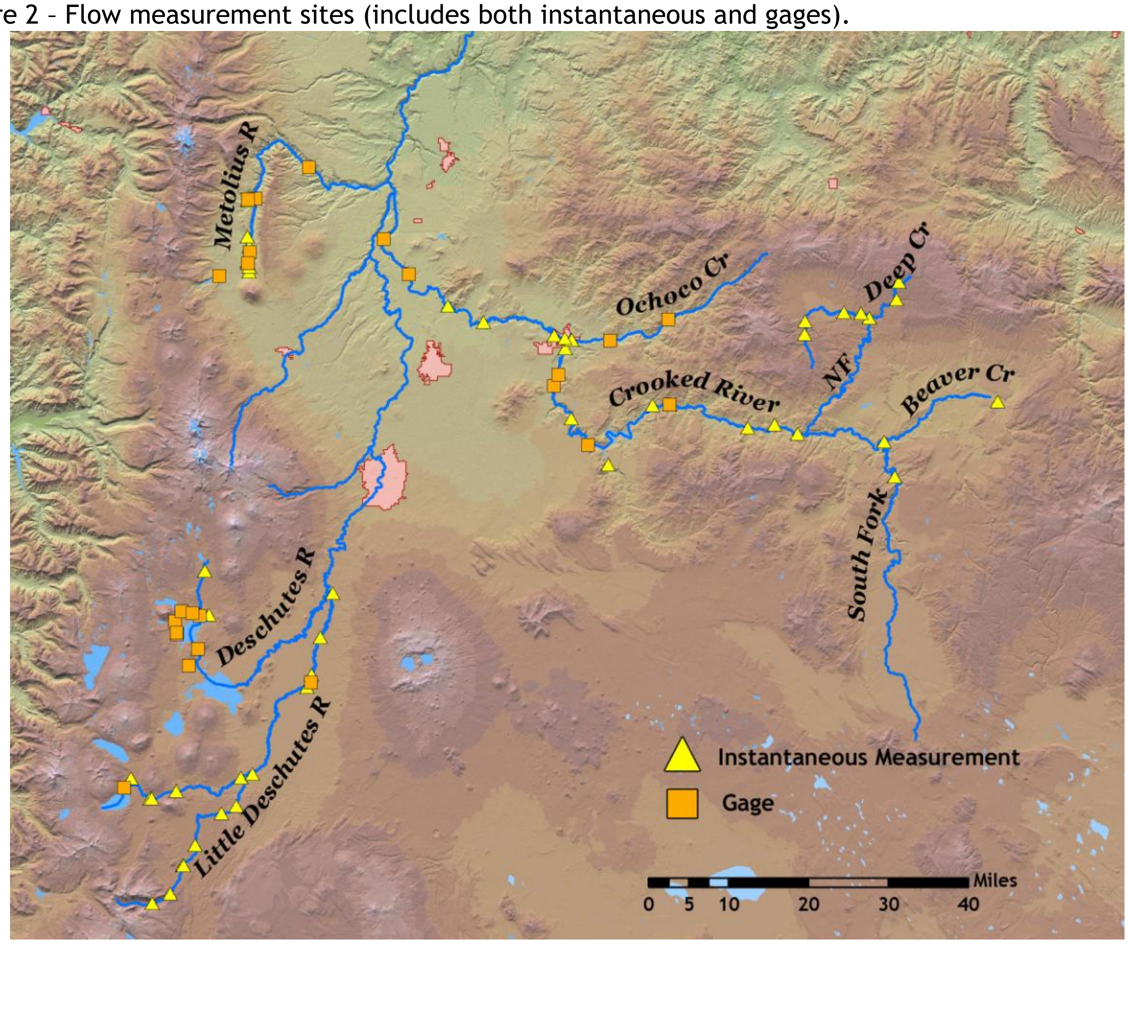


Table 1 – Upper Deschutes River Drainage instantaneous stream flow measurement summary.

| River System | Site | RM | Date | Flow (cfs) | width (feet) | avg depth (feet) | avg velocity (ft/sec) |
|---|---|---|---|---|---|---|---|
| Crescent Creek | Cold Spring Creek @ Crescent Lake Rd. | 28.3 | 7/24/2001 | 10.58 | 11 | 0.82 | 0.892 |
| | Crescent Creek us/ Big Marsh Creek (channel #1) | 23.3 | 7/24/2001 | 77.2 | 22.7 | 1.43 | 1.662 |
| | Crescent Creek us/ Big Marsh Creek (channel #2) | 23.3 | 7/24/2001 | 49.17 | 30 | 0.77 | 1.732 |
| | Crescent Creek at Highway 58 | 22.9 | 7/24/2001 | 158.11 | 52.5 | 0.96 | 2.31 |
| | Crescent Creek @ Crescent Creek Campground | 19.2 | 7/24/2001 | 212.02 | 46 | 1.15 | 2.776 |
| | Crescent Creek at Road 62 | 3.0 | 7/25/2001 | 181.14 | 55 | 1.37 | 1.631 |
| Deschutes River | Deschutes River d/s Little Lava Lake | 22.5 | 7/24/2001 | 12.62 | 54 | 0.27 | 0.564 |
| | Snow Creek at Mouth | 15.4 | 7/24/2001 | 20.24 | 18 | 1.73 | 0.595 |
| | Deschutes River u/s Snow Creek | 15.3 | 7/24/2001 | 45.11 | 18 | 1.22 | 2.012 |
| Little Deschutes River | Little Deschutes River near Wilderness Boundary | 102.2 | 7/24/2001 | 20.98 | 12.5 | 1.54 | 0.912 |
| | Little Deschutes River at Cow Camp | 97.9 | 7/24/2001 | 13.19 | 18 | 2.05 | 0.354 |
| | Hemlock Creek at Mouth | 92.5 | 7/24/2001 | 2.35 | 11.5 | 0.82 | 0.188 |
| | Little Deschutes River u/s Hemlock Creek | 92.5 | 7/24/2001 | 18.43 | 22 | 0.65 | 1.343 |
| | Little Deschutes off Rd 5825 | 87.3 | 7/24/2001 | 20.74 | 21.5 | 0.82 | 1.089 |
| | Little Deschutes River off Crescent Cutoff Road | 74.5 | 7/24/2001 | 13.12 | 21 | 2.05 | 0.234 |
| | Little Deschutes u/s Gilchrist Mill Pond | 70.5 | 7/24/2001 | 19.49 | 30 | 1.72 | 0.37 |
| | Little Deschutes River at Road 62 | 62.8 | 7/27/2001 | 3.67 | 17.7 | 1.79 | 0.098 |
| | Long Prairie Slough @ mouth | 31.1 | 7/24/2001 | 5.46 | 5 | 1.4 | 0.615 |
| | Little Deschutes River at Burgess Road | 27.3 | 7/24/2001 | 134.16 | 48 | 1.87 | 1.533 |
| | Little Deschutes @ State Rec Rd. | 14.7 | 7/24/2001 | 141.91 | 54 | 2.89 | 0.821 |
| | Little Deschutes River at Crosswater | 1.0 | 7/24/2001 | 131.38 | 67 | 2.79 | 0.623 |

| River System | Site | RM | Date | Flow (cfs) | width (feet) | avg depth (feet) | avg velocity (ft/sec) |
|---|---|---|---|---|---|---|---|
| Metolius River | Metolius River at Headwaters #1 | 39.8 | 7/26/2001 | 116.21 | 111.7 | 0.62 | 1.027 |
| | Metolius River u/s Tract C bridge | 39.1 | 7/26/2001 | 125.13 | 30.4 | 1.59 | 1.98 |
| | South Fork Lake Creek at Mouth | 38.6 | 7/25/2001 | 67.35 | 27.5 | 1.74 | 1.291 |
| | Spring Creek at Mouth | 38.3 | 7/25/2001 | 101.85 | 48 | 0.89 | 1.951 |
| | Metolius River u/s First Creek | 36.2 | 7/25/2001 | 313.75 | 100.5 | 1.08 | 2.064 |
| | Canyon Creek at Mouth | 34.5 | 7/26/2001 | 55.35 | 27 | 1.16 | 1.328 |
| | Candle Creek u/s Road 1290 | 29.0 | 7/26/2001 | 74.01 | 21 | 1.11 | 2.436 |
| | Jefferson Creek u/s Road 1290 | 28.2 | 7/26/2001 | 63.22 | 30.3 | 1.01 | 1.416 |

Table 2 – Crooked River Drainage instantaneous stream flow measurement summary.

| River System | Site | RM | Date | Flow (cfs) | width (feet) | avg depth (feet) | avg velocity (ft/sec) |
|---|---|---|---|---|---|---|---|
| Beaver Creek | SF Beaver at Puett Road | 23.5 | 8/4/05 | 2.57 | 9 | 0.32 | 0.64 |
| Crooked River | Crooked River d/s North Fork Crooked River | 110.0 | 8/4/05 | 3.13 | 26 | 0.42 | 0.237 |
| | Crooked River d/s North Fork at "Bridge Out" | 110.0 | 8/11/05 | 3.7 | 33 | 0.31 | 0.301 |
| | Crooked River d/s Lost Creek | 106.2 | 8/5/05 | 1.7 | 24 | 0.33 | 0.166 |
| | Crooked River d/s FS Road 17 at TNC Property | 102.0 | 8/5/05 | 2.26 | 30 | 0.23 | 0.265 |
| | Crooked River d/s FS Road 17 at TNC Property | 102.0 | 8/11/05 | 2.11 | 24 | 0.3 | 0.157 |
| | Crooked R u/s of Res. @ N Shore Rd | 86.1 | 7/13/05 | 35.23 | 47 | 0.59 | 1.044 |
| | Bear Creek at mouth | 73.7 | 7/12/05 | 4.99 | 5.9 | 1.03 | 0.655 |
| | Bear Creek at Mouth | 73.7 | 8/17/05 | 1.61 | 4.6 | 0.61 | 0.412 |
| | Crooked River at Castle Rock | 63.8 | 8/11/05 | 225.34 | 117.3 | 1.1 | 1.288 |
| | Crooked R at Les Schwab County Park | 50.2 | 8/5/05 | 60.87 | 35 | 0.65 | 2.131 |
| | Crooked River at Les Schwab County Park | 50.2 | 8/11/05 | 56.14 | 43.7 | 0.8 | 1.283 |
| | Crooked River d/s Prineville WWTP | 47.4 | 8/5/05 | 61.81 | 50 | 0.66 | 1.209 |

| River System | Site | RM | Date | Flow (cfs) | width (feet) | avg depth (feet) | avg velocity (ft/sec) |
|---|---|---|---|---|---|---|---|
| Crooked River | Crooked River d/s Prineville WWTP | 47.4 | 8/11/05 | 67.28 | 51 | 0.71 | 1.221 |
| | Crooked River downstream Dry Canyon | 33.6 | 8/5/05 | 109.47 | 50 | 0.71 | 1.966 |
| | Crooked River downstream Dry Canyon | 33.6 | 8/11/05 | 125.49 | 49 | 0.78 | 2.276 |
| | Crooked River u/s Smith Rocks footbridge | 25.2 | 8/11/05 | 42.76 | 71 | 0.93 | 0.508 |
| Deep Creek | Deep Creek d/s Happy Camp/Jackson confluence | 8.5 | 8/4/2005 | 0.6 | 10 | 0.26 | 0.166 |
| | Little Summit Creek near Mouth | 5.7 | 8/4/2005 | 0.53 | 9 | 0.14 | 0.258 |
| | Deep Creek near Mouth | 0.0 | 8/4/2005 | 7.08 | 25 | 0.35 | 0.569 |
| North Fork Crooked River | North Fork Crooked River near Post, OR | 88.5 | 8/10/2005 | 1.58 | 12 | 0.446 | 0.31 |
| | North Fork Crooked River at 050 Road | 43.9 | 8/4/2005 | 0.12 | 25 | 0.21 | 0.157 |
| | N. Fork Crooked u/s 42 Rd. (d/s BLM meadow) | 41.0 | 8/4/2005 | 0.56 | 5.5 | 0.23 | 0.272 |
| | North Fork Crooked River d/s Big Summit Prairie | 30.7 | 8/4/2005 | 0.5 | 10 | 0.23 | 0.151 |
| | North Fork Crooked River u/s Deep Creek | 27.9 | 8/4/2005 | 1.03 | 15.5 | 0.26 | 0.224 |
| Ochoco Creek | Ochoco Ck d/s Combs Flat Rd. & OID return flow | 5.1 | 8/5/2005 | 32.38 | 23.8 | 0.56 | 2.217 |
| | OID return flow d/s Combs Flat Rd. | 5.1 | 8/5/2005 | 10.75 | 24 | 0.67 | 0.528 |
| | Ochoco Creek @ d/s end of City Park (near fire station) | 4.1 | 8/5/2005 | 20.02 | 21 | 0.64 | 1.455 |
| South Fork Crooked River | S. Fork Crooked @ Jake Place Ford | 10.1 | 8/4/2005 | 14.01 | 15.5 | 0.71 | 0.975 |
| | South Fork Crooked River at Mouth | 0.3 | 8/10/05 | 1.49 | 13.4 | 0.475 | 0.25 |
| | S. Fork Crooked River @ Hwy 380 (near mouth) | 0.3 | 8/4/2005 | 3.75 | 12.5 | 1.23 | 0.181 |
| | S. Fork Crooked River @ Hwy 380 (near mouth) | 0.3 | 8/11/2005 | 3.04 | 15 | 1.41 | 0.109 |

Table 3 and Table 4 summarize the stream gages where daily data is available during the desired simulation time period. There is some historical gage data available in the study area, however the simulations require data that corresponds to the 2001 or 2005 simulation periods. The historical data is not included in this data summary because it will not be used for the temperature simulations.

Table 3 – Upper Deschutes River drainage gages.

| River | Gage Description | River Mile | Period of Record |
|---|---|---|---|
| Crescent Cr | Below Crescent Lake | 29.9 | 6/1/2001-9/30/2001 |
| Deschutes River | Cultus River | 15.6 | 6/1/2001-5/31/2005 |
| | Downstream Snow Creek | 15.2 | 6/1/2001-5/31/2008 |
| | Cultus Creek | 13.3 | 6/1/2001-5/31/2004 |
| | Charlton | 12.6 | 6/1/2001-5/31/2003 |
| | Deer Creek | 12.6 | 6/1/2001-5/31/2006 |
| | Quinn | 12.6 | 6/1/2001-5/31/2009 |
| | Below Crane Prairie Reservoir | 9.9 | 6/1/2001-5/31/2007 |
| | Browns Crossing | 7.5 | 6/1/2001-5/31/2002 |
| L. Deschutes R | La Pine | 29.6 | 6/1/2001-9/30/2001 |
| Metolius River | Lake Creek | 37.1 | 10/1/2000-10/1/2001 |
| | Allingham | 37.1 | 10/1/1910-9/30/2008 |
| | Jefferson | 28.2 | 6/1/2001-9/30/2001 |
| | Grandview | 12.2 | 6/1/2001-9/30/2001 |

Table 4 – Crooked River drainage gages.

| River | Gage Description | River Mile | Period of Record |
|---|---|---|---|
| Crooked River | Near Post, OR | 88.5 | 6/1/2005-9/30/2005 |
| | Below Bowman Dam | 71.5 | 6/1/2005-4/30/2006 |
| | Ochoco ID Diversion from Crooked R. | 57.5 | 6/1/2005-4/30/2006 |
| | Feed Canal Diversion | 55.9 | 10/1/2004-9/30/2006 |
| | Terrebonne | 27.7 | 6/1/2005-9/30/2005 |
| | Osborne Canyon | 13 | 6/1/2005-9/30/2005 |
| | Opal Springs | 6.6 | 6/1/2005-9/30/2005 |
| Ochoco Cr | Below Marks Creek | 20.8 | 6/1/2005-9/30/2005 |
| | Below Ochoco Dam | 11.0 | Data not yet received |

In addition to the data collected by the Oregon DEQ, there is synoptic stream flow data that was collected during other years. The NRCS did a flow study on the Lower Crooked River in 2008 (final report not yet completed). The OWRD performed a synoptic flow survey on the lower Crooked River between Bowman Dam and Smith Rocks in 2007. That data cannot be directly used within the simulations because it was collected in years other than those being simulated. However, the synoptic data will be examined and may be used as a basis for estimating the flow profile of the simulation years if necessary. This will be done on an as-needed basis if there are large data gaps or unmeasured gains or losses occurring in the streams being simulated. In any case, all assumptions and values will be thoroughly documented within the Heat Source calibration report (Task 3 of this contract).

**Stream Temperature – Hourly Data**

The state of Oregon stream temperature criteria is based upon the 7-day average daily maximum (7DADM). The rearing and migration numeric criterion is a 7DADM temperature of 18°C, which applies to all streams at all times. The Bull Trout criterion (12°C) applies to the Metolius River, the upper portion of the Little Deschutes River, Crescent Creek, and the Deschutes River above Wickiup Reservoir.

Hourly stream temperature data was collected by the Oregon DEQ and others during the critical summertime periods that are intended to be simulated for the temperature TMDL (during 2001 in the Upper Deschutes River drainage and during 2005 in the Crooked River drainage). DEQ provided that temperature data which is summarized in Figure 3. The 7DADM temperature statistics were calculated for each site and are included in Table 5 and Table 6 on the following pages.

Figure 3 - Stream temperature monitoring locations.

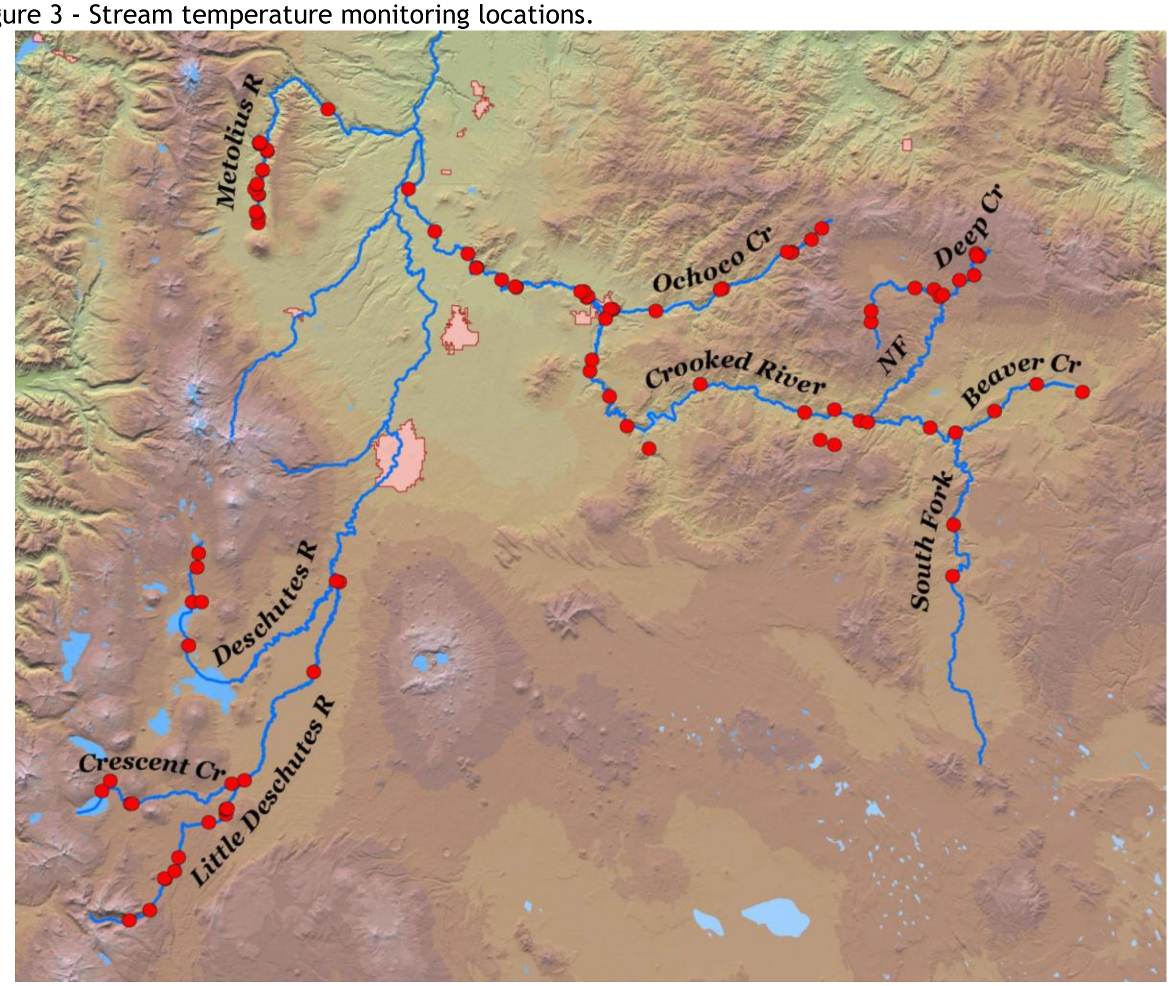


Table 5 – Stream temperature monitoring locations and 7DADM statistics of the Upper Deschutes River drainage.

| River System | Site (in 7DADM stats data) | River Mile | Begin Date | End Date | 7DADM Date | 7DADM[1] |
|---|---|---|---|---|---|---|
| Crescent Creek | Crescent Creek @ USGS Gauge Station (d/s of station approx 50 yds) | 29.9 | 4/18/01 | 9/13/01 | 8/11/01 | 20.7 |
| | Crescent Creek @ USGS Gauge Station (u/s of station approx 50 yds) | 29.9 | 4/18/01 | 10/8/01 | 8/11/01 | 20.6 |
| | Cold Cr at Mouth | 0.0 | 5/9/01 | 10/29/01 | 7/2/01 | 12.3 |
| | Crescent Creek u/s of Confluence w/ Big Marsh Creek | 23.3 | 5/8/01 | 10/8/01 | 8/10/01 | 22.2 |
| | Crescent at Hwy 58 | 22.9 | 5/9/01 | 9/30/01 | 8/10/01 | 22.2 |
| | Crescent Creek @ Rd 62 (mouth) | 3.0 | 5/10/01 | 9/30/01 | 7/4/01 | 21.5 |
| Deschutes River | Deschutes d/s Little Lava Lake and Blue Pool | 22.5 | 7/4/01 | 11/1/01 | 7/4/01 | 15.8 |
| | Deschutes River d/s Little Lava Lake and Blue Pool | 22.5 | 7/4/01 | 9/19/01 | 7/4/01 | 16.0 |
| | Deschutes at Cow Camp | 15.4 | 5/10/01 | 10/14/01 | 7/3/01 | 19.0 |
| | Snow Creek at Cow Camp | 0.0 | 5/10/01 | 10/14/01 | 5/21/01 | 13.7 |
| | Deschutes at Brown Crossing | 9.3 | 5/10/01 | 10/15/01 | 8/11/01 | 24.0 |
| Little Deschutes River | Little Deschutes near Wilderness Boundary | 102.2 | 7/11/01 | 10/8/01 | 8/5/01 | 14.3 |
| | Little Deschutes River @ Cow Camp (Spur Road 300) | 97.9 | 5/8/01 | 10/8/01 | 8/5/01 | 15.7 |
| | Little Deschutes River u/s of Hemlock Creek | 92.5 | 5/8/01 | 10/8/01 | 8/5/01 | 20.3 |
| | Little Deschutes off 090 Spur Rd | 90.7 | 5/9/01 | 9/30/01 | 8/6/01 | 20.2 |
| | Little Deschutes @ USFS boundary & 5825 RD | 87.3 | 5/8/01 | 10/8/01 | 8/6/01 | 20.4 |
| | Little Deschutes River off 100 Rd near Crescent | 74.5 | 4/28/01 | 8/6/01 | 7/4/01 | 22.6 |
| | Little Deschutes u/s Gilchrist Mill Pond | 70.5 | 7/13/01 | 11/1/01 | 8/5/01 | 24.5 |
| | Little Deschutes d/s Gilchrist Mill Pond and Crown Pacific Road bridge | 69.7 | 7/13/01 | 11/1/01 | 8/9/01 | 23.7 |
| | Little Deschutes at Road 62 | 62.8 | 5/10/01 | 9/30/01 | 7/4/01 | 23.7 |
| | Little Deschutes River u/s of Burgess Road | 27.3 | 4/18/01 | 11/1/01 | 7/4/01 | 23.9 |
| | Little Deschutes River @ Crosswater Golf Course Bridge | 1.0 | 4/18/01 | 11/6/01 | 7/4/01 | 24.4 |
| | Little Deschutes River u/s of Crosswater Clubhouse Bridge | 0.2 | 5/17/01 | 11/8/01 | 7/4/01 | 24.2 |
| Metolius River | Metolius Headwater Springs | 39.8 | 5/19/01 | 10/10/01 | 8/1/01 | 9.2 |
| | Metolius River @ Track C Bridge | 39.1 | 5/9/01 | 10/1/01 | 7/2/01 | 11.7 |
| | Metolius Tract C Bridge | 39.1 | 5/19/01 | 10/1/01 | 7/2/01 | 11.5 |
| | Lake Creek at Mouth | 0.0 | 5/19/01 | 10/1/01 | 7/4/01 | 12.2 |
| | Spring Creek @ Mouth | 0.0 | 5/9/01 | 10/1/01 | 5/20/01 | 9.1 |

[1] The 7DADM reported in this table is the maximum value calculated between the begin and end dates which is the period of record for which the thermistor was deployed.

| River System | Site (in 7DADM stats data) | River Mile | Begin Date | End Date | 7DADM Date | 7DADM[1] |
|---|---|---|---|---|---|---|
| Metolius River | Metolius Gorge CG | 36.2 | 5/19/01 | 10/1/01 | 7/2/01 | 11.9 |
| | First Creek at Mouth | 0.0 | 5/9/01 | 10/1/01 | 6/15/01 | 12.7 |
| | Jack Creek at Mouth | 0.0 | 7/26/01 | 10/30/01 | 8/5/01 | 7.1 |
| | Metolius River u/s Canyon Creek | 34.6 | 5/9/01 | 10/11/01 | 5/20/01 | 9.1 |
| | Canyon Creek at Mouth | 0.0 | 5/9/01 | 10/2/01 | 7/2/01 | 10.6 |
| | Metolius River @ Wizard Falls outfall | 31.9 | 5/9/01 | 10/1/01 | 7/3/01 | 11.5 |
| | Wizard Falls Hatchery discharge | 0.0 | 7/13/01 | 10/1/01 | 9/11/01 | 13.3 |
| | Metolius Bridge 99 USFS | 29.4 | 5/19/01 | 10/1/01 | 7/4/01 | 9.7 |
| | Metolius River @ Lower Bridge | 29.3 | 5/9/01 | 10/1/01 | 7/2/01 | 10.1 |
| | Candle Creek at Mouth | 0.0 | 5/9/01 | 10/1/01 | 5/21/01 | 7.0 |
| | Jefferson Creek at Mouth | 0.0 | 5/9/01 | 10/1/01 | 8/10/01 | 9.1 |
| | Jefferson Creek road 1290 USFS | 0.0 | 5/19/01 | 10/10/01 | 8/10/01 | 9.2 |
| | Metolius River u/s Gauging Station | 12.2 | 7/7/01 | 10/21/01 | 8/5/01 | 11.7 |

Table 6 - Stream temperature monitoring locations and 7DADM statistics of the Crooked River drainage.

| River System | Site (in 7DADM stats data) | RM | Begin Date | End Date | 7DADM Date | 7DADM[2] |
|---|---|---|---|---|---|---|
| Beaver Creek | S. Fork Beaver Cr. @ Puett Rd. | 0.0 | 6/2/05 | 10/20/05 | 7/17/05 | 23.4 |
| | Beaver Creek @ Beaver Creek Rd. | 15.0 | 6/2/05 | 10/20/05 | 7/20/05 | 24.5 |
| | Beaver Creek @ Post-Paulina Hwy | 6.5 | 6/2/05 | 10/20/05 | 7/20/05 | 23.3 |
| Crooked River | Crooked River @ BLM Guard Station | 122.3 | 6/2/05 | 11/29/05 | 7/20/05 | 25.3 |
| | Crooked River @ TNC property d/s Lost Cr. | 106.2 | 7/28/05 | 10/10/05 | 8/5/05 | 26 |
| | Drake Cr. @ 1680 Rd. | 0.0 | 6/16/05 | 10/16/05 | 8/4/05 | 17.2 |
| | Shotgun Cr. @ FS Boundary | 0.0 | 6/16/05 | 10/16/05 | 8/4/05 | 16.4 |
| | Crooked River @ Pine Creek bridge (FS Rd 17) | 102.0 | 6/2/05 | 10/20/05 | 8/3/05 | 27.8 |
| | Crooked River u/s Reservoir | 86.1 | 6/2/05 | 10/20/05 | 8/5/05 | 29 |
| | Bear Creek Mouth | 0.0 | 7/13/05 | 8/15/05 | 7/13/05 | 20.8 |
| | Crooked River d/s Bowman Dam | 71.5 | 6/1/05 | 11/30/05 | 10/25/05 | 13.1 |
| | Crooked River @ Castle Rock CG | 63.8 | 8/2/05 | 10/11/05 | 8/8/05 | 16.5 |
| | Crooked River u/s Stearns Dam | 59.2 | 7/28/05 | 10/11/05 | 8/5/05 | 16.5 |
| | Crooked River @ Les Schwab Park | 50.2 | 6/1/05 | 11/9/05 | 7/20/05 | 20.6 |
| | Crooked River u/s Ochoco Creek | 46.1 | 6/1/05 | 11/9/05 | 7/20/05 | 24.4 |
| | McKay Creek @ Hwy 26 | 0.0 | 6/1/05 | 11/9/05 | 7/20/05 | 22.8 |
| | Crooked River d/s McKay Creek | 45.1 | 6/1/05 | 11/9/05 | 7/20/05 | 24.2 |
| | Crooked u/s Dry | 33.9 | 4/30/05 | 9/29/05 | 7/25/05 | 26.2 |
| | Dry Canyon @ mouth/return flow | 0.0 | 4/30/05 | 11/8/05 | 7/28/05 | 26.3 |
| | Crooked d/s Dry | 33.6 | 4/30/05 | 9/29/05 | 7/28/05 | 28.0 |

[2] The 7DADM reported in this table is the maximum value calculated between the begin and end dates which is the period of record for which the thermistor was deployed.

| River System | Site (in 7DADM stats data) | RM | Begin Date | End Date | 7DADM Date | 7DADM[2] |
|---|---|---|---|---|---|---|
| Crooked River | Crooked River @ Lone Pine Rd. | 29.7 | 6/1/05 | 11/9/05 | 7/23/05 | 25.5 |
| | Crooked River @ Canyon's Ranch | 20.9 | 6/2/05 | 6/19/05 | 6/16/05 | 20.5 |
| | Crooked River d/s Osborne Canyon | 13.0 | 6/1/05 | 10/31/05 | 7/22/05 | 20.6 |
| | Crooked R inflow into LBC | 6.3 | 1/1/05 | 12/31/05 | 7/12/05 | 14.4 |
| Deep Creek | Happy Camp u/s Jackson Cr | 0.0 | 5/16/05 | 9/7/05 | 7/15/05 | 23.6 |
| | Jackson u/s Happy Camp Cr | 0.0 | 5/16/05 | 9/7/05 | 6/29/05 | 23.8 |
| | Deep Creek d/s Jackson/Happy Camp confluence | 8.5 | 8/5/05 | 10/11/05 | 8/12/05 | 24.1 |
| | Little Summit u/s Deep Cr | 0.0 | 5/16/05 | 9/7/05 | 7/15/05 | 20.2 |
| | Crazy u/s Deep * | 0.0 | 5/16/05 | 9/7/05 | - | - |
| | Deep Creek @ mouth | 0.0 | 6/1/05 | 9/20/05 | 7/21/05 | 24.7 |
| North Fork Crooked River | Gray Creek @ FSR 4225 crossing | 0.0 | 5/16/05 | 9/7/05 | 7/14/05 | 26.4 |
| | N. Fork Crooked @ 050 Rd | 43.9 | 6/21/05 | 9/29/05 | 7/25/05 | 23.5 |
| | N. Fork Crooked d/s 42/30 bridge | 30.7 | 6/21/05 | 9/29/05 | 7/15/05 | 26.1 |
| | N. Fork Crooked above Deep Creek | 27.9 | 6/21/05 | 9/29/05 | 7/15/05 | 26.0 |
| | N. Fork Crooked d/s Deep Cr. | 26.1 | 6/21/05 | 9/29/05 | 7/14/05 | 26.1 |
| | N. Fork Crooked Near mouth (Hwy 380) | 0.0 | 6/2/05 | 10/20/05 | 7/23/05 | 29.9 |
| Ochoco Creek | Ochoco us Ahalt | 39.9 | 6/3/05 | 9/28/05 | 7/14/05 | 16.0 |
| | Ochoco RD22-126 | 38.0 | 6/3/05 | 9/28/05 | 8/3/05 | 20.3 |
| | Ochoco us Canyon | 34.9 | 6/4/05 | 10/5/05 | 7/17/05 | 20.8 |
| | Canyon at Mouth | 0.0 | 6/3/05 | 10/4/05 | 8/21/05 | 18.1 |
| | Ochoco USFS Boundary | 34.1 | 6/4/05 | 10/5/05 | 8/3/05 | 21.2 |
| | Marks Cr. @ Hwy 26 | 0.0 | 6/1/05 | 11/9/05 | 8/10/05 | 25 |
| | Ochoco Creek u/s Reservoir (?QA) | 15.41 | 6/1/05 | 11/30/05 | 8/10/05 | 24.1 |
| | Ochoco ds Ochoco Dam | 11.2 | 7/15/05 | 10/10/05 | 9/1/05 | 16.8 |
| | Ochoco Cr. @ Combs Flat Rd. | 5.1 | 6/1/05 | 11/9/05 | 7/20/05 | 22.7 |
| | OID canal flow into Ochoco Creek | 0.0 | 8/3/05 | 10/10/05 | 8/10/05 | 16.2 |
| | Ochoco Middle School 2870 | 4.8 | 8/19/05 | 10/31/05 | 8/19/05 | 18.2 |
| | Ochoco Middle School 2870 | 4.8 | 6/8/05 | 8/18/05 | 7/17/05 | 20.8 |
| | Ochoco Cr. @ Madras Hwy | 0.7 | 6/1/05 | 11/9/05 | 7/23/05 | 20.9 |
| South Fork Crooked River | SF Crooked at GI BLM Boundary | 33.2 | 6/14/05 | 11/3/05 | 7/14/05 | 24.7 |
| | SF Crooked BLM below Crookfelt Ranch ds 12 mile | 18.7 | 6/17/05 | 11/3/05 | 7/27/05 | 25.5 |
| | SF Crooked Mouth | 0.3 | 6/2/05 | 9/30/05 | 8/3/05 | 25.6 |

* Data quality of this site is questionable. Thermistor appears to have been out of water or within stagnant pool.

Figure 4 and Figure 5 summarize the calculated 7DADM stream temperatures for each of the drainages. In both drainages, the seasonal peak 7DADM stream temperatures occurred in July and August. July and August are the critical summertime period when aquatic species are most at risk of thermally related disease and death. Each of the drainages has multiple recorded stream temperature criteria violations.

Recall that the applicable criteria are unique to the particular stream reach where the thermistor was located. The rearing and migration criterion of 18°C applies to all streams at all times. The Bull Trout criterion of 12°C applies to some of the upper stream reaches within the Upper Deschutes River drainage. More details are provided on the following pages as the 7DADM temperatures are discussed for the individual streams of interests.

Figure 4 – Peak 7-day average daily maximum temperatures recorded at each stream temperature monitoring site in the Upper Deschutes River drainage (2001).

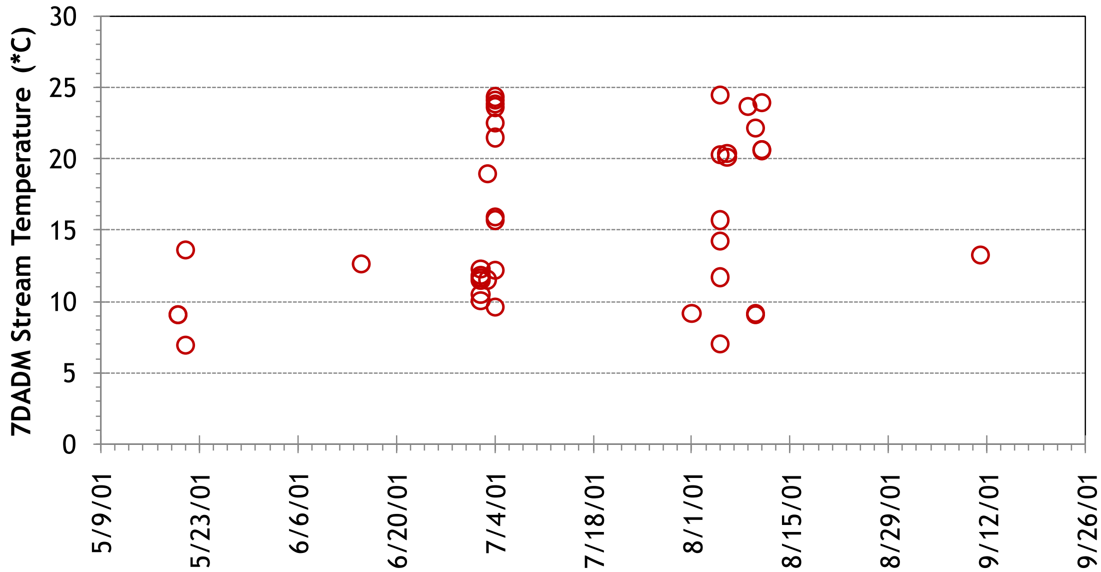
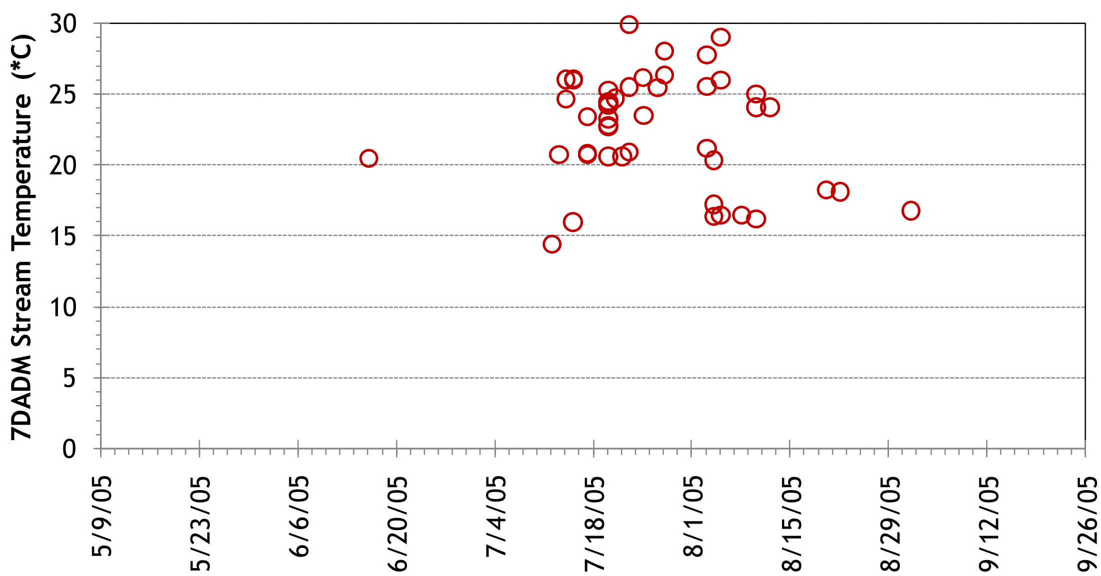



Figure 5 - Peak 7-day average daily maximum temperatures recorded at each stream temperature monitoring site in the Crooked River drainage (2005).



This section presents the 7-day average daily maximum stream temperatures for selected sites on each stream. The graphs are intended to help identify the critical summertime period, the magnitude of stream temperature criterion violations, and spatial variability. Some monitoring sites have been excluded from the charts in order to make them easier to read. Typically, the critical summertime period (highest stream temperatures) occurs during late July and early August in the Upper Deschutes and Crooked River drainages.

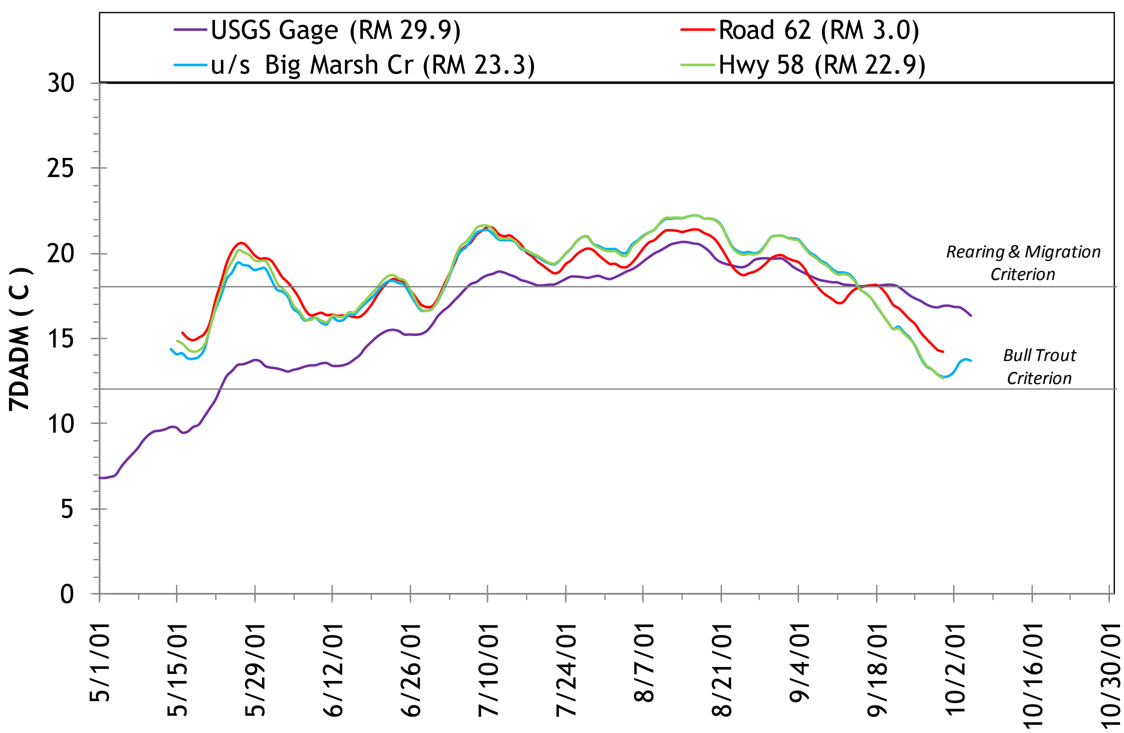
## Upper Deschutes River Drainage

### *Crescent Creek*

Crescent Creek violated the rearing and migration criterion at each of its monitoring sites during the summer of 2001. The rearing and migration criterion applies to the entire stream, while the Bull Trout criterion applies to the upper reaches. In Figure 6, the upper three sites should be evaluated against the Bull Trout criterion.

The USGS gage site is located just below the outlet of Crescent Lake, which helps to explain its unique cooler temperature pattern earlier in the season. Later in the season the stream temperatures just below the lake are warmer than the other monitoring sites.

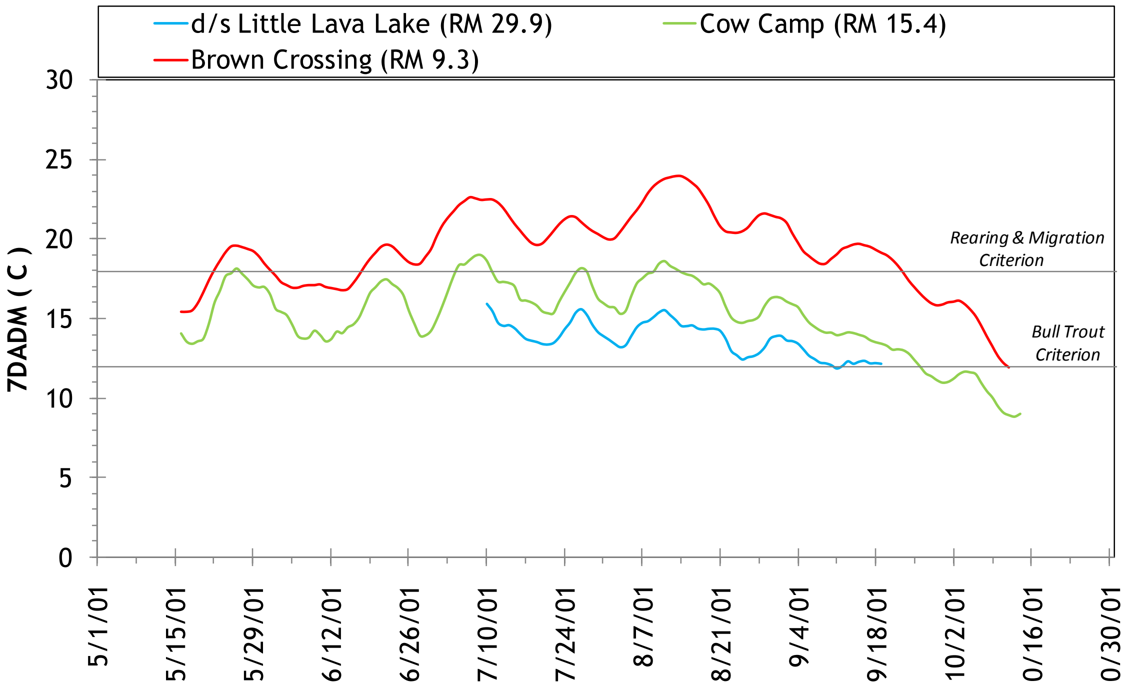
Figure 6 – Crescent Creek 7-day average daily maximum stream temperatures.



*Deschutes River*

The Deschutes River above Wickiup Reservoir violated the stream temperature criterion during 2001. The Bull Trout criterion is the applicable criterion above Wickiup Reservoir. The monitoring site at Brown Crossing is located between Crane Prairie Reservoir and Wickiup Reservoir. Crane Prairie reservoir releases much warmer water, contributing to the stream temperature criteria violations. The Cow Camp monitoring site is just above Crane Prairie Reservoir, and has much cooler temperatures, which illustrates how much warming is occurring within the reservoir.

Figure 7 – Deschutes River (above Wickiup Reservoir) 7-day average daily maximum stream temperatures.

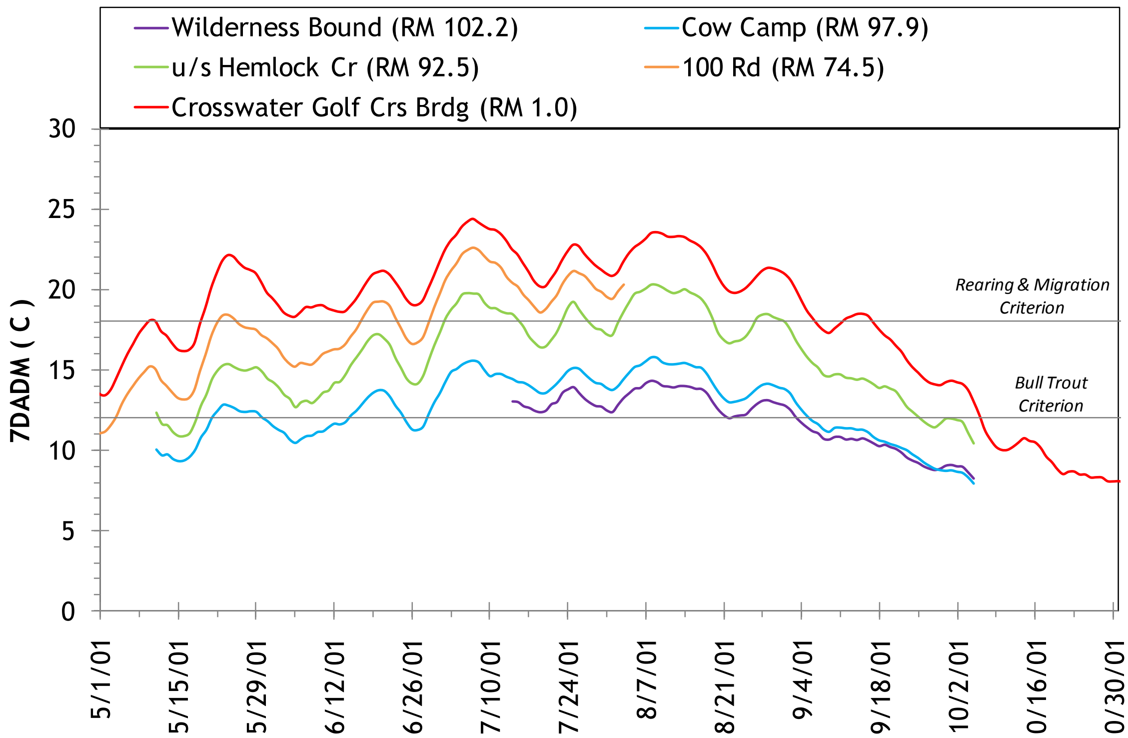


*Little Deschutes River*

The Bull Trout criterion applies to the upper three monitoring sites shown in Figure 8, while the rearing and migration criterion applies to the lower two sites. There were stream temperature criteria violations at all of the monitoring locations during the summer of 2001.

The Little Deschutes River gradually heats as it flows downstream. The golf course site is about 1 river mile from the mouth and had the most extreme criterion violations. At this site, there were rearing and migration criterion violations during the full months of June, July, and August 2001.

Figure 8 – Little Deschutes River 7-day average daily maximum stream temperatures.



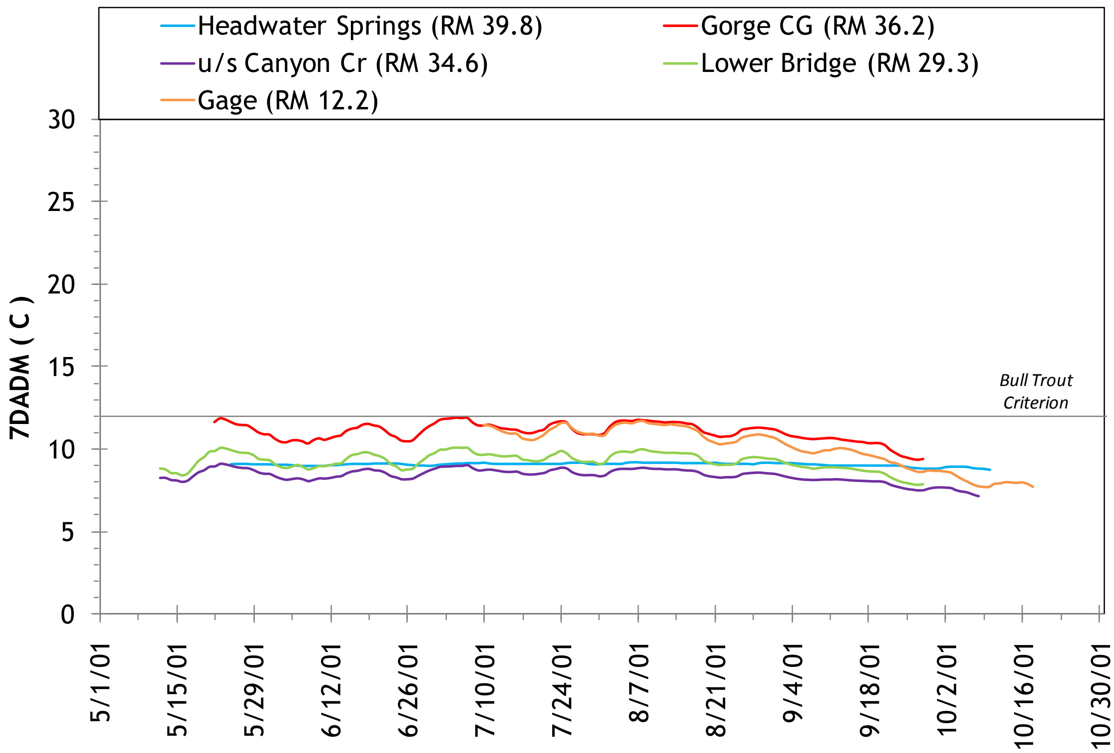
*Metolius River*

The Metolius River is unique because it originates from large cold springs. During the summertime, the river originates from the ground at a maximum temperature of about 9°C (~48°F). The applicable temperature criterion is the Bull Trout criterion of 12°C. There were no violations recorded on the Metolius River during the 2001 monitoring season.

The coolest temperatures were recorded at the site upstream of Canyon Creek. There are several cool tributaries just above this location which help to reduce river temperatures even further below the headwater springs temperature of 9°C.

Another interesting note is that the Metolius River is the only stream in the Upper Deschutes and Crooked drainages that is known to currently have a Bull Trout population. The Bull Trout criterion applies to other stream reaches in the Upper Deschutes River drainage based solely on historical presence.

Figure 9 – Metolius River 7-day average daily maximum stream temperatures.

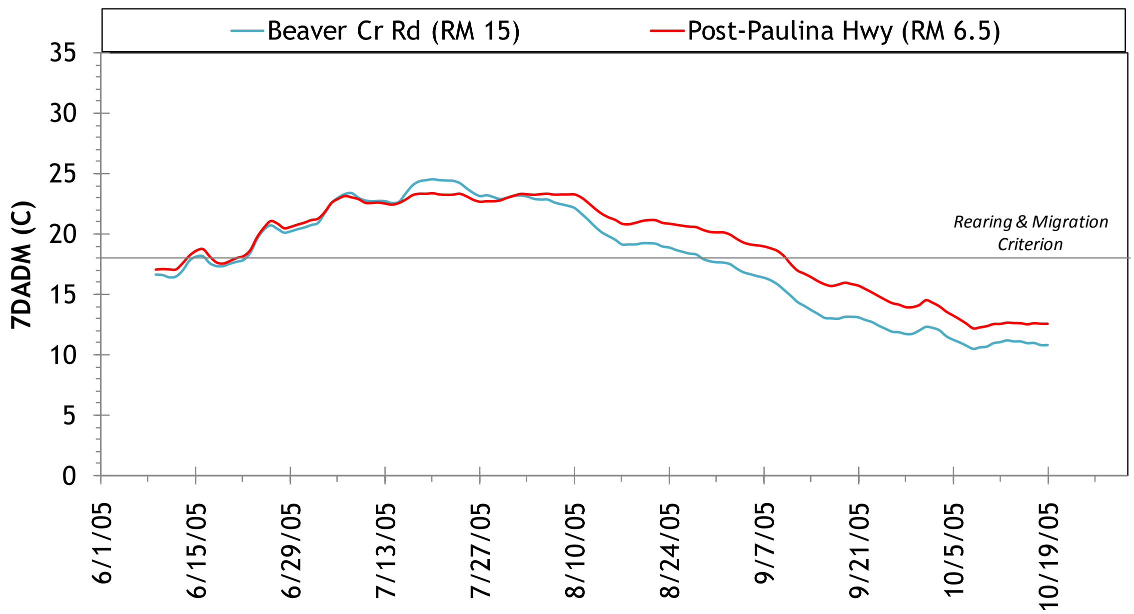


## Crooked River Drainage

### *Beaver Creek*

Beaver Creek experiences peak stream temperatures during July and August. The rearing and migration criterion of 18°C was violated at each of the monitoring sites plotted in Figure **10**.

Figure 10 - Beaver Creek 7-day average daily maximum stream temperatures.



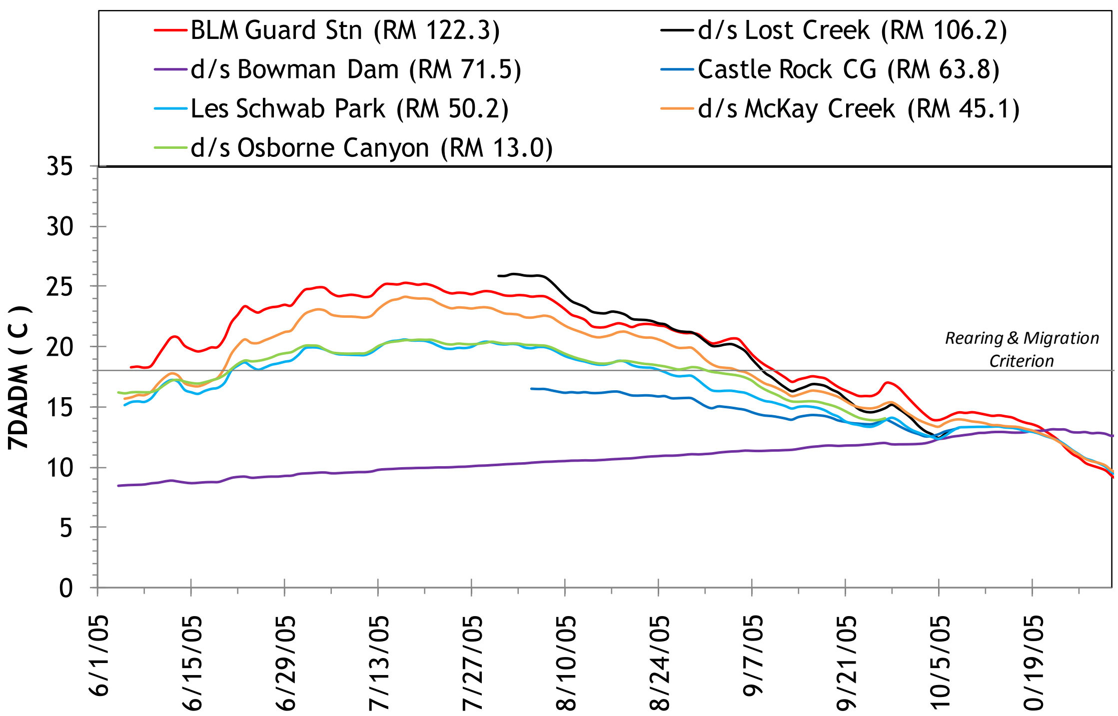
*Crooked River*

The Crooked River exceeds the rearing and migration criterion by over 7°C during the critical summertime period. Due to stratification in the reservoir, the stream temperatures below the dam were very cool throughout the summer, but then are warmer than the rest of the river during early autumn. Additional data is not available to examine the effects of the reservoir during other times of the year.

The warmest stream temperatures were recorded downstream of Lost Creek. The upper Crooked River (above Prineville Reservoir) is diverted for irrigation, has relatively little shade, is wide, and low gradient. These factors contribute to higher stream temperatures above the reservoir.

Temperatures below the reservoir initially start off cool, but heat rapidly in the downstream direction. There are also irrigation diversions downstream of the reservoir which reduce the instream flow volumes and could contribute to warmer temperatures. In the lowest reaches of the Crooked River, just above Lake Billy Chinook, there are several springs that increase flow volumes and decrease bulk stream temperatures.

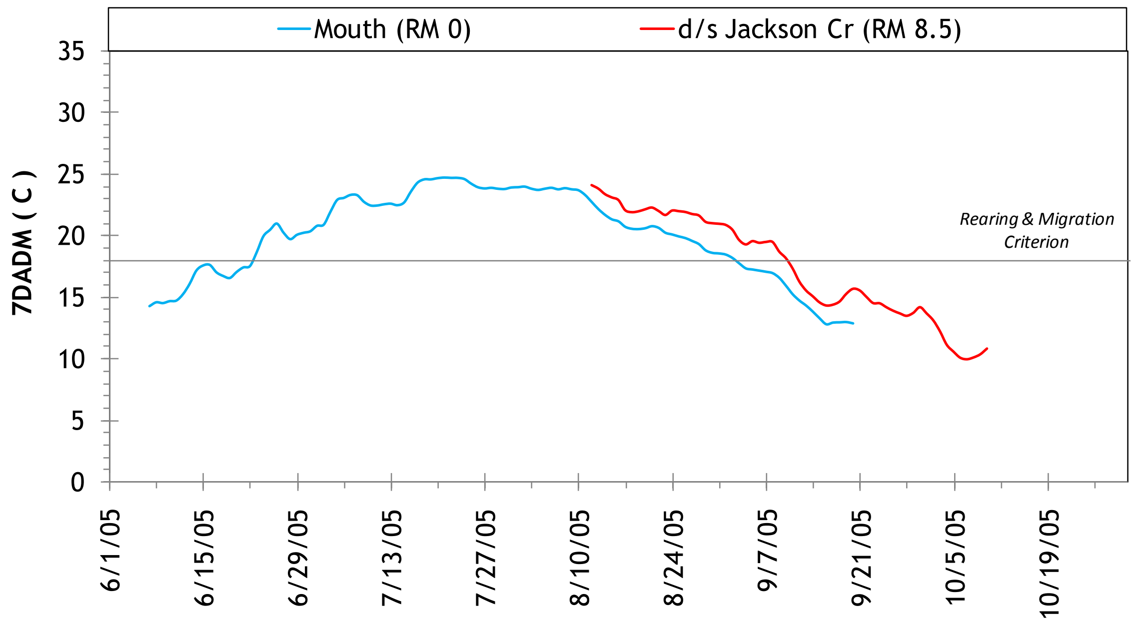
Figure 11 – Crooked River 7-day average daily maximum stream temperatures.



*Deep Creek*

Deep Creek had only two locations where hourly stream temperature was recorded in 2005. Both sites violated the rearing and migration criterion during the summer. Deep Creek is a relatively small stream that flows mostly through National Forest lands.

Figure 12 – Deep Creek 7-day average daily maximum stream temperatures.

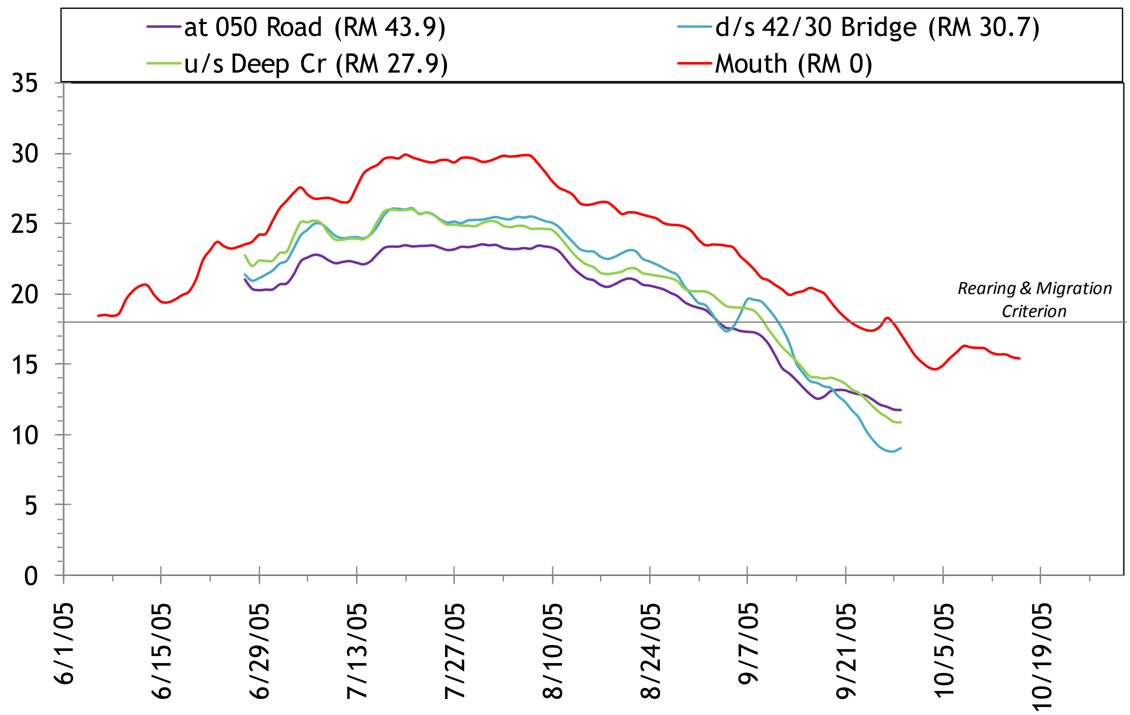


*North Fork Crooked River*

The North Fork Crooked River has severe and extended criterion violations. The mouth of the river violated the criterion during the months of June, July, August, and September. The temperatures at the mouth exceeded 30°C (86°F) during late July and early August. Such temperatures are lethal to salmonids.

The North Fork Crooked River upper reaches are primarily agricultural and lower gradient. There is very little shade and lower flow volumes in the upper reaches, which contributes to rapid stream heating. The warm stream temperatures are maintained as it continues to flow downstream, past Deep Creek and toward the mouth. The terrain below Deep Creek is steeper and the river flows through more forested canyon areas.

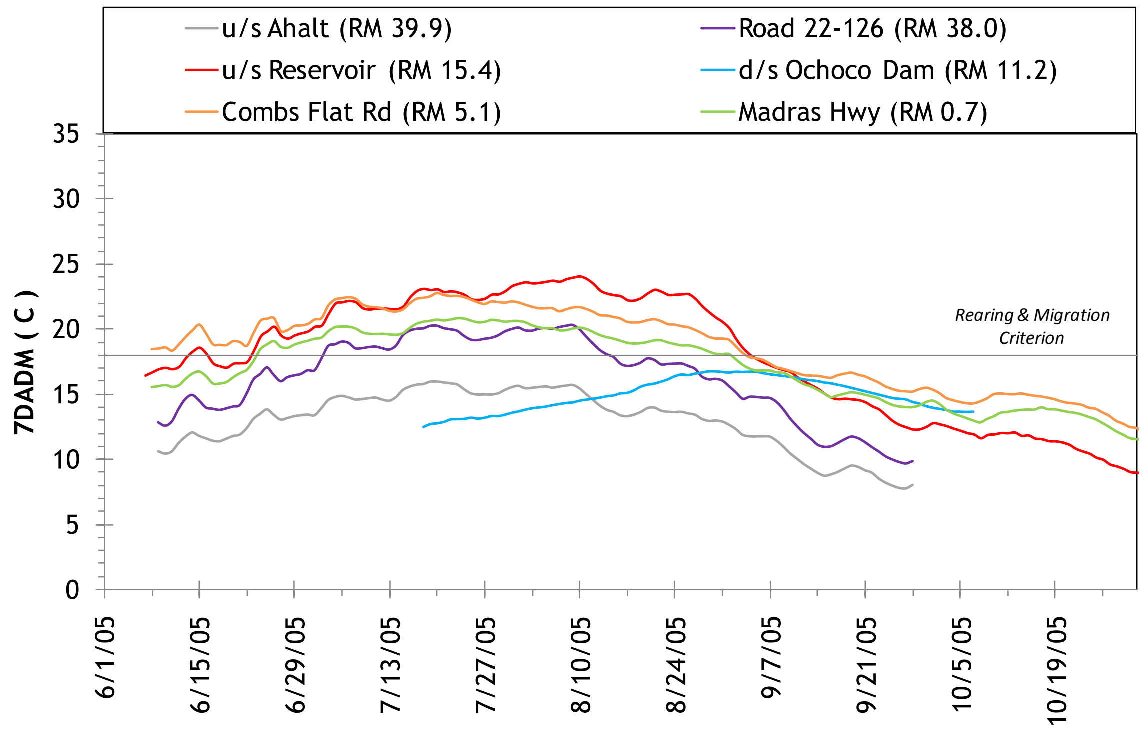
Figure 13 – North Fork Crooked River 7-day average daily maximum stream temperatures.



*Ochoco Creek*

Ochoco Creek experienced stream temperature criterion violations, particularly upstream of Ochoco Reservoir. Violations happened during most of July and August. Upstream of the reservoir, there is very low flow in Ochoco Creek. Its small size in the upper reaches is one contributor to the warm stream temperatures. Stratification within the reservoir produces much cooler temperatures in the hypolimnion, which gets released at the dam. However, that cool reservoir water rapidly heats to above the criterion as it approaches the mouth.

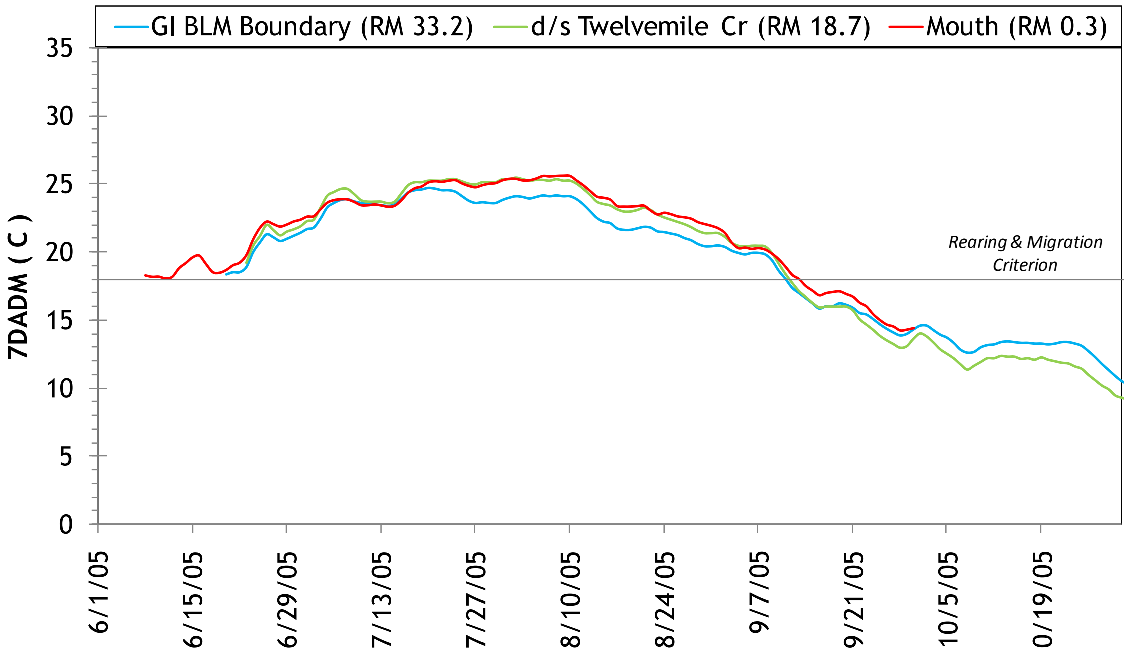
Figure 14 – Ochoco Creek 7-day average daily maximum stream temperatures.



*South Fork Crooked River*

The South Fork Crooked River violated the rearing and migration criterion from June through September. Figure 15 displays the 7-day average daily maximum stream temperatures at three locations along the river during the summer of 2005. The temperatures downstream Twelvemile Creek and at the mouth were very similar.

Figure 15 – South Fork Crooked River 7-day average daily maximum stream temperatures.



**Stream Temperature – Thermal Infrared**

The Oregon DEQ contracted Watershed Sciences to collect TIR stream temperature data for the Upper Deschutes River drainage in 2001 and the Crooked River drainage in 2005 (Watershed Sciences 2002 and 2006). The 2005 TIR imagery was orthorectified and was used to digitized streams, banks, and near stream land cover in the Crooked River drainage. The TIR-derived longitudinal stream temperature profiles will be used to calibrate the Heat Source models and for deriving flow mass balances of each stream.

Figure 16 shows the locations and dates of TIR data that will be used for stream temperature modeling. (The remainder of the Deschutes River, Tumalo Creek, and Whychus Creek were also collected during the 2001 TIR survey but are not being simulated as part of this project. They were simulated using Heat Source under a previous contract that Watershed Sciences had with Oregon DEQ. The models developed under this contract will compliment the models from the previous contract.)

Figure 16 – TIR survey dates and extents.

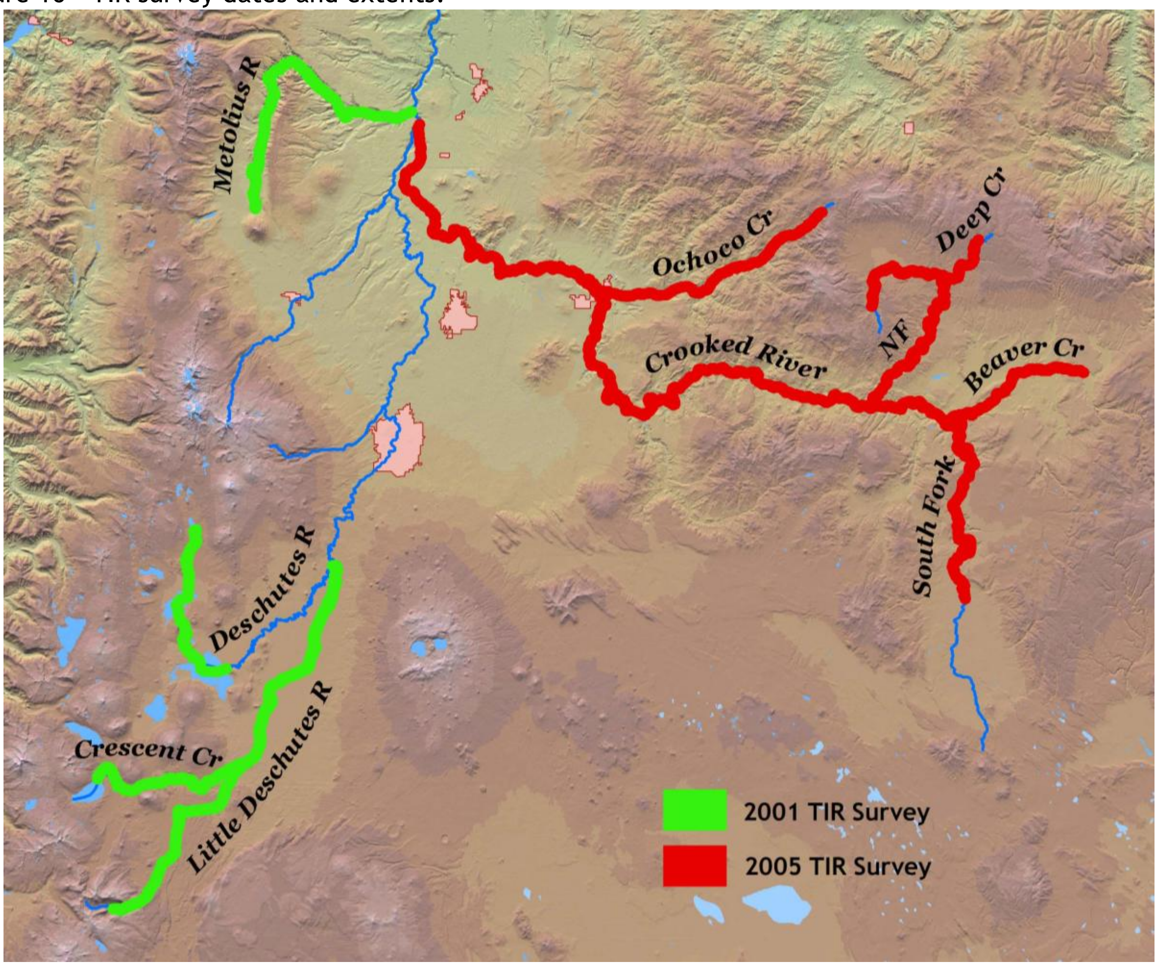


Figure 17 is an example of TIR (left) and true color (right) imagery collected on Beaver Creek near the Paulina Creek confluence. Paulina Creek had a dramatic influence on water temperatures in Beaver Creek lowering main stream temperatures by ~3.5°C. The stream temperature data provided in the TIR imagery is useful for calculating longitudinal flow profiles via mass balance calculations when at least one measured flow is available.

Figure 17 – Sample of TIR imagery along Beaver Creek.

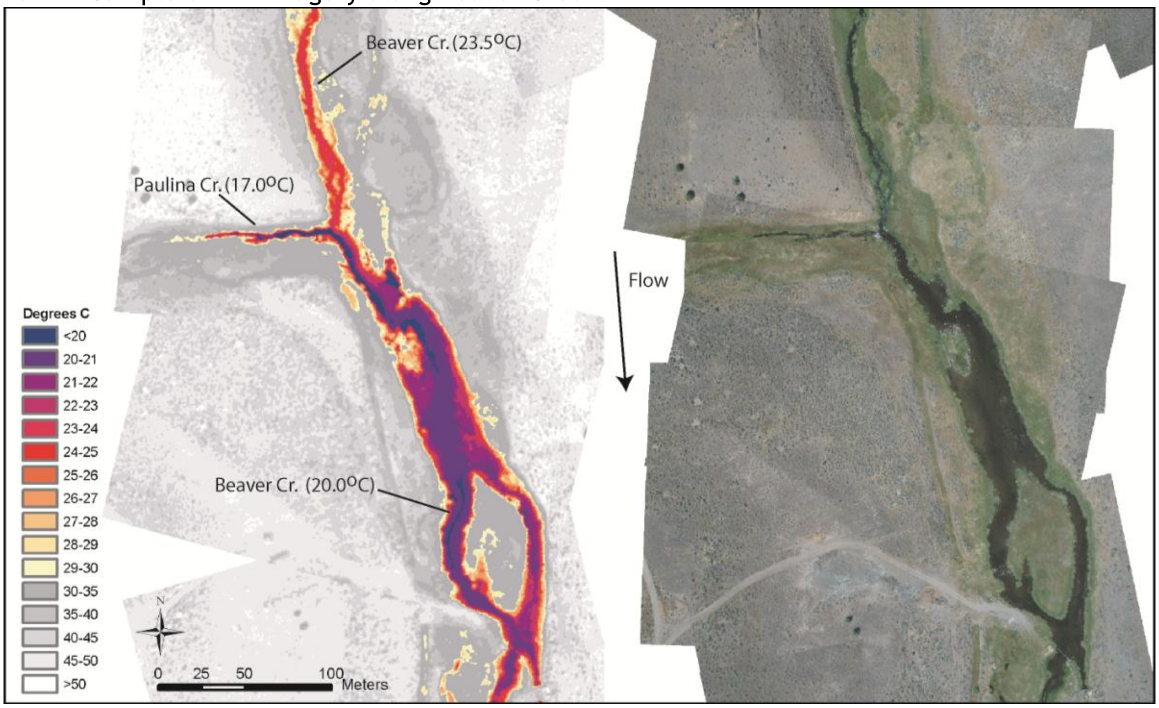
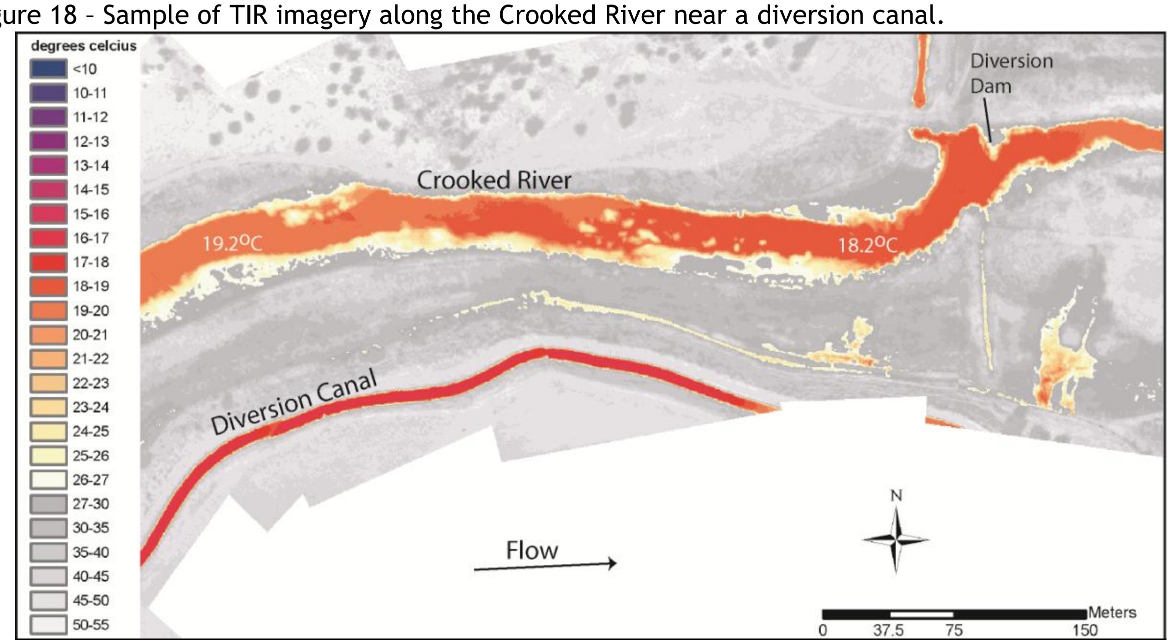



Figure 18 is an example of TIR imagery along the Crooked River. An active diversion is visible in the upper right hand corner and an active canal is flowing parallel to the river. The TIR imagery is useful for identifying and mapping active diversions, which can be included in the Heat Source models.

Figure 18 – Sample of TIR imagery along the Crooked River near a diversion canal.



<u>Upper Deschutes River Drainage</u>

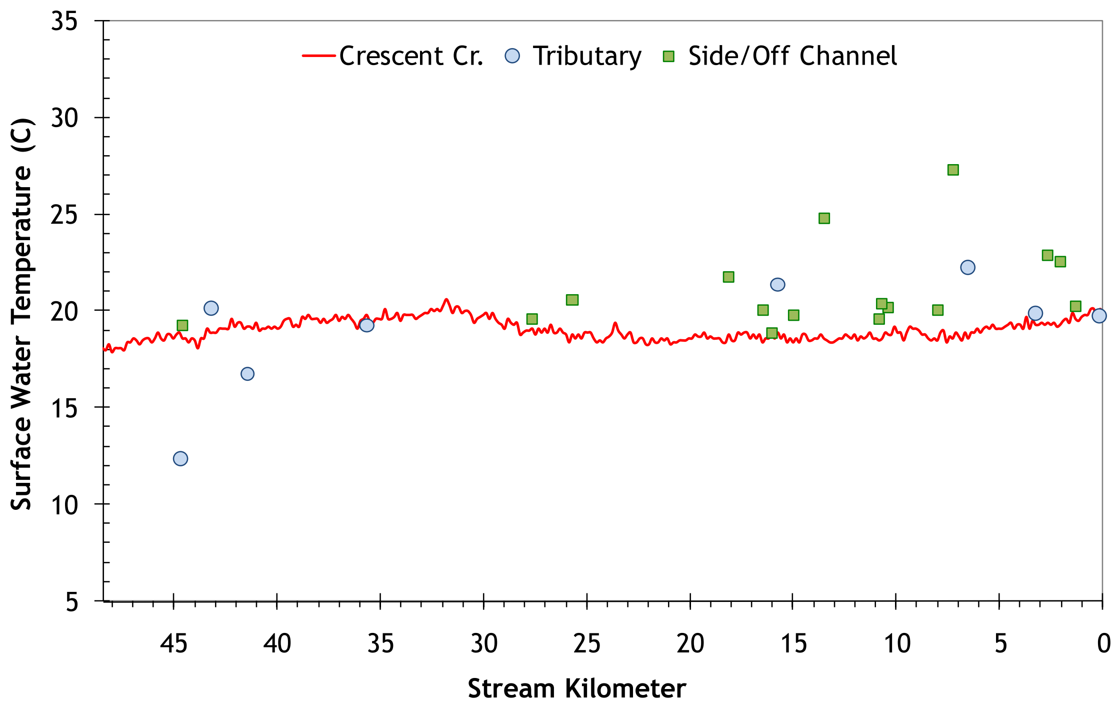
The TIR stream temperature profiles collected in the Upper Deschutes River drainage during the summer of 2001 are presented on the following pages. The y-axis (surface water temperature) has been standardized in order to easily compare temperatures between the different streams. Unless otherwise noted, the stream kilometer is the distance from the mouth, as calculated from the digitized stream.

*Crescent Creek*

Crescent Creek TIR data was collected on July 25, 2001 from 14:02-14:36 in the upstream direction. The stream temperature was approximately 19°C (66°F) during the survey. Several tributaries were measured and multiple side channels were identified in the survey. Typically, the side channels were warmer than the main channel, likely due to reduced flow velocities or volumes. There were no diversions identified in the TIR data report; however, the imagery will be examined for diversions during the stream temperature model set up process.

Crescent Creek was surveyed to Crescent Lake (stream kilometer 48). The warm lake water releases explain why the stream starts off warm. Several side-channel temperatures were recorded in the TIR data. But most of the side channels were not free flowing and the data will likely not be included in the stream temperature modeling since they are not considered a mass inflow or outflow.

Figure 19 – Crescent Creek TIR stream temperature profile.

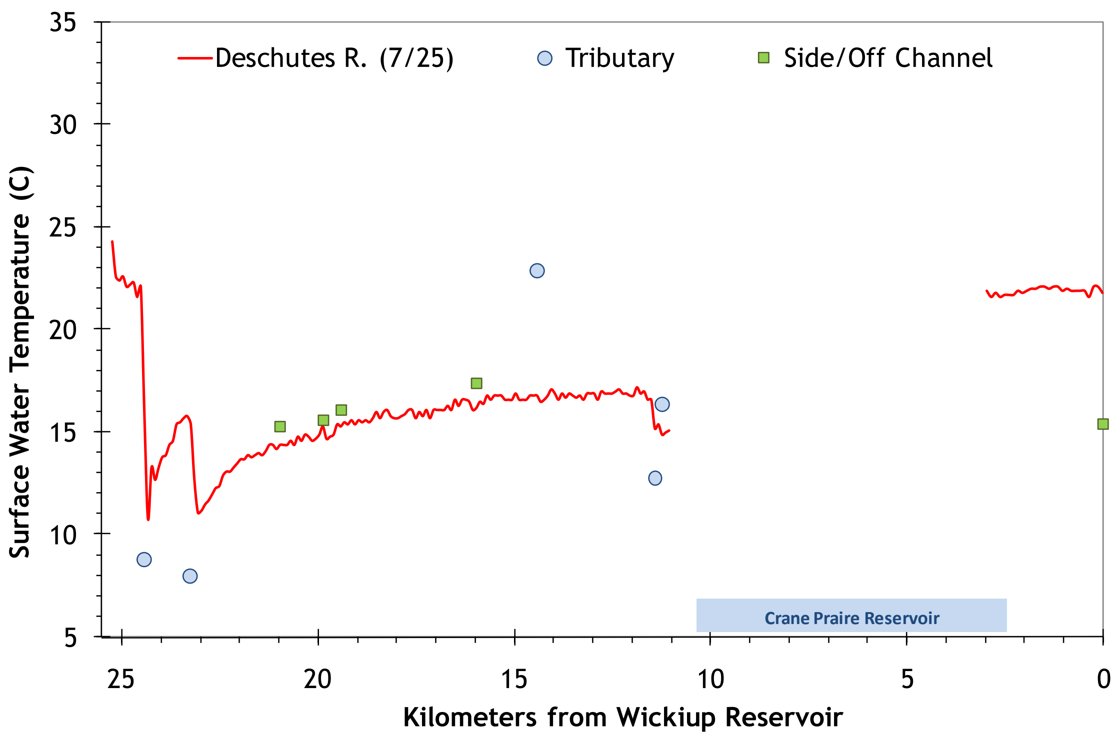


*Deschutes River*

The Deschutes River TIR data (between Wickiup Reservoir and the headwaters) was collected on July 25, 2001 from 15:07-15:31. The Deschutes River was surveyed all the way to Lake Billy Chinook as part of this mission; however, Figure 20 shows only the reach that is being simulated as part of this project. There were no diversions identified in the TIR data report; however, the imagery will be examined for diversions during model set up.

It is interesting to note that there was approximately a 5 degree Celsius difference in stream temperature between the inlet and outlet of Crane Prairie Reservoir. The reservoir effectively heats the stream several degrees.

Figure 20 – Deschutes River TIR stream temperature profile (kilometer 0 is where the stream is no longer free-flowing at the top of Wickiup Reservoir).

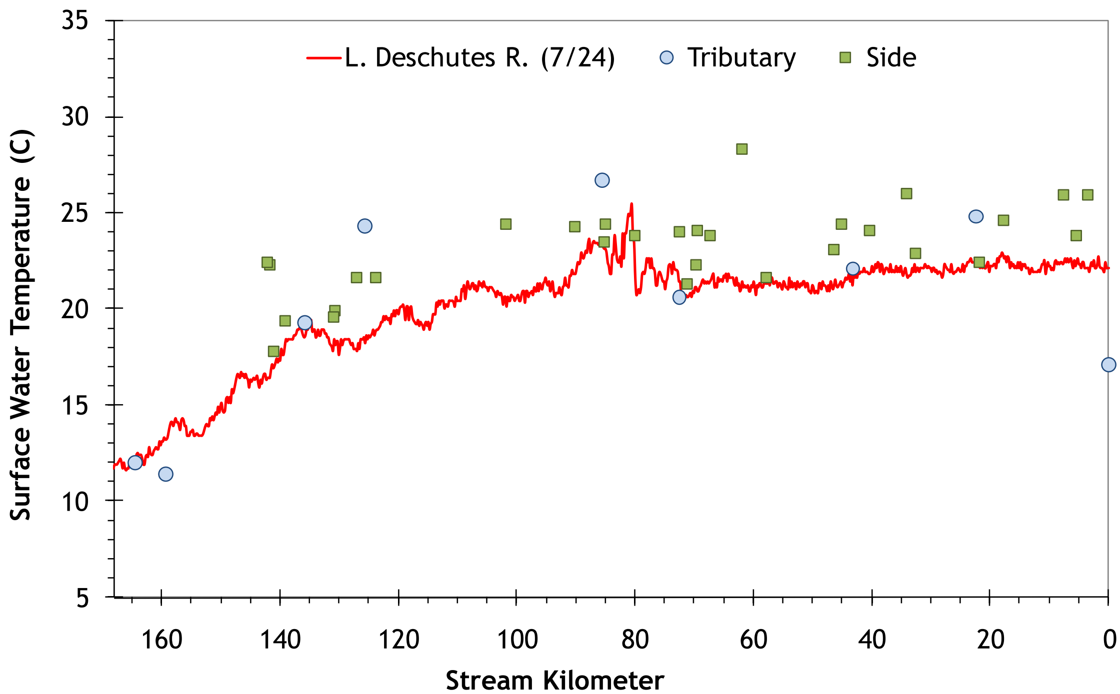


*Little Deschutes River*

The Little Deschutes River TIR data was collected on July 24, 2001 from 14:09-15:56 in the downstream direction. The river started at about 12°C (53.6°F) and gradually increased to about 22°C (71.6°F) in the lower reaches. The Little Deschutes River is very sinuous and has many side channels. The side channels were sampled and are shown in the profile. There were no diversions identified in the TIR data report; however, the imagery will be examined for diversions during model set up.

Crescent Creek enters the Little Deschutes River near stream kilometer 100. The water from Crescent Creek makes up the majority of the Little Deschutes River flow at this point, which helps to moderate the stream temperatures from there to the mouth. Downstream of Crescent Creek, the temperatures hover around 22°C.

Figure 21 – Little Deschutes River TIR stream temperature profile.

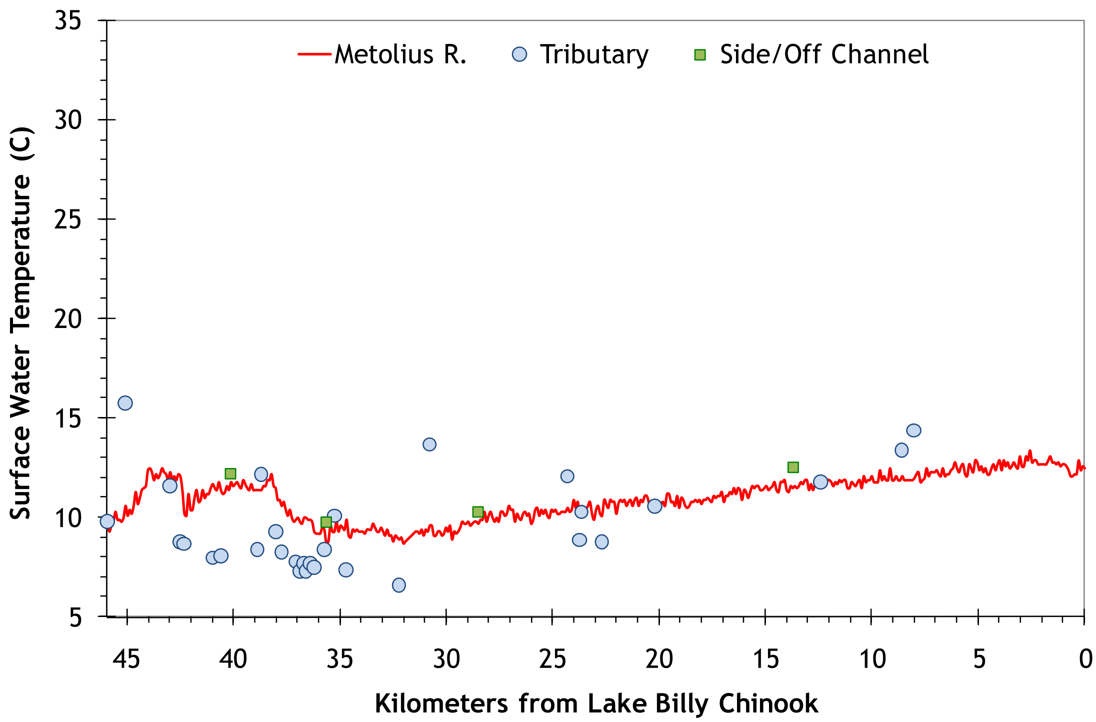


*Metolius River*

The Metolius River TIR data was collected on July 7, 2001 from 15:06-15:51 in the downstream direction. The Metolius River originates from springs which are 9°C (48°F) or cooler. The flow was over 100 cfs during the TIR survey, and such large flow helps to maintain cooler stream temperatures. The maximum temperature recorded in the river was slightly over 12°C (53.6°F) during the TIR survey. There were no diversions identified in the TIR data report; however, the imagery will be examined for diversions during model set up.

There were also several significant tributaries which contributed cool water to the Metolius River during the survey. Those tributaries are also responsible for helping the river temperatures remain below the Bull Trout temperature criterion of 12°C.

Figure 22 – Metolius River TIR stream temperature profile (kilometer 0 is at the top of the reservoir where the river is no longer free-flowing).



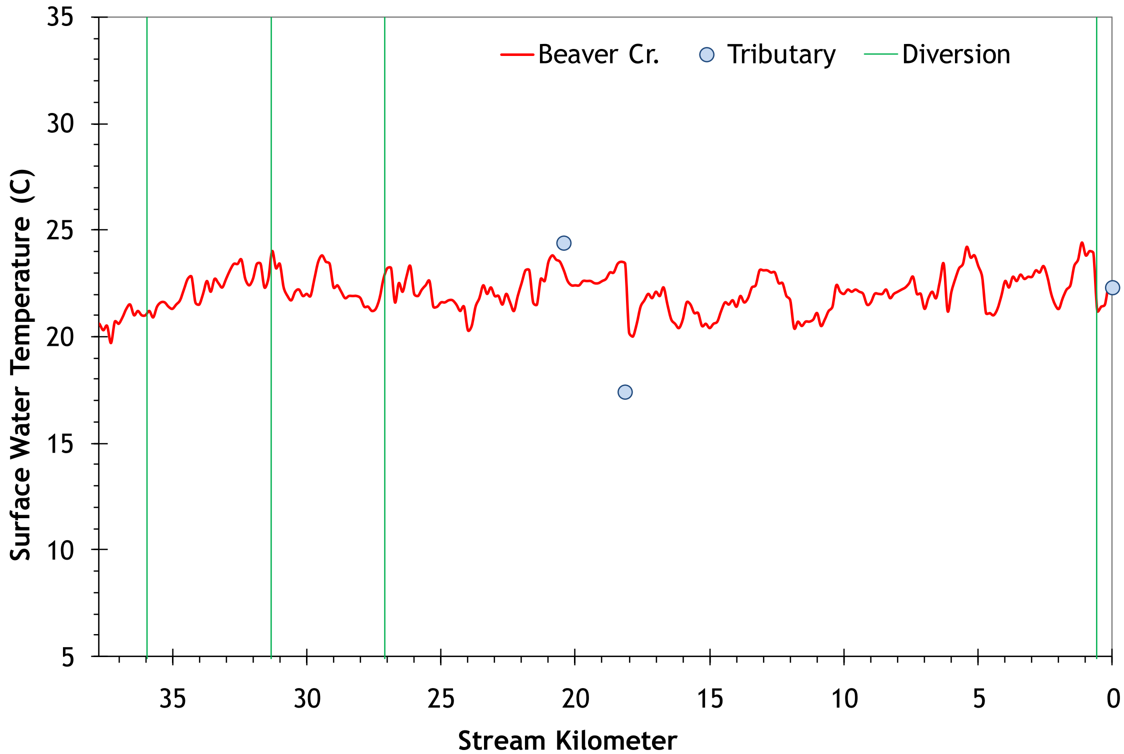
Crooked River Drainage

The Crooked River drainage TIR survey was conducted during the summer of 2005. The thermal and day video imagery was orthorectified, making it useful for digitizing the stream, banks, and vegetation. The TIR report also identified diversions in the 2005 flights, which are useful Heat Source inputs. The y-axis (surface water temperature) has been standardized in each of the following charts for easy comparison between streams. Unless otherwise noted, the stream kilometer is the distance from the mouth, as calculated from the digitized stream.

*Beaver Creek*

Beaver Creek TIR data was collected on August 7, 2005 from 14:29-14:59 in the upstream direction. Temperatures were typically near 22˚C (71.6˚F). Active irrigation diversions were identified in the TIR imagery and are indicated in Figure 23. Since Beaver Creek is a small stream with low flow, the thermal profile is variable over short distances.

Figure 23 – Beaver Creek TIR stream temperature profile.

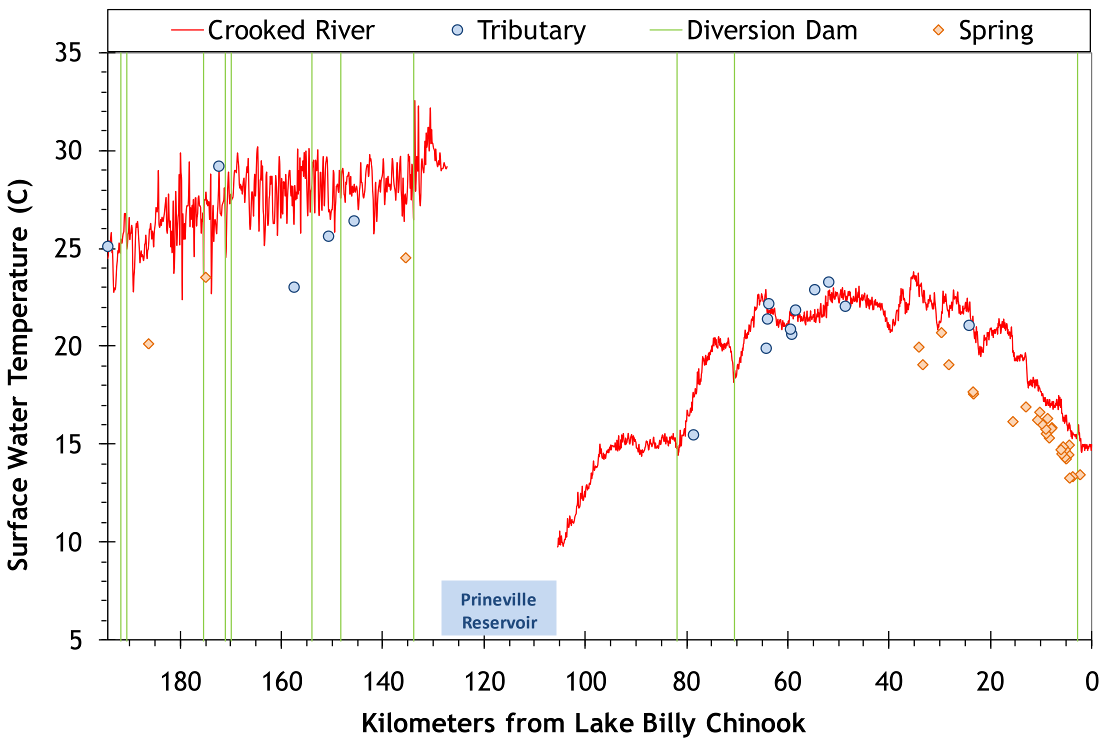


*Crooked River*

The Crooked River TIR data was collected on August 6, 2005 from 13:32-17:32 in the upstream direction. Several active irrigation diversions were noted in the TIR imagery. Springs and tributaries were also identified and sampled. The upper Crooked River was much warmer than below Prineville Reservoir primarily due to lower flow volumes. The lower Crooked River started off cooler from Bowman dam and gradually warmed as it flowed downstream. Closer to Lake Billy Chinook, a series of springs helped lower the stream temperature again.

Above Prineville Reservoir, the stream temperature was quite variable. Rapid heating and cooling occurred over short distances because of the small flow volumes, low gradients, and wide widths. The upper river also flows through a broader valley and has less topographic shade than the lower river which flows through steeper box canyons in many areas.

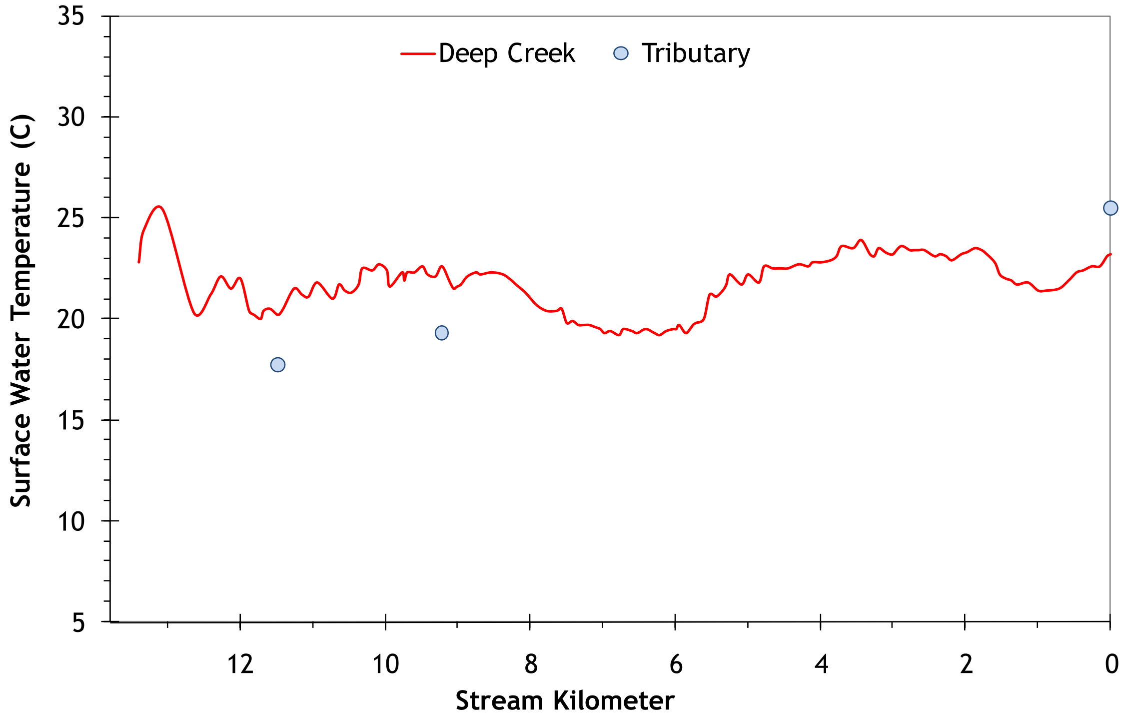
Figure 24 – Crooked River TIR stream temperature profile.



*Deep Creek*

Deep Creek TIR data was collected on August 8, 2005 from 14:43-14:59 in the upstream direction. Temperatures were typically within the lower 20°C range. There were no active irrigation diversions identified in the imagery.

Figure 25 – Deep Creek TIR stream temperature profile.

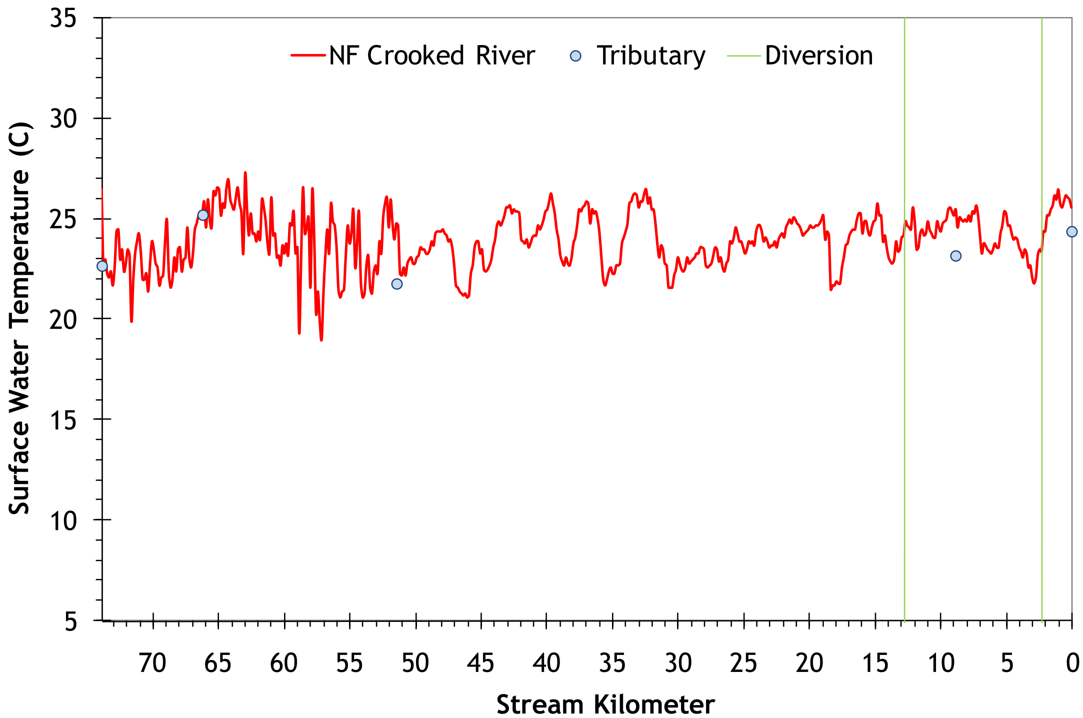


*North Fork Crooked River*

The North Fork Crooked River TIR data was collected on August 8, 2005 from 13:20-14:36 in the upstream direction. Stream temperatures started off fairly warm in the upper reaches of the North Fork Crooked River, and remained warm throughout the entire length. There were areas of localized cooling; however, the river quickly warmed again in most areas. There were two active diversions identified in the lower river.

The upper 25 kilometers of the stream temperature profile are in agricultural and grazing lands. The flows are smaller in these upper reaches, the gradient is lower, and there is virtually no shade. These factors are responsible for the warm and highly variable temperatures in the upper reaches.

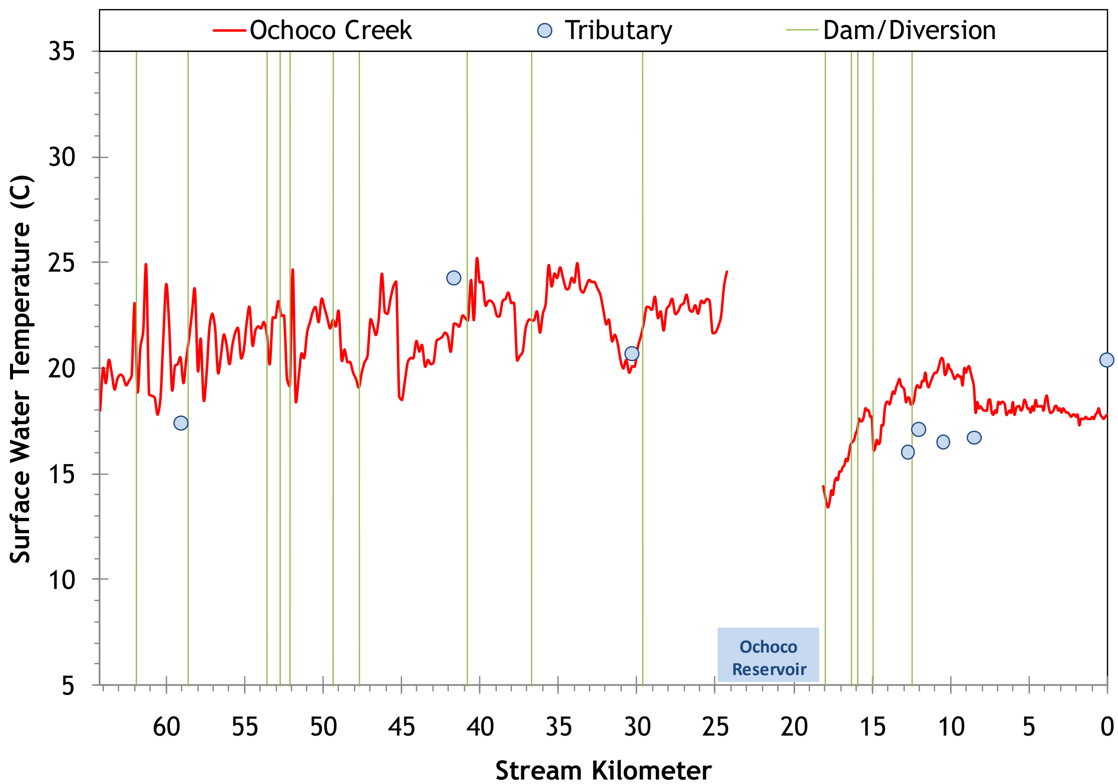
Figure 26 – North Fork Crooked River TIR stream temperature profile.



*Ochoco Creek*

Ochoco Creek TIR data was collected on August 5, 2005 from 13:33-14:29 in the upstream direction. Several active diversions were identified in the TIR imagery. Upstream of Ochoco Reservoir, stream temperatures were quite warm and variable. The flows above the reservoir were very low during the TIR survey. Downstream of the reservoir, the stream temperatures were much cooler and less variable because of the larger volume of cool water being released at the dam. In addition, there were irrigation water returns near Combs Flat Road.

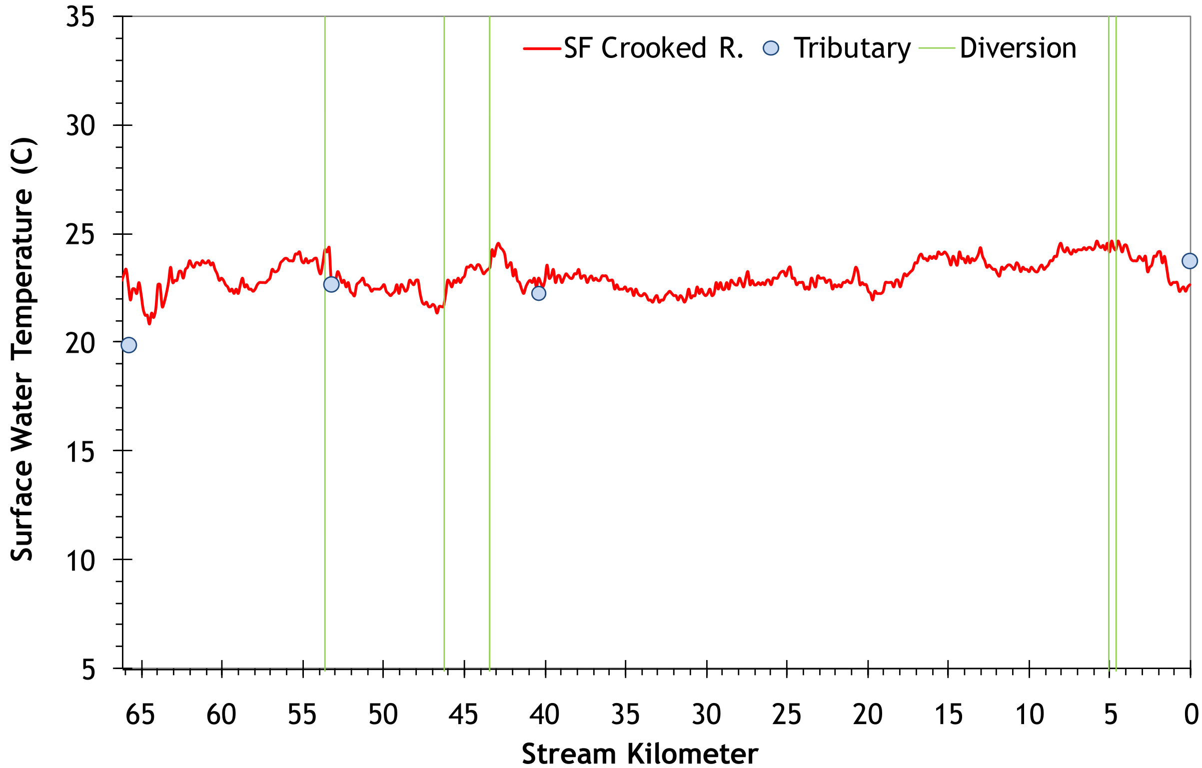
Figure 27 – Ochoco Creek TIR stream temperature profile.



*South Fork Crooked River*

The South Fork Crooked River TIR data was collected on August 7, 2005 from 13:11-14:08 in the upstream direction. There were five active diversions identified in the imagery and four tributaries. Temperatures were in the lower 20°C range throughout the reaches surveyed.

Figure 28 – South Fork Crooked River TIR stream temperature profile.



**Habitat Data**

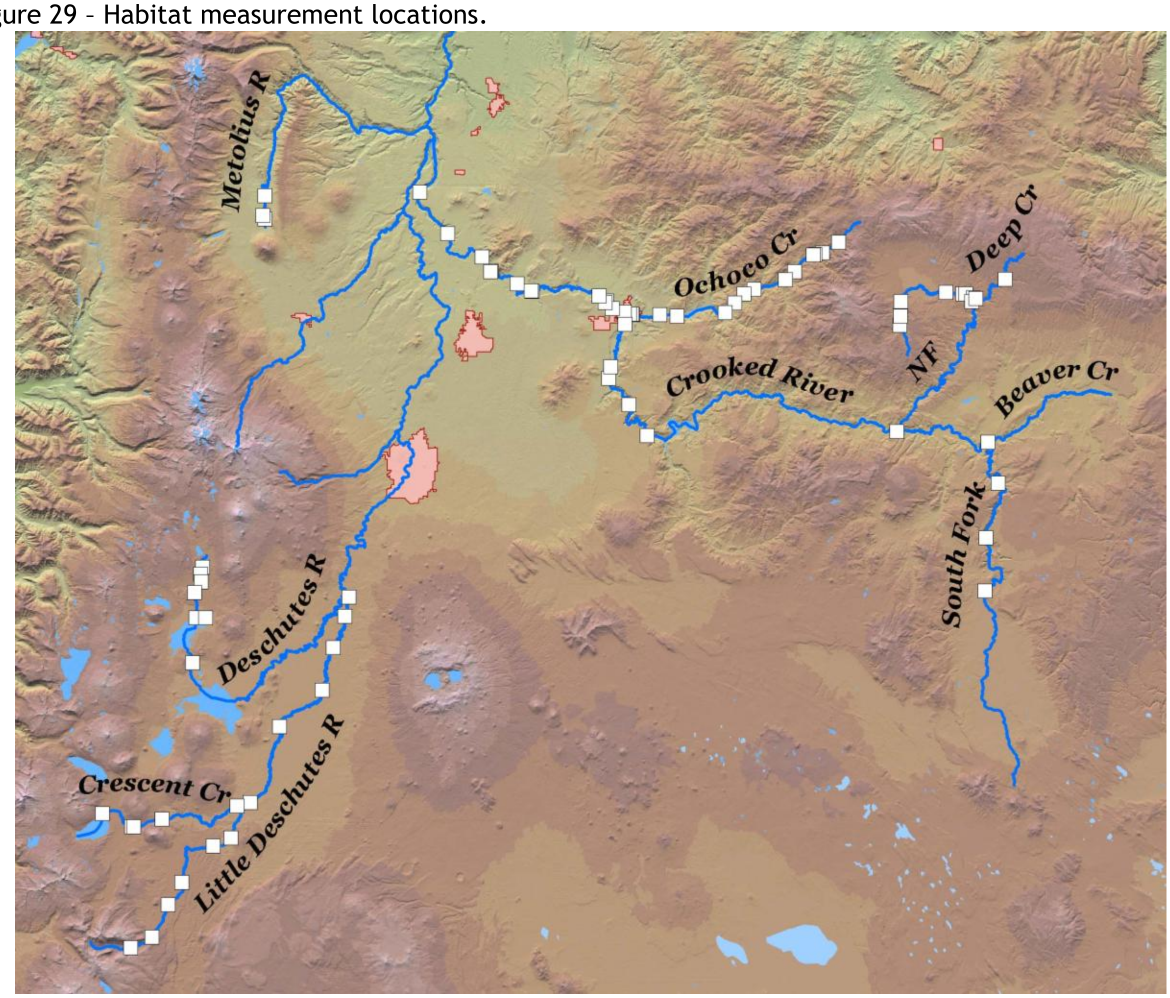
Stream channel and habitat measurements were collected at various locations by the Oregon DEQ and others during the same time periods that the flow and temperature data were being collected for TMDL development. Oregon DEQ provided the habitat data which is summarized in Figure 29 and Table 7 and Table 8 on the following pages.

Habitat data may include the following types of data, depending upon the location and the party who collected it:

- Active channel width
- Wetted width
- Substrate composition
- Substrate embeddedness
- Channel incision
- Near stream vegetation species composition
- Near stream vegetation height
- Near stream vegetation overhang
- Solar Pathfinder measurements (effective shade)

The habitat data will be used as Heat Source input and for simulation validation. The data will be compared with the simulation results both graphically and statistically where applicable.

Figure 29 – Habitat measurement locations.




There is additional stream habitat survey data available through the Oregon Department of Fish and Wildlife which may be used to supplement channel and vegetation inputs for stream temperature models; however, that data is not summarized in this report

Table 7 – Habitat data collection locations in the Upper Deschutes River drainage.

| River System | Location | River Mile |
|---|---|---|
| Crescent Creek | Crescent Creek below lake @ OWRD Gauge Station | 29.9 |
| | Crescent Creek u/s Big Marsh Creek | 23.3 |
| | Crescent Creek d/s Big Marsh Creek (u/s Hwy 58) | 22.9 |
| | Crescent Creek @ Crescent Ck Campground | 19.2 |
| | Crescent Creek @ Rd 62 (near mouth) | 3.0 |
| Deschutes River | Deschutes d/s Blue Pool | 22.5 |
| | Deschutes @ Mile Campground (Day Use) | 21.4 |
| | Deschutes @ Deschutes Bridge Campground | 20.8 |
| | Deschutes off Rd 46 | 18.7 |
| | Snow Creek @ mouth | 15.4 |
| | Deschutes u/s Snow Creek | 15.3 |
| | Deschutes @ Brown's Crossing | 9.3 |
| Little Deschutes River | Little Deschutes @ Wilderness Boundary | 102.2 |
| | Little Deschutes @ Spur Rd off Rd 300 (cow camp) | 97.9 |
| | Little Deschutes u/s Hemlock Creek | 92.5 |
| | Little Deschutes @ USFS boundary & Rd 5825 | 87.3 |
| | Little Deschutes off 100 Rd near Crescent | 74.5 |
| | Little Deschutes u/s Gilchrist Mill Pond | 70.5 |
| | Little Deschutes @ Rd 62 (u/s Crescent Ck) | 62.8 |
| | Little Deschutes @ Masten Rd | 41.7 |
| | Little Deschutes @ Burgess Rd. | 27.3 |
| | Little Deschutes @ State Park Rd. | 14.7 |
| | Little Deschutes @ Fall River Rd. (Hwy 42) | 5.6 |
| | Little Deschutes @ Crosswater road bridge | 1.0 |
| Metolius River | Metolius u/s tract C bridge - ODEQ | 39.1 |
| | South/Middle Forks Lake Creek @ mouth | 38.6 |
| | Metolius u/s First Creek (Gorge CG) | 36.2 |

Table 8 – Habitat data collection locations in the Crooked River drainage.

| River System | Location | River Mile |
|---|---|---|
| Crooked River | Crooked River d/s Bowman Dam | 71.5 |
| | Crooked River @ Castle Rock | 63.8 |
| | Crooked River u/s Stearns Dam near BLM pullout | 59.2 |
| | OID Diversion | 57.5 |
| | Crooked River @ Les Schwab Park u/s of Prineville | 50.2 |
| | Crooked River 600 ft d/s Prineville WWTP outfall | 47.4 |
| | Crooked River u/s Ochoco Cr. | 46.1 |
| | Crooked River d/s McKay Creek | 45.1 |
| | Crooked River u/s Dry Creek | 33.9 |
| | Crooked River d/s Dry Canyon | 33.6 |

| River System | Location | River Mile |
|---|---|---|
| Crooked River | Crooked River @ Lone Pine Rd. | 29.7 |
| | Crooked River u/s Smith Rocks footbridge | 25.2 |
| | Crooked River d/s Smith Rocks footbridge | 25.1 |
| | Crooked River @ Canyons Ranch (d/s Smith Rocks) | 20.9 |
| | Crooked River d/s Osborne Canyon | 13.0 |
| | Crooked River below Opal Springs | 6.6 |
| Deep Creek | Deep Creek u/s Little Summit Creek | 5.7 |
| | Deep Creek above mouth | 0.2 |
| North Fork Crooked River | N. Fork Crooked u/s Rd 100 | 45.6 |
| | N. Fork Crooked @ 050 Rd (above Big Summit Prairie) | 43.9 |
| | N. Fork Crooked u/s Rd 42 | 41.0 |
| | N. Fork Crooked d/s 42/30 bridge | 30.7 |
| | N. Fork Crooked ~1 mile u/s Deep Creek CG | 28.3 |
| | N. Fork Crooked above Deep Creek @ old USGS gauge | 27.9 |
| | N. Fork Crooked @ Deep Creek CG | 26.7 |
| | N. Fork Crooked d/s Deep Cr. @ old USGS gauge station | 26.1 |
| | N. Fork Crooked near mouth @ Hwy 380 | 0.0 |
| Ochoco Creek | Ochoco Cr. @ 22/126 Rd junction | 38.0 |
| | Ochoco Cr. Above Ranger Station #1 | 35.4 |
| | Ochoco Cr. @ 2610 Rd bridge above Ranger Station | 34.3 |
| | Ochoco Cr. @ FS Boundary | 34.1 |
| | Ochoco Cr. u/s Rd 22 crossing | 29.8 |
| | Ochoco Cr. @ Duncan Creek Rd. | 27.7 |
| | Ochoco Creek near Hwy 26/Rd 22 split | 22.5 |
| | Ochoco Creek d/s Marks Creek @ gauge station | 20.8 |
| | Ochoco Creek above reservoir #2, river close to road | 19.2 |
| | Ochoco Creek above reservoir #1, @ turnout | 17.5 |
| | Ochoco Creek d/s Ochoco Dam | 11.2 |
| | Ochoco Creek in residential area d/s dam | 8.8 |
| | Ochoco Creek d/s Combs Flat Rd. | 5.1 |
| | Ochoco Creek d/s Combs Flat Rd. & OID return | 5.1 |
| | Ochoco Creek @ Middle School | 4.8 |
| | Ochoco Creek near fire station @ d/s end of City park | 4.1 |
| | Ochoco Creek @ Madras Hwy (Hwy 26) | 0.7 |
| South Fork Crooked River | South Fork Crooked @ GI Ranch/BLM boundary | 33.2 |
| | S. Fork Crooked 1.5 miles d/s Twelvemile Cr. | 18.7 |
| | South Fork Crooked @ Jake Place Ford | 10.1 |
| | S. Fork Crooked @ Hwy 380 (mouth) | 0.3 |

**LiDAR Data**

The USGS collected light detection and ranging (LiDAR) data along several stream corridors in the greater Deschutes River Basin in 2003. Watershed Sciences received the LiDAR point data in its native text file format and processed the areas where stream temperature modeling is to be performed. The LiDAR point data was processed with MicroStation to render 2-meter bare earth and 2-meter highest hit digital elevation models (DEMs) in raster format. The LiDAR DEMs will be used to map stream features and to sample near stream land cover heights which will be used as input for the Heat Source temperature models.

Figure 30 shows where LiDAR coverage exists within the study area. Note that the LiDAR coverage on the Metolius only covers the Metolius branch of Lake Billy Chinook. Heat Source will be used to simulate only the free-flowing portions of streams (i.e., lakes and reservoirs will not be simulated). Therefore, there will be no LiDAR data used in the Metolius River simulation. LiDAR will be used in the Heat Source simulations within the following reaches:

- Crooked River below Prineville Reservoir
- Ochoco Creek below Ochoco Reservoir
- Little Deschutes River downstream of Crescent Creek
- Crescent Creek below Crescent Lake
- Deschutes River between Crane Prairie and Wickiup Reservoirs

Figure 30 – LiDAR data coverage area.

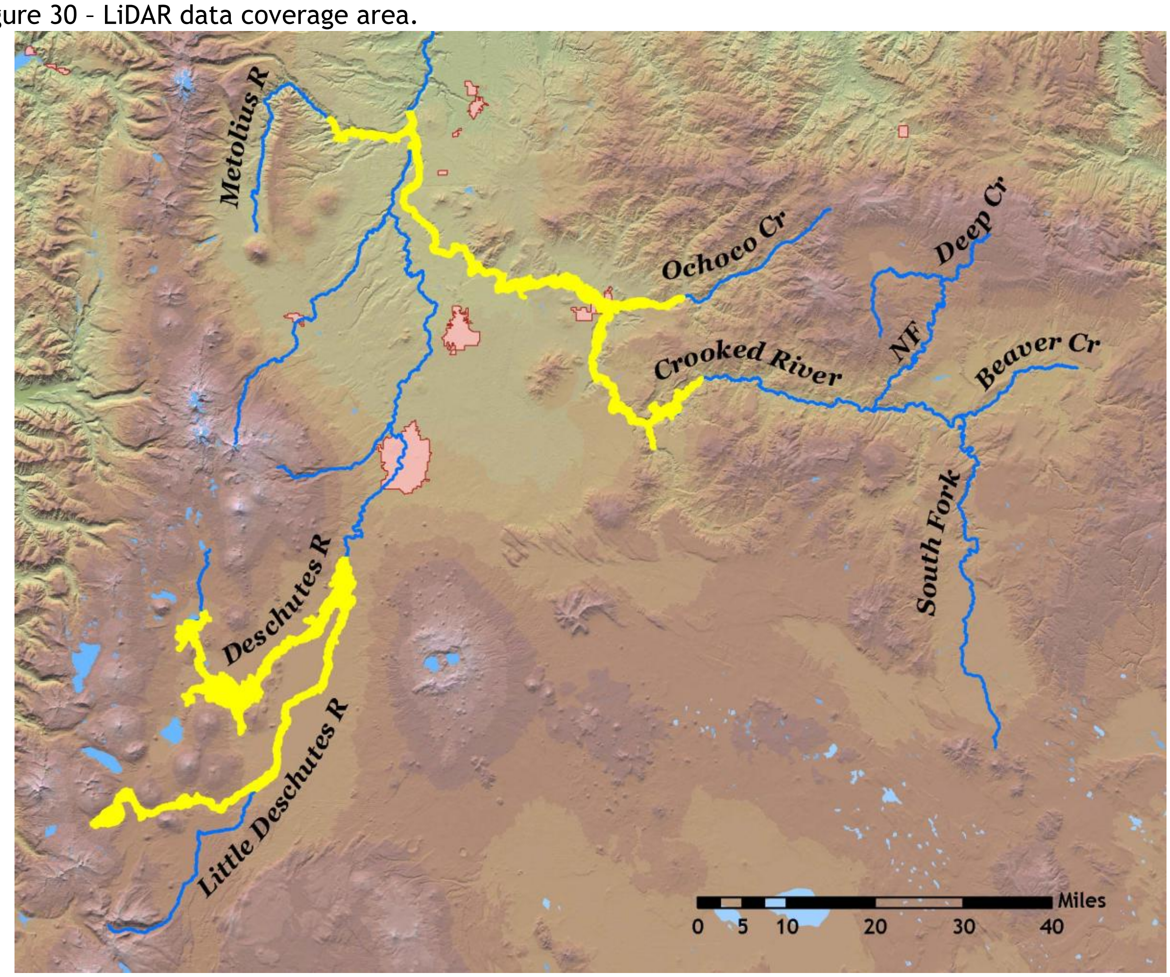
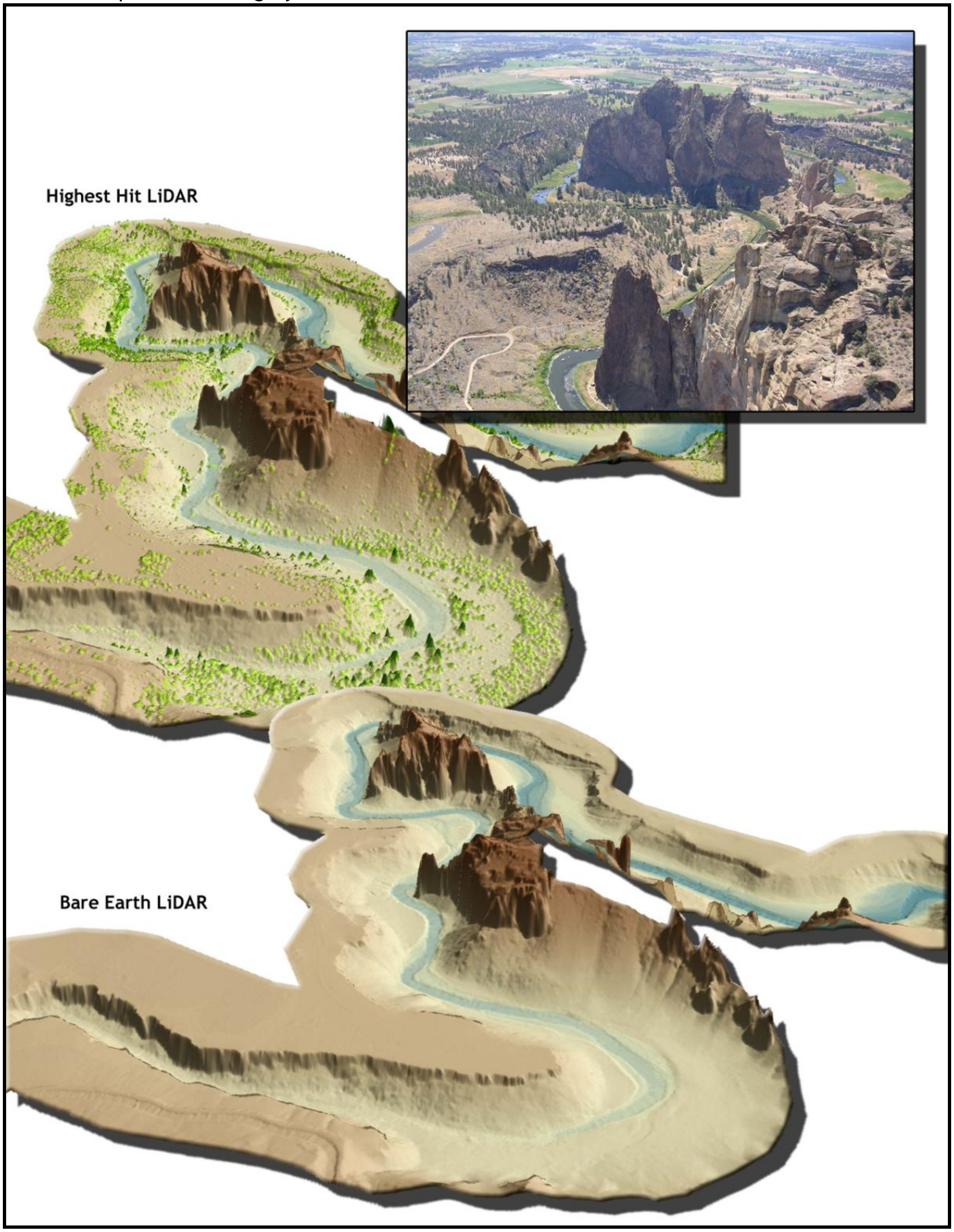


Figure 31 is an example of the LiDAR data available for this project. The rasters have 2-meter pixel size and the coverage typically captures only the immediate stream corridor.

Figure 31 – Sample LiDAR imagery near Smith Rocks on the Crooked River.



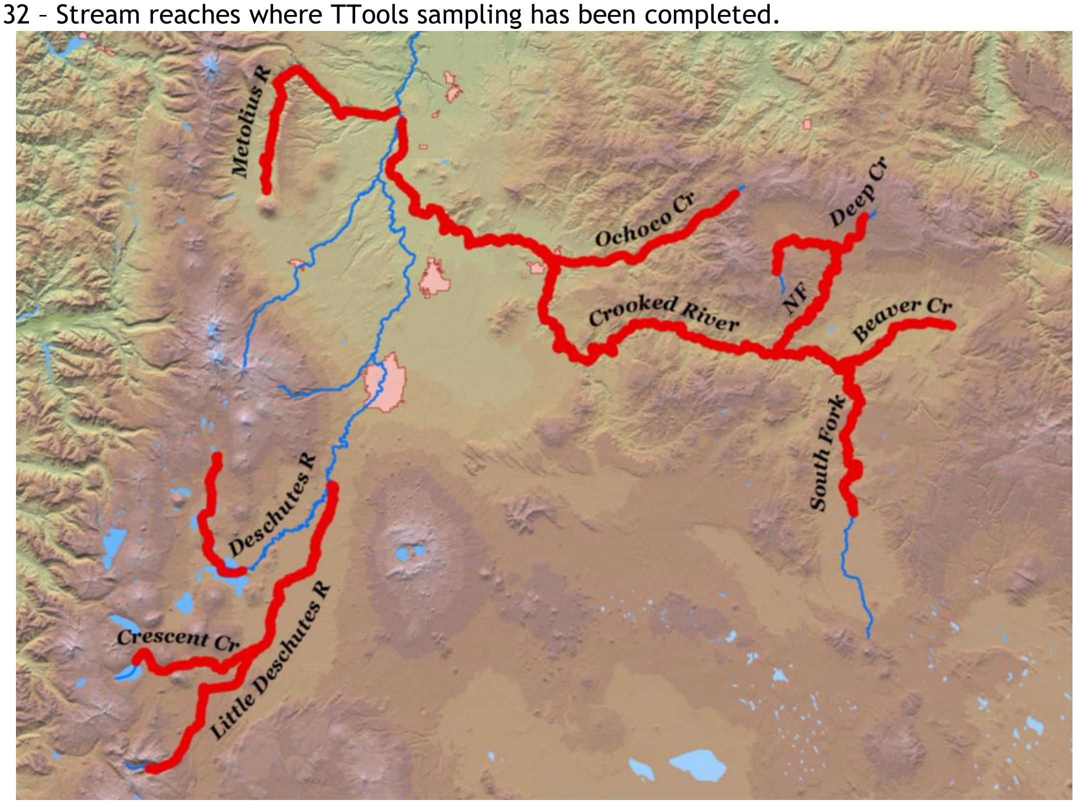
## Section 2 - Digitization and TTools

Streams, banks, and near stream vegetation were digitized on 471.5 stream miles. TTools was used to segment the streams into 50-meter segments and sample the aspect, elevation, gradient, topographic shade, near stream land cover, and TIR stream temperatures. This section presents the digitization and TTools sampling results.

Table 9 – Stream reaches and mileages of digitized streams.

| Drainage | Stream | Reach Boundaries | Estimated Stream Miles in Contract | Actual Stream Miles (Digitized) |
|---|---|---|---|---|
| Upper Deschutes River Drainage | Crescent Creek | Mouth to Crescent Lake | 26 | 30.1 |
| | Deschutes River | Wickiup Reservoir to Headwaters | 25 | 23.8 |
| | Little Deschutes River | Mouth to Clover Creek | 90 | 104.6 |
| | Metolius River | Lake Billy Chinook to Headwaters | 30 | 40.1 |
| Crooked River Drainage | Beaver Creek | Mouth to North Fork | 23 | 23.5 |
| | Crooked River | Lake Billy Chinook to South Fork | 114 | 113.8 |
| | Deep Creek | Mouth to Happy Camp Creek | 9 | 8.6 |
| | North Fork Crooked River | Mouth to Gray Creek | 42 | 45.9 |
| | Ochoco Creek | Mouth to Ahalt Creek | 33 | 39.9 |
| | South Fork Crooked River | Mouth to Marsh near Headwaters | 33 | 41.1 |
| | | TOTAL: | 425 | 471.5 |

Figure 32 – Stream reaches where TTools sampling has been completed.

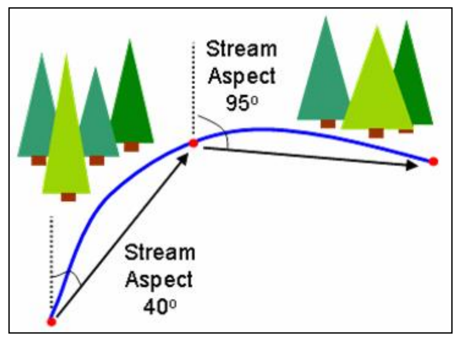


TTools was used to sample the LiDAR elevations, gradients, and vegetation on stream reaches where LiDAR data is available. In most cases, the LiDAR data covered only a portion of the stream of interest. Table 10 summarizes the reaches where TTools sampled the LiDAR data. Also within those reaches, the near stream land cover heights will be calculated by subtracting the bare earth LiDAR elevation from the highest hit LiDAR elevations at each near stream land cover sampling location.

Table 10 – Summary of reaches where LiDAR data was sampled with TTools.

| Drainage | Stream | Reaches where LiDAR Available |
|---|---|---|
| **Upper Deschutes River Drainage** | Crescent Creek | Crescent Lake to Mouth (entire simulated length) |
| | Deschutes River | Between Crane Prairie and Wickiup Reservoirs |
| | Little Deschutes River | Between Crescent Creek confluence and mouth |
| | Metolius River | None |
| **Crooked River Drainage** | Beaver Creek | None |
| | Crooked River | Between Prineville Reservoir and mouth |
| | Deep Creek | None |
| | North Fork Crooked River | None |
| | Ochoco Creek | Between Ochoco Reservoir and mouth |
| | South Fork Crooked River | None |

The stream aspect is the stream flow direction (degrees from north) calculated at each of the 50-meter segments. This is an important stream temperature modeling input because it helps determine the locations of shadow and sunlight on the surface of the stream throughout the day.




Vegetation height values have not been plotted because they will be determined on a stream by stream basis as each Heat Source model is set up and calibrated. Stream reaches where the vegetation was digitized manually will have height and density values assigned to the polygons based on field observation data.

The gradient values shown in each of the following charts are the raw sampled values. It is common, especially on 10-meter DEMs, for there to be artificial “stair steps” in elevation which is an artifact of the grid resolution. During Heat Source set up and calibration, the gradient values may be smoothed in locations where artificial stair-stepping is apparent.

The “channel widths” were digitized from orthorectified TIR imagery within the Crooked River drainage. In those areas, the term “channel width” generally refers to the wetted channel width observed in the TIR imagery unless otherwise noted. Since the simulation time period corresponds to the TIR acquisition time period, the digitized wetted widths are optimal for Heat Source input since they represent the current hydraulic conditions.

The “channel widths” for the Upper Deschutes River drainage represent the approximate wetted widths observed in the NAIP orthophotos. Since the NAIP orthophotos were taken during different years than the simulation time period, they may not precisely represent the conditions during the desired simulation period. In most reaches, the visible wetted area appeared to be very close to the “active” or “scoured” channel.

The following pages present the TTools sampling results for each of the streams. Reservoirs or lakes are excluded from the charts because they will not be simulated as part of this project. The y-axis of each chart has been standardized for the individual parameters in order to facilitate relative comparison of values between the different streams. The x-axis of each chart is the TTools-derived stream kilometer; with zero representing the stream mouth unless otherwise noted.

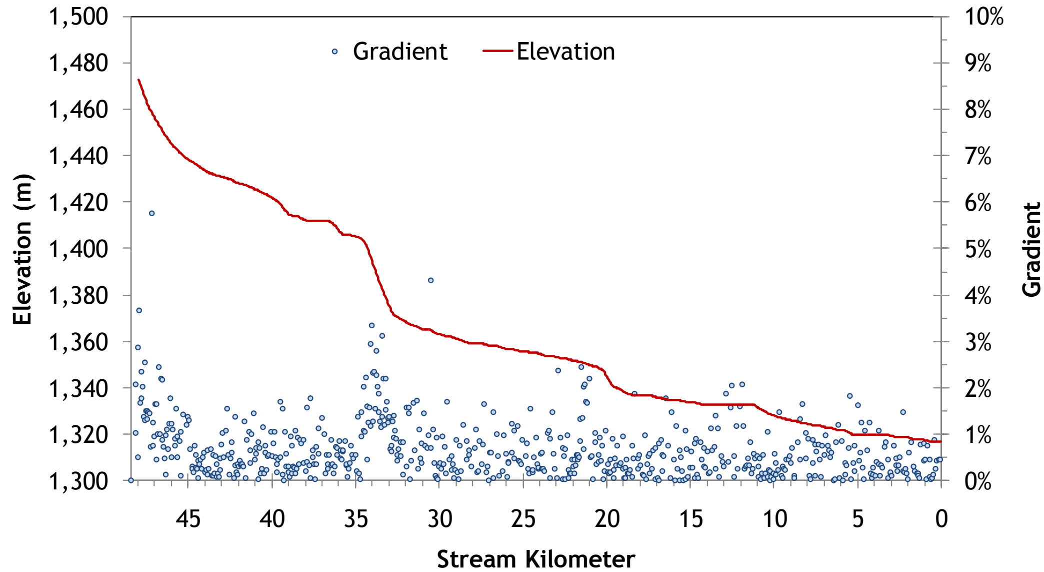
**TTools Results**

Upper Deschutes River Drainage

*Crescent Creek*

Stream elevations and gradients for Crescent Creek are presented in Figure 33. All of the elevation and gradient data for Crescent Creek was sampled from the LiDAR data.

Figure 33 – Crescent Creek elevations and gradients.




Crescent Creek channel widths were digitized from the NAIP orthophotos. The orthophotos were collected at different time than the simulation period and therefore the channel widths are approximate wetted widths.

Figure 34 – Crescent Creek channel widths.

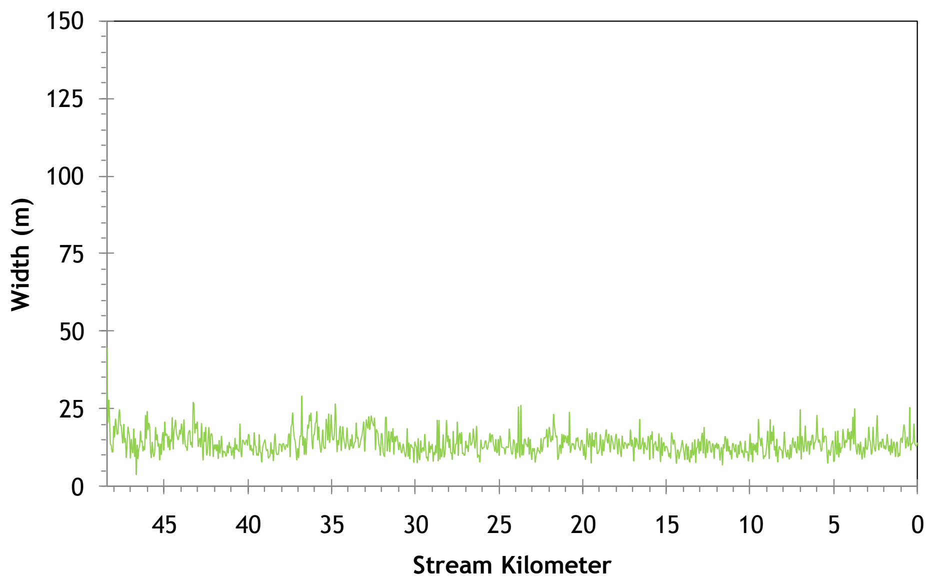
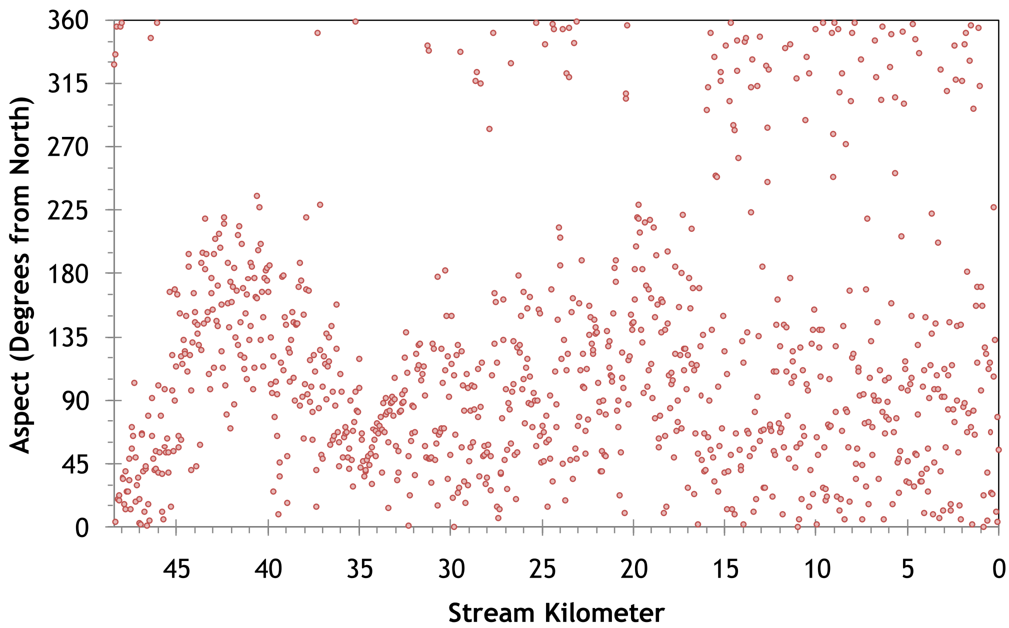


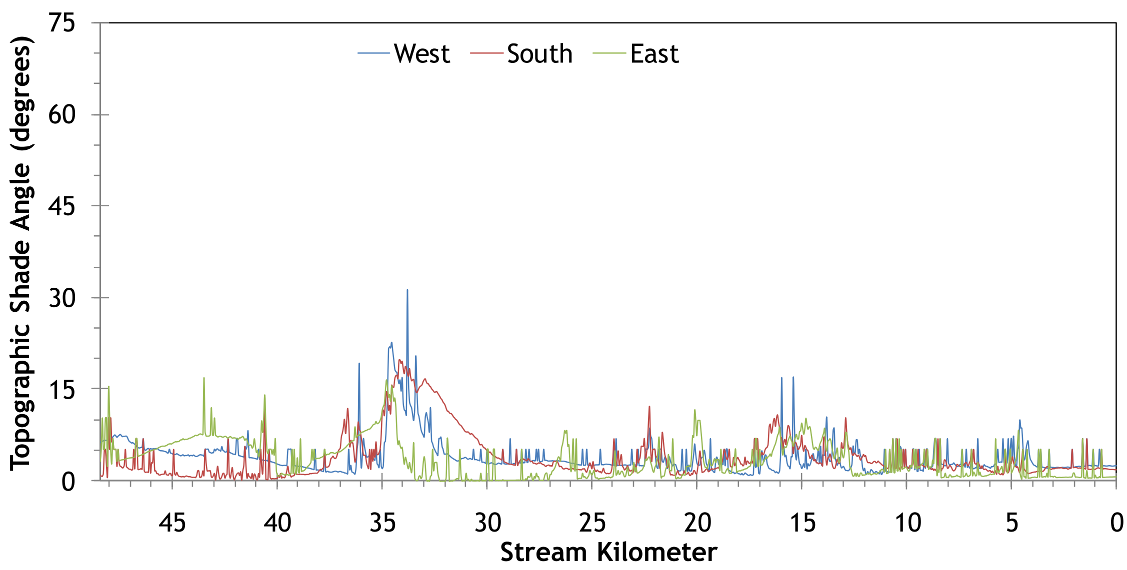
Figure 35 shows the sampled stream aspects for each of the 50-meter segments in Crescent Creek. In general, the stream flows toward the east.

Figure 35 - Crescent Creek stream aspects.




Crescent Creek's topographic shade angles are presented in Figure 36. The majority of topographic shade angles are less than 10 degrees on this stream.

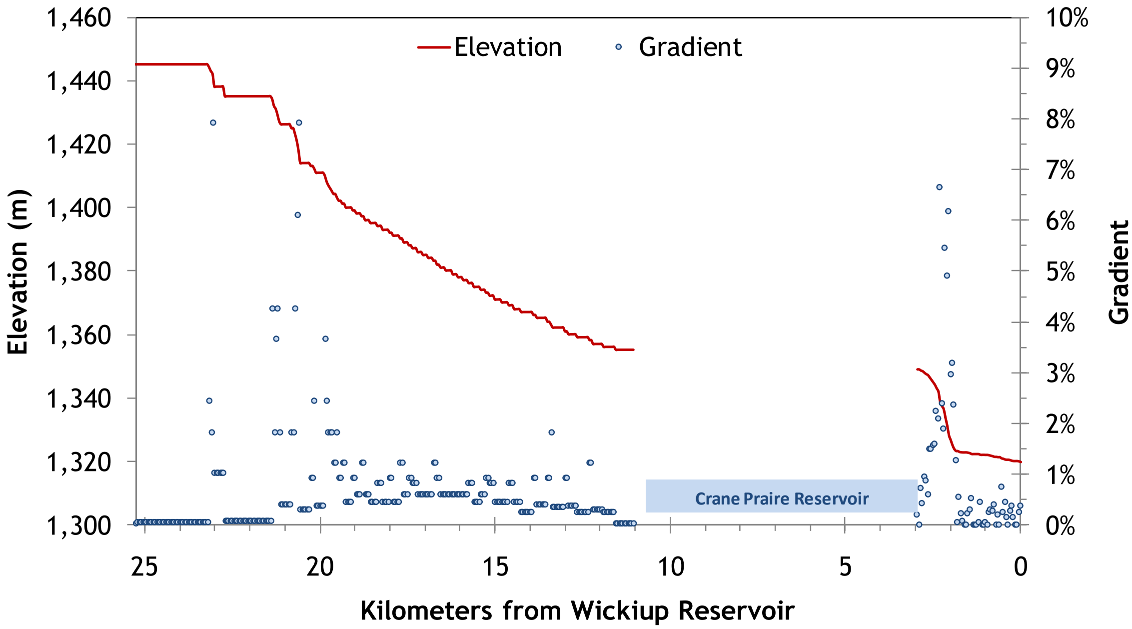
Figure 36 – Topographic shade angles on Crescent Creek.



*Deschutes River*

The Deschutes River was digitized and sampled between Wickiup Reservoir and the headwaters. Above Crane Prairie Reservoir, the elevation and gradient was sampled from the 10-meter DEM. Between Crane Prairie and Wickiup reservoirs, the data was sampled from LiDAR data.

Figure 37 – Deschutes River elevations and gradients.




The channel widths were digitized from the NAIP orthophotos and represent the wetted channel as observed in the photos. In the upper 4 stream kilometers, the wide widths are where the edges of a marsh were used to represent the banks. Everything downstream was based on the wetted perimeter.

Figure 38 - Deschutes River channel widths.

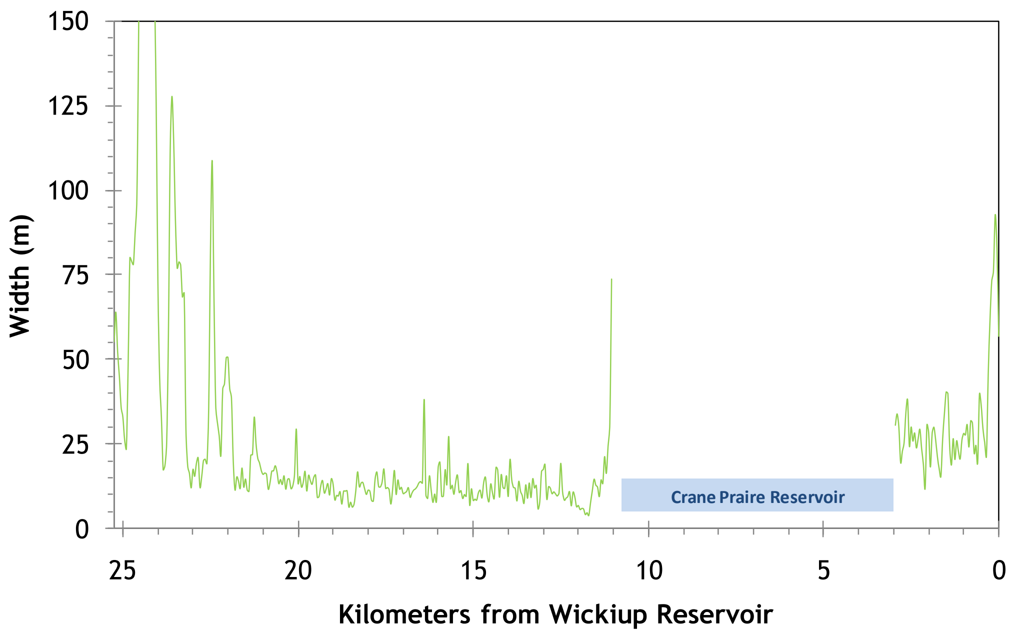
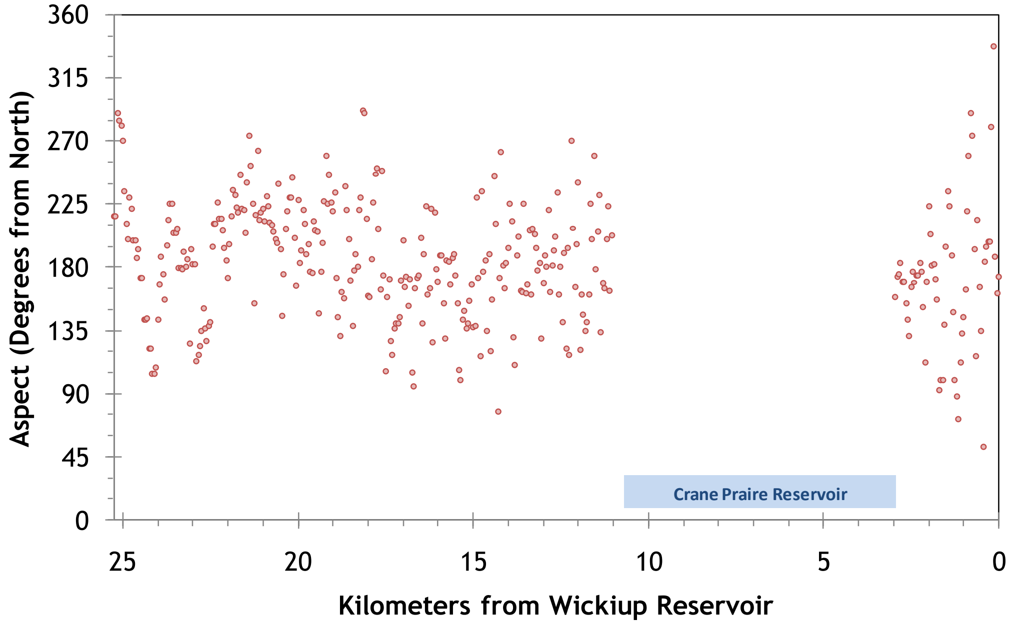


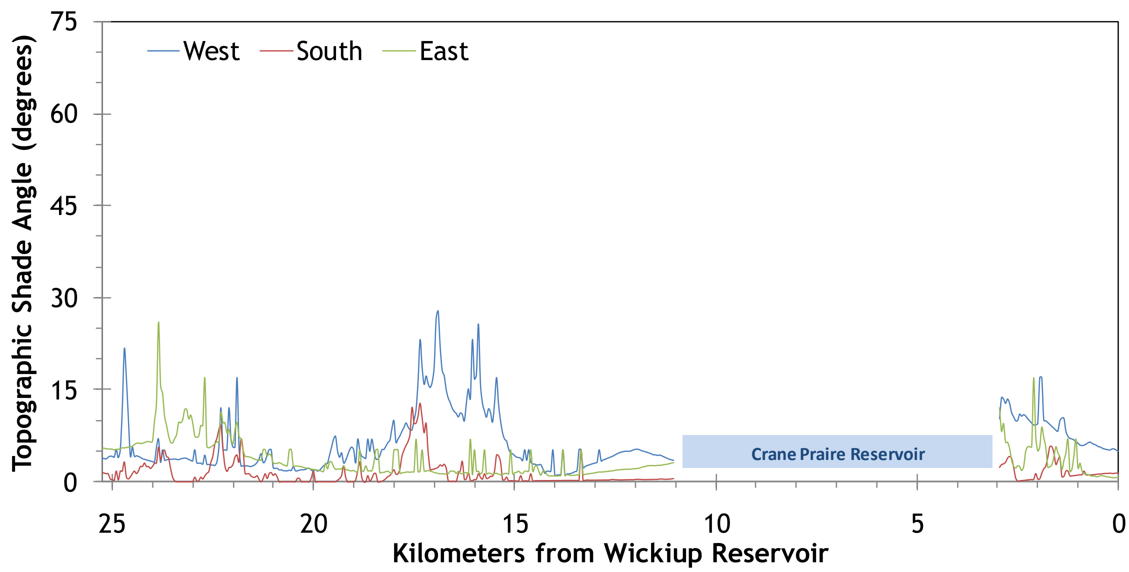
Figure 39 shows the stream aspects sampled every 50 meters along the Deschutes River.

Figure 39 – Deschutes River stream aspects.




Topographic shade angles are shown in Figure 40. There is relatively little topographic shade in the upper Deschutes River area.

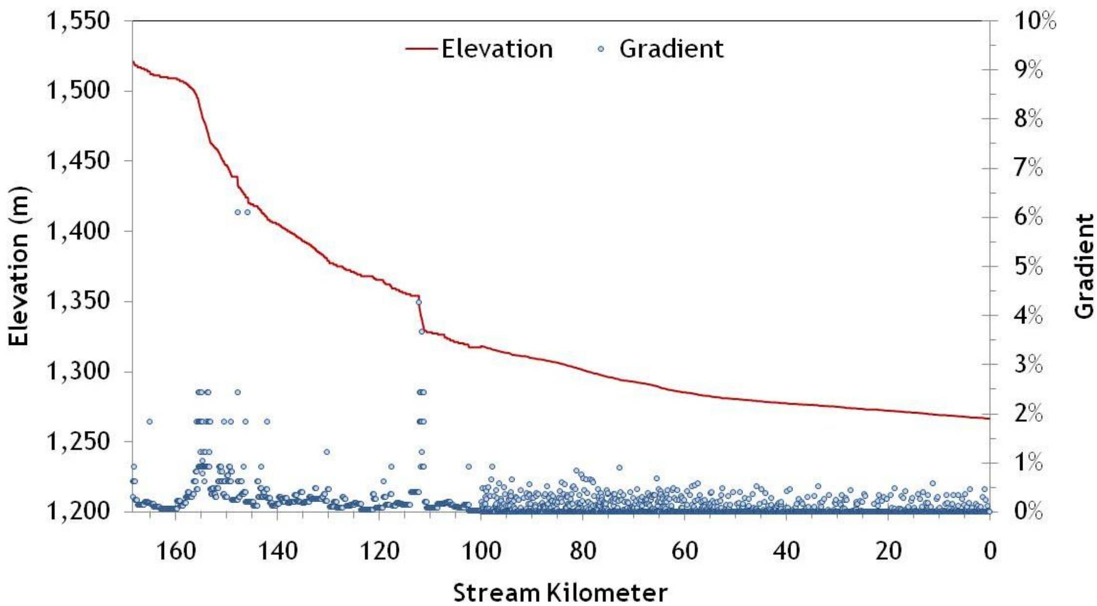
Figure 40 – Deschutes River topographic shade angles.



*Little Deschutes River*

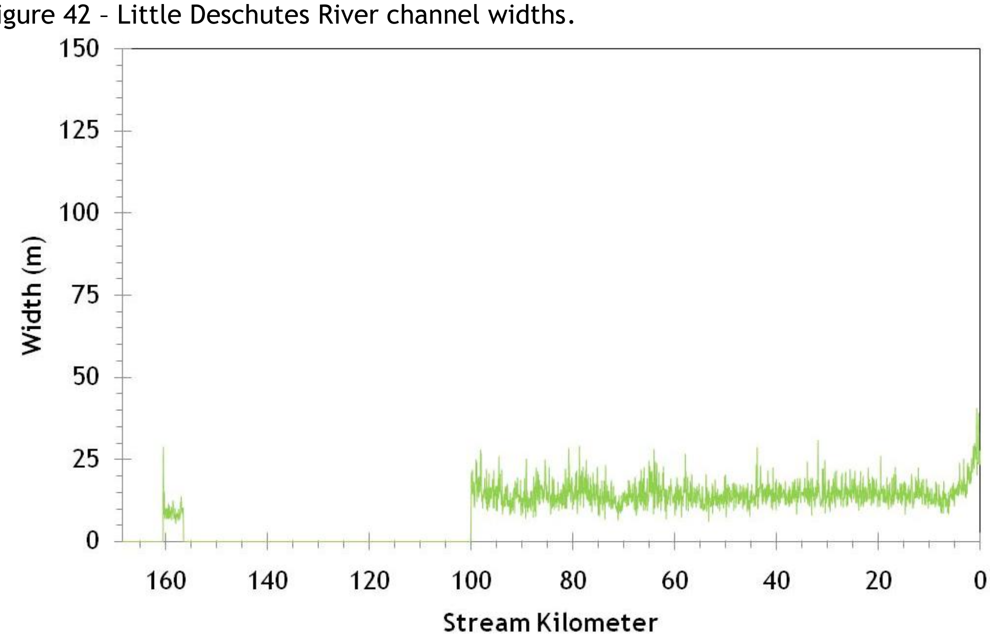
Stream elevations and gradients for the Little Deschutes River are shown in Figure 41. The values were sampled from the 10-meter DEM above Crescent Creek (stream kilometer 100) and from the LiDAR data everywhere downstream. The river is also more sinuous and has a lower gradient downstream of Crescent Creek

Figure 41 – Little Deschutes River stream elevations and gradients.




Little Deschutes River channel widths were digitized from the NAIP orthophotos wherever the river was large enough and the photos were clear enough to accurately determine the wetted edges. The wetted edges are approximately equal to the active channel edges throughout most of its length. Areas that were not digitized will have channel widths interpolated from field measurements during model setup

Figure 42 – Little Deschutes River channel widths.



The Little Deschutes River is very sinuous. Figure 43 shows the stream aspects at each of the 50-meter segments. Generally, the stream flows toward the northeast.

Figure 43 – Little Deschutes River stream aspects.

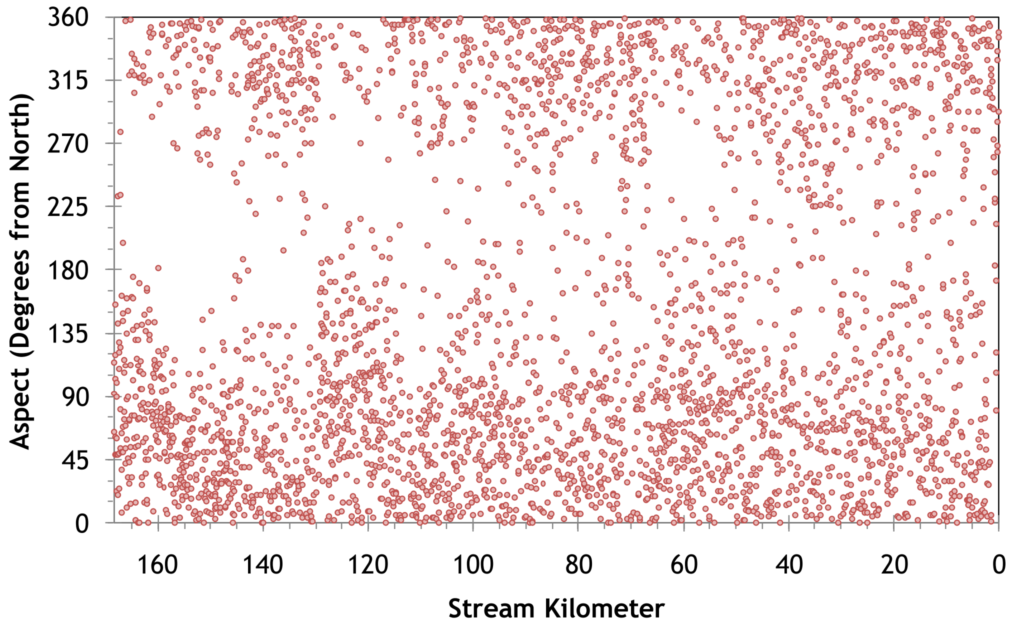
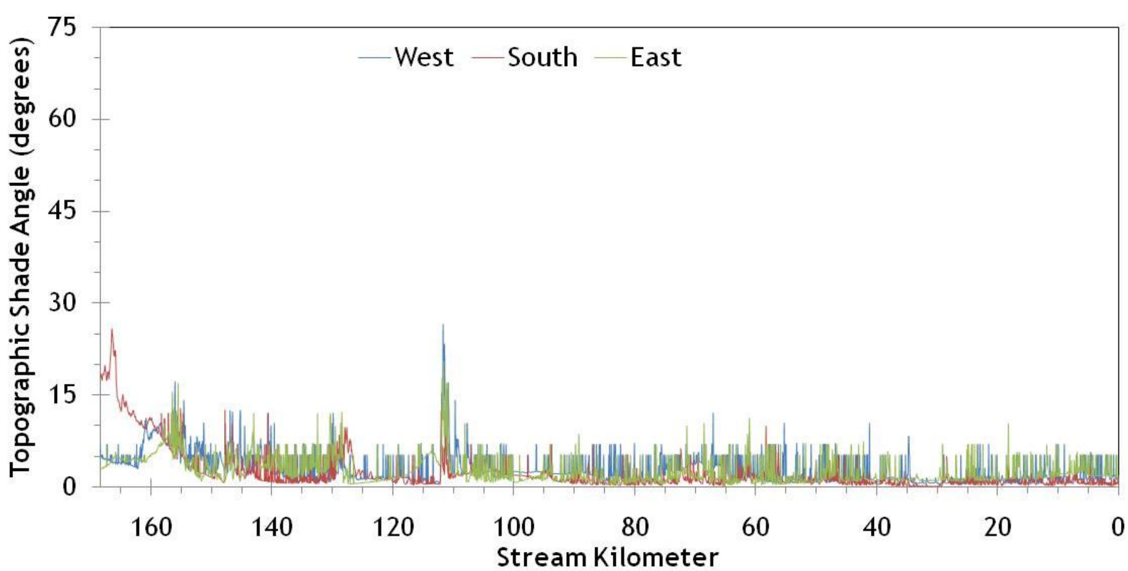



Figure 44 shows the topographic shade angles sampled from the 10-meter DEM. The LiDAR data was not used for topographic shade sampling because it is not wide enough coverage to capture the far-field topographic features.

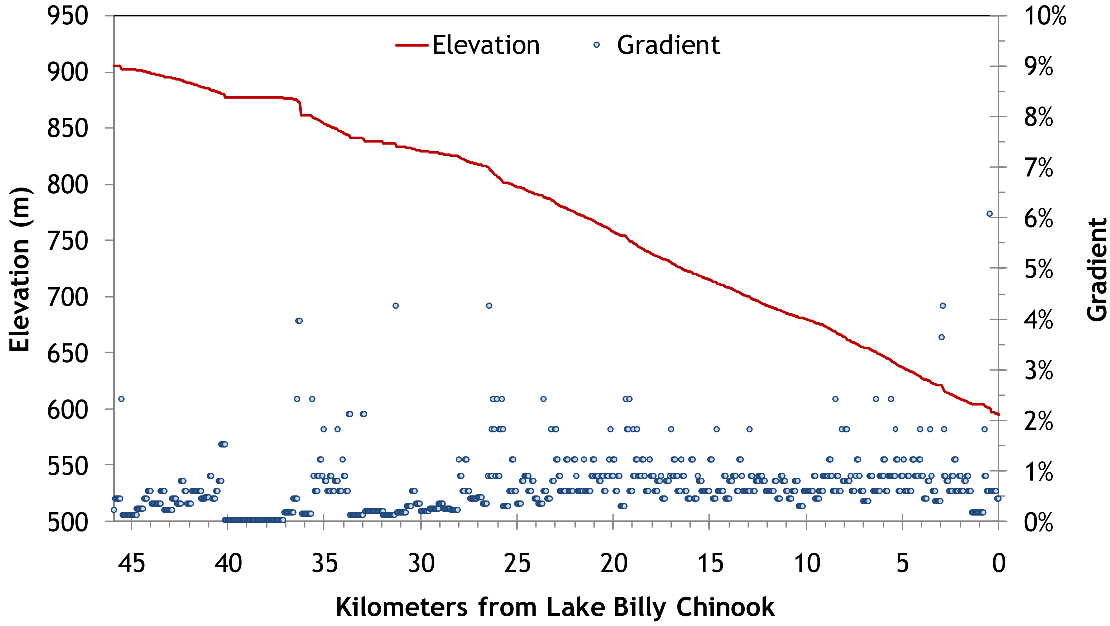
Figure 44 – Little Deschutes River topographic shade angles.



*Metolius River*

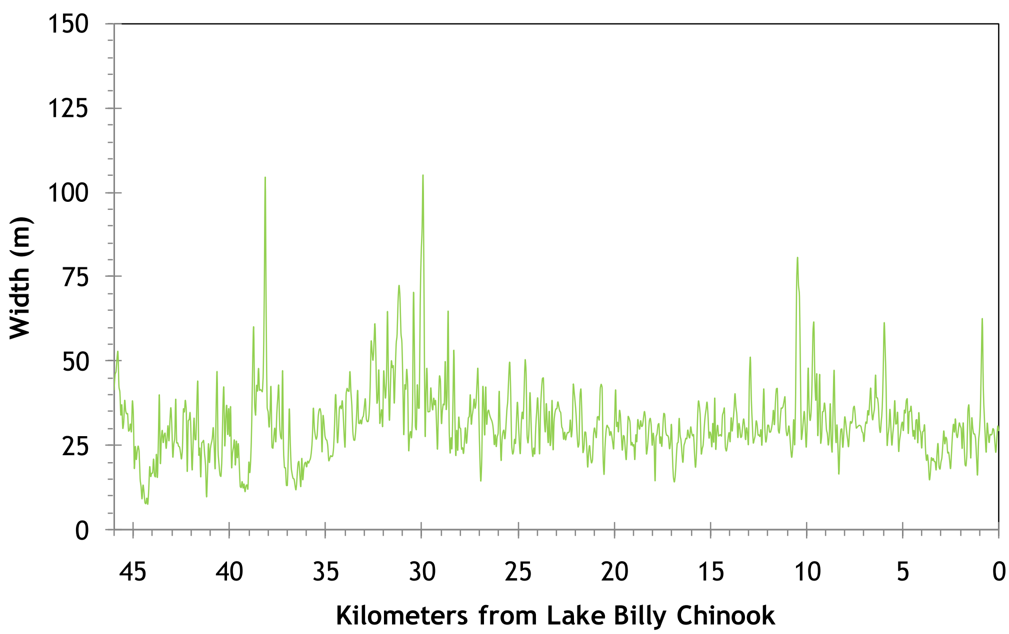
The Metolius River was digitized and sampled from its headwaters to Lake Billy Chinook. There is no LiDAR available for the Metolius River above Lake Billy Chinook, therefore the elevations and gradients were sampled from the 10-meter DEM.

Figure 45 – Metolius River elevations and gradients.



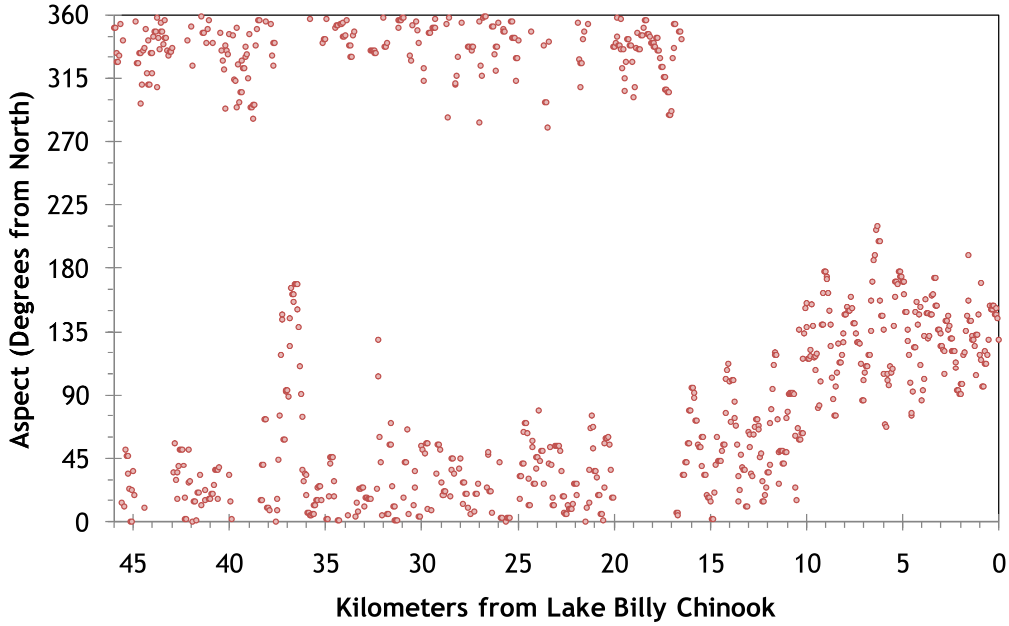

The Metolius River channel widths were digitized from the NAIP orthophotos. The river is typically between 20 and 40 meters wide (Figure 46). Generally, the wetted edges observed in the NAIP orthophotos were equivalent to the active channel.

Figure 46 – Metolius River channel widths.



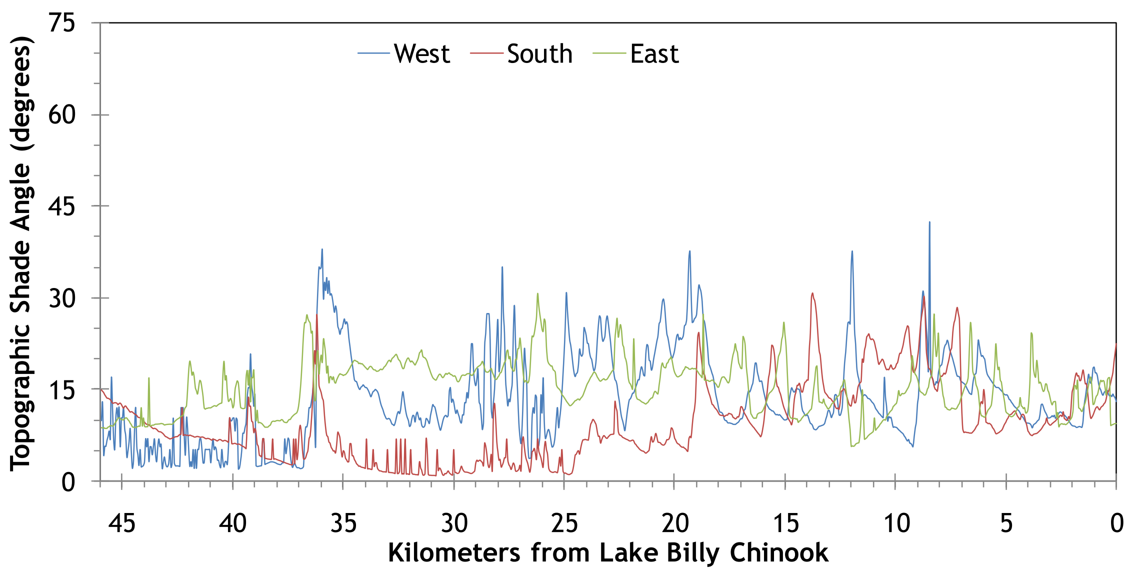
The Metolius River starts off flowing northward and then bends toward the southeast/east below kilometer 16. Figure 47 shows the sampled stream aspects.

Figure 47 – Metolius River stream aspects.




Topographic shade angles are somewhat high along the Metolius River (Figure 48). The stream flows through a v-shaped valley or canyon throughout much of its course.

Figure 48 – Metolius River topographic shade angles.



## Crooked River Drainage

### *Beaver Creek*

Figure 49 shows the raw (non-smoothed) stream elevations and gradients sampled from the 10-meter DEM. Beaver Creek is generally a low-gradient stream, dropping less than 200 meters over 38 kilometers.

Figure 49 – Beaver Creek stream elevations and gradients.

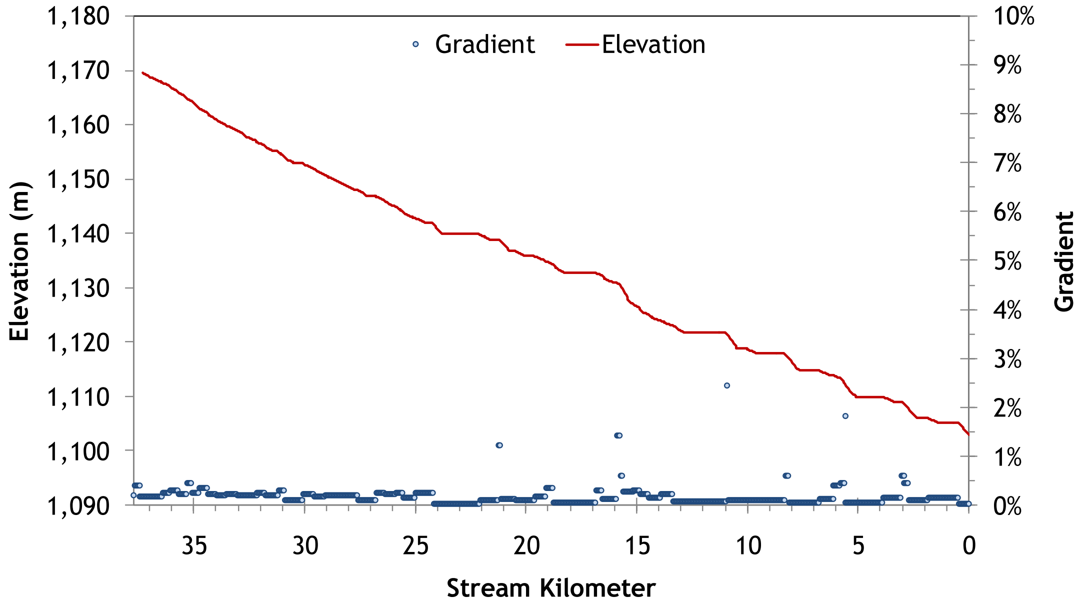



Figure 50 shows the sampled active channel widths on Beaver Creek. The active channel edges were estimated based upon what appeared to be scoured areas or wetland grasses in the orthorectified TIR true color images. Along most of the stream, the wetted perimeter was too narrow to be digitized.

Figure 50 – Beaver Creek channel widths.

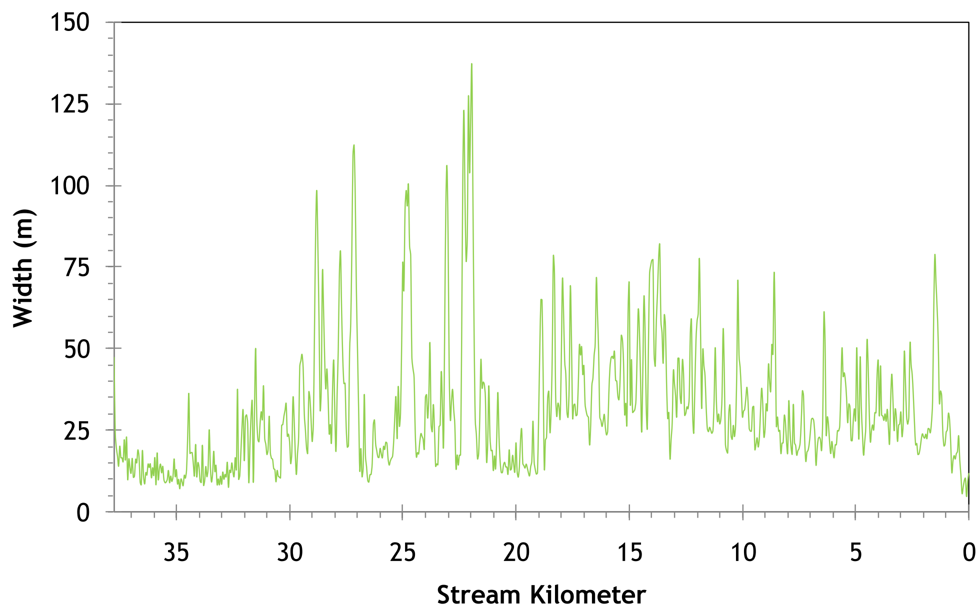


Figure 51 shows the stream aspects for each 50-meter reach of Beaver Creek. Generally, the stream is flowing at about 270 degrees from north, or in the westerly direction.

Figure 51 – Stream Aspects of Beaver Creek.

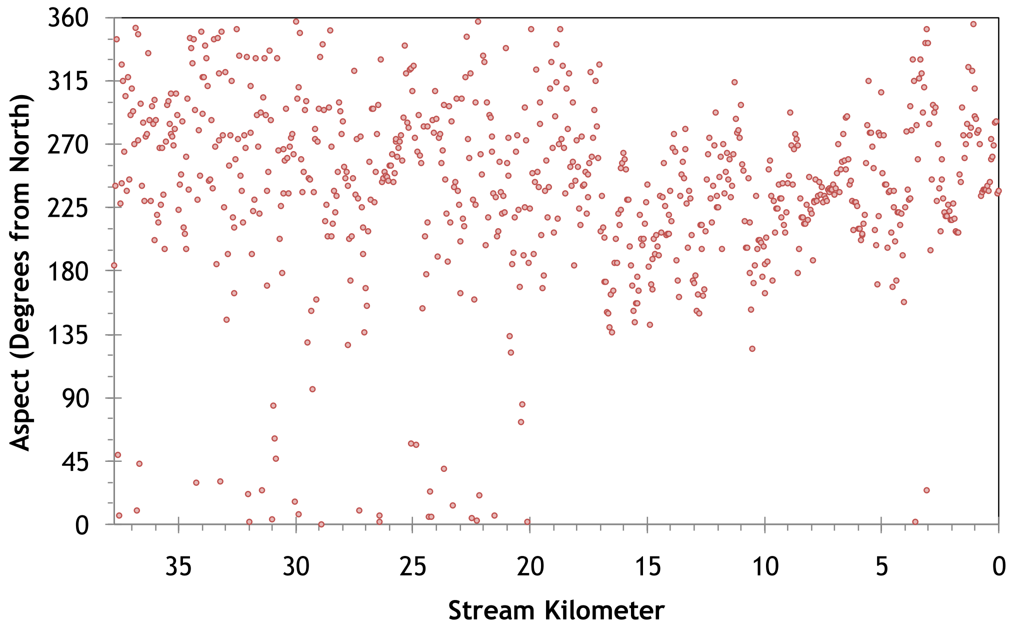
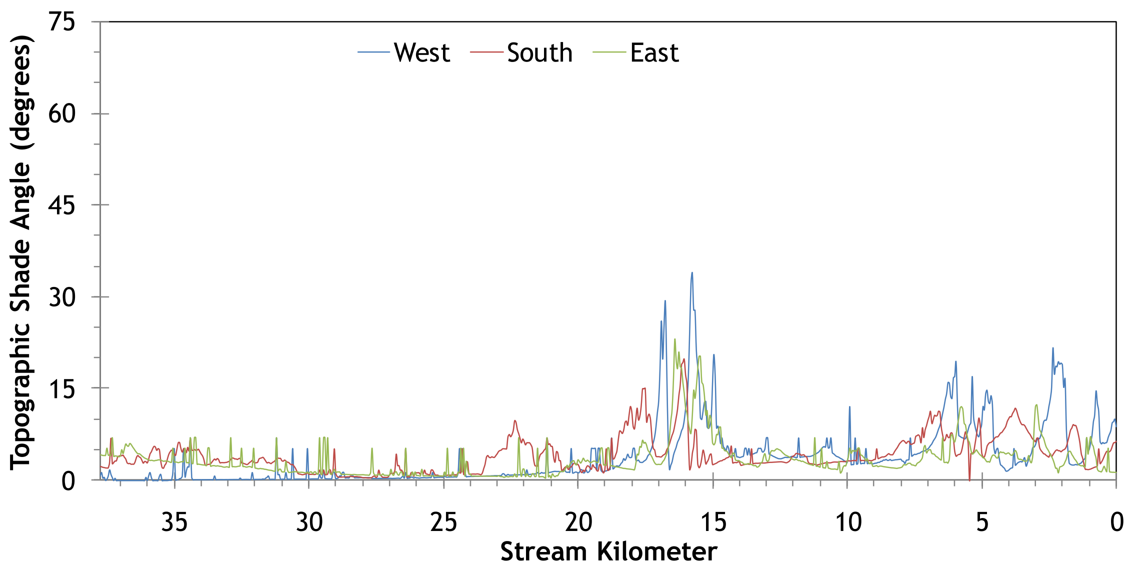



Figure 52 shows the topographic shade angles sampled from the 10-meter DEM. Most of Beaver Creek flows through a somewhat flat valley and there is relatively little topographic shade except for in a few reaches.

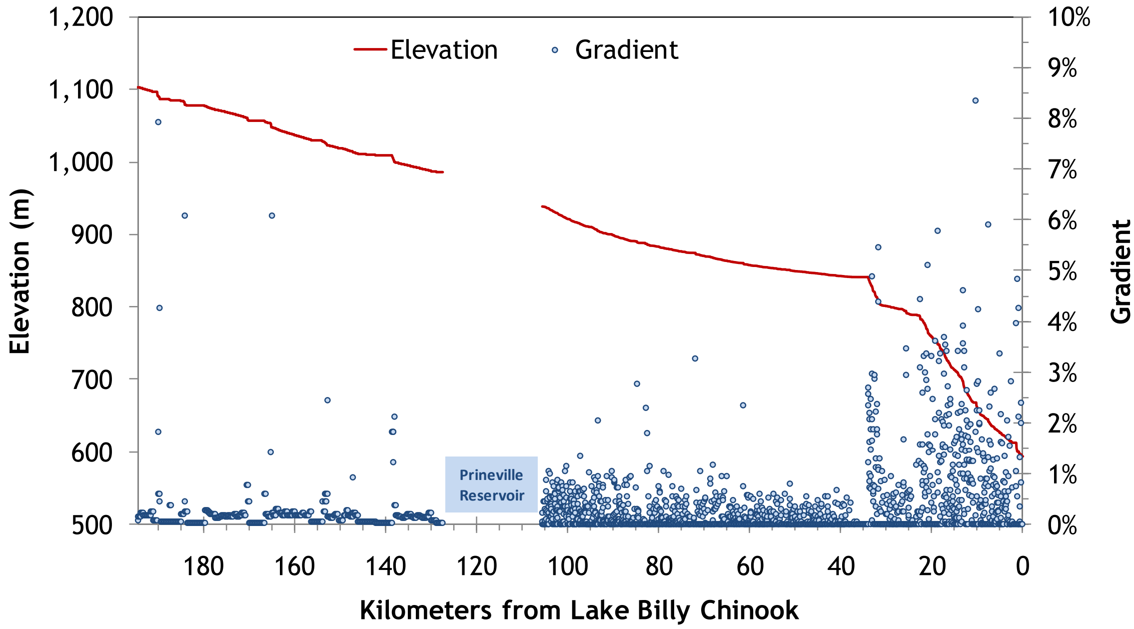
Figure 52 – Topographic Shade Angles on Beaver Creek.



*Crooked River*

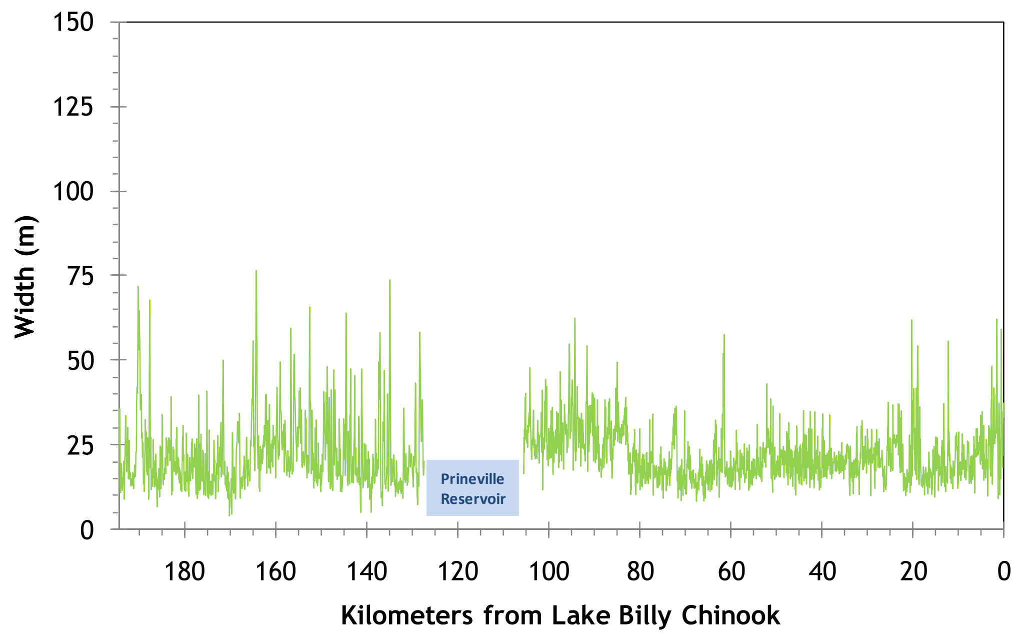
Crooked River elevations and gradients are presented in Figure 53. The values were sampled from the 10-meter DEM above Prineville Reservoir, and from LiDAR data below the reservoir. Below kilometer 30, the stream gradient increases as it approaches Lake Billy Chinook.

Figure 53 – Crooked River Elevations and gradients.




The wetted channel edges were digitized from the orthorectified TIR imagery. This data will provide accurate hydraulic inputs for the stream temperature model because they correspond directly to the simulation period.

Figure 54 – Crooked River stream channel widths.



Crooked River stream aspects are shown in Figure 55 for each of the 50-meter segments. Generally, the Crooked River flows toward the northwest.

Figure 55 – Crooked River stream channel aspects.

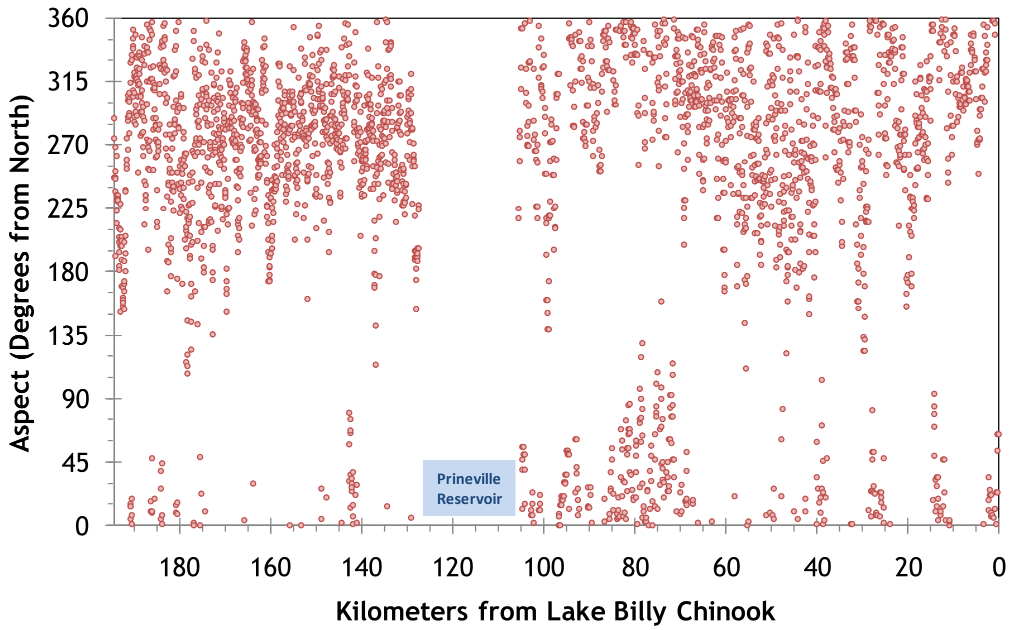
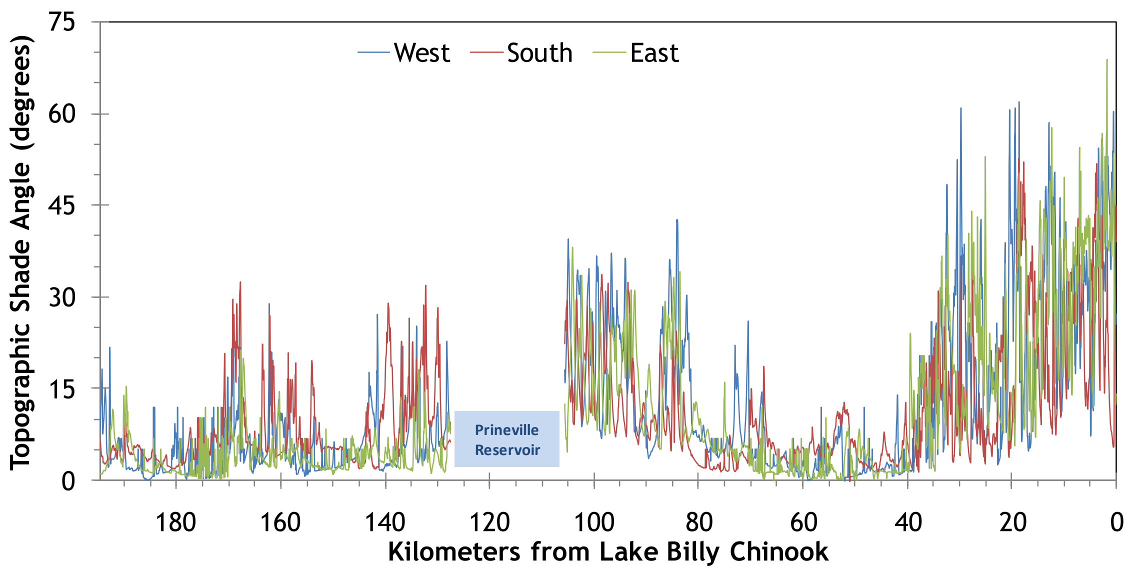



Figure 56 displays the topographic shade angles sampled along the Crooked River. The data were sampled from the 10-meter DEM. (LiDAR data has insufficient coverage for far-range topographic shade sampling.) The lower 40 stream kilometers flow through confined canyons with steep cliffs that produce high topographic shade angles.

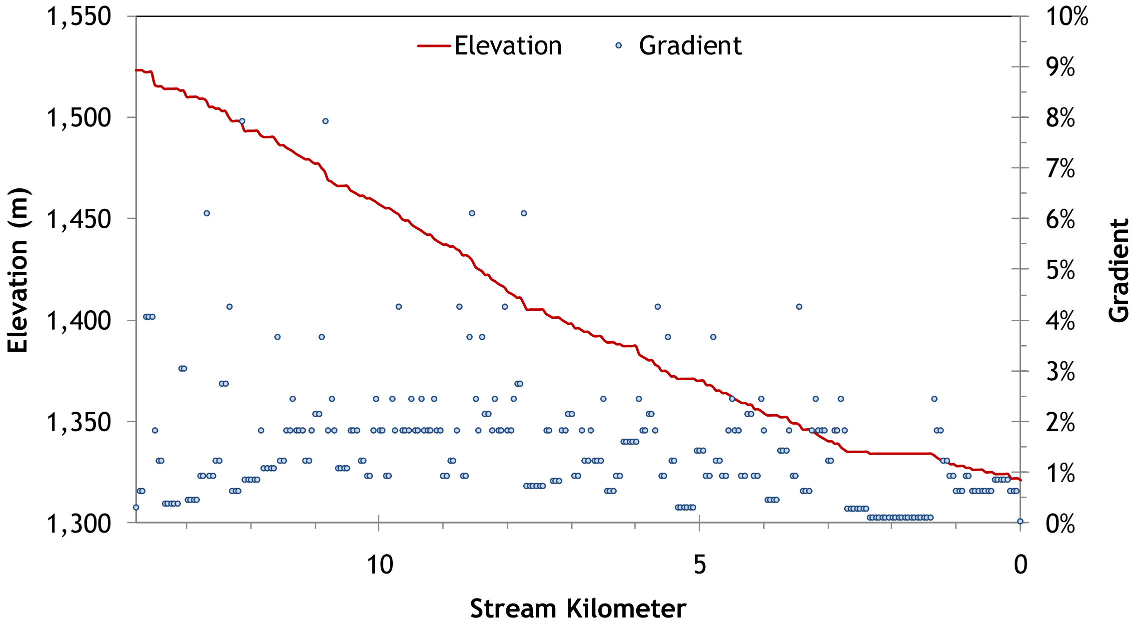
Figure 56 – Crooked River topographic shade angles.



*Deep Creek*

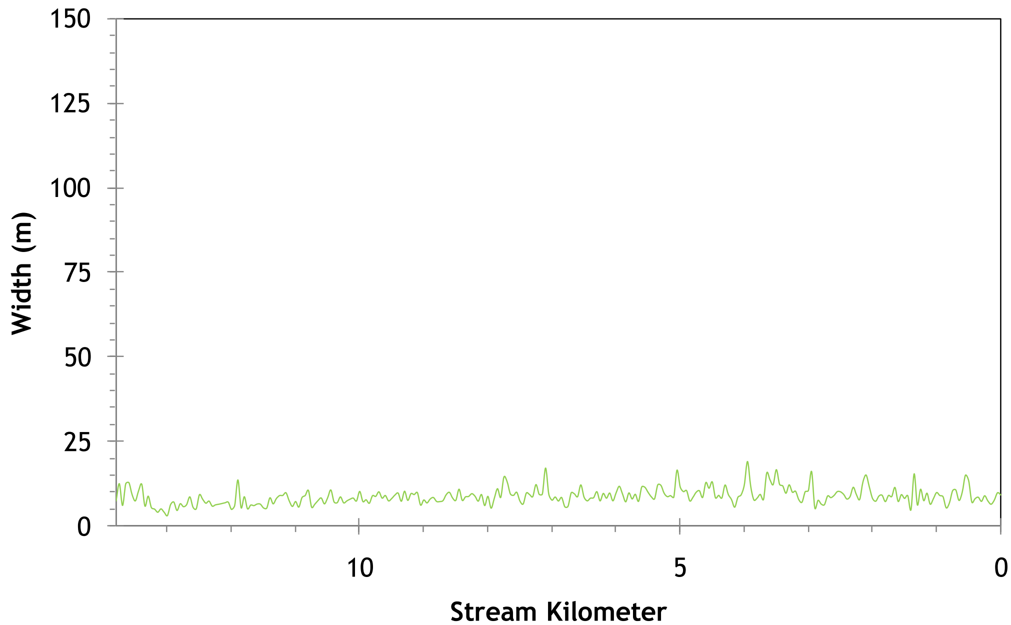
Stream elevations and gradients were sampled from the 10-meter DEM for Deep Creek. Figure 57 displays the results.

Figure 57 – Deep Creek elevations and gradients.



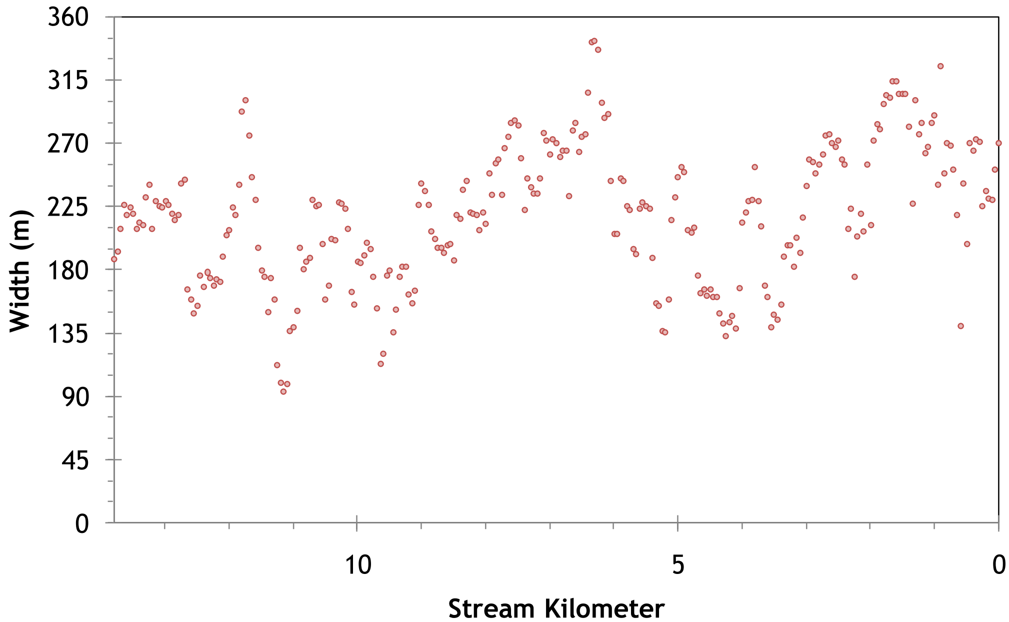

Deep Creek wetted channel widths were sampled from the true color orthorectified TIR imagery. Deep Creek is a smaller stream, with widths ranging between 5 and 15 meters.

Figure 58 – Deep Creek channel widths.



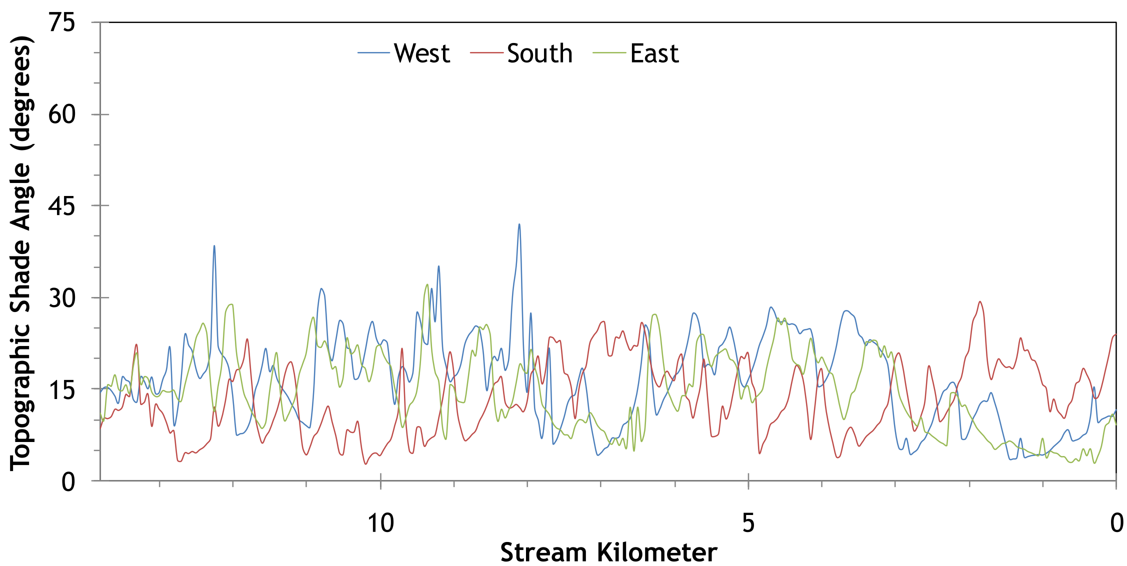
Deep Creek aspects for each 50-meter segment are displayed in Figure 59. The stream generally flows in the south/southwest direction.

Figure 59 – Deep Creek stream aspects.




Deep Creek receives a fair amount of shade from topographic features. Much of the stream flows through a v-shaped valley with significant terrain relief.

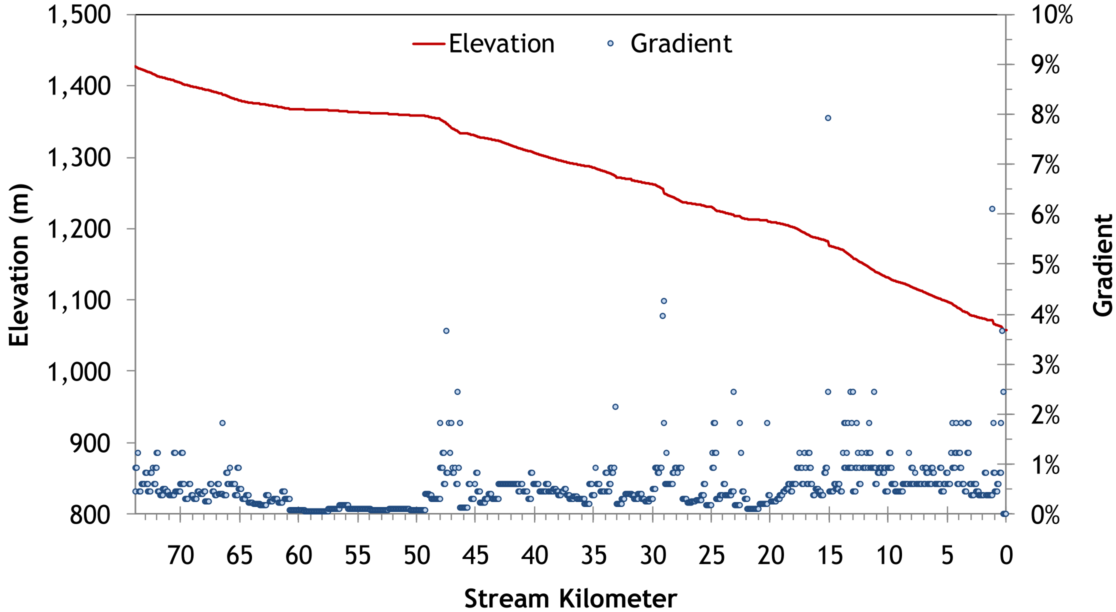
Figure 60 – Deep Creek topographic shade angles.



*North Fork Crooked River*

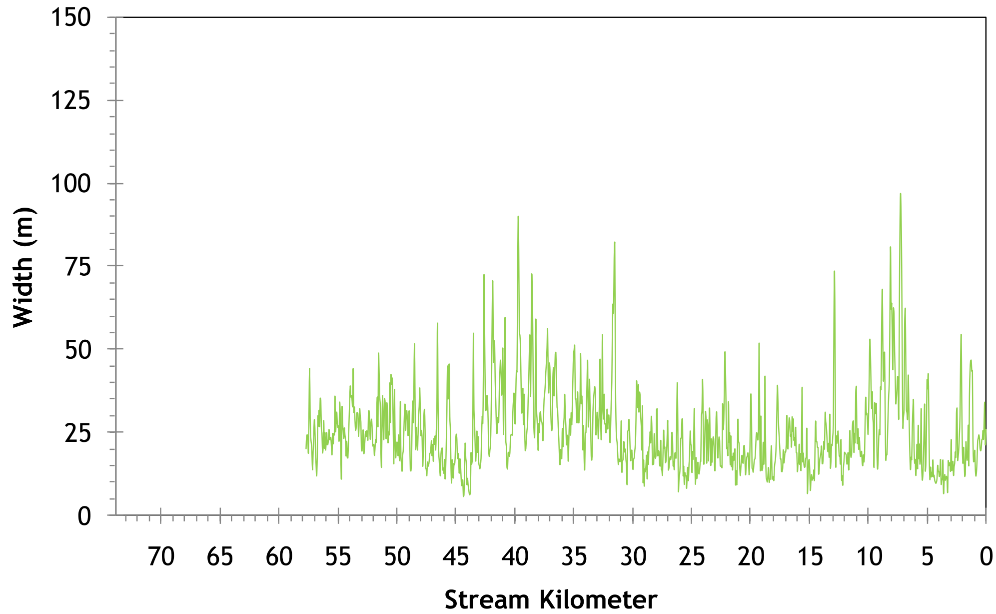
The North Fork Crooked River elevations and gradients are presented in Figure 61. They were sampled from the 10-meter DEM because there is no LiDAR data for that area. The steepest gradients recorded are in the lower one third of the river.

Figure 61 - North Fork Crooked River elevations and gradients.



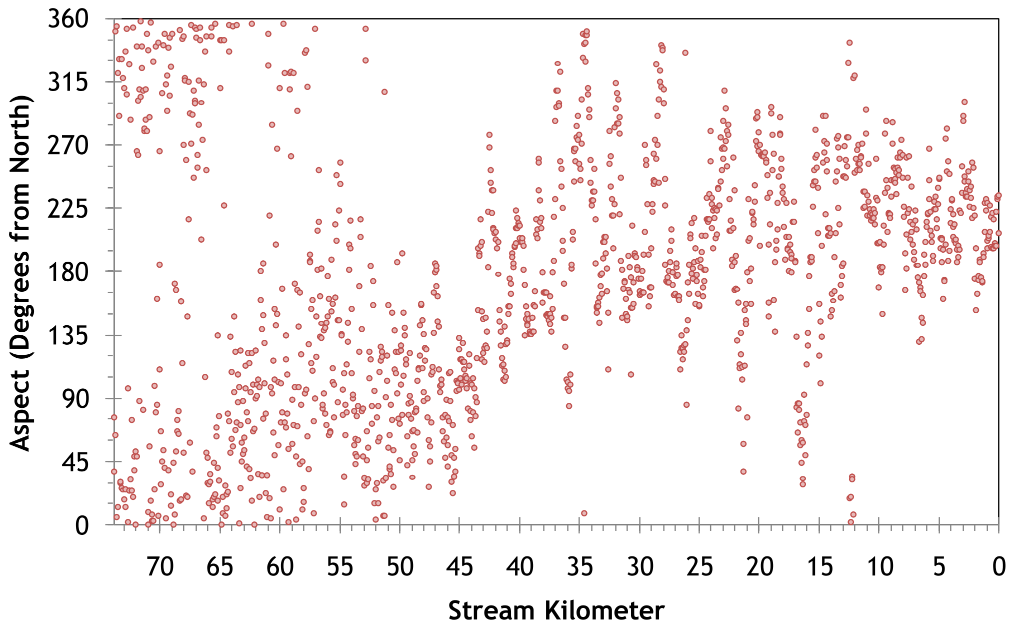

The North Fork Crooked River channel edges were digitized from high resolution orthorectified true color images obtained during the TIR survey. The widths presented here represent the active or scoured channel widths. The upper reaches flow through agricultural grazing land and were too small to be accurately digitized in this area. Many reaches were too narrow for digitizing the wetted widths; however the imagery will be examined and some wetted edges will be measured during model set up.

Figure 62 – North Fork Crooked River active channel widths.


150
125
100
75
50
25
0
Width (m)
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Stream Kilometer

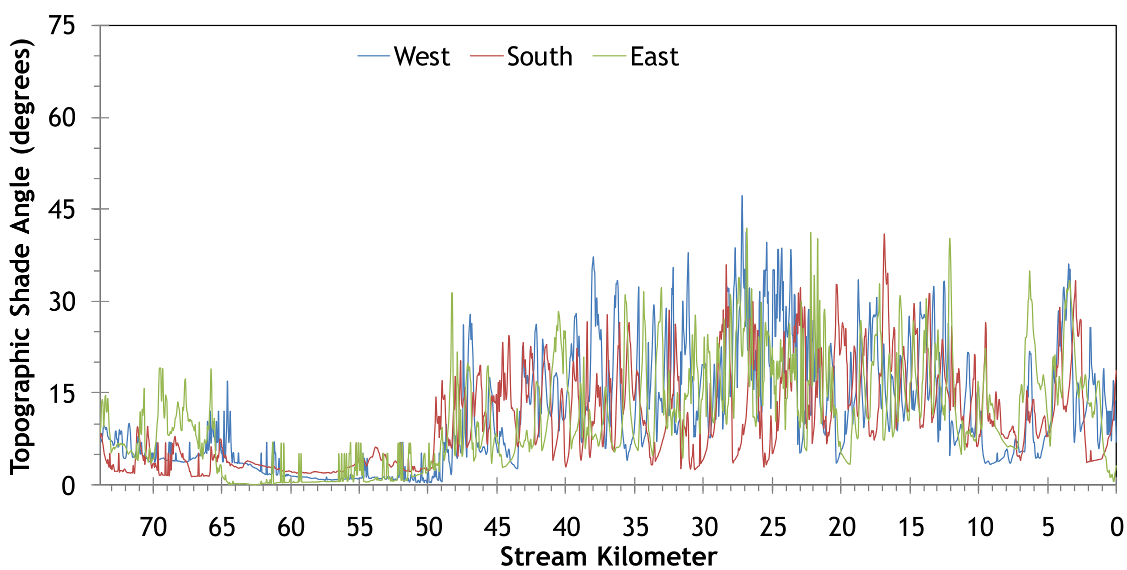
The North Fork Crooked River stream aspects are shown in Figure 63.

Figure 63 – North Fork Crooked River stream aspects.




Much of the North Fork Crooked River flows through confined canyons with steep walls that produce high topographic shade angles. The sampled topographic shade angles are displayed in Figure 64. Note that the upper reaches flow through a broad agricultural valley as opposed to through confined canyons.

Figure 64 – North Fork Crooked River topographic shade angles.



*Ochoco Creek*

Ochoco Creek elevations and gradients were sampled from the 10-meter DEM upstream of Ochoco Reservoir (stream kilometers 18 to 24) and from LiDAR data downstream of the reservoir. Figure 65 shows that Ochoco creek is fairly steep, especially in the upper reaches.

Figure 65 – Ochoco Creek elevations and gradients.

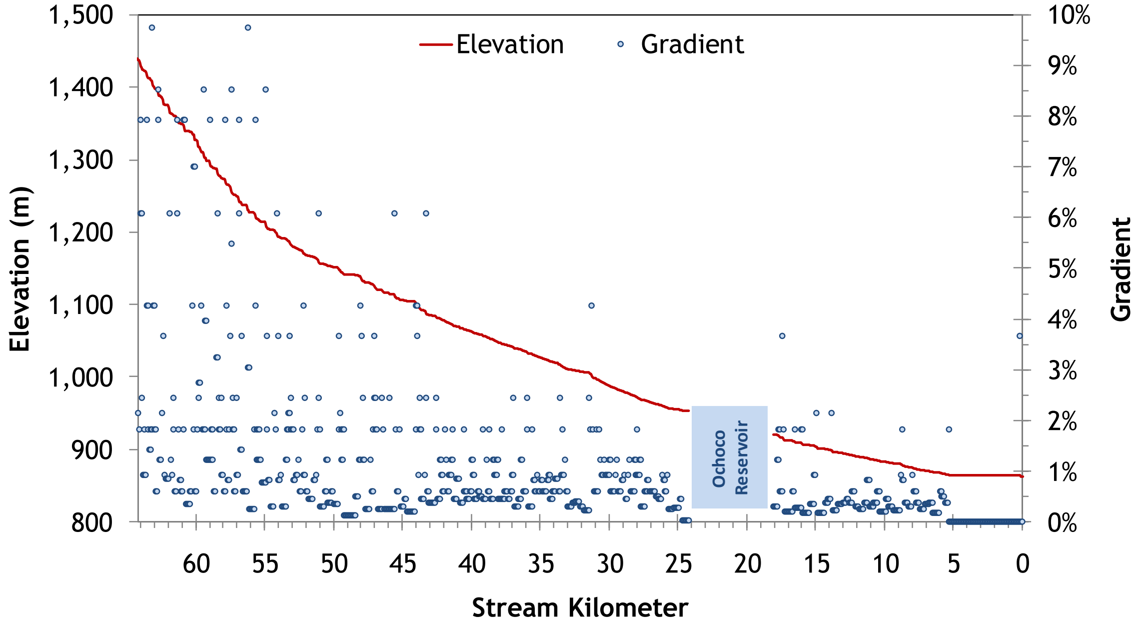



Figure 66 shows the digitized active channel widths for Ochoco Creek. The wetted perimeter was generally too narrow to be digitized, so the active edges were classified as whatever appeared to have wet grasses in the orthorectified TIR imagery. The wetted widths will be estimated when setting up the model.

Figure 66 – Ochoco Creek channel widths.

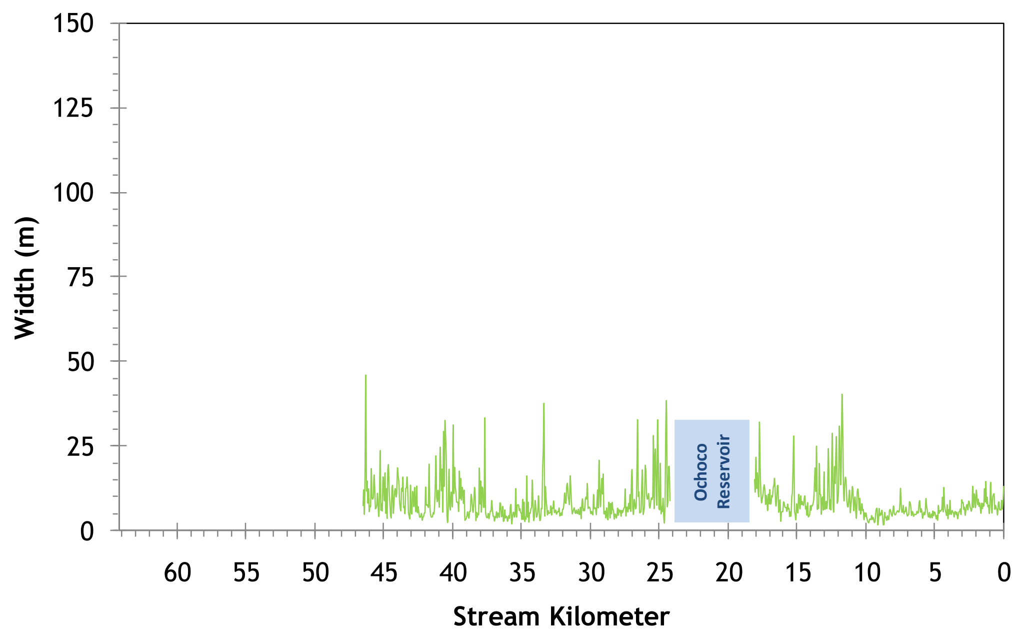
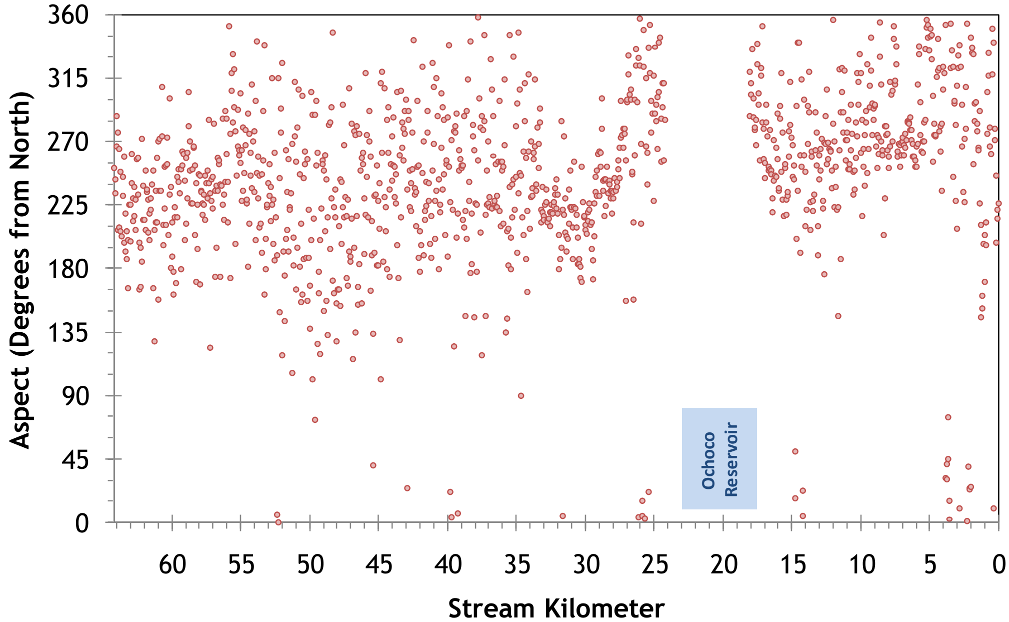


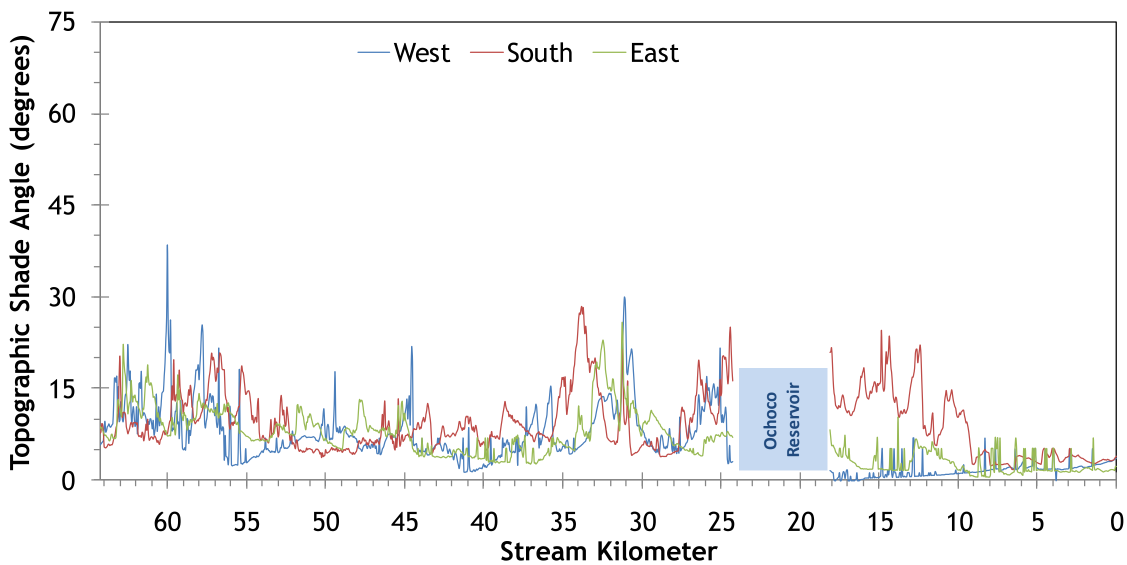
Figure 67 shows the sampled stream aspects for Ochoco Creek. The stream flows toward the west/southwest.

Figure 67 – Ochoco Creek stream aspects.




Ochoco Creek is moderately shaded by topographic features (Figure 68). The stream drains a mountainous area, but does not have the steep box canyons like the North Fork Crooked River.

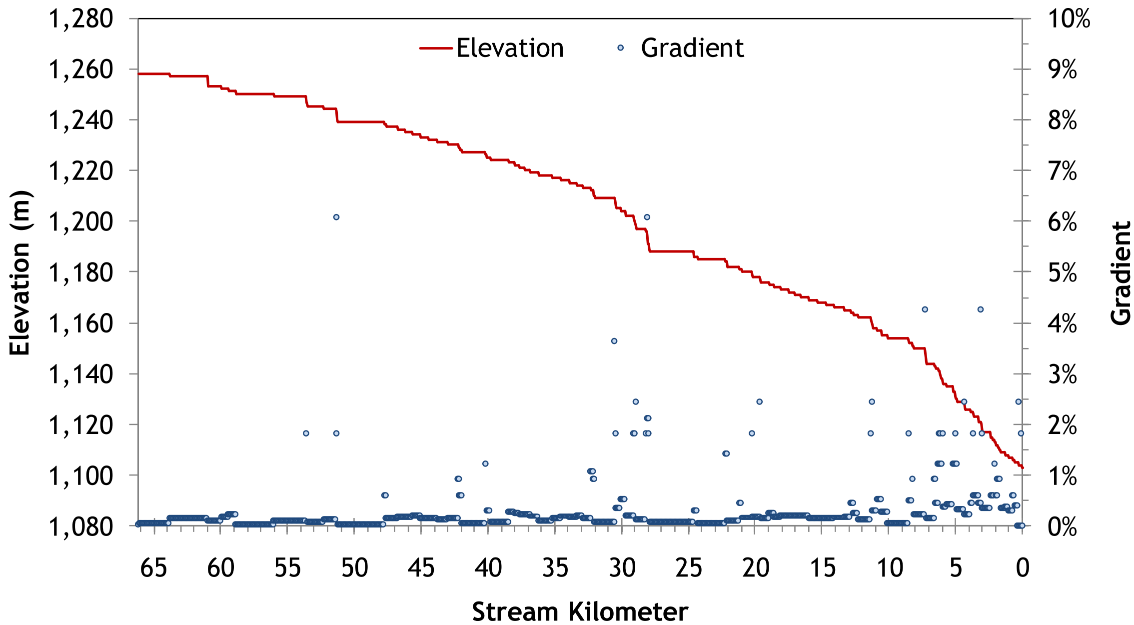
Figure 68 – Ochoco Creek topographic shade angles.



*South Fork Crooked River*

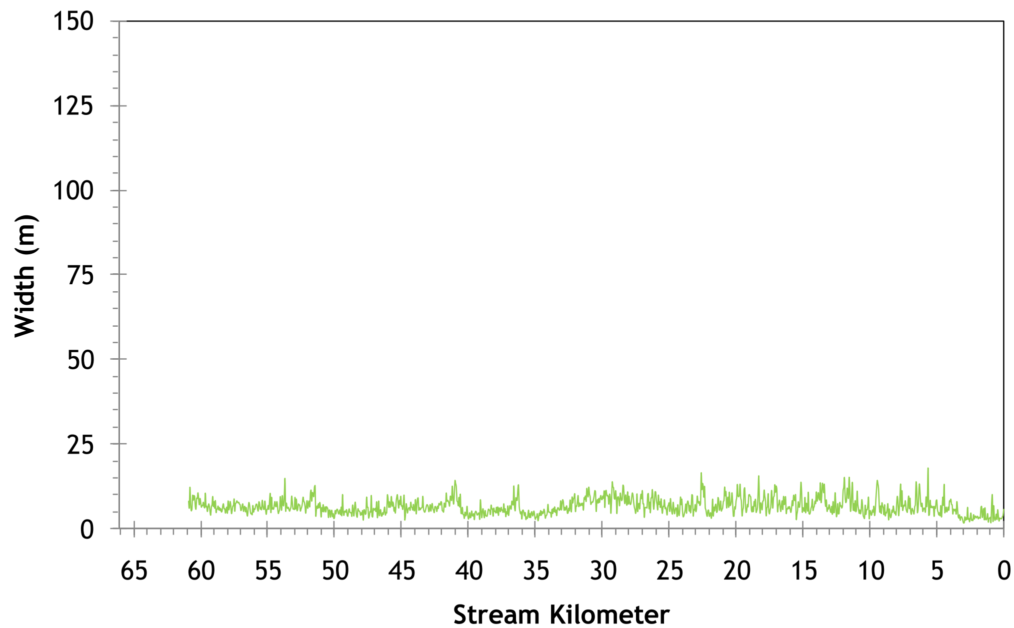
The South Fork Crooked River elevations and gradients are displayed in Figure 69. They were sampled from the 10-meter DEM because there is no LiDAR data available for that area. The stream is fairly low gradient throughout its length, dropping just about 250 meters over 66 kilometers.

Figure 69 – South Fork Crooked River elevations and gradients.



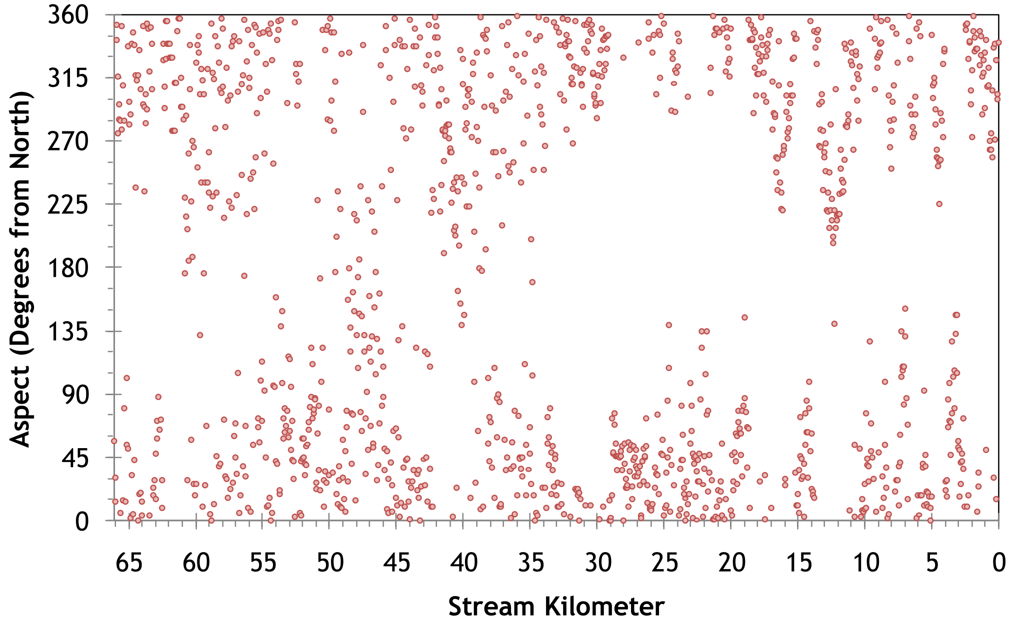

The South Fork Crooked River wetted channel widths were usually between 5 and 15 meters. The wetted channel edges were digitized from the high resolution true color photos collected during the TIR survey. The upper few kilometers were not digitized because the stream flows through an expansive marsh area where there is no definite channel (those widths will be estimated during the model set up process.

Figure 70 – South Fork Crooked River channel widths.



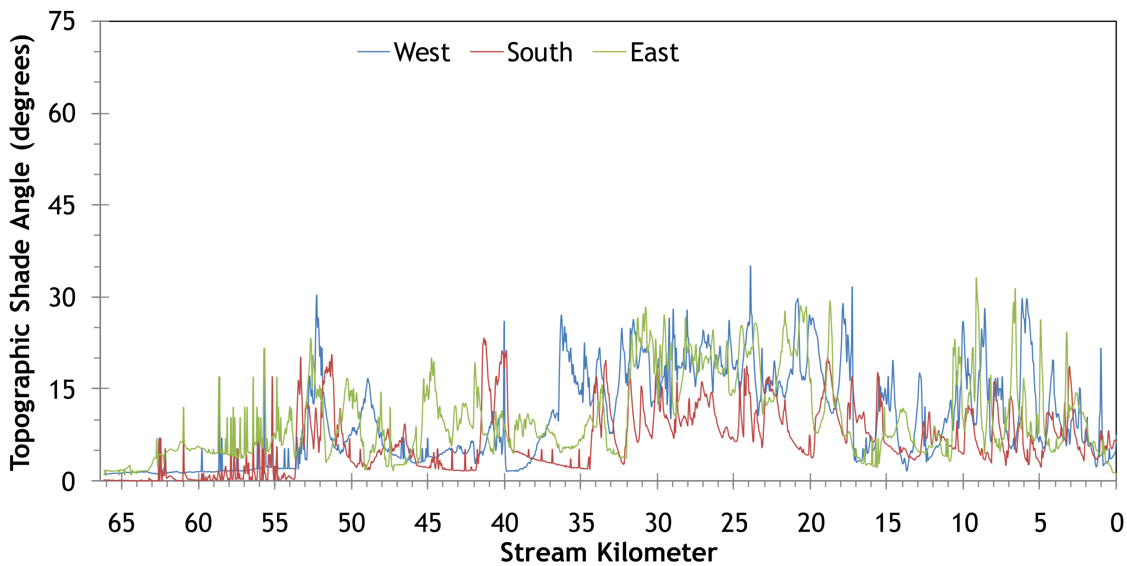
The South Fork Crooked River flows mostly northward. Figure 71 shows the stream aspects sampled at each 50-meter segment.

Figure 71 – South Fork Crooked River stream aspects.




The South Fork Crooked River receives significant topographic shade as it flows through a somewhat confined valley area below the marsh. Figure 72 plots the topographic shade angles measured from the 10-meter DEM.

Figure 72 – South Fork Crooked River topographic shade angles.



**Digitized Near Stream Land Cover**

Near stream land cover was digitized within 100 meters of the stream banks at a 1:5000 scale or better where LiDAR data was not available (Figure 73). In the Crooked River subbasin, the high resolution true color imagery collected during the TIR flights was used for digitizing. In the Upper Deschutes River subbasin, the NAIP orthophotos were used for digitizing (National Agriculture Imagery Program 2005). Near stream land cover polygons were coded based upon unique land cover type, height class, and density class. The near stream land cover polygons were then converted to a 1-meter raster and TTools was used to sample the values at each 50-meter stream segment. Heights will be assigned to the vegetation codes on a stream-by-stream basis as the Heat Source models are set up. Heights will be based upon field measurements provided by the Oregon DEQ.

Crescent Creek, the lower Crooked River, and the lower Little Deschutes River are included in the modeling scope; however LiDAR data is available in those reaches and will be used to sample near stream land cover heights.

Figure 73 – Digitized near stream vegetation.

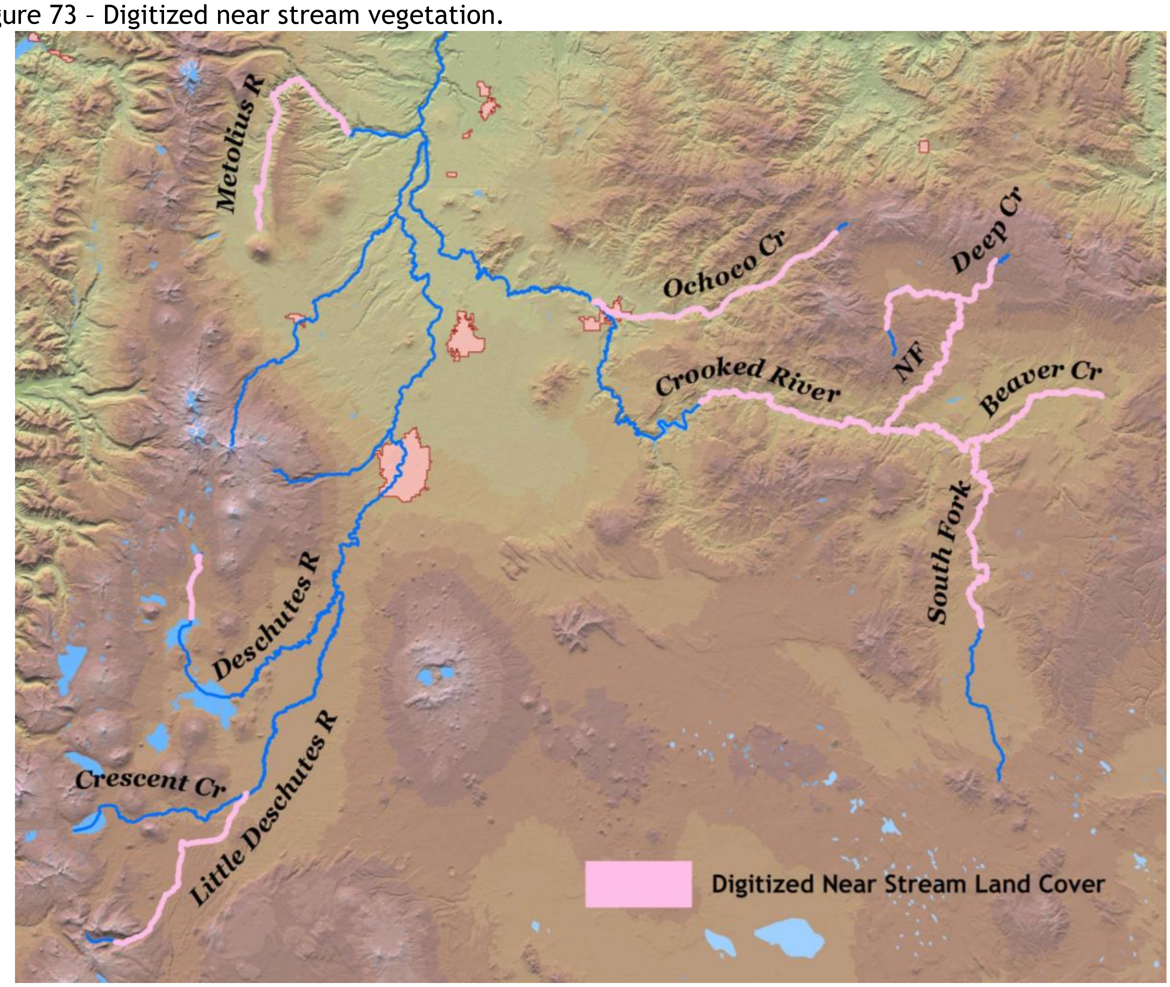


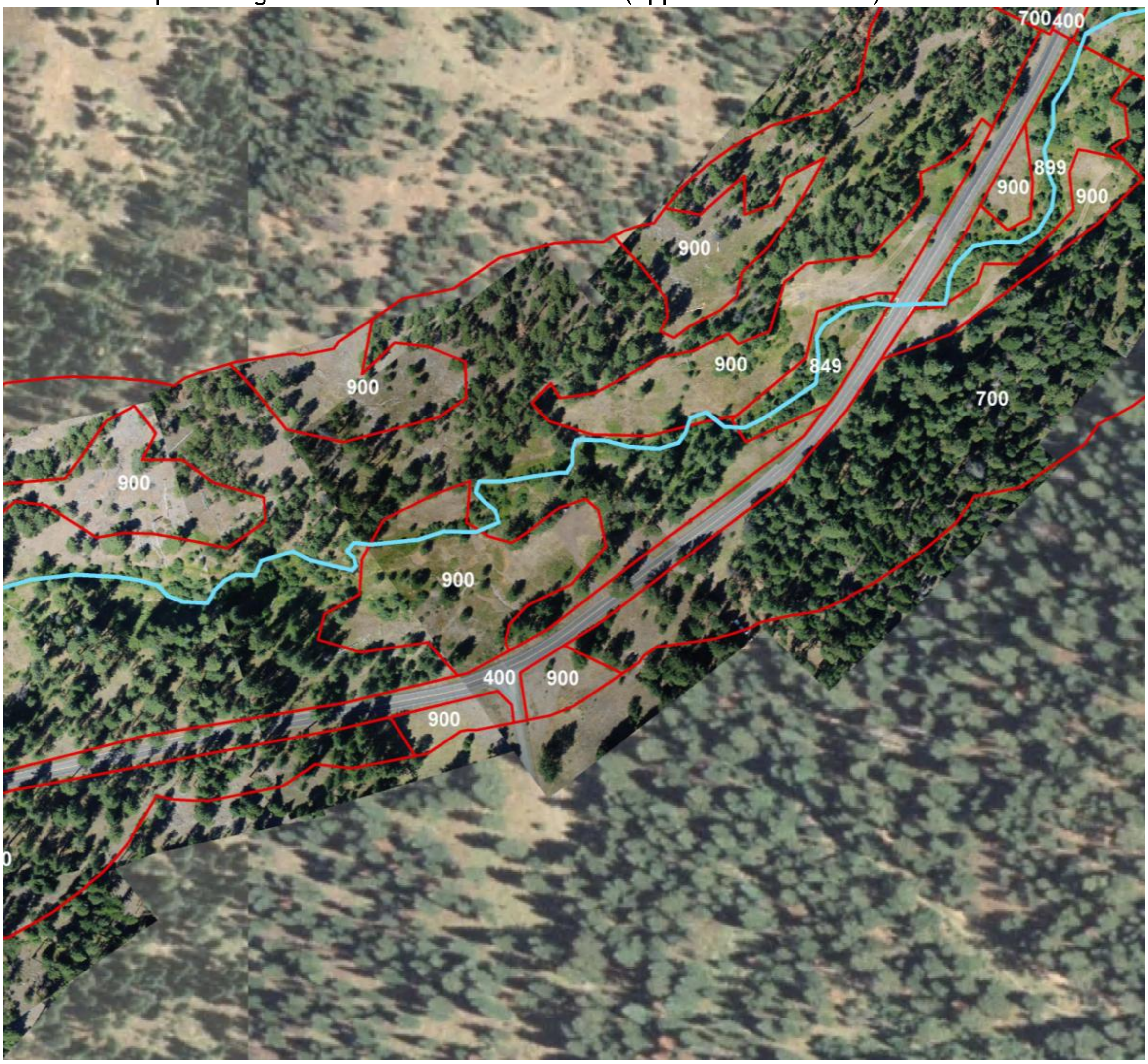
Table 11 summarizes the near stream land cover codes that were assigned to the digitized polygons. The codes are the same set that was used in a previous modeling effort on the Deschutes River, Whychus Creek, and Tumalo Creeks.

Table 11 – Near stream land cover codes and descriptions.

| Code | Description |
|---|---|
| 500 | Mixed Forest, Large, Higher Density |
| 550 | Mixed Forest, Large, Lower Density |
| 501 | Mixed Forest, Small, Higher Density |
| 551 | Mixed Forest, Small, Lower Density |
| 700 | Conifer Forest, Large, Higher Density |
| 750 | Conifer Forest, Large, Lower Density |
| 701 | Conifer Forest, Small, Higher Density |
| 751 | Conifer Forest, Small, Lower Density |
| 850 | Shrubs |
| 849 | Riparian Shrubs, Large |
| 899 | Riparian Shrubs, Small |
| 499 | Juniper, Sage |
| 477 | Recently Disturbed Forest |
| 315 | Clearcut with >50% Regeneration Saplings |
| 302 | Pasture, Cultivated or Lawn |
| 900 | Dry Grasses |
| 901 | Wet Grasses |
| 902 | Golf Course |
| 304 | Rock |
| 305 | Embankment |
| 306 | Campground or Park |
| 307 | Gravel Pit |
| 308 | Clearcut |
| 309 | Clearcut with <50% Regeneration Saplings |
| 400 | Road (paved) |
| 401 | Road (unpaved forest) |
| 403 | Road (unpaved agricultural) |
| 404 | Railroad |
| 310 | Barren |
| 311 | Recently Burned Forest, <50% Regeneration |
| 3248 | Residential Structure |
| 3249 | Commercial Structure |
| 3011 | River Bottom, Flood Plain |
| 301 | Water |
| 3252 | Dam |

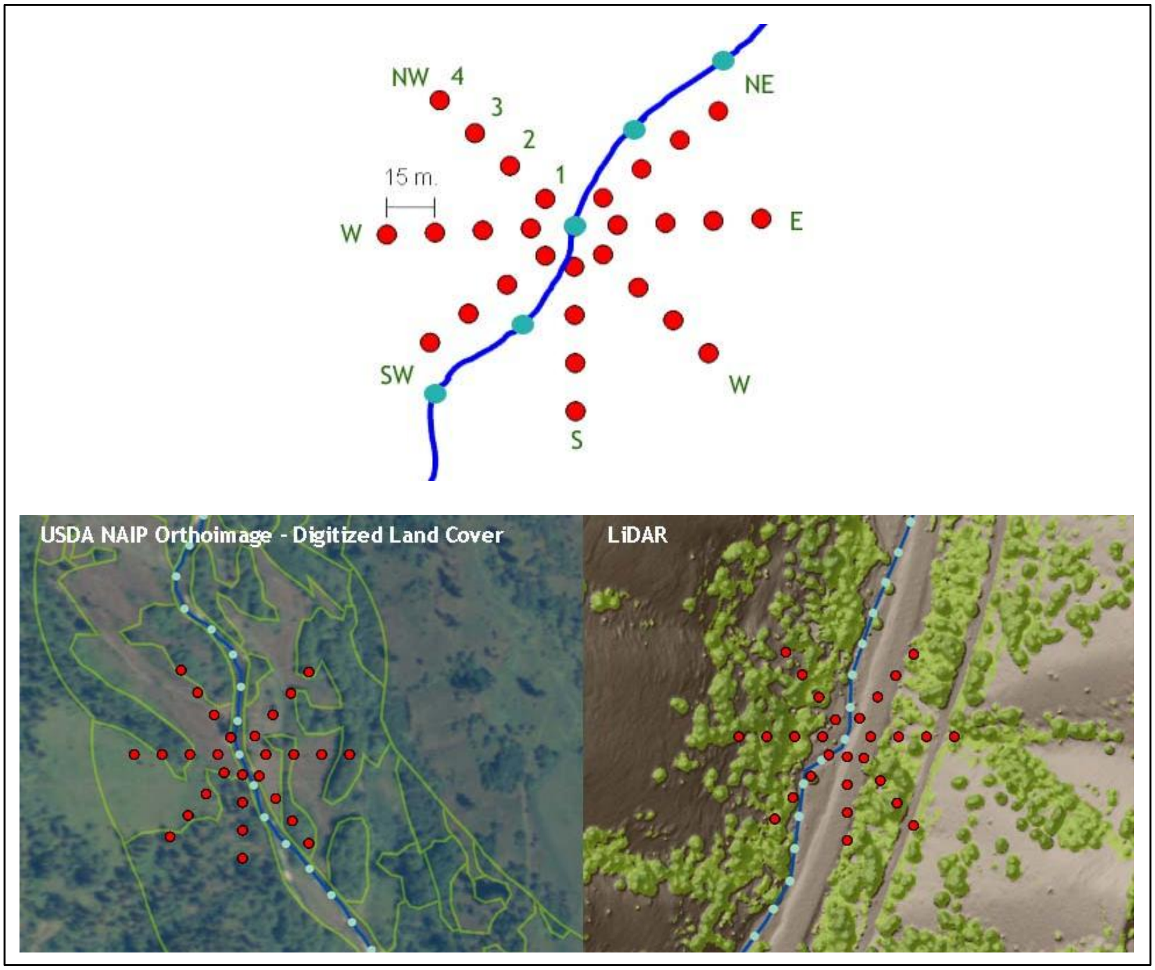
Figure 74 is an example of the orthorectified TIR imagery (8-inch pixels) overlaid on a standard NAIP orthophoto (1-meter pixels). The red lines are the digitized polygons and the light blue line is the digitized stream. In this example, the stream was too small to accurately digitize the right and left banks. The TIR imagery is higher resolution than the NAIP orthophoto and reveals more detailed vegetation. During the digitization process, the NAIP orthophoto was kept visible beneath the TIR imagery because there were many areas along the edges where TIR imagery did not fully extend.

Figure 74 – Example of digitized near stream land cover (upper Ochoco Creek).



Sampling land cover heights from the LiDAR data is an iterative process that requires unique TTools settings depending upon the stream size, terrain, and riparian composition. TTools samples the near stream land cover in a radial pattern at each of the 50-meter nodes (Figure 75).

Figure 75 – Radial sampling pattern used by TTools for near stream land cover at each 50-meter stream segment.

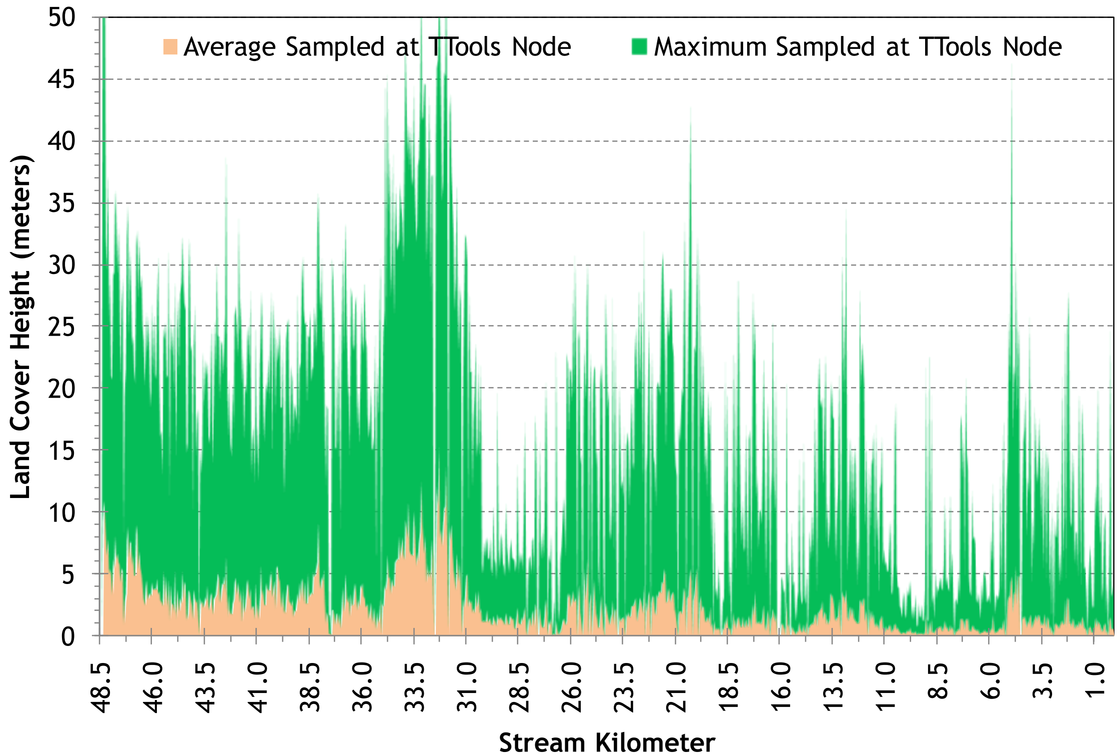



Wide streams may require a larger distance between sampling points in order to reach far enough to assess the riparian area. Some landscapes have sparse vegetation patterns (e.g., individual junipers grow far apart from one another) and may require the stream to be segmented at a step less than the traditional 50 meters so that the radial sampling patterns have more overlap. Then statistics have to be run on that data to translate it back to the 50-meter input step required by Heat Source. Sampling rates may have to be changed multiple times along the course of a single stream, resulting in a mixed sampling density that best classifies the existing vegetation.

LiDAR-based near stream land cover sampling will be performed during the model set up process and manually cross-checked with the LiDAR rasters at various locations until an optimal sampling routine is achieved. This also involves running the Heat Source model in order to assess the resultant effective shade calculations. LiDAR-based near stream land cover sampling methods and results will be presented within the documentation for Task 3 of this project.

Figure **76** is an example of preliminary land cover height sampling along Crescent Creek, using 50-meter TTools nodes and a 15-meter radial sampling pattern. Note that this data may be refined during the model set up process. The key point is that LiDAR data facilitates accurate land cover height assessment at a very high resolution, making stream temperature simulations more robust.

Figure 76 – Example of preliminary land cover height sampling from Crescent Creek LiDAR.




**Next Steps**

Task 3 of the Deschutes basin TMDL modeling contract is to set up and calibrate the Heat Source temperature models for each stream. During this process, vegetation heights will be sampled from the LiDAR and used as model input. Field data will be used to assign heights to the digitized near stream land cover polygon codes on a stream by stream basis.

During the model set up process, the TIR and true color imagery will be re-examined as diversion canals, springs, and tributaries are verified and assigned as model inputs. It is common for the digitized streams, banks, and near stream land cover to undergo edits or refinements during this stage of the project. Therefore, the deliverables for Task 3 will include a revised set of TTools shapefiles.

## References

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