Final

CITY OF BEND AMBIENT RIVER WATER QUALITY MONITORING: 2021-2023

Deschutes River and Tumalo Creek

Prepared for
City of Bend
Utility Department
62975 Boyd Acres Road
Bend, OR 97701

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Prepared by:
Environmental Science Associates | ESA
2863 NW Crossing Dr., Suite 200
Bend, OR 97701

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Abbreviations and Acronyms

7DADM	seven-day average maximum temperature
AU	assessment unit
AWQMS	Ambient Water Quality Monitoring System
BENO	Benham Falls
BOR	Bureau of Reclamation
City	the City of Bend
°C	degree Celsius
CFS	cubic feet per second
CM	criteria met
COID	Central Oregon Irrigation District
CWA	Clean Water Act
DBBC	Deschutes Basin Board of Control
DBHCP	Deschutes Basin Habitat Conservation Plan
DCMO	Deschutes County MID Canal
DEBO	Deschutes River Below Bend
DEQ	Department of Environmental Quality
DL	detection limit
DNA	deoxyribonucleic acid
DO	dissolved oxygen
DR	Deschutes River
EPA	Environmental Protection Agency
ESA	Environmental Science Associates
FY	fiscal year
IR	Integrated Report
ISWMP	Integrated Stormwater Management Plan
mg/L	milligrams per liter
µS/cm	microSiemens per centimeter
mL	milliliters
MOU	memorandum of understanding
MPN	most probable number
MS4	Municipal separate storm sewer system
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity units
OAR	Oregon Administrative Rule
OSP	Oregon spotted frog
OWRD	Oregon Water Resources Department
UDWC	Upper Deschutes Watershed Council
POR	period of record
PSU	Portland State University
QAPP	quality assurance project plan
QA/QC	quality assurance/quality control
RM	river mile
TC	Tumalo Creek
TID	Tumalo Irrigation District
TMDL	total maximum daily load
TP	total phosphorus
TSS	total suspended solids
TUMO	Tumalo Creek below Tumalo Feed Canal
UDWC	Upper Deschutes Watershed Council
UGB	urban growth boundary
USDA	United States Department of Agriculture
SM	Standard Methods

CITY OF BEND AMBIENT RIVER WATER QUALITY MONITORING: 2021-2023

Deschutes River and Tumalo Creek

Introduction

The City of Bend (the City) has been monitoring water quality from Tumalo Creek and from the Deschutes River as it enters the City near the southern urban growth boundary (UGB) to where it leaves near the northern UGB. This monitoring has occurred from 2004 through 2023, in accordance with a series of Water Quality Monitoring Plans approved by the City. These data improve understanding of changing conditions over time and data are provided to Oregon Department of Environmental Quality (DEQ). The City selected 12 sampling locations in the Deschutes River and one location along Tumalo Creek to provide a basis for understanding water quality in surface waters within the City, answer water quality questions, and inform ecological processes and protection policies regarding these waterbodies as they flow through the City. The specific objectives of this report that captures the results of the ambient monitoring program activities are to:

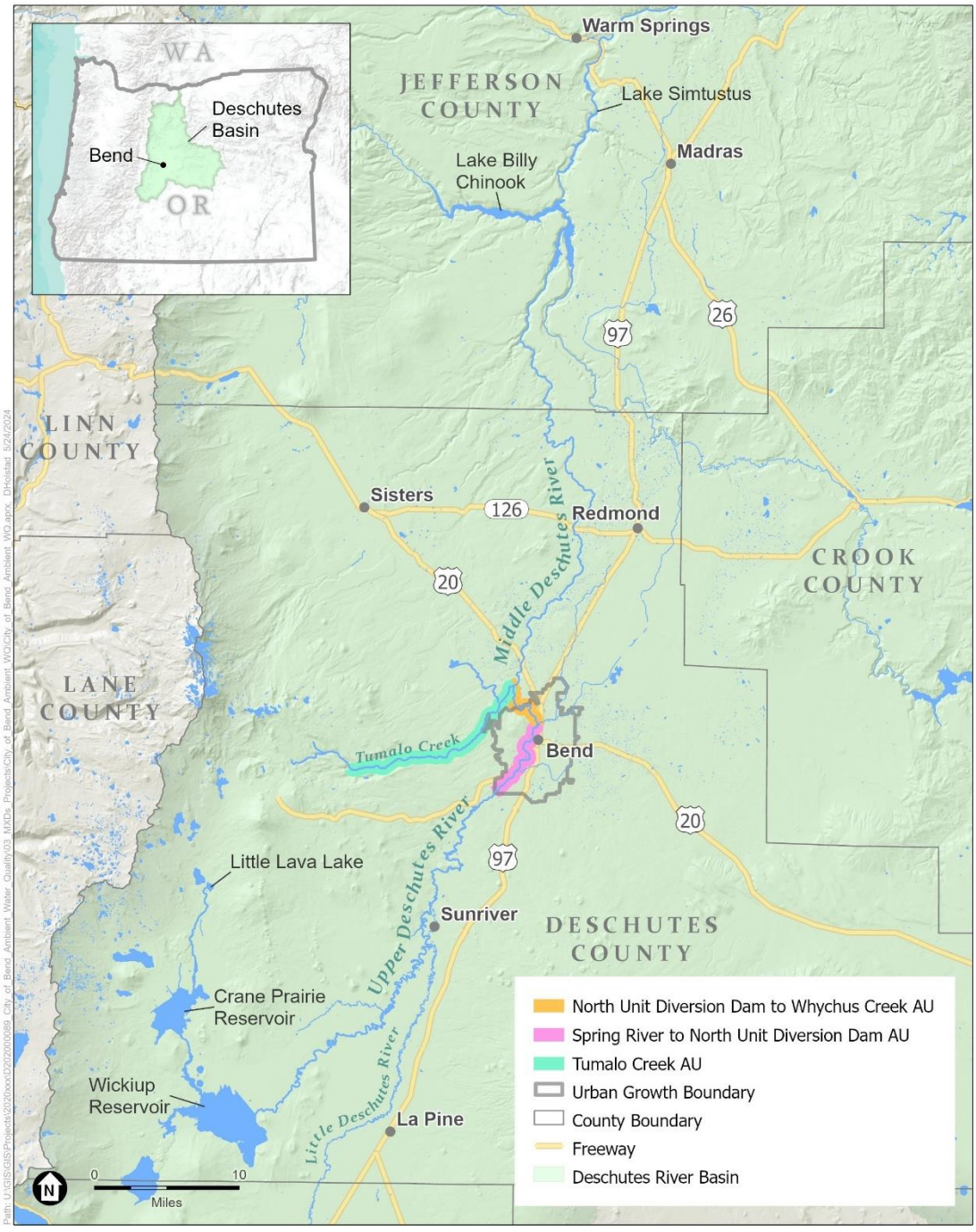
- Increase understanding of seasonal and annual variations for conventional water quality parameters in the Deschutes River,
- Satisfy element IX (Monitoring) of the City's *Integrated Stormwater Management Plan* (ISWMP) – a required component under the City's National Pollutant Discharge Elimination System (NPDES) permit number 102901,
- Gather legally defensible data leading to improved understanding and potentially to the listing or de-listing of local waterways under the Federal Clean Water Act Section 303(d) with the Oregon Department of Environmental Quality (DEQ) and the United States Environmental Protection Agency (USEPA),
- Gather legally defensible data to aid in establishment of DEQ's total daily maximum load (TMDL) values for the Deschutes River (and Tumalo Creek, limited data included in this study), and
- Inform staff and local authorities in addressing sediment issues in Mirror Pond on the Deschutes River.

From 2004 to 2009, water quality monitoring was performed under a memorandum of understanding (MOU) between the City and the Upper Deschutes Watershed Council (UDWC) and were summarized in *City of Bend Ambient Water Quality Monitoring: Deschutes River and Tumalo Creek 2005-2008 (Bend Oregon)* (UDWC 2010). In

subsequent years, water quality data collected within the Deschutes River through the City of Bend reach and portions of Tumalo Creek were collected by the City and summarized in *City of Bend Ambient River Water Quality Monitoring: Deschutes River 2008-2017* (Environmental Science Associates [ESA] and MaxDepth Aquatics (2019). The main objective was to assess the water quality of the Deschutes River coming into, within, and leaving the City, and to further compare those results to the prior UDWC (2010) report to analyze any changes. The water quality data collected also inform the upper tier of effectiveness evaluation and assist in understanding the health of the river over time. This report builds upon previously reported data with an emphasis on data collected between 2020 and 2022.

Study Area

Central Oregon is located within the counties of Deschutes, Jefferson, and Crook; flanked by the Cascade Mountain Range to the west and the Ochoco Mountains to the east (**Figure 1**). Unlike most communities on the west side of the Cascades, the region is characterized by dry and sunny summers with precipitation largely falling as snow during the winter months. Average annual precipitation for Bend is 13 inches (AgACIS for Deschutes County 2021). The City of Bend is in Deschutes County and is the largest city in Central Oregon. The population of Deschutes County was estimated at 212,141 in 2023, making it the 7th largest county in the state and the fastest growing at a 7% increase between April 2020 and July 2023 (PSU 2024). The population of the City of Bend was estimated at 106,275 in July 2023, or the 6th largest city in the state (PSU 2024). The City is projected to reach 109,389 in 2025 (City of Bend 2024). Located along the bank of the Deschutes River, it was originally settled as a logging town but is now considered a gateway community to numerous outdoor activities including skiing, biking, rafting, golf, camping, tubing, and fishing – many of which are enjoyed on the Deschutes River.



SOURCE: ODOT, 2015; BLM, 2015, USGS, 2020; ESRI, 2020

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Study Area
City of Bend Ambient River Water Quality Monitoring

Figure 1. Study area for the City of Bend Ambient River Water Quality Monitoring

The Deschutes River has its headwaters along the eastern flanks of the Cascade Mountains. Its headwaters are routinely attributed to Little Lava Lake; however, groundwater that flows through porous geologic formations throughout the upper Deschutes Basin are the primary drivers of its upper watershed hydrology (Lite and Gannett 2002).

From Little Lava Lake, the Deschutes River flows into Crane Prairie Reservoir, then Wickiup Reservoir (**Figure 1**). Wickiup Reservoir is a productive system that can support summer algae blooms, as well as elevated primary productivity. These conditions, when combined with dramatic changes in seasonal storage and discharge, can affect and influence downstream water quality conditions (e.g., turbidity, total suspended sediments, temperature, and dissolved oxygen). Below Wickiup, the Little Deschutes River (just south of the community of Sunriver) enters the Deschutes River. Water quality conditions along the Little Deschutes are known to generate exceedances for temperature (year-round) and dissolved oxygen (spawning and year-round) (DEQ 2022). Near the City's southern UGB, a diversion canal operated by the Central Oregon Irrigation District (COID) is located at river mile (RM) 170.75. Below the COID diversion, within the City, the river flows freely about three miles where it is flanked by the Deschutes River Trail and characterized by a series of waterfalls, riffles, and pools before Colorado Street (**Figure 2**).

Figure 2. Example of the Deschutes River as it enters the City of Bend

The Colorado Street Dam, once located at RM 167.55, was built in 1915 to serve as a mill pond for lumber mills. In 2014/2015, portions of the dam were removed and extensive improvements were made to allow for instream passage of boaters, and enhancements for fish and wildlife habitat. Downstream, the Pacific Power and Light Hydroelectric Dam forms Mirror Pond, an iconic feature of the City flanked by a number of city parks, private homes, and downtown businesses. Less than a half mile downstream is the Steidl and Tweet Dam operated by Tumalo Irrigation District (TID). Approximately three quarters of a mile downstream is the North Canal Dam, which diverts water for Swalley, North Unit and Central Oregon irrigation districts. Beginning in February 2016 and again in August 2017, sections of the Pilot Butte Canal were added to the National Register of Historic Places. Beyond the city limits, Tumalo Creek joins the Deschutes River from the southwest. Further downstream, the Deschutes River is once again impounded by the Pelton Round Butte Hydroelectric Complex, a series of three dams, which in order, create Lake Billy Chinook, Lake Simtustus, and an unnamed reregulation reservoir before continuing to its confluence with the Columbia River.

Tumalo Creek is a tributary to the Deschutes River with the confluence being located approximately 2.5 river miles downstream of the City of Bend's northern UGB (Figure 1). Tumalo Creek begins where the Middle Fork Tumalo Creek and North Fork Tumalo Creek meet in the eastern Cascade Range and travels past scenic waterfalls such as Tumalo Falls, located about 15 miles west of Bend, is a stunning 97-foot waterfall popular with tourists and photographers then skirting the westernmost boundary of the City limits as it travels through Shevlin Park (**Figure 3**) on its way to the confluence with the Deschutes River just upstream of Tumalo State Park. The Bridge Creek Fire in 1979 and subsequent salvage logging left three miles of Tumalo Creek without large woody debris for fish habitat and bank stabilization. Between 2003 and 2008, a number of partners, including the Upper Deschutes Watershed Council, the Deschutes National Forest, Oregon Watershed Enhancement Board, National Forest Foundation, City of Bend, the Deschutes River Conservancy, and the Oregon Department of Fish and Wildlife, implemented major restoration efforts to areas most affected by the fire.

Figure 3. Tumalo Creek as it runs through Shevlin Park

Historically, spring-fed inputs to the Deschutes River resulted in very stable hydrologic regimes on daily, monthly, and even annual timescales (USDA 1996). However, impoundments and diversions along the length of the river have dramatically altered these natural flow regimes. In the Deschutes Basin, water is legally diverted from the river to meet various water rights from early to mid-April through mid- to late October to provide for mostly agriculture demands in Central Oregon. Due to the topography of the surrounding lands, irrigation districts and related diversion points both above and within Bend, divert a substantial portion of the Deschutes River's streamflow to meet the water rights of the various districts and their patrons. Several of the Districts all have supplemental water rights that allow for seasonal storage in Wickiup, Crane Prairie and Crescent lakes. These combined operations result in low flows in winter months while filling reservoirs, and in summer months, release of the storage rights, create higher than historic flows upstream of Bend. The combined district diversions result in low flows downstream of Bend, most noticeably below the North Canal Dam. These large discharge swings and reductions in streamflow have contributed to degradation in streambank and fish habitat, fish passage and water quality. Within the Middle Deschutes River (between the City of Bend and Lake Billy Chinook), modern day flows are significantly lower during the summer irrigation season though recent strides have been made by numerous stakeholders in the Deschutes Basin to increase instream flow and decrease overall fluctuations. Significant drivers of flow improvements are related to

the relicensing of the Pelton project, which reintroduced listed Steelhead in 2007, and led to the start of the Habitat Conservation Plan (HCP). Steelhead were included as an experimental population which delayed the need for an incidental take permit. Later, while the HCP study was already underway, in August 2017 U.S. Fish and Wildlife Service listed the Oregon spotted frog (OSP) (*Rana pretiosa*) as threatened, and that species was added to the HCP planning.

The Deschutes Basin HCP (DBHCP) was finalized and approved by the U.S. Fish and Wildlife Service December 31, 2020. The HCP is a large-scale planning effort intended to help the City of Prineville and the eight irrigation district members of the Deschutes Basin Board of Control (DBBC) meet their current and future water needs while enhancing fish and wildlife habitat (USFWS 2020). Conservation measures in the DBHCP are intended to minimize and mitigate impacts caused by the “take” of covered listed species (OSP, bull trout, spring Chinook salmon, sockeye salmon and steelhead) that may result from the storage, release, diversion and return of irrigation water by the member irrigation districts and the City of Prineville. Under the Proposed Action, minimum fall/winter flows in the Deschutes River below Wickiup Dam would be increased incrementally to 400 cubic feet per second (cfs) within the next 30 years.

Methods

Since 2008, the City has monitored a number of sites along the Deschutes River (DR) and Tumalo Creek (TC) both within and outside the city limits and sites have shifted somewhat over time (**Figure 4 and Figure 5; Table 1**). The monitoring sites are grouped by Assessment Unit (AU) per the Oregon Department of Environmental Quality (DEQ) 2022a Integrated Report (see Regulatory Framework section below). Monitoring parameters included: (1) grab samples for laboratory analysis of total coliform, *E. coli*, chloride, fluoride, sulfate, orthophosphate, total phosphate, nitrate, nitrite, and total suspended solids from all sites (2) continuous (e.g., 30-minute interval) temperature monitoring using temperature-specific loggers at all sites, and (3) continuous (e.g., 15-minute interval) monitoring with a multi-parameter sonde for temperature, dissolved oxygen (DO), specific conductance, and pH at a limited number of sites. The frequency and types of parameters measured varied slightly by site and between years but have been more consistent in recent years (**Table 2**). Specific information on analytical methods is provided in **Table 2**.

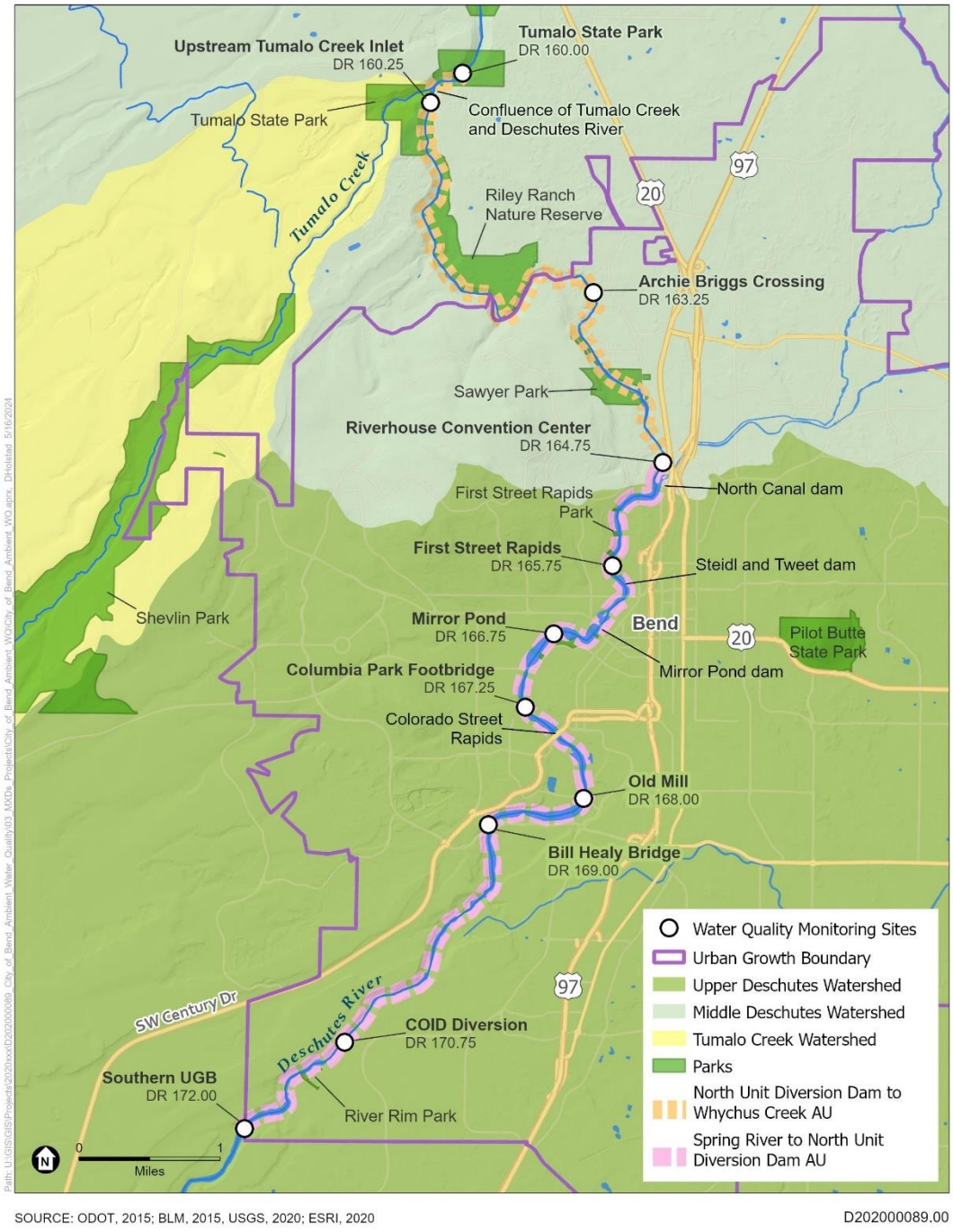


Figure 4. Water quality monitoring sample sites, parks, and assessment units along the Deschutes River

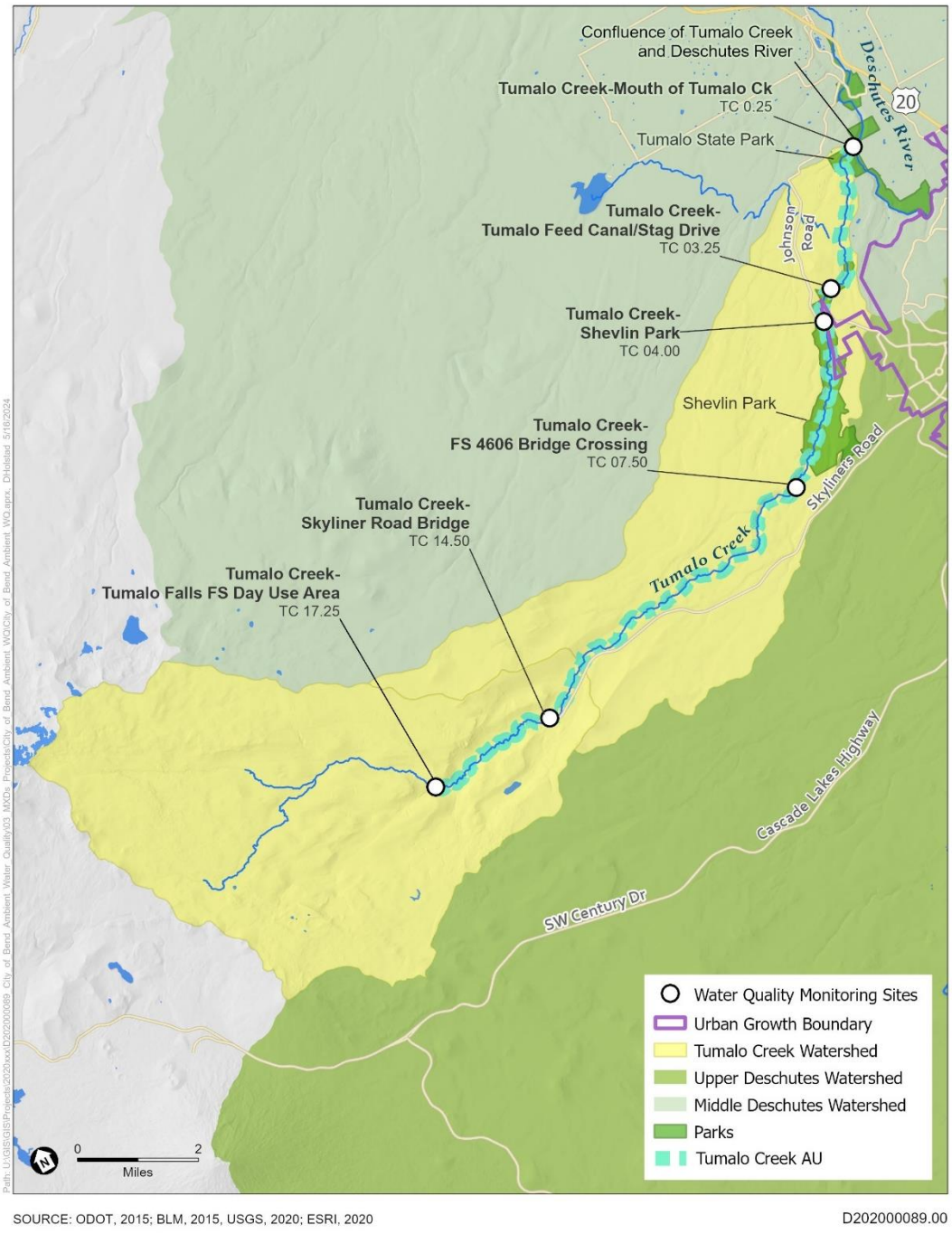


Figure 5. Water quality monitoring sample sites, parks, and assessment unit on Tumalo Creek

TABLE 1. ASSESSMENT UNITS AND SAMPLE SITE NAMES AND LOCATIONS

Assessment Unit	Site No.	Site Name	Latitude	Longitude	2021	2022	2023
Tumalo Creek	TC 0.25	Mouth of Tumalo Ck	44.115950	-121.339290	■ ▲	■ ▲	■ ▲
	TC 3.25	Tumalo Feed Canal/Stag Drive	44.040564	-121.330014	■ ▲	■ ▲	■ ▲
	TC 4.00	Shevlin Park	44.082873	-121.376368	■ ▲	■ ▲	■ ▲
	TC 7.50	FS 4606 Bridge Crossing	44.051480	-121.411349	■ ▲	■ ▲	■ ▲
	TC 14.50	Skyliner Road Bridge	44.032310	-121.520430	■ ▲	■ ▲	■ ▲
	TC 17.25	Tumalo Falls FS Day Use Area	44.031218	-121.564654	■ ▲	■ ▲	■ ▲
North Unit Diversion Dam to Whychus Creek	DR 160.00	Tumalo State Park	44.117746	-121.334802	■ ▲ ◊	■ ▲ ◊	■ ▲ ◊
	DR 160.25	Upstream Tumalo Creek Inlet (note 1)	44.114726	-121.339286	■ ▲	■ ▲	■ ▲
	DR 163.25	Archie Briggs Crossing	44.095352	-121.315838	■ ▲ ◊	■ ▲ ◊	■ ▲ ◊
	DR 164.75	Riverhouse Convention Center	44.077958	-121.305693	■ ▲	■ ▲	■ ▲
Spring River to North Unit Diversion Dam	DR 165.75	First Street Rapids	44.067314	-121.313013	■ ▲	■ ▲	■ ▲
	DR 166.75	Mirror Pond (note 2)	44.060242	-121.320994	■ ▲ ◊	■ ▲ ◊	■ ▲ ◊
	DR 167.25	Columbia Park Footbridge	44.05269	-121.324939	■	■	■
	DR 168.00	Old Mill	44.043359	-121.316476	■ ▲	■ ▲	■ ▲
	DR 169.00	Bill Healy Bridge	44.040564	-121.330014	■ ▲	■ ▲	■ ▲
	DR 170.75	COID Diversion (note 3)	44.01808	-121.350176	■ ▲ ◊	■ ▲ ◊	■ ▲ ◊

NOTES:

1. Site is located on the Deschutes River, above the confluence with Tumalo Creek
2. Located within the central portion of Mirror Pond
3. Located at the diversion structure

■ Grab samples
▲ Continuous temperature loggers
◊ Continuous multi-parameter sonde measurements

TABLE 2. CONTINUOUS AND GRAB SAMPLE PARAMETERS AND METHODS

Parameters	Analysis Technique/Equipment[a]
Grab Sample Monitoring (Quarterly)	
Coliform, Total (MPN/100 ml)	SM 9223 B
Coliform, E. coli (MPN/100 ml)	SM 9223 B
Chloride (Cl) (mg/L)	SM 4110 B
Dissolved Oxygen (mg/L)	Multiparameter sonde (YSI Pro DSS)
Fluoride (F) (mg/L)	SM 4110 B
Orthophosphate (PO4) (mg/L)	SM 4110 B 0
Nitrate (NO3) (mg/L)	SM 4110 B
Nitrite (NO2) (mg/L)	SM 4110 B
pH	Multiparameter sonde (YSI Pro DSS)
Phosphate, Total (PO4) (mg/L)	SM 4500-PE
Specific Conductance (µS/cm)	Multiparameter sonde (YSI Pro DSS)
Sulfate (SO4) (mg/L)	SM 4110 B
Temperature (°C)	Multiparameter sonde (YSI Pro DSS)
Total Suspended Solids (TSS) (mg/L)	SM 2540D
Turbidity (FNU)	Field probe HACH 2100P
Ambient and Continuous Monitoring	
Temperature (°C)	Multiparameter sonde (YSI EX02); continuous data logger (Vemco)
Dissolved Oxygen (mg/L)	Multiparameter sonde (YSI EX02)
Specific Conductance (µS/cm)	Multiparameter sonde (YSI EX02)
pH	Multiparameter sonde (YSI EX02)

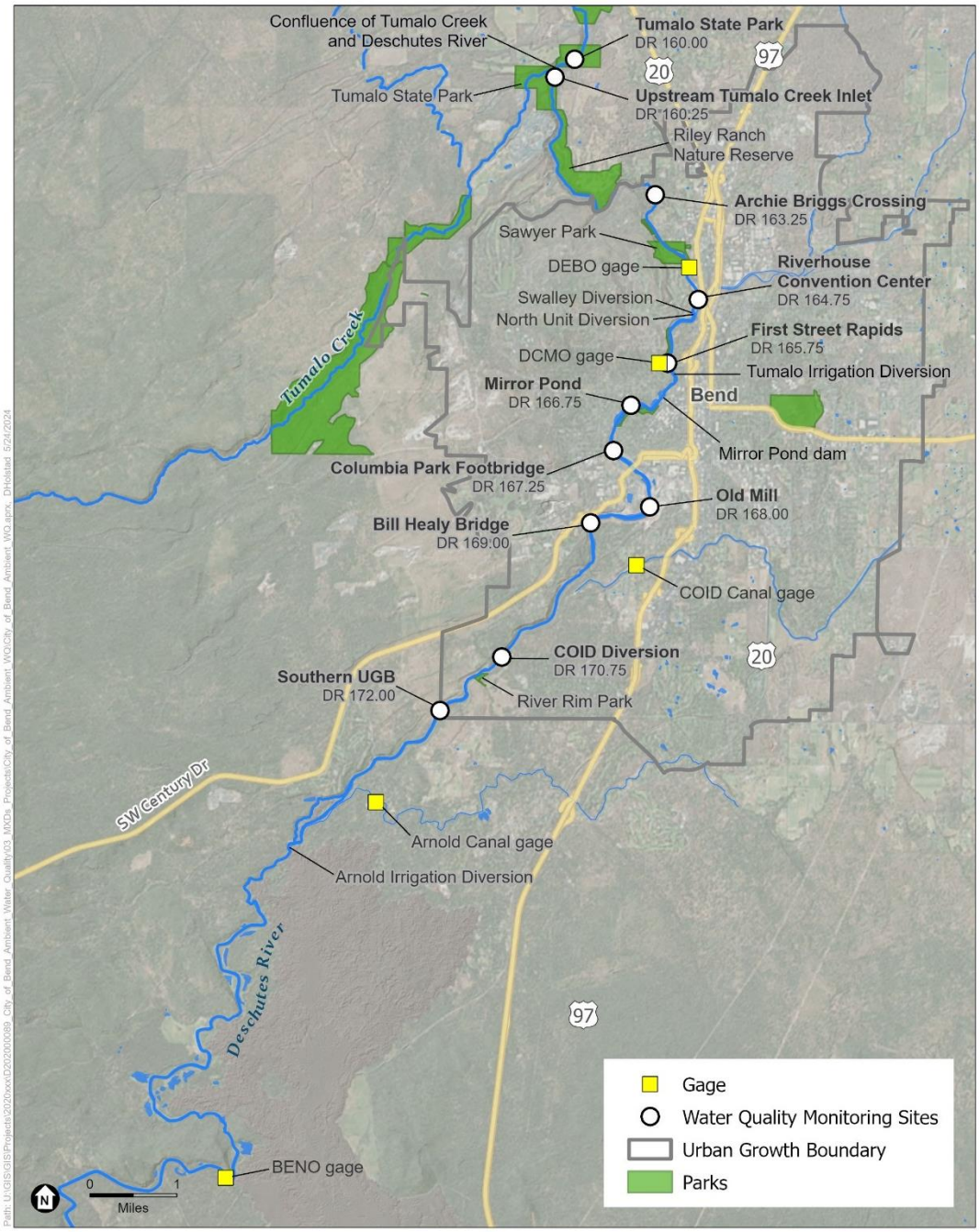
NOTES:

[a] Equipment listed are current and do not reflect improvements made over time.

Daily mean water flow data from 2021 to 2023 for the Deschutes River, Tumalo Creek, and applicable irrigation canals were taken from Bureau of Reclamation (BOR) and Oregon Water Resources Department (OWRD 2024) gaging stations.

Figure 6 illustrates the location of gages in relation to monitoring sites and other landmarks along the Deschutes River. **Figure 7** illustrates the location of gages in relation to monitoring sites and other landmarks along Tumalo Creek. **Figure 8** illustrates the river reaches between gaging stations. The Benham Falls (BENO) gage is located upstream of the COID and Arnold Irrigation District diversions. Information from this gage, combined with the Arnold diversion at Lava Falls, provides an estimate of flow at the upstream UGB and is used to describe flow rates at the Southern UGB site[1] (DR 172.00) to the COID Diversion site (DR 170.75). Flows from the COID diversion were further subtracted to provide estimated rates for sites from the Bill Healy Bridge (DR 169.00) to Mirror Pond (DR 166.75). Flows from the Deschutes County Mid Canal (DCMO) gage were further subtracted to provide estimated rates for the First Street Rapids site (DR 165.75). The Deschutes River Below Bend (DEBO) gage is downstream of the major diversions within the city. The DEBO gage was used to estimate flows below the North Unit and Swalley Irrigation District diversions but prior to the confluence with Tumalo Creek. This stretch encompasses the Riverhouse Convention Center site (DR 164.75) to the Upstream Tumalo Creek Inlet site (DR 160.25). Lastly, flows from the Tumalo Creek below Tumalo Feed Canal (TUMO) gage was added to the DEBO gage to estimate flows below the confluence of the Deschutes River and Tumalo Creek at the Tumalo State Park site (DR 160.00). Flows for the Tumalo Creek – Shevlin Park site (TC 4.00) were taken from the OWRD gage located at Skyliners Road (downstream of TC 14.50). A second Tumalo Creek gage located downstream of TC 4.00 and the Tumalo Feed Canal represents conditions at the mouth of Tumalo Creek site (TC 0.25). The dataset for this gage, however, was more limited compared to the gage at Skyliners Road. It should be noted that the flow rates are based solely on previously described gage information and do not account for gains and losses from groundwater recharge, canal leakage, or evaporation as detailed in Gannett et al. (2017).

[1] Monitoring at the Southern UGB site (DR 172.00) was moved farther downstream in 2015 to the COID Diversion site (DR 170.25).



SOURCE: ODOT, 2015; BLM, 2015, USGS, 2020; ESRI, 2020

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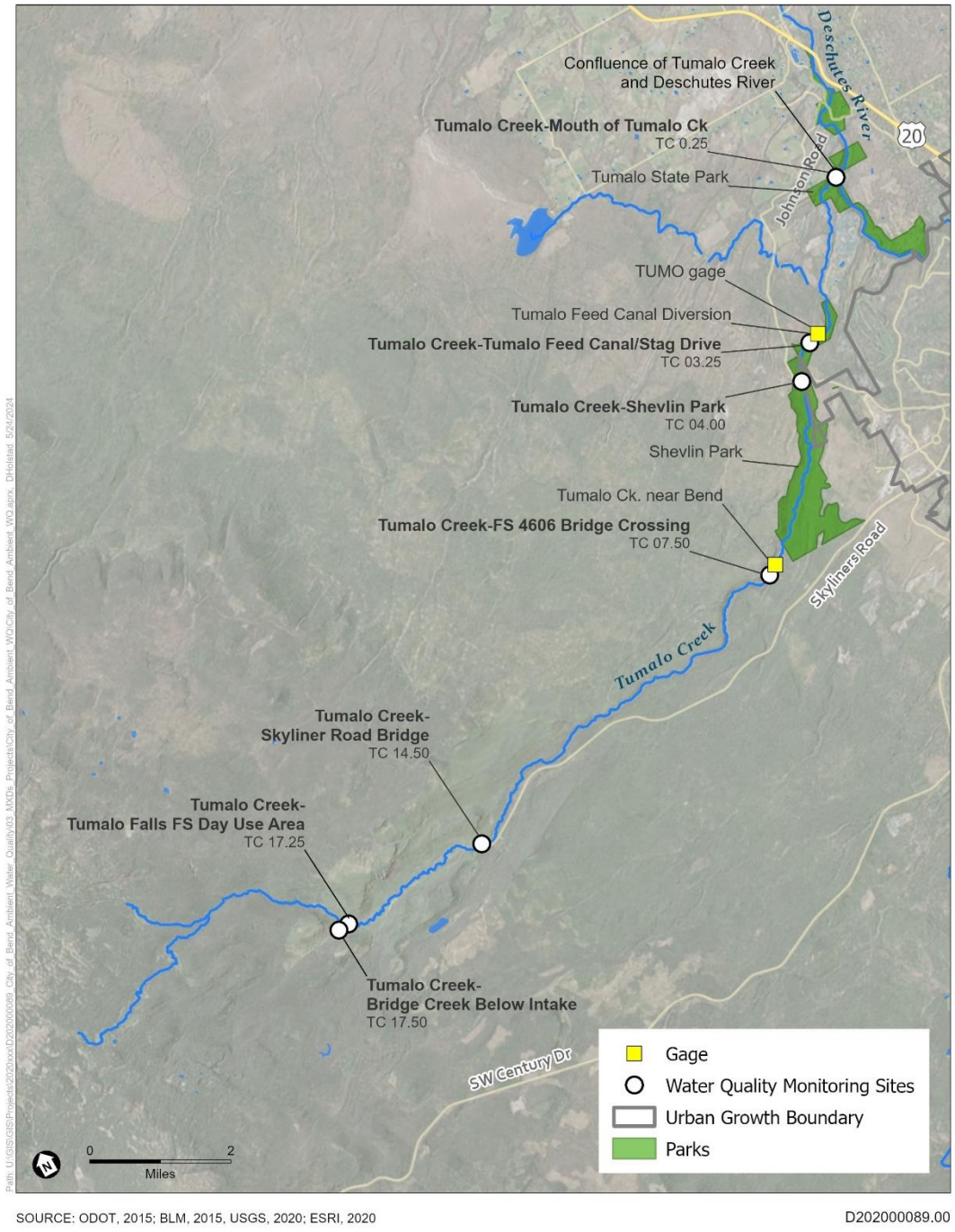
River Streamflow Gauge Stations
City of Bend Ambient River Water Quality Monitoring

Figure 2. Location of river flow gages in relation to sample sites along the Deschutes River (see text for full gage names)



SOURCE: ODOT, 2015; BLM, 2015, USGS, 2020; ESRI, 2020

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River Streamflow Gauge Stations
City of Bend Ambient River Water Quality Monitoring

Figure 7. Location of river flow gages in relation to sample sites along Tumalo Creek (see text for full gage names)

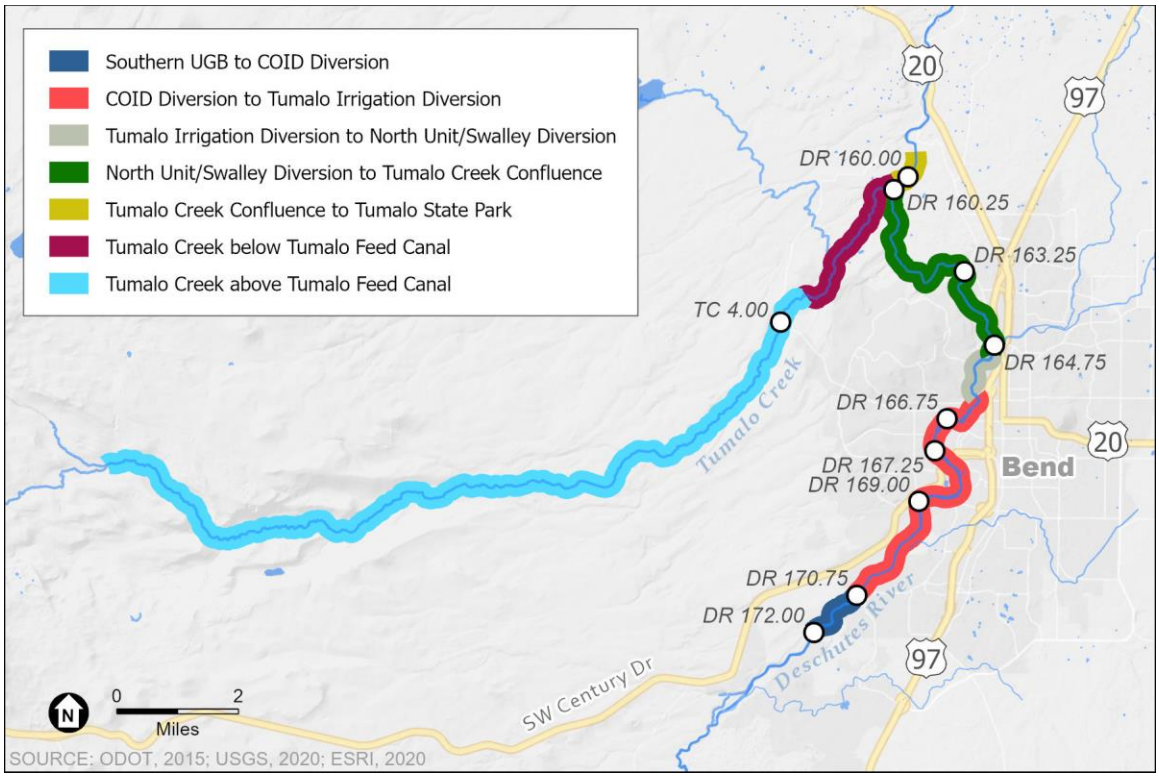

Figure 8. Location of river reaches between gaging stations and water quality monitoring sites.

As previously mentioned, irrigation canals divert a substantial portion of the Deschutes River's streamflow, resulting in low flows in winter months, and in summer months high flows upstream of Bend and low flows downstream of Bend. **Figure 9** illustrates these seasonal changes in flow between sites for the period of 2021 to 2023. The "ramp up" process for irrigation releases is set by the OWRD and begins in April of each year with complete releases not reached until mid-May. Seasonal changes in flow rates in Tumalo Creek are less dramatic but still higher above the irrigation diversion at the Tumalo Feed Canal (Figure 9).

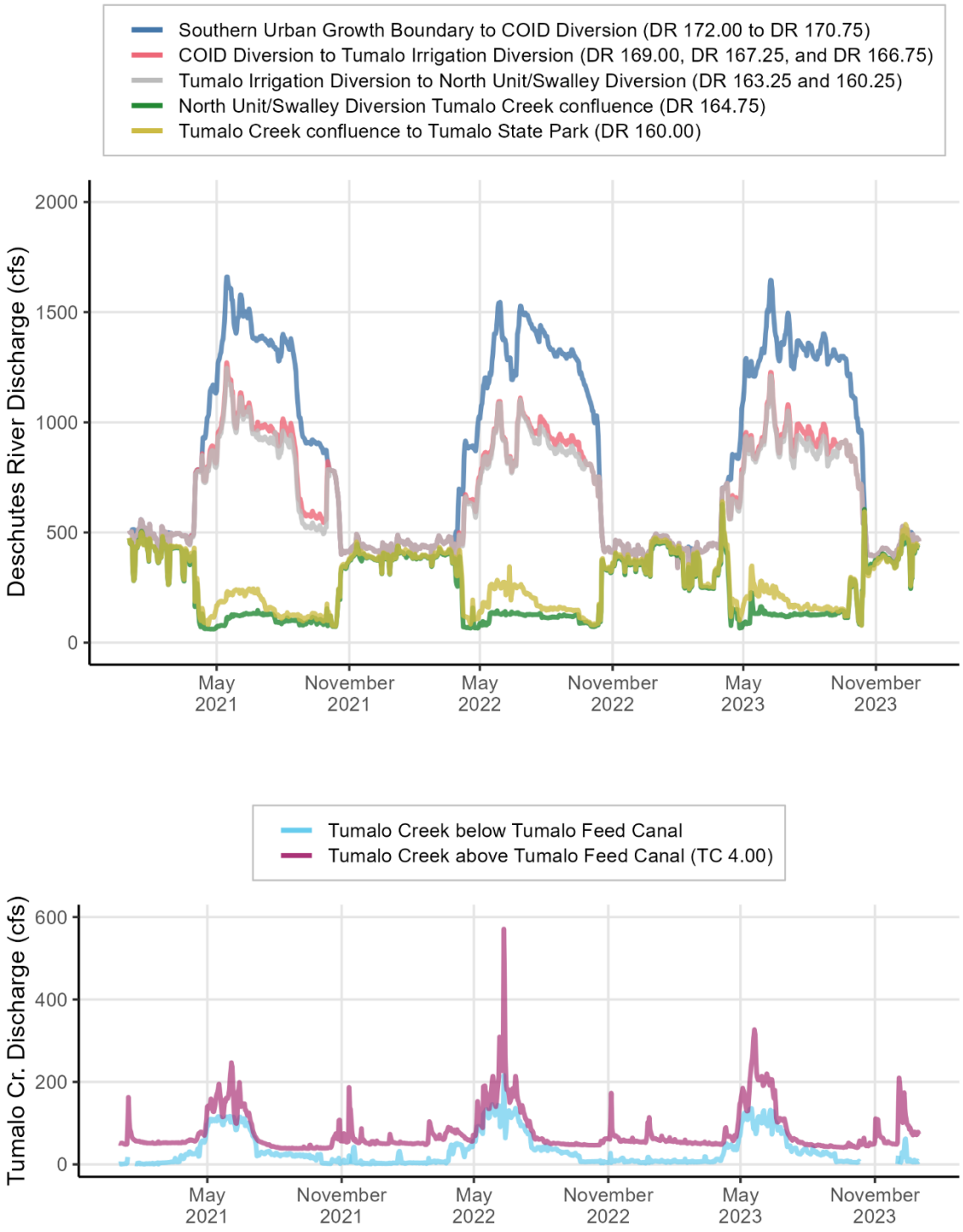

Figure 9. Mean daily discharge (cubic feet per second, cfs) in Deschutes River reaches from the southern urban growth boundary (UGB) to below the northern UGB and the confluence with Tumalo Creek (top panel); and in Tumalo Creek above and below the Tumalo Feed Canal (bottom panel). Water quality monitoring sites within each reach are listed in parentheses - City of Bend 2021-2023

Quality Assurance/Quality Control

Data for this effort were collected by City staff following a *City of Bend Water Quality Monitoring Plan* (Monitoring Plan) (**Appendix A**). The continuous data were taken from (1) multi-parameter data sondes and (2) temperature-specific loggers. Continuous data were first culled for accurate deployment dates and times then carefully reviewed in order to identify anomalous data that were collected likely due to equipment error or field conditions. Data Validation Criteria for Water Quality Parameters Measured in the Field was developed by DEQ (2013) and adopted by the City and is included in the Monitoring Plan.

During certain low flow periods, decreased water levels results in probes exposed to air causing erroneous data. During these periods, data sondes continued to log temperature data (i.e., air temperature), but not other parameters. Instances where air temperature was recorded is generally identified by a sharp change, usually occurring over a 15- to 30-minute period. These data were removed from further analysis, as were data for other parameters collected during these time periods. Limited periods were also identified when data were skewed by equipment malfunction. These time periods were typically identified by unrealistically high or low outliers observed over a period of time. These anomalies could be further confirmed by comparing output from the continuous multi-parameter sondes with one time *in situ* multi-parameter data sonde measurements collected at the same day and site when grab samples were collected and loggers were often redeployed. Where errant, these data were flagged and excluded from further consideration. Multi-parameter data sondes were calibrated according to manufacturer's specifications. Only data that passed the quality assurance/quality control (QA/QC) process are included in this report. Continuous and grab data included here have been properly graded against the Oregon Water Quality Data Matrix (DEQ 2013).

Regulatory Framework

The Federal Clean Water Act (CWA) requires Oregon to report on the quality of its surface waters every two years. Oregon surface waters are assessed to determine if they contain pollutants at levels that exceed protective water quality standards. The result of these analyses and conclusions is called the "Integrated Report" because it combines the requirements of Clean Water Act section 305(b) to develop a status report and the section 303(d) requirement to develop a list of impaired waters.

The Integrated Report assigns a Category to all assessed waterbody segments. DEQ uses data to evaluate the most common beneficial uses, such as aquatic life, drinking water or recreation. If waterbodies exceed protective water quality standards, they are placed on the 303(d) list of impaired waters. Placing a waterbody on the 303(d) list initiates the prioritization and development of a Total Maximum Daily Load (TMDL). The 303(d) list portion of the Integrated Report is submitted to the U.S. EPA for final approval.

DEQ submitted the complete 2012 Integrated Report to EPA in 2014. That portion of the Deschutes River between RM 116 to 222.2 (which includes that portion in the City of Bend) was placed on the 303(d) list of impaired waters for DO. Specifically, the January 1 – May 15 criteria for resident trout spawning where DO should not be less than 11.0 mg/L or 95% of saturation. Between RM 168.2 and 189.4, the Deschutes River was listed for Chlorophyll *a* due to exceedances above 0.0015 mg/L during the summer months. Lastly, RM 126.4 to 162.6 was listed for pH exceedances (below 6.5/above 8.5) during all seasons.

The 2022 Integrated Report (IR) introduced the use of Assessment Units (AUs) to group stretches of river miles where impaired listings are identified. Three AUs apply to the study area: Spring River to North Unit Diversion Dam (DR 170.75 to 165.75), North Unit Diversion Dam to Whychus Creek (DR 164.75 to 160.00), and Tumalo Creek (**Figure 10**). The 2022 IR was approved by EPA September 1, 2022. **Figure 10** and **Table 4** summarize the applicable 303(d) listed impaired AUs in the study area. Notable changes on the Deschutes River between the 2018/2020 and 2022 IRs include listing pH for the Spring River to North Unit Diversion Dam AU and delisting pH for the North Unit Diversion Dam to Whychus Creek AU. DEQ released the draft 2024 IR on Surface Water Quality and 303(d) List of Impaired Waters April 2024 and accepted comments through July 1, 2024. DEQ released a Draft 2024 IR Supplemental using previously unsubmitted data from the U.S. Geological Survey. The supplemental data do not include the Deschutes River or Tumalo Creek. Listings in this report are based on the final 2022 IR; however, there are no proposed listings or delistings on the Deschutes River or Tumalo Creek within the study area. According to DEQ, waterbodies are delisted for a variety of reasons, including:

1. current data indicate that water quality standards are attained, and the waterbody is no longer impaired,
2. there is an error in the original Category 5 determination,
3. water quality standards, such as through updated science or improved measuring processes, have changed or no longer apply to a waterbody,
4. the expression of water quality standard pollutant has changed (e.g., now being measured as the dissolved fraction, when previously had been measured as the total amount of the pollutant),
5. a TMDL or other pollution control plan is in place, or
6. the impairment is caused by pollution rather than a known pollutant (i.e., flow or habitat modification) (DEQ 2022).

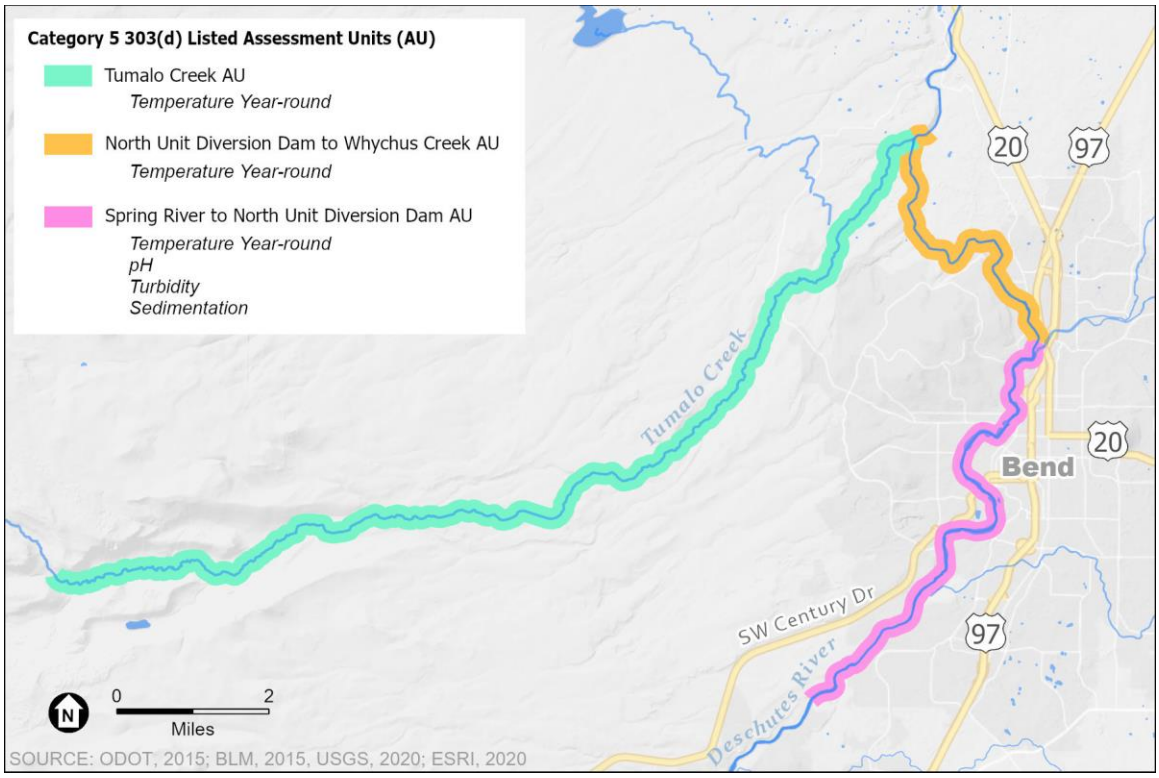

Figure 10. DEQ 2022 Category 5 303(d) Listed Assessment Units (AU) for the Tumalo Creek Watershed AU, North Unit Diversion Dam to Whychus Creek AU, and the Spring River to North Unit Diversion Dam AU

TABLE 3. APPLICABLE CATEGORY 5 303(D) LISTED ASSESSMENT UNITS WITHIN THE STUDY AREA

Parameter	Season	Criteria	Spring River to North Unit Diversion Dam (DR 170.75 to 165.75)	North Unit Diversion Dam to Whychus Creek (DR 164.75 to 160.00)	Lower Tumalo Creek (TC 00.25 to TC 07.50)	Upper Tumalo Creek (TC 14.50 to TC 17.25)
Flow Modification			303(d)	303(d)	303(d)	NA
Habitat Modification			303(d)	NA	NA	NA
Sedimentation	Undefined	Note 1	303(d)	NA	NA	NA
Temperature	Year Round (non-spawning)	< 18°C; 7DADM Note 2, Note 3	303(d)	303(d)	303(d)	303(d)
Turbidity	Spring/ Summer	10% NTU increase Note 4	303(d)	NA	NA	NA
pH	Year Round	6.5-8.5	303(d)	CM	CM	IN

CM = Criteria Met; 303(d) = AU is listed on the 2022 DEQ Integrated Report - State Final as being Category 5 303(d) listed - Impaired a TMDL is needed, IN = Insufficient data for assessment, NA =not assessed.

NOTES:

1. The formation of appreciable bottom or sludge deposits or the formation of any organic or inorganic deposits deleterious to fish or other aquatic life or injurious to public health, recreation, or industry may not be allowed. Data to support evaluation of this standard was not directly evaluated under this study.
2. "Seven-Day Average Daily Maximum Temperature (7DADM)" means a calculation of the average of the daily maximum temperatures from seven consecutive days made on a rolling basis (OAR 340-041-0002(56)).
3. The Upper Tumalo Creek AU Year-Round criterion is 12°C.
4. Turbidity should not increase by more than 10% during the early spring when irrigation water is released, according to the state standard. Historically, turbidity increased substantially when irrigation water is released in the spring.

The ambient water quality data collected by the City of Bend is provided to DEQ when requests for data are made by the agency every two years. The City is not required to collect stormwater monitoring data for the NPDES municipal separate storm sewer system (MS4) Phase II permit; however, per the permit, any data that is collected is submitted to DEQ. DEQ last issued a call for data between February 6, 2023, through April 7, 2023. The next call for data is expected in 2025.

Results

The City has analyzed ambient river water conditions since 2004 when grab sampling began. Over time, the program has added analytical parameters, shifted sites, and improved in situ measurement approaches and laboratory practices. The sections below summarize results of water samples collected between 2021 and 2023 to illustrate within-year variations during the most recent sampling compared to trends from previous years in narrative DEQ has an established Ambient Water Quality Monitoring System (AWQMS) sample site co-located with DR 166.75 (Mirror Pond). When possible, City staff monitor this site at the same time as DEQ.

First presented are results of parameters included in the EPA approved 2022 Integrated Report, followed by parameters no longer on the 303(d) list, nutrients, and other

parameters. Applicable numeric criteria are included on figures for temperature, pH, and dissolved oxygen.

Temperature

Temperature is a critical determinant of most biological and physiochemical processes in water, for example, chemical equilibria, water density, photosynthesis, and respiration (Wetzel 2001). By extension, water temperature determines the preferred habitat and life history of aquatic species. Excessive water temperature causes fish stress and increases vulnerability to parasites and reduced dissolved oxygen (Raleigh et al. 1984, Dorson and Touchy 1981). In Oregon, specific temperature standards have been established for waterbodies, including the Deschutes River within the City. The applicable standard within the Deschutes River reaches examined here include a year-round seven-day average of the daily maximum (7DADM) water temperature below 18°C for the protection of salmon and bull trout rearing and migration.

The same criterion applies to Tumalo Creek from the mouth of Tumalo Creek monitoring site (TC 0.25) upstream to the Forest Service Road 4606 Bridge (TC 7.00) site. Further upstream, a 12°C criterion to protect bull trout spawning and juvenile rearing applies to the Skyliner Road Bridge (TC 14.50) and Tumalo Falls Forest Service Day Use Area (TC 17.25) sites.

Presented are results from continuous temperature monitoring between 2021 and 2023 from 10 sites in the Deschutes River and six sites in Tumalo Creek using temperature-specific loggers (**Table 1**). When data from temperature specific loggers were unavailable at a site due to logger malfunction or deployment problems, data gaps were filled with multiparameter sonde temperature data when available. Specific start and end times varied by site and between years; however, more recently, the continuous temperature loggers were set to a 30-minute interval and multiparameter sondes were set to a 15-minute interval. Temperature data are presented as the 7DADM and plotted by monitoring site and grouped by AU[2] (**Figures 11 and 12**).

Seasonally, water temperatures at the Deschutes River sites ranged from at or near freezing in winter months to approximately 20°C in the summer, with the highest 7DADM temperatures occurring in mid to late July (**Figure 11**). Temperatures generally increased moving downstream in the Spring River to North Unit Diversion Dam and the North Unit Diversion Dam to Whychus Creek reaches (**Figures 11, Table 4**). During 2023 the warmest 7DADM of any of the Deschutes River sites was 20.8°C at Archie Briggs Crossing (DR 163.25) which was 1.4°C cooler than in 2022 and 2.1°C cooler than in 2021 at the same site. The lowest maximum 7DADM temperature during 2023 was 18.9°C at the upstream most site, the COID Diversion site (DR 170.75). The maximum

[2] Seven-Day Average Maximum Temperature" means a calculation of the average of the daily maximum temperatures from seven consecutive days made on a rolling basis. (OAR 340-041-0002)

annual 7DADM at the COID Diversion site during 2023 was 1°C cooler than in 2022 and 1.7°C cooler than in 2021.

Taken together, temperature monitoring data from the Deschutes River between 2021 and 2023 do not meet the DEQ criteria for year-round (non-spawning) 7DADM temperature criteria of 18°C for a substantial period each summer. It is important to note that the Deschutes River at the COID Diversion (DR 170.75) site, which is located upstream of other irrigation diversions and urban impacts within the UGB, exceeds the 7DADM temperature criterion each summer. While the number of days exceeding the criteria could not be calculated at each site due to missing data at the start or end of the exceedance period, exceedance days during 2023 ranged from 85 days at DR 164.75 to 49 days at DR 170.75 (**Table 4**). Although maximum 7DADM temperatures were higher in 2021 and 2022 than 2023, the period of exceedance was not shorter during 2023 at all sites. At the COID Diversion site (DR 170.75) the number of days exceeding the temperature criteria was 49 days during 2023, 67 during 2022, and 60 during 2021. At the Archie Briggs Crossing (DR 163.25), however there was a longer exceedance period in 2023 (82 days) than 2022 (79 days) and 2021 (71 days). Temperature data from 2021 to 2023 are comparable to those presented in previous summaries of ambient river conditions in the Deschutes River and are consistent with the 2022 IR 303(d) listings.

Temperatures measured at the Tumalo Creek sites during 2023 were also at or near freezing during the winter and warmest during late July (**Figure 12**). Maximum 7DADM temperatures warmed substantially moving downstream, with a maximum summer 7DADM temperature 11.9°C at the Tumalo Falls Forest Service Day Use Area site (TC 17.25) and 19.3°C at the Mouth of Tumalo Creek site (TC 0.25) (**Table 4**).

Temperatures measurements in both the Upper and Lower Tumalo Creek AUs during 2023 are consistent with the 2022 IR 303(d) listings based on measurements at one site within each AU. In the Lower Tumalo Creek AU there were 36 days of exceedances of the 18°C criterion at the Mouth of Tumalo Creek site (TC 0.25) during 2023, 32 days during 2022, and 51 days during 2021 (**Table 4**). 7DADM criterion exceedances in the Lower Tumalo Creek also occurred at the Tumalo Feed Canal/Stag Drive site (TC 3.25) on five days during 2021.

In the Upper Tumalo Creek AU there were 45 days of exceedances of the 12°C Bull Trout Spawning and Rearing criterion at Skyliner Bridge Road (TC 14.5) during 2023, 56 days during 2022, and 78 days during 2021. There were no exceedances at the other Upper Tumalo AU site (Tumalo Falls Forest Service Day Use Area, TC 17.5) during 2022 or 2022, and just nine days of exceedances during 2021.

The seasonal timing and extent of daily water temperature fluctuations were dependent on the waterbody and site. Greatest daily temperature fluctuations in the Deschutes River were observed at downstream sites ranging up to 5.8°C during the 2021-2023 period while at Tumalo State Park (DR 160.00) fluctuations furthest upstream at the COID Diversion site (DR 170.75) only ranged up to 4.4°C daily. The seasonal timing of

higher daily fluctuations varied substantially between the up-river and down-river sites. Fluctuations at COID Diversion site (DR 170.75) peaked during late March and early May while fluctuations at Tumalo State Park (DR 160.00) peaked during mid- to late-June.

Daily fluctuations in Tumalo Creek, especially lower Tumalo Creek, were much greater than in the Deschutes River ranging up to 8.4°C per day at the Mouth of Tumalo Creek site (TC 0.25) and up to 6.3°C at the Tumalo Falls Forest Service Day Use Area site (TC 17.25). The timing of greatest daily fluctuation was during late June and early July at all Tumalo Creek sites.

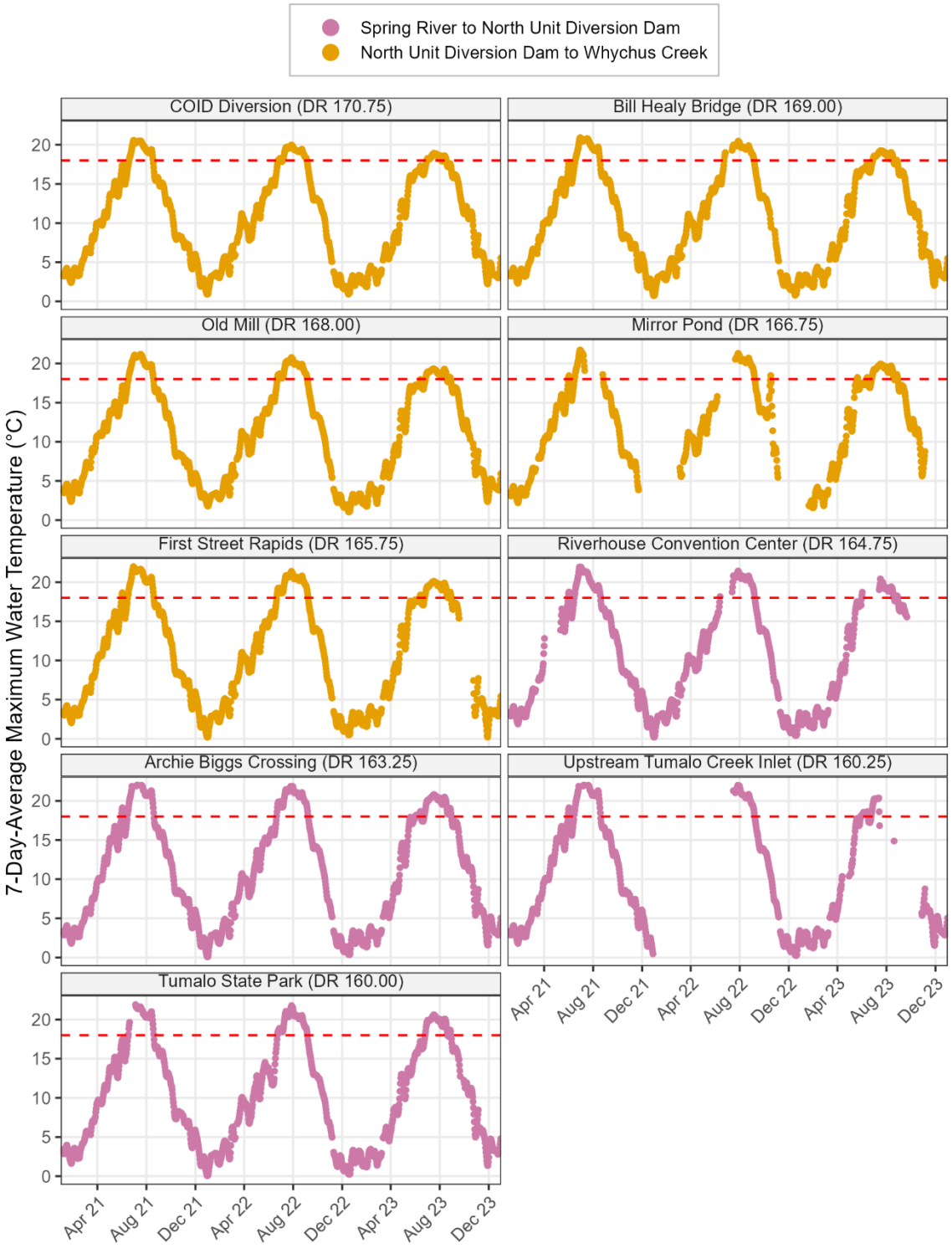

Figure 11. The 7DADM water temperature for the monitoring stations in the Deschutes River Spring River to North Unit Diversion Dam Assessment Unit (AU) (DR 170.75 to DR 166.75), and the North Unit Diversion Dam to Whychus Creek AU (DR 163.25 to 160.00). - City of Bend 2021-2023. The dashed red line indicates the 18°C temperature criterion.

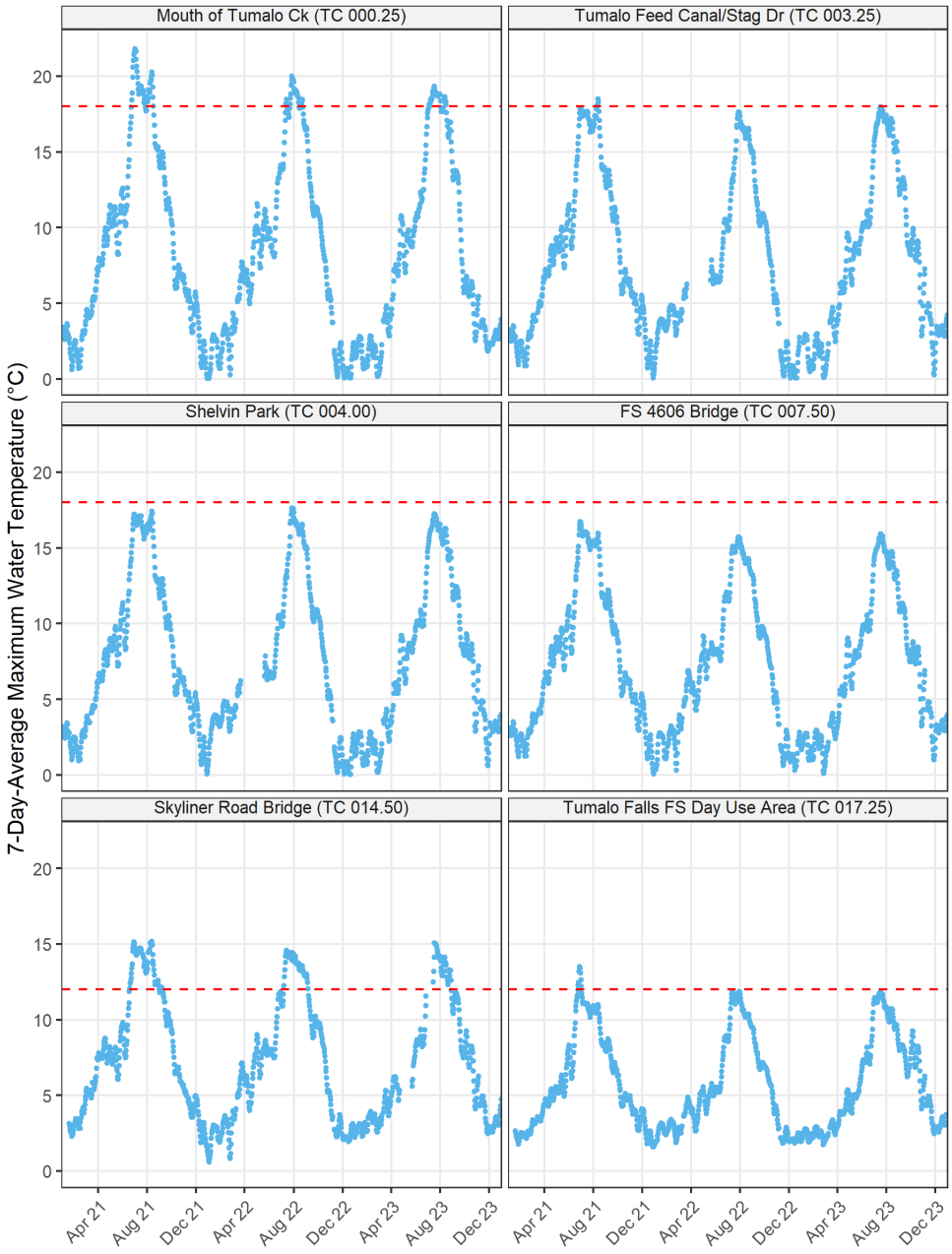

Figure 12. The 7DADM water temperature for the monitoring stations in the Upper and Lower Tumalo Creek AUs. - City of Bend 2021-2023. The dashed red lines indicate the 18°C and 12°C temperature criteria.

TABLE 4. MAXIMUM ANNUAL 7DADM TEMPERATURES AND COUNT OF DAYS EACH YEAR EXCEEDING TEMPERATURE CRITERIA IN THE DESCHUTES RIVER AND TUMALO CREEK.

Site	7DAM temperature criterion	Maximum annual 7DADM Temp. (°C)			Count of days exceeding criterion		
		2021	2022	2023	2021	2022	2023
DR 160.00	18°C	22.4	21.9	20.6	64	75	62
DR 160.25	18°C	22.9	22.1	20.4	71	*	*
DR 163.25	18°C	22.9	22.2	20.8	71	79	82
DR 164.75	18°C	22.2	21.4	20.4	70	87	85
DR 165.75	18°C	22.0	21.3	20.1	69	78	66
DR 166.75	18°C	21.7	21.3	19.9	75	*	66
DR 168.00	18°C	21.2	20.8	19.3	62	76	57
DR 169.00	18°C	20.9	20.5	19.3	61	*	55
DR 170.75	18°C	20.6	19.9	18.9	60	67	49
TC 0.25	18°C	21.8	20.0	19.3	51	32	36
TC 3.25	18°C	18.5	17.6	18.0	5	0	0
TC 4.00	18°C	17.4	17.6	17.3	0	0	0
TC 7.50	18°C	16.7	15.7	15.9	0	0	0
TC 14.5	12°C	15.2	14.6	15.1	78	56	45
TC 17.25	12°C	13.5	11.9	11.9	9	0	0

* Could not be calculated due to missing data at start or end of exceedance period.

pH

pH describes the measurement of how acidic or basic a substance is, with values below 7.0 being acidic and above being basic. The pH of water determines the solubility and bioavailability of chemical constituents. For example, pH drives the availability and form of nutrients such as phosphorus and nitrogen, but also the solubility and toxicity of heavy metals such as lead and copper. Daily and seasonal fluctuations in pH can occur due to phytoplankton and aquatic plants growing in the water. As these organisms photosynthesize, pH measured in the water increases. As photosynthesis declines, so does pH. In slow moving water with high photosynthetic activity, a daily pattern can be quite evident from early morning (lowest pH), to midday (peak pH), to evening (lower pH). Values in pH can also be influenced by snow melt, rain, groundwater and inputs from tributaries. Most of the Deschutes River within the study area are included on the DEQ 303(d) for pH. Specifically, for pH values below 6.5 or above 8.5 (OAR 340-041-0135).

Presented are pH results from continuously logging multi-parameter data sondes between 2021 and 2023 from four sites set at 30-minute intervals (**Table 2**). Specific start and end times varied by site and between years. Measurements of pH are presented as the raw data by site and year with the DEQ 6.5 minimum and 8.5 maximum pH criteria indicated (**Figure 13**).

Seasonally, pH values are highest in late August and early September, due primarily to increased photosynthetic activity. Across sites, pH values were highest during the late summer at Mirror Pond (DR 166.75) and Archie Biggs Crossing (DR 163.25) ranging up to approximately 8.7. The lowest summer maximum pH was at the COID Diversion (DR 170.75) was 8.4. Daily fluctuations in pH were more dramatic in areas of slower moving water. For example, pH values on an average July in Mirror Pond (DR 166.75) increased by up to 1.4 pH units; however, upstream at the COID Diversion (DR 170.75) pH ranged by up to 0.7 units.

When evaluating the continuously recorded data considered in this report (2021 to 2023), average pH for all sites was 7.8 (SD 0.3) in 2021 and 2022 and 7.9 (SD 0.3) 2023. There were no pH exceedances above 8.5 at the COID Diversion (DR 170.75) between 2021 and 2023 (**Table 5**). Downstream, pH exceedances were greatest in Mirror Pond (DR 160.00) with 152 days in 2023, 73 in 2022, and 86 in 2021. Exceedances of pH above 8.5 occurred at Archie Biggs Crossing (DR 163.25) for 45 days during 2023, 73 days during 2022 and 72 days during 2021.Exceedances were recorded at Tumalo State Park (DR 160.00) during part of one day during 2023, no exceedances in 2022, and 32 in 2021.

Low pH exceedances (less than 6.5) were not measured at any site during the 2021 through 2023 period.

Observations of elevated continuously monitored pH compared to the maximum criteria of 8.5 are consistent with the 2022 IR 303(d) listing for the Spring River to North Unit Diversion Dam AU. However, the removal of the North Unit Diversion Dam to Whychus Creek AU from the 2022 303(d) list was not supported due to continuously monitored pH exceedances at the Archie Briggs Crossing site during 2021 through 2023 period. Continuous monitoring of pH was not performed in Tumalo Creek; however, it should be noted that no pH exceedances were measured during grab sample measurements.

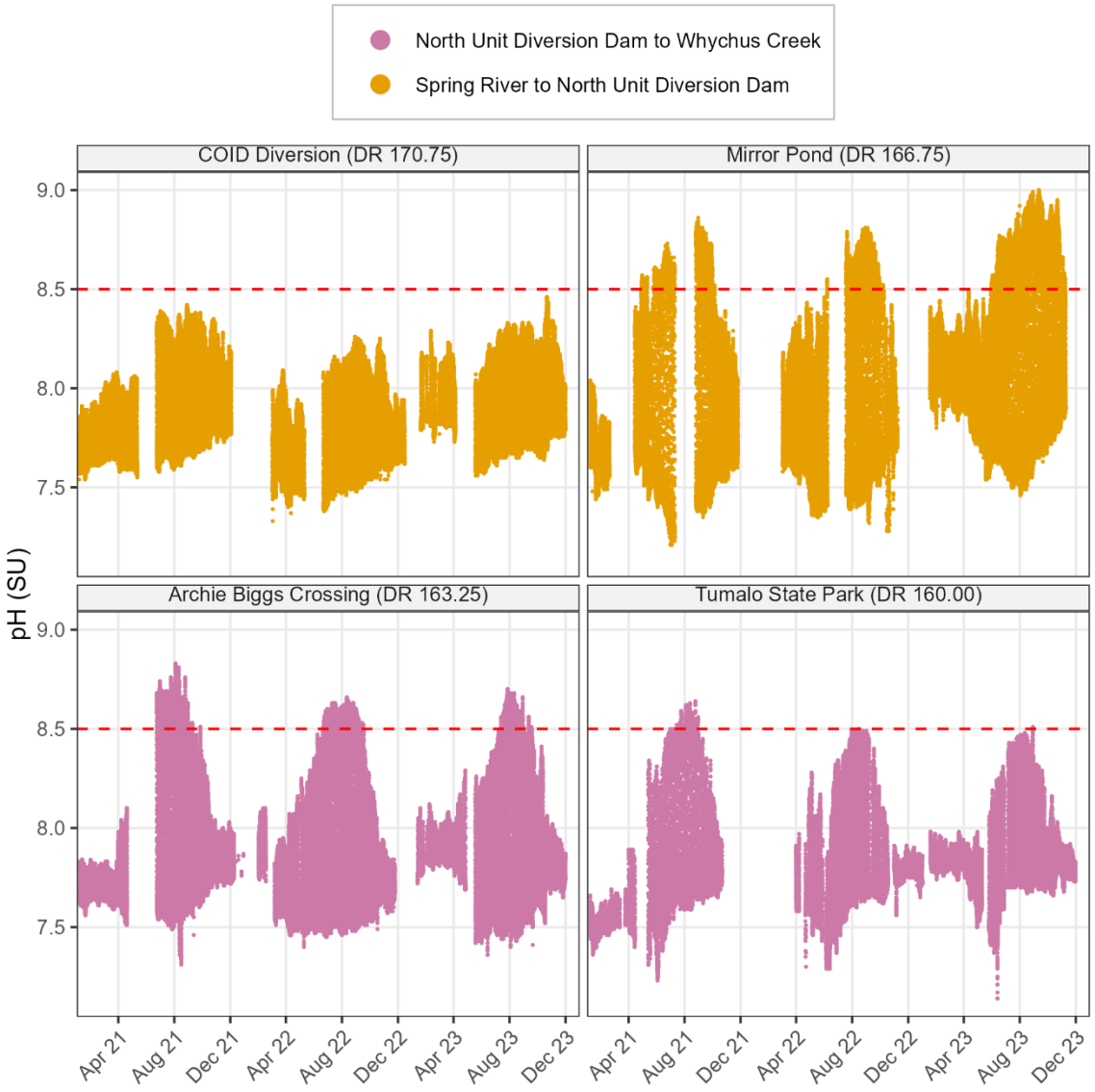

Figure 33. Continuous pH measurements for the monitoring stations in the Spring River to North Unit Diversion Dam Assessment Unit (AU) (DR 170.75 to DR 166.75) (orange dots) and the North Unit Diversion Dam to Whychus Creek AU (DR 163.25 to 160.00) (pink dots) - City of Bend 2021-2023. Dashed red lines indicate the maximum 8.5 pH criteria

TABLE 5. COUNT AND RANGE OF DATES AT CONTINUOUS SONDE DEPLOYMENT SITES WITH PH VALUES EXCEEDING THE PH 8.5 CRITERION

Monitoring Site and Assessment Unit	Days exceeding pH criterion per year (date range)		
	2021	2022	2023
COID Diversion (DR 170.75), Spring River to North Unit Diversion Dam AU	0	0	0
Mirror Pond (DR 166.75), Spring River to North Unit Diversion Dam AU	86 (Apr 29-Oct 5)	73 (June 7-Oct 7)	152 (May 31-Nov 7)
Archie Biggs Crossing (DR 163.25), North Unit Diversion Dam to Whychus Creek AU	72 (June 23-Sept 26)	73 (June 21-Sept 17)	45 (July 13-Sept 17)
Tumalo State Park (DR 160.00), North Unit Diversion Dam to Whychus Creek AU	32 (July 14-Aug 30)	0	1 (8/29/23)

Turbidity

Turbidity is an optical property of water resulting from the suspension of particles in the water column. Turbidity sources include erosion from the watershed or river sediments. Land disturbance and high flow often increase turbidity while dams can decrease turbidity via sedimentation in relatively still water. The particles that cause turbidity scatter, reflect, and refract (change direction) light penetration in the water. High levels of particulates block light available for photosynthetic algae and macrophytes, can be harmful to aquatic organisms, and can attach and carry harmful pollutants. High turbidity levels are considered harmful to beneficial uses, including resident fish, other aquatic life, and water supply.

There is no specific numeric criterion for high turbidity in Oregon. Oregon Administrative Rule 340-041-0036, however, states that “no more than a ten percent cumulative increase in natural stream turbidities may be allowed, as measured relative to a control point immediately upstream of the turbidity causing activity.” Since turbidity measurement relative to an upstream control was not conducted, the ten percent cumulative increase in turbidity criteria is not applicable. Comparisons against undisturbed watersheds is informative, however. During the wet season, median turbidity in most undisturbed watersheds in Oregon is below 5 NTU (Oregon DEQ 2014).

Discrete turbidity measurements were collected using a field turbidity meter at ten Deschutes River sites and six Tumalo Creek sites from 2021 to 2023 (**Figure 14**). Continuous turbidity was measured at 15- or 30-minute intervals at a subset of four Deschutes River sites (**Figure 15)**.

Average turbidity measured with the field turbidity meter over the three-year period in the Spring River to North Unit Diversion Dam Assessment Unit AU was 2.4 (1.3 SD) NTU

while the North Unit Diversion Dam to Whychus Creek AU was slightly lower at 2.2 (1.3 SD) NTU. Turbidity at the Tumalo Creek AU sites (mean 1.2, SD 0.8 NTU) was approximately half that of the Deschutes River sites. During 2023, the same trends held, with slightly higher turbidity at Spring River to North Unit Diversion Dam Assessment Unit AU (mean 2.5, SD 1.9 NTU) and lower turbidity at the North Unit Diversion Dam to Whychus Creek AU (mean 2.3, SD 1.6 NTU) (**Figure 14**).

The observed decrease in turbidity from upstream to downstream agrees with reporting by UDWC (2010) and ESA and MaxDepth Aquatics (2018). It is presumed that the dam at Mirror Pond traps sediment that would otherwise contribute to downstream turbidity. Mirror Pond has not been dredged since 1984 and is the subject of discussion for future dredging efforts. In general, there were no trends in turbidity across at each site over the entire 2021 - 2023 period (Figure 14). The highest average turbidity during the 2021 to 2023 period (2.6, SD 1.8 NTU) was measured at the Bill Healy Bridge site (DR 169.00). The lowest average turbidity over the period (0.8, SD 0.3 NTU) was measured at the furthest upstream Tumalo Creek site (TC 17.25, Tumalo Falls Forest Service Day Use Area).

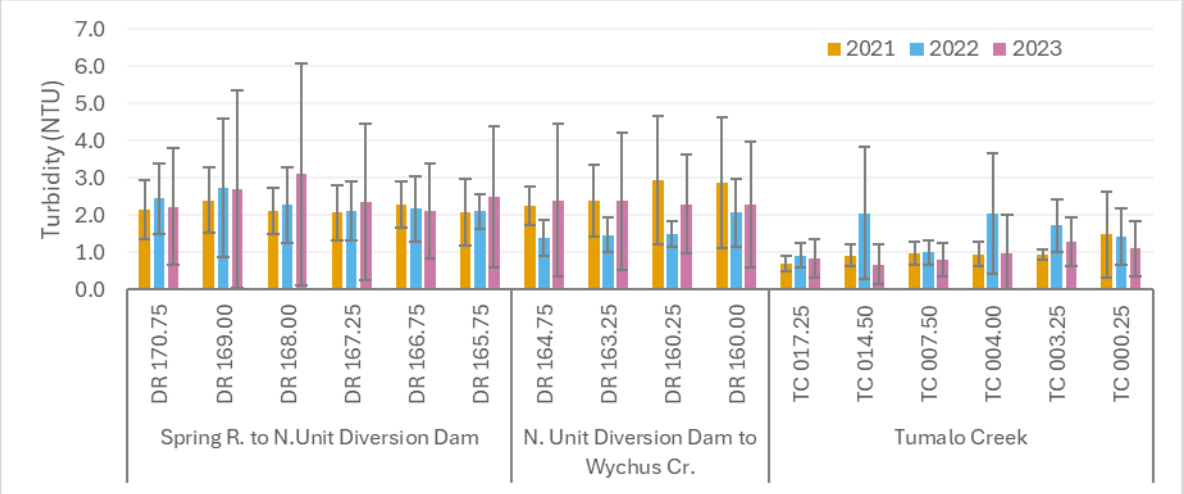

Figure 14. Average annual turbidity from 2021 to 2023 for samples collected at monitoring stations in the Spring River to North Unit Diversion Dam Assessment Unit (AU) (DR 170.75 to DR 166.75), the North Unit Diversion Dam to Whychus Creek AU (DR 163.25 to 160.00), and the Tumalo Creek AU. Error bars are ± 1SD - City of Bend 2021-2023

Continuous turbidity monitoring data at the four Deschutes River sites tells a more complicated story. In general, turbidity at the most upstream site (COID Diversion, DR 170.75) was lower and less variable than at the sites downstream (**Figure 15**). Most values at the COID Diversion site were below 2.5 NTU, however, there were occasional spikes above 5 NTU. Turbidity values at the other sites were higher and much more variable than at the COID Diversion site. Seasonally, higher turbidity values tended to occur during higher flows in the spring and fall. Some of the variability may be due to temporary fouling as particles settle and are washed off the sensor.

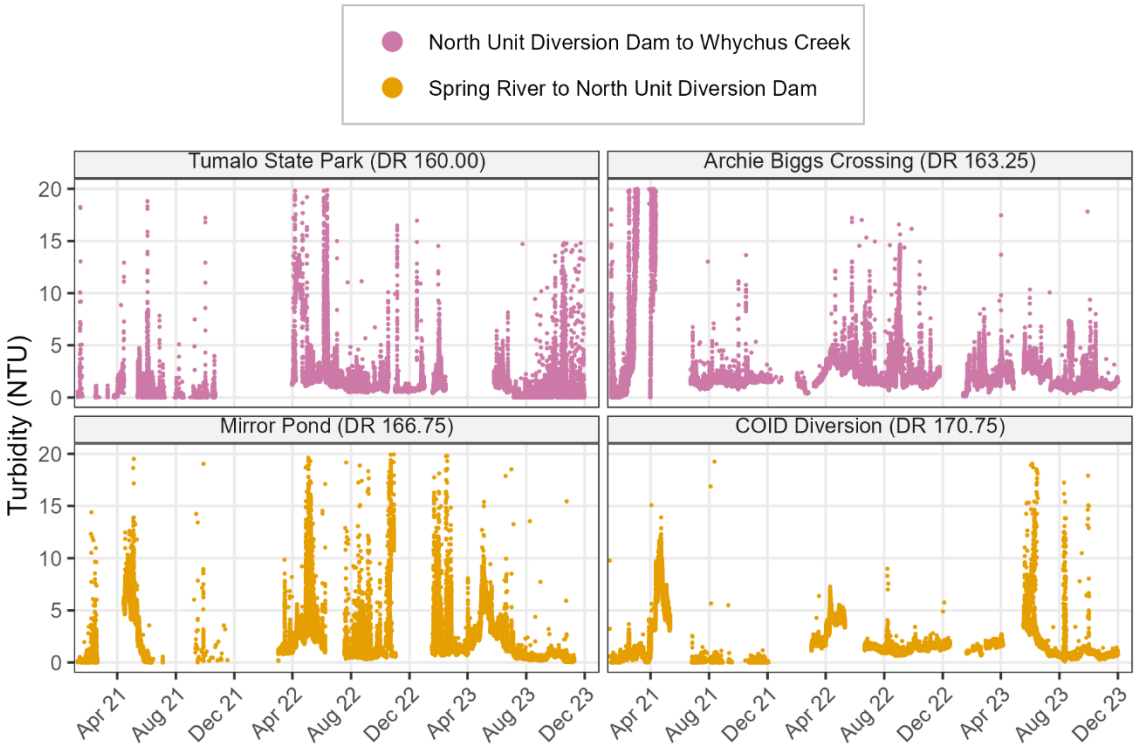

Figure 15. Results of *in situ* turbidity measured at 15- or 30-minute intervals at monitoring stations in the Spring River to North Unit Diversion Dam AU (DR 170.75 and DR 166.75) (orange points) and the North Unit Diversion Dam to Whychus Creek AU (DR 163.25 and 160.00) (pink points) - City of Bend 2021-2023

Total Suspended Solids

Like turbidity, total suspended solids (TSS) are derived from similar sources, but TSS measurements include particles (including phytoplankton) greater than 0.45 microns. Therefore, generally the smaller particles that do not settle out by gravity and instead remain suspended in the water column are not incorporated in TSS and are considered total dissolved solids (TDS) (not considered here). High levels of TSS reduces light availability and photosynthesis, can increase water temperature, reduce the ability of fish to see, clog fish gills, and harm egg and larval development.

Presented are results from samples analyzed for TSS from monthly to quarterly grab samples between 2021 and 2023 (**Figure 16**). Overall, TSS ranged from the reporting limit of 2.5 mg/L to a high of 18.3 at Tumalo State Park (DR 160.0) during October 2021 in the Deschutes River (including Mirror Pond) with an overall average of 5.1 (SD 3.9), 4.1 (SD 2.0), and 3.5 (SD 1.6) mg/L TSS during 2021, 2022, and 2023 respectively. TSS concentrations were less than 5.0 mg/L except early and late during each year. There was no significant trend across river miles observed during any of the years. Only one sample was analyzed for TSS from Tumalo Creek. The May 2021 TSS measurement near the Tumalo Creek mouth (TC 0.25) was 3.5 mg/L.

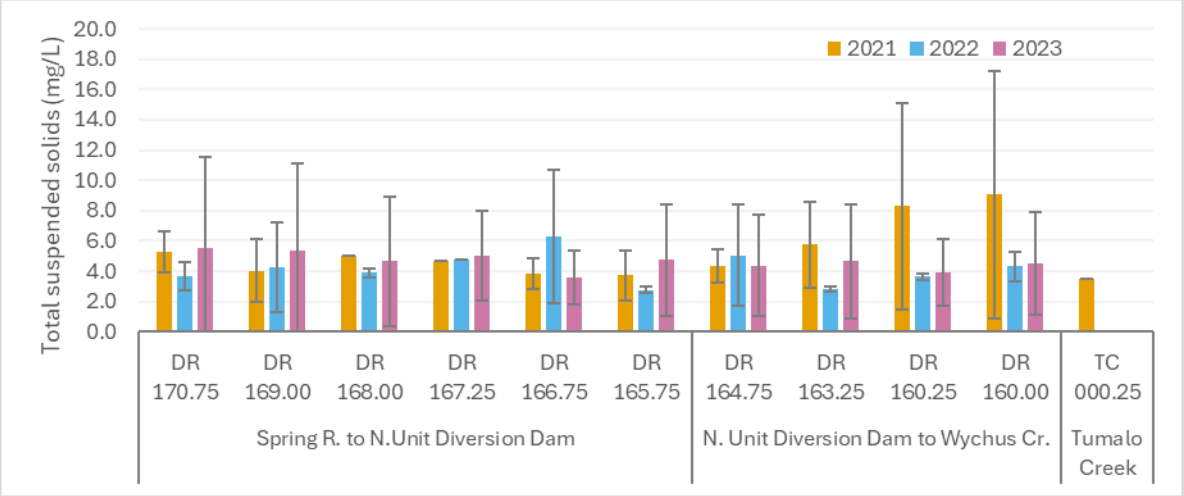

Figure 16. Average annual total suspended solids concentrations of samples collected at monitoring stations in the Spring River to North Unit Diversion Dam Assessment Unit (AU) (DR 170.75 to DR 165.75), the North Unit Diversion Dam to Whychus Creek AU (DR 164.75 to 160.00) and Tumalo Creek from 2021 to 2023 - City of Bend 2021-2023

Dissolved Oxygen

Dissolved oxygen (DO) is fundamental to the metabolism of aerobic organisms, including fish, invertebrates, bacteria, and plants growing in aquatic environments. DO concentration when at saturation with the atmosphere is influenced by external factors such as water temperature, salinity and atmospheric pressure. Water with higher temperature, higher salinity, and lower pressure contains less DO when at equilibrium with the atmosphere. As such, seasonal and regional variations are observed in the DO capacity of an aquatic system. Hydrologic influences such as atmospheric inputs through wind mixing, aeration from waterfalls and rapids, groundwater discharge, dam releases, and pumps also influence DO concentrations. More importantly, the balance between the biological factors of primary productivity, respiration, and decomposition impact deviations from atmospheric saturated DO concentrations within an aquatic environment. When the DO saturation is near 100% air saturation, it is said to be in equilibrium. DO concentration below saturation levels are often attributed to the dominance of respiration and decomposition over primary productivity. Low DO

concentrations can be lethal to sessile aquatic organisms that depend on DO. Conversely excessive DO concentrations can lead to supersaturation which has long been known to be detrimental to fish health (Weitkamp and Katz 1980). Similar to pH, fluctuations in DO commonly occur throughout the day as photosynthesis increases to an afternoon peak and decreases into the evening and night. The 2022 IR provides separate DO criteria for the stream AUs for each of the Deschutes River AUs and the Tumalo Creeks AUs included in the study (**Table 6**).

TABLE 6. DISSOLVED OXYGEN CRITERIA BY ASSESSMENT UNIT

Season[1]	Spring River to North Unit Diversion Dam[1] (DR170.75 to DR165.75) and Lower Tumalo Creek (TC00.25 to TC07.25)	North Unit Diversion Dam to Whychus Creek[1] (DR164.75 to DR160.00)	Upper Tumalo (TC14.50 and TC17.25)
Year Round (Non-spawning)	"Cold water" Not less than 8.0 mg/L as an absolute minimum	"Cool water" Not less than 6.5 mg/L as an absolute minimum	"Cold water" Not less than 8.0 mg/L as an absolute minimum
Year Round (Non-spawning)	8.0 mg/L as a 30-day mean minimum	Minimum 6.5 mg/L of the 30 consecutive-day floating averages of the calculated daily mean dissolved oxygen concentration (OAR 340-041-0002)	8.0 mg/L as a 30-day mean minimum
Year Round (Non-spawning)	6.5 mg/L as a 7-day mean minimum	Minimum 5.0 mg/L of the seven consecutive-day floating average of the calculated daily mean dissolved oxygen concentration (OAR 340-041-0002)	6.5 mg/L as a 7-day mean minimum
Year Round (Non-spawning)	6.0 mg/L absolute minimum	Absolute minimum 4.0 mg/L for surface samples when applying the averaging period, spatial median of IGDO2 (OAR 340-041-0016)	6.0 mg/L absolute minimum
(Spawning)	Not less than 11.0 mg/L 7-day mean minimum (January 1 – May 15)		Not less than 11.0 mg/L 7-day mean minimum (August 15 – June 15)

1 Dissolved oxygen criteria for resident trout spawning is applied differently between Assessment Units (AU).

2 "Spatial Median" means the value that falls in the middle of a data set of multiple intergravel dissolved oxygen (IGDO) measurements taken within a spawning area. Half the samples should be greater than and half the samples should be less than the spatial median. (OAR 340-041-0002).

Presented are DO concentrations from continuously logging multi-parameter sondes between 2021 and 2023 from four Deschutes River sites set at 15- or 30–minute intervals. (**Table 2**). Specific start and end times varied by site and between years. Measurements of DO are presented as the 30-day mean minimum (**Figure 17**) and seven-day mean minimum (**Figure 18**) by AU. Although continuous monitoring data is not available from the Tumalo Creek AUs, the lowest synoptic grab sample measurement was 9.4 mg/L, considerably higher than the absolute minimum criterion of 8.0 mg/L.

No instances of falling below the 30-day mean minimum of 8.0 mg/L for the Spring River to North Unit Diversion Dam AU were observed at the COID Diversion (DR 170.75);

however, a limited number of instances were observed below 8.0 mg/L in Mirror Pond (DR 166.75) for 34 days during the summer of 2022, and no days during the summer of 2023. Concentrations were below the criteria during only 16 days during 2021, however, no data was available at the Mirror Pond site for 44 days during that summer. The lowest 30-day mean minimum value observed was 7.7 mg/L at the Mirror Pond site on August 11, 2022. There were no instances of dissolved oxygen falling below the 30-day mean minimum of 6.5 mg/L criteria for the North Unit Diversion Dam to Whychus Creek AU. That is, monitoring data from the Deschutes River since 2016 meet the DEQ criteria for year-round (non-spawning) 30-day mean minimum DO criteria the vast majority of the time with the exception of the Mirror Pond site during June-July 2021, and July-August 2022.

In addition to the year-round non-spawning DO criteria, each assessment unit has a seven-day mean minimum spawning criteria of 11.0 mg/L for specific designated spawning periods. For the Deschutes River and Lower Tumalo Creek AUs, the spawning period extends from January 1 to May 15 within a respective year. The spawning period for the Upper Tumalo Creek AU, designated for Bull Trout spawning, extends from August 15 to June 15. For all sample sites in both Deschutes River AUs, the seven-day mean minimum of 11.0 mg/L was exceeded every year from 2021-2023 (**Figure 17**). In 2022, two monitoring locations (COID Diversion DR 170.75 and Mirror Pond; DR 166.75) in the Spring River to North Unit Diversion Dam AU had 7-day mean minimum DO concentrations below the January 1 to May 15 spawning period criteria of 11 mg/L. Two monitoring sites in the North Unit Diversion Dam to Whychus Creek AU (Archie Briggs Crossing; DR 163.25 and Tumalo State Park; DR 160.00) similarly had 7-day mean minimum concentrations below 11.0 mg/L during the January 1 to May 15 spawning period. In both AUs, exceedances tended to start during March or April and continued through the end of the spawning periods.

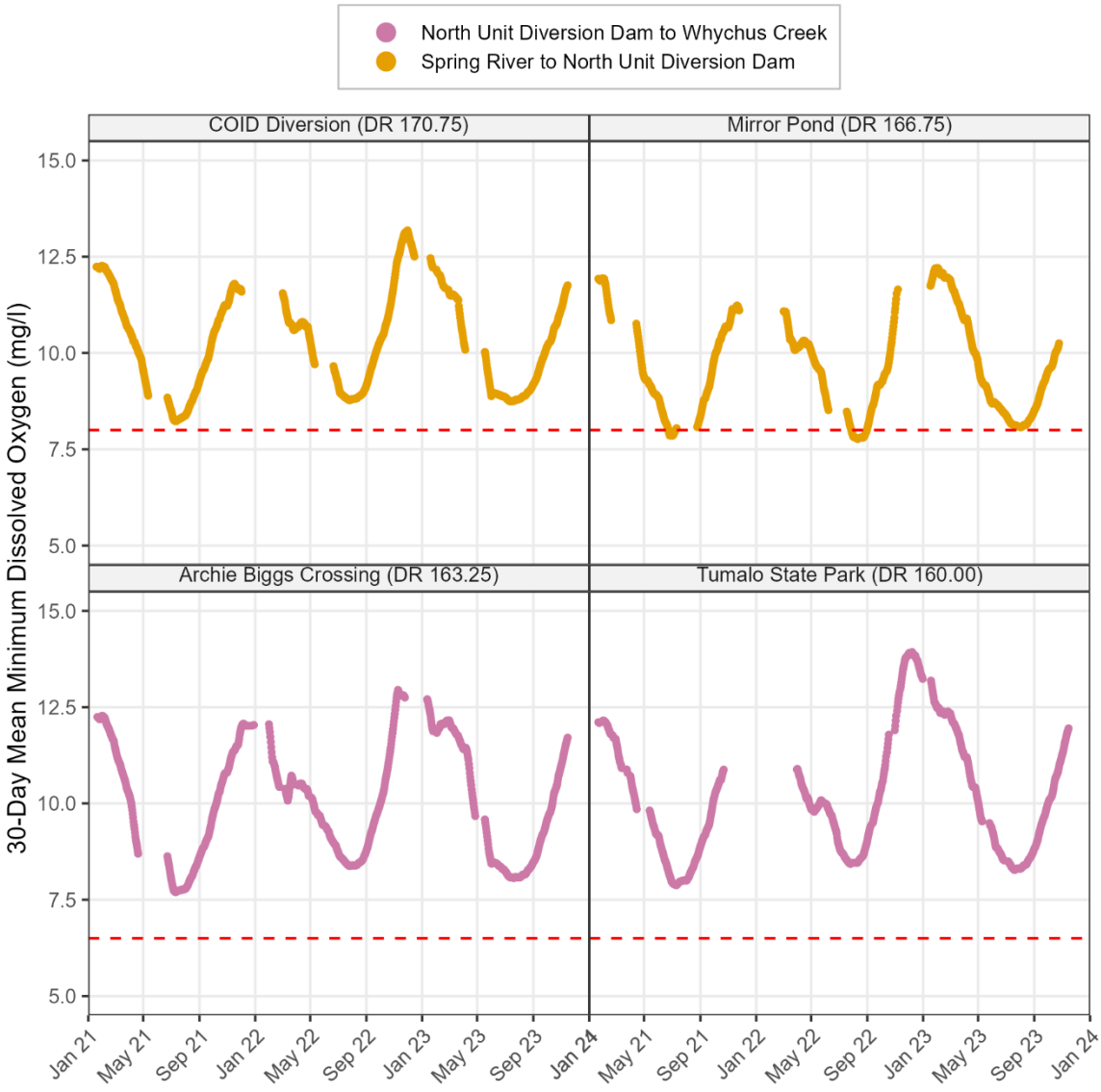

Figure 17. The 30-day mean minimum dissolved oxygen concentrations for the monitoring stations in the Spring River to North Unit Diversion Dam Assessment Unit (AU) (DR 170.75 to DR 166.75) (orange lines) and the North Unit Diversion Dam to Whychus Creek AU (DR 163.25 to 160.00) (pink lines) - City of Bend 2021-2023. The red line indicates the DEQ 8.0 mg/L year-round non-spawning for the Spring River to North Unit Diversion Dam AU (top panels) and the 6.5 mg/L year- round non-spawning criteria for the North Unit Diversion Dam to Whychus Creek AU

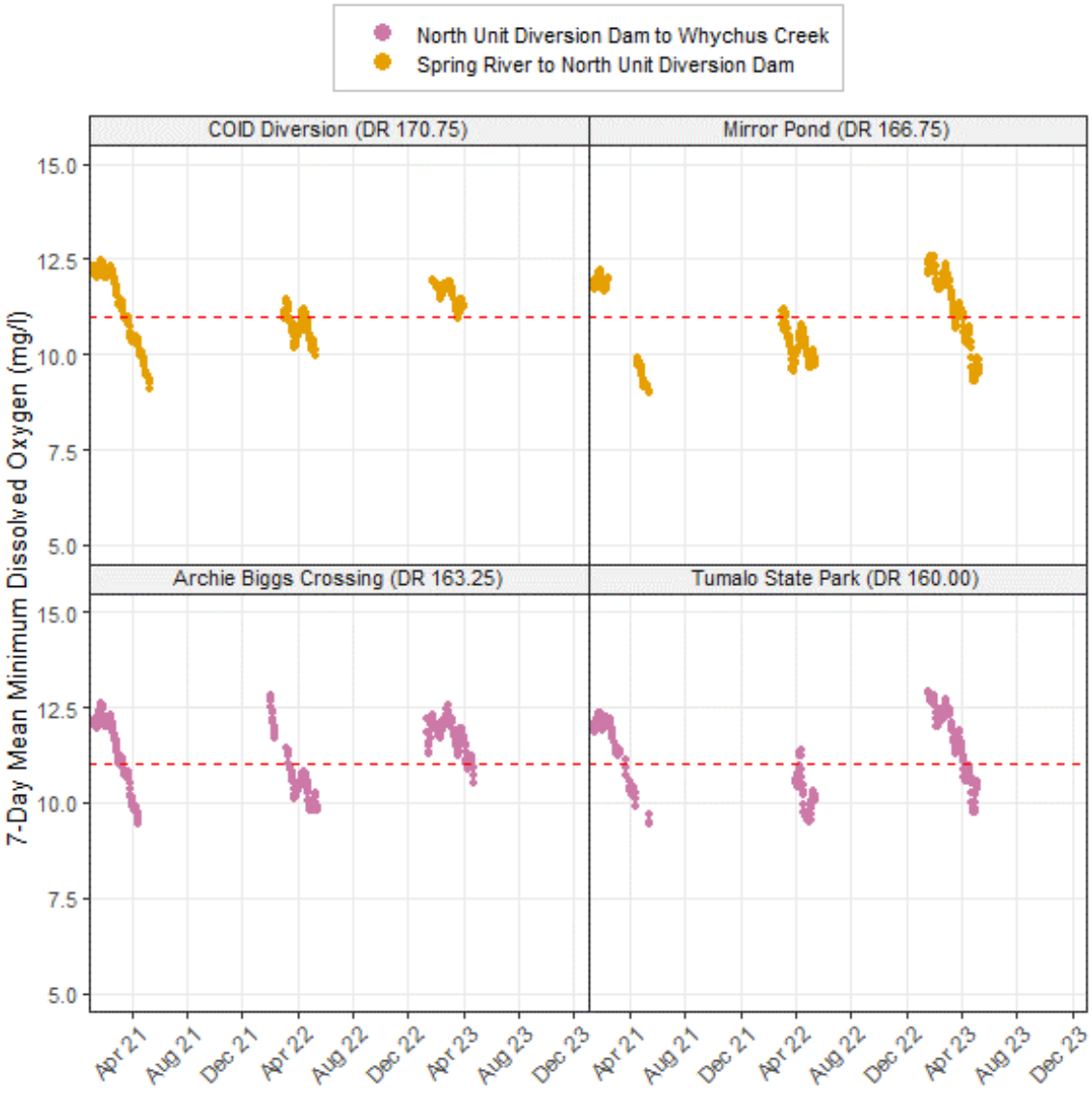

Figure 4. The seven-day mean minimum dissolved oxygen concentrations during designated spawning periods for the monitoring stations in the Spring River to North Unit Diversion Dam Assessment Unit (AU) (DR 170.75 to DR 166.75) (top panels in orange) and the North Unit Diversion Dam to Whychus Creek AU (DR 163.25 to 160.00) (bottom panels in pink) - City of Bend 2021-2023. The dashed red line indicates the DEQ 11.0 mg/L spawning criteria for January 1 to May 15.

Specific Conductance

The specific conductance of water is highly correlated to the concentration of major ions in the water such as calcium, magnesium, and sodium. Natural sources of these major ions are weathering of soil and rock in the watershed, the atmosphere, and regional climate, but pollutant discharges can also lead to notable changes in conductance due to the high concentrations of chloride, phosphate or nitrate which would appreciably raise conductance above ambient concentrations.

Presented are specific conductance results from continuously logging multi-parameter sondes between 2021 and 2023 from four sites set at 15- or 30–minute intervals (**Table 2**; **Figure 19**). Specific start and end times varied by site and between years.

Prior to the confluence with Tumalo Creek, average specific conductance in the three Deschutes River sites were very similar ranging from an average of 65.2 (SD 5.6) µS/cm at Mirror Pond site (DR 166.75) to 66.4 (SD 5.4) µS/cm at Archie Briggs Crossing site (DR 163.25). Marked seasonal variation with similar trends were present across the three sites with higher values in the summer and lower values in the winter (**Figure 19**). Specific conductance at the Tumalo State Park site (DR 160.00) below the confluence with Tumalo Creek was lower and more variable seasonally (mean 59.7, SD 7.7 µS/cm). Based on a more limited number of samples taken at the same time as grab samples, average conductance in Tumalo Creek sites was even lower at 36.4 (SD 10.4) µS/cm. Below the confluence at Tumalo State Park (DR 160.00), specific conductance in the Deschutes River is highly driven by inflows from Tumalo Creek and, presumably, seasonal irrigation practices. The lowest specific conductance concentrations measured at the Tumalo State Park site (DR 160.00) corresponded with the summer irrigation season when the contribution of water from Tumalo Creek accounts for over 60 percent of instream flow at that site resulting in dilution of specific conductance.

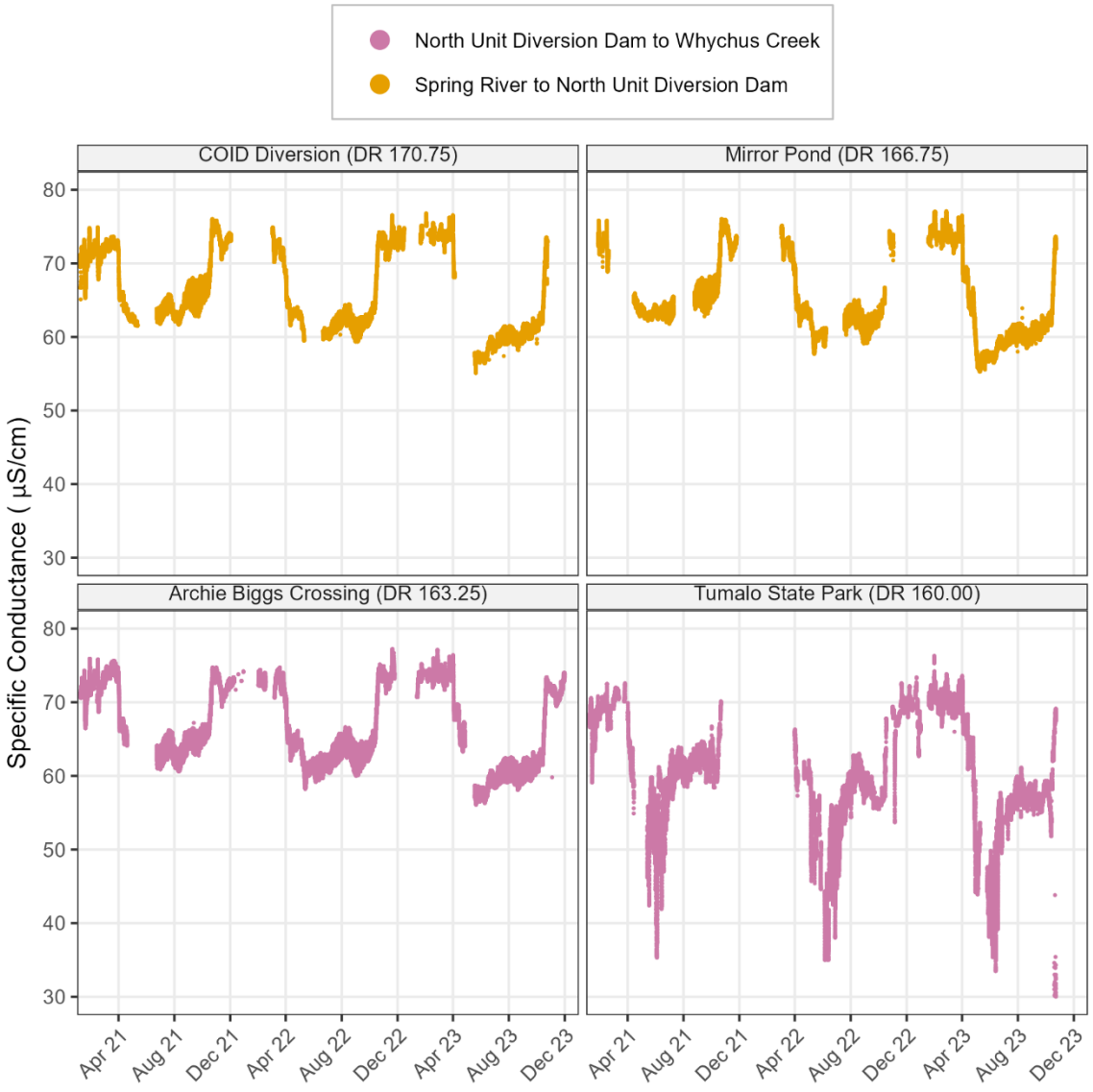

Figure 5. Continuous specific conductance measurements for the monitoring stations over period of 2021 to 2023 in the Spring River to North Unit Diversion Dam Assessment Unit (AU) (DR 170.75 to DR 166.75) (orange dots) and the North Unit Diversion Dam to Whychus Creek AU (DR 163.25 to 160.00) (pink dots) - City of Bend 2019-2023

Nitrate, Nitrite, and Ammonia-Nitrogen

Nitrogen is an essential nutrient for plant and animal growth. Nitrogen in water occurs in several bioavailable forms; in particular, nitrate (NO_3-N), nitrite (NO_2-N), and ammonia (NH_3^+- N). Transformation between nitrogen forms is facilitated by aerobic bacteria as a means of generating energy for growth. This process, nitrification, is a two-step bacterial mediated oxidation of ammonia, to nitrite, to nitrate (NO_3-N). In anerobic conditions, denitrification can occur where a set of different bacteria transform nitrate to nitrogen gas (N_2) to generate energy, which also results in loss of nitrogen to the atmosphere. Nitrate plus nitrite is generally measured in the lab as nitrite is readily oxidized to nitrate. Runoff from fertilizers, sewage, animal manure, and ground disturbance can lead to excessive nitrogen in surface and groundwater. Excess nitrogen in surface water can lead to problems including excessive growth of algae and aquatic plants which can lead to high pH during period of growth and DO depletion upon decomposition. The Deschutes River is known to be nitrogen-limited (Jones 2003), thus all bio-available forms of nitrogen forms are rapidly consumed by algae and aquatic plants during primary production. EPA (2000) provides guidance on total nitrogen for Ecoregion II but no other forms of nitrogen.

Grab samples were collected monthly for nitrate plus nitrite-nitrogen analysis from 2021 to 2023. Concentrations were at or below method reporting limits (0.050 or 0.0513 mg/L depending on the laboratory analysis batch) for all samples except for five sites on March 23, 2022, and one site on October 20, 2021. Concentrations of these sample were only slightly greater than the reporting limits (up to 0.061 mg/L), thus no figures are included for this nitrate plus nitrite. As such, mean nitrate plus nitrite-nitrogen across all sites in the Deschutes River and all years was below the method reporting limit. Nitrate plus nitrite was greater than the reporting limit in one sample collected from TC 4.00 between 2021 and 2023.

None of the nitrate-nitrogen samples that were collected had concentrations greater than the reporting limits and only two samples had concentrations greater than the method detection limit.

Ammonia-nitrogen concentrations were above the 0.05 mg/L reporting limit in 34 of the 126 samples collected from 2021 to 2023, thus, ammonia-nitrogen figures are not included. Samples more than two times greater than the reporting limit occurred during four sampling periods: March 22-23, 2022 (at eight Deschutes River sites and three Tumalo Creek sites), June 8-9, 2022 (at DR 170.75 and TC 017.25), July 26, 2022 (at five Deschutes River sites), and August 7-8, 2023 (at DR 163.25 and TC 017.25). The highest ammonia-nitrogen concentrations were measured on March 22, 2022, at DR 160.00 (1.46 mg/L) and DR 168.00 (1.1 mg/L).

Phosphorus

Phosphorus is essential to biological metabolism, including cellular DNA, yet it is often the nutrient most limiting to primary productivity (e.g., algae growth). Despite this, excess

loading to aquatic ecosystems can result in algae blooms and subsequent cascading events such as low DO, aesthetic issues, taste and odor problems, and toxigenic harmful algae. While sources of phosphorus can be naturally occurring, excessive anthropogenic loading results from run-off (urban, pastures, croplands), streambank erosion, and sewage seepage. Phosphorus is present in organic (organic biomass) and inorganic (orthophosphate) forms. Inorganic phosphorus is the preferred form for primary productivity as it is readily available for biological uptake requiring minimal energy utilization. Total phosphorus (TP) is the combination of all organic and inorganic forms of phosphorus in the water column.

Table 7 summarizes state and federal guidance concentrations and exceedances for phosphorus as well as other evaluated parameters.

TABLE 7. GUIDANCE/STANDARDS SUMMARY WITHIN THE STUDY AREA

Parameter	Guidance[a]	DEQ[b]	EPA[c, d]	2021-2023 Exceedances	Max. Exceedance Observed 2021-2023
Total phosphorus (mg/L)[a]			Aggregate Nutrient Ecoregion II = 0.010	All sites monitored	Deschutes R. 0.11, Tumalo Cr. 0.26
Chloride (mg/L)[b]		860.0 (acute) 230.0 (chronic)	860.0 (acute) 230.0 (chronic)	None	
Fluoride (mg/L)	0.50			None	
Sulfate as SO_4 (mg/L)			250	None	
E. coli (MPN/100m)		126 (90-day mean); 406 (single sample)		None	

MPN = Most Probable Number

SOURCES:

[a] Carmago (2003)

[b] DEQ (2022b)

[c] EPA (2000)

[d] EPA (2003); secondary maximum contaminant level (SMCL) based on aesthetic effects (i.e., taste and odor)

Presented are results from samples analyzed for orthophosphate and TP from monthly grab samples between 2021 and 2023 (**Figure 20** and **Figure 21**, respectively). Orthophosphate concentrations in Deschutes River sites during 2021-2023 ranged from below reporting limits (0.05 mg/L) to 0.102 mg/L (measured at DR 167.25 in February 2021). Mean orthophosphate at Deschutes River sites was 0.058 mg/L in the Spring River to North Unit Diversion Dam AU and 0.055 mg/L in the North Unit Diversion Dam to Whychus Creek AU. Concentrations were lower at sites within the Tumalo Creek AU averaging 0.035 mg/L. There was little notable variation between years or sites (**Figure 20**). Temporal variability in orthophosphate availability was observed throughout the Deschutes River, with reduced concentrations in the late-spring to early-summer

periods. This orthophosphate depletion may be attributed to increased primary productivity, warmer water temperatures and solar irradiance.

During the 2021 to 2023 period at the Deschutes River sites, TP concentrations ranged from 0.050 mg/L to 0.100 mg/L. The average concentration in the Spring River to North Unit Diversion Dam AU 0.075 mg/L and the average concentration in the North Unit Diversion Dam to Whychus Creek AU was 0.073 mg/L (**Figure 21**). Concentrations were lower in the Tumalo Creek sites averaging 0.0.043 mg/L over the three-year period. All Tumalo Creek concentrations were lower than 0.055 mg/L with two exceptions: 0.26 mg/L on August 7, 2023, and 0.12 mg/L on October 24, 2023. Both high concentrations were measured at FS 4606 Bridge Crossing (TC 007.50).

All measurements at the Deschutes River and Tumalo Creek sites exceeded total phosphorus guidance values 0.01 mg/L for EPA Aggregate Nutrient Ecoregion II (**Table 7**; **Figure 21**). Elevated phosphorous values are likely derived primarily from natural sources, due to weathering of phosphorous-rich volcanic rocks (mostly basalt). In addition, relatively low concentrations of nitrogen result in nitrogen limitation of algal growth and excess availability of phosphorus. This process drives naturally high phosphorous measurements across much of central and eastern Oregon. Bedrock geology has been mapped for the entire Pacific Northwest and it documents the importance of basalt and other rocks of volcanic origin for this region (Johnson and Raines 1995). The weathering products from basalts are well known and show a disproportionately high rate of weathering of phosphorus from these rocks by hydrolysis (Krauskopf 1979; Colman 1982). The weathering of phosphorus is readily apparent in the three major tributaries to Lake Billy Chinook, including from the Deschutes River (Eilers and Vache 2020). As previously mentioned, excess TP, and nitrogen concentrations can lead to cascading environmental events such as depleted DO due to algae growth followed by decomposition.

The UDWC (2010) report indicated exceedances in 91 percent of reported values (354 exceedances out of 389 total observation) of the TP ecoregion thresholds, with the highest concentrations (0.40 mg/L) measured at a site further downriver than was evaluated in this report.

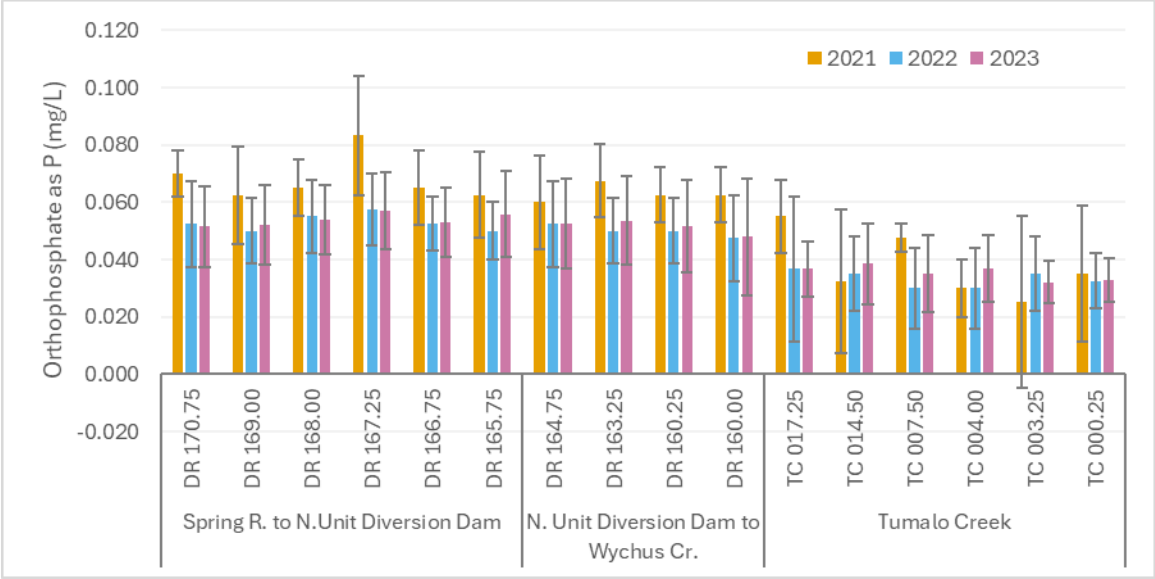

Figure 6. Deschutes River and Tumalo Creek mean annual orthophosphate concentrations (± 1 standard deviation) in grab samples collected from the Spring River to North Unit Diversion Dam, North Unit Diversion Dam to Wychus Creek, and Tumalo Creek AU sites from 2021 through 2023 – City of Bend 2021 to 2023

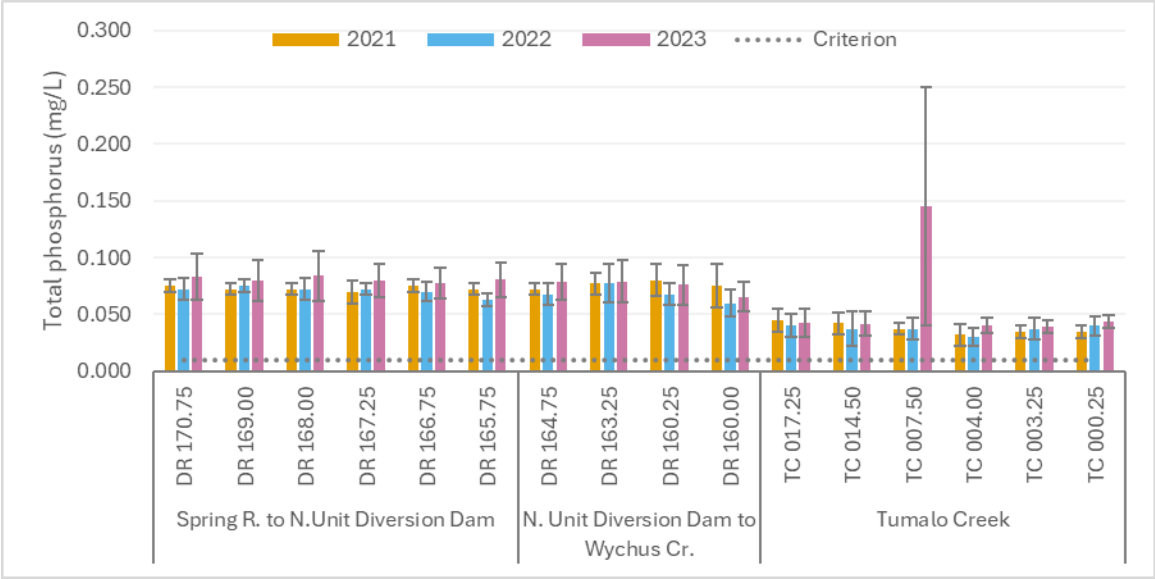

Figure 21. Deschutes River and Tumalo Creek mean annual total phosphorus concentrations (± 1 standard deviation) in grab samples collected from the Spring River to North Unit Diversion Dam, North Unit Diversion Dam to Wychus Creek, and Tumalo Creek AU sites from 2021 through 2023. The dashed line is the EPA guidance criteria for aggregate Nutrient Ecoregion III.

Chloride, Fluoride, and Sulfate

Chloride is not generally a dominant anion in freshwater environments except for waterbodies near marine areas where wind can transport saltwater spray to adjacent freshwaters. Additional anthropogenic sources including run-off from road salting and wastewater discharge can harm aquatic life by disrupting osmoregulation (the process by which biological organisms maintain proper levels of salt). Presented are results from grab samples collected monthly between 2021 and 2023 and analyzed for chloride (**Figure 22**). Measurements in Deschutes River sites ranged from 0.50 mg/L to 1.46 mg/Land averaged 1.10 mg/L in the Spring River to North Unit Diversion Dam AU and 1.05 mg/L in the North Unit Diversion Dam to Whychus Creek AU. Concentrations in the Tumalo Creek AU averaged 0.46 mg/L and ranged from 0.18 mg/L to 0.98 mg/L; half the concentrations measured in Deschutes River sites. In general, there is a slight seasonal increase in chloride measurements during fall though spring, presumably due to the application of magnesium chloride for road deicing.

Fluorides are naturally occurring through geologic processes but can also be released directly to the environment through human activities, including industrial manufacturing processes, the use of fluoride-containing pesticides, and the addition of fluoride to drinking water (though fluoride is not provided in the City of Bend's drinking water). Naturally occurring concentrations of fluoride in fresh surface waters is generally less than 1 mg/L. Substantially higher concentrations can be found in groundwater. Presented are results from grab samples collected monthly between 2021 and 2023 and analyzed for fluoride (**Figure 22**). Measurements in Deschutes River sites ranged from 0.03 mg/L to 0.11 mg/L and averaged 0.06 mg/L in the Spring River to North Unit Diversion Dam AU and 0.06 mg/L in the North Unit Diversion Dam to Whychus Creek AU. Concentrations in Tumalo Creek sites ranged from 0.02 mg/l to 0.21 mg/L and averaged 0.052 mg/L, slightly lower than at Deschutes River sites. There were three

Sulfate also naturally occurs from the breakdown of organic material, geological processes, and atmospheric deposition. Specific anthropogenic sources include runoff from pulp mills or agricultural areas. Living organisms utilize forms of sulfur, depending on the redox status of the cycle (sulfate being bonded with oxygen), including bacteria responsible for decomposing organic matter which contributes to the cycling of other nutrients in ecosystems (Wetzel 2001). Presented are results from grab samples collected monthly between 2021 and 2023 and analyzed for sulfate (**Figure 22**). Measurements averaged 0.85 (SD 0.21) mg/L and ranged from 0.33 mg/L to 1.02 mg/L in the Deschutes River sites from 2021 to 2023 and measurements at Tumalo Creek sites averaged 0.55 (SD 0.19) mg/L and ranged from 0.25 mg/L to 1.10 mg/L.

No exceedances were reported for the subject parameters in UDWC (2010) or ESA and MaxDepth Aquatics (2018) and all were within EPA guidance (**Table 7**).

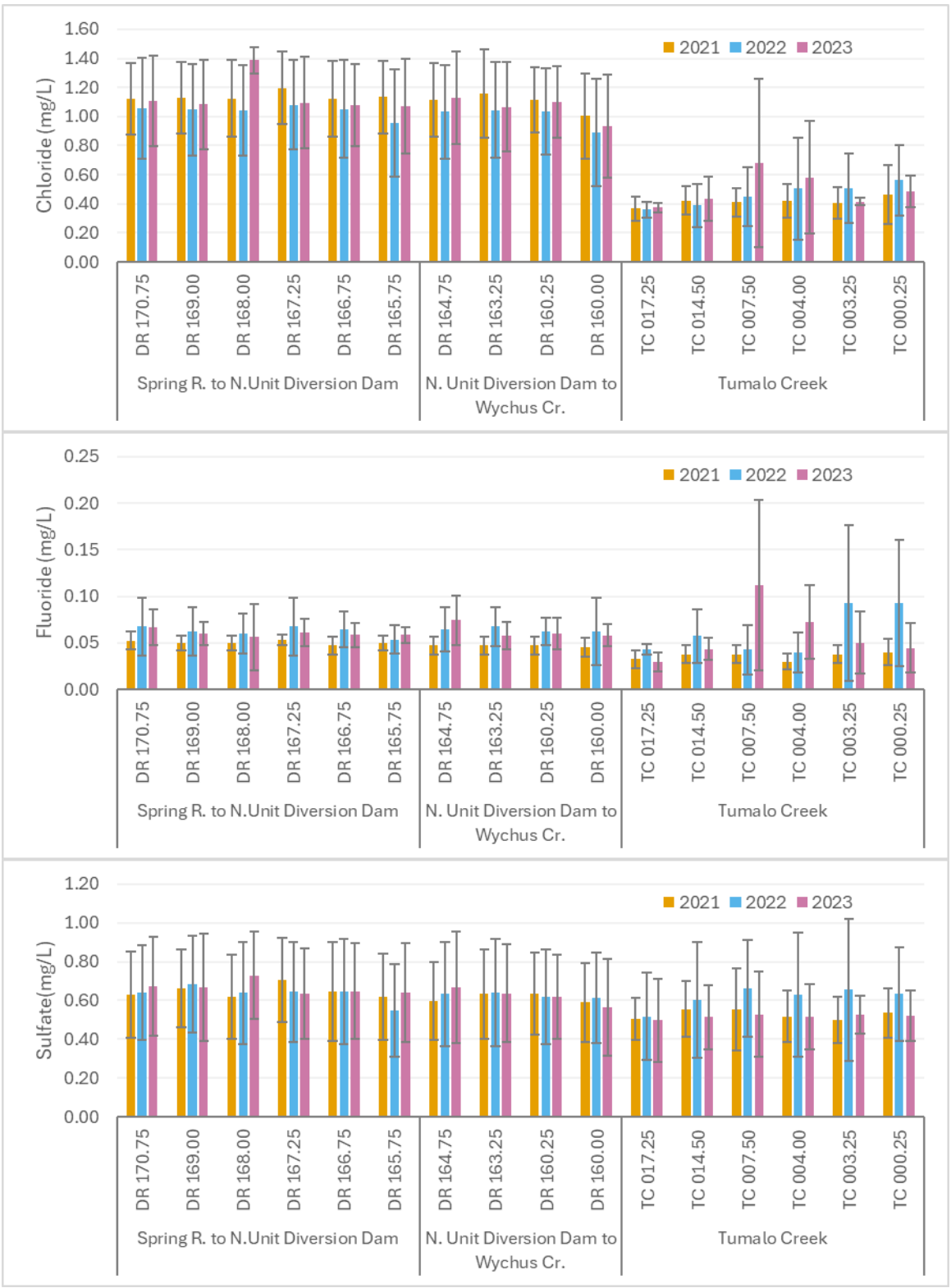

Figure 22. Deschutes River and Tumalo Creek mean annual chloride fluoride, and sulfate concentrations (± 1 standard deviation) in grab samples collected from the Spring River to North Unit Diversion Dam, North Unit Diversion Dam to Wychus Creek, and Tumalo Creek AU sites from 2021 through 2023 – City of Bend 2021 to 2023.

Total Coliform and *E. coli*

Total coliforms are a group of bacteria that exist in soil and water and are used as an indicator for other potential pathogens because they are relatively easy to identify, commonly occur in large numbers and generally respond to the environment in the same way as more detrimental pathogens. *Escherichia coli* (*E. coli*) is a major species that make up total coliforms and is found in the large intestines of humans and other warm-blooded animals. *E. coli* is used as an indicator for fecal contamination and subsequently whether pathogenic or disease-causing organisms may also be present. Samples were analyzed for total coliform and *E. coli* monthly with sampling occurring more frequently in the summer months. Monthly maximums were routinely observed during summer months.

Between 2021 and 2023, total coliform in the Deschutes River ranged from 15.8 MPN/100 mL (most probably number per 100 mL) to 2,419.6 MPN/100 mL (the upper quantification limit) and averaged 509 (SD 593) MPN/100 mL in the Spring River to North Unit Diversion Dam AU and 687 (SD 684) MPN/100 mL in the North Unit Diversion Dam to Wychus Creek AU (**Figure 23**). Total coliform in Tumalo Creek ranged from 3.1 to 1203.3 MPN/100 mL and averaged 213 (SD 251) MPN/100 mL. *E. coli* ranged greatly from less than one detection to 290.9 MPN/100 in the Deschutes River and from no detections to 95.9 MPN/100 mL in Tumalo Creek (**Figure 24**). There were not clear spatial trends in *E. coli* or total coliform concentrations. The numeric criteria for *E. coli* for freshwater contact recreation is a 90-day geometric mean of 126 organisms/100 mL and a single sample of 406 organisms/100 mL (DEQ 2018) (**Table 7**). Thus, no exceedances of *E. coli* have been observed within the study area for the period 2021 to 2023.

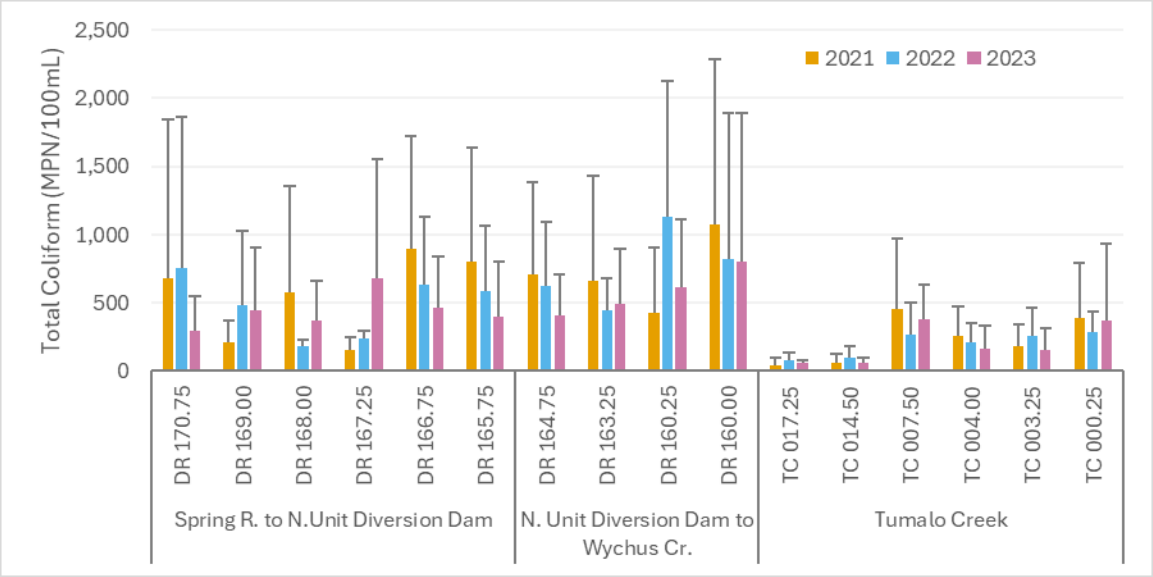

Figure 23. Deschutes River total coliform concentrations (most probable number, MPN per 100 mL) (± 1 standard deviation) in grab samples collected from the Spring River to North Unit Diversion Dam, North Unit Diversion Dam to Wychus Creek, and Tumalo Creek AU sites from 2021 through 2023 – City of Bend 2021 to 2023

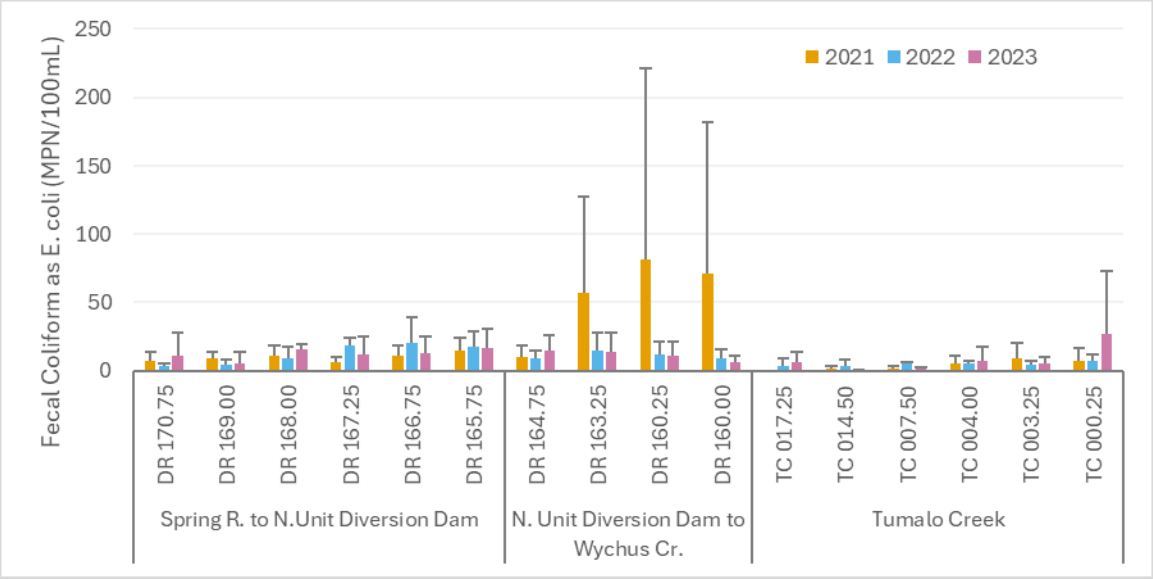

Figure 24. Deschutes River *E. coli* concentrations (most probably number, MPN per 100 mL) (± 1 standard deviation) in grab samples collected from the Spring River to North Unit Diversion Dam, North Unit Diversion Dam to Wychus Creek, and Tumalo Creek AU sites from 2021 through 2023 – City of Bend 2021 to 2023

Summary

The City of Bend has been collecting ambient water quality from the Deschutes River since 2004 and this report summarizes results of grab samples and in situ monitoring from 2021 to 2023. It is anticipated that this report will be updated annually to include results from the previous year. While there have been minor shifts in monitoring locations, improvements in analytical methods and equipment upgrades have greatly increased data reliability by decreasing instrument drift, lowering method detection limits, and reducing sensor fouling. This dataset spans an important time in the City as it sideboards an era of rapid population growth, important restoration efforts, and changes in water allocation.

Key findings and recommendations from the review of data collected from 2021 to 2023 have not changed appreciably since the 2022 report and include the following:

- Water temperatures in the Deschutes River exceeded the year-round (non-spawning) seven-day moving average maximum temperature criterion of 18°C in both AUs in the summer, occurring at a greater percentage of the time in more downstream sites compared to upstream sites. Maximum seven-day moving average maximum temperatures were cooler during 2023 than 2021 and 2022; however, the period of exceedance was similar between years (see **Table 5**). These findings are consistent with the 2022 IR 303(d) listing.
- Water temperatures in at least one site in each Tumalo Creek AU exceeded the applicable 18°C or 12°C criteria which is consistent with the 2022 IR for 303(d) listings. Maximum seven-day moving average maximum temperatures increased

considerably moving downstream from approximately 12°C from the uppermost site to approximately 20°C.

- Exceedances of pH above 8.5 occurred in at least one site in each Deschutes River AU at some point each year from 2021 to 2023. This is consistent with the 2018/2020 IR 303(d) listing for both AUs; however, the 303(d) listing for pH in the North Unit Diversion Dam to Whychus Creek AU was removed in the 2022 IR,which is not consistent with observations. The longest and most consistent summertime periods of pH exceedance were observed at the Mirror Pond site (DR 166.75) as early as late April in 2021 and as late at early November 2023. There were no pH 8.5 criteria exceedances at the site at the upstream end of the City of Bend (COID Diversion, DR 17.075) and no minimum pH 6.5 exceedances were observed at any site.

- During the period from 2021 to 2023 period, turbidity in Tumalo Creek sites (mean 1.2, SD 0.8 NTU) was half that of the Deschutes River sites and fairly consistent.

- DO concentrations met the DEQ year-round (non-spawning) 30-day mean minimum criterion of 6.5 mg/L in the North Unit Diversion Dam to Whychus Creek AU from 2021 through 2023. The 8.0 mg/L 30-day mean minimum criteria applicable for the Spring River to North Unit Diversion Dam was not met at the Mirror Pond site (DR 166.75) for short periods during the late summers of 2021 and 2022.

- The spawning period seven-day average minimum DO concentration criterion of 11.0 mg/L was exceeded at all Deschutes River sample sites each year from 2021 through 2023. Exceedances tended to start during March or April and continued through the end of the spawning period on May 15.

- Specific conductance at all Deschutes River sites was lower during the summer (near 60 µS/cm) and higher during winter (above 70 µS/cm). The lowest values were observed below the contribution of Tumalo Creek, particularly when Deschutes River flows were low. Specific conductance in Tumalo Creek averaged 38.9 µS/cm and exhibited far less seasonal variation than the Deschutes River.

- Inorganic nitrogen concentrations were consistently low at or near method reporting limits at all sites. Total phosphorus concentrations at all sites exceeded the 0.01 mg/L EPA Aggregate Nutrient Ecoregion II guidance value. Orthophosphate was also high across all sites in the Deschutes River (average of 0.056 mg/L) and Tumalo Creek (0.035 mg/L). Low nitrogen and high phosphorus levels are typical for the region due to weathering of phosphorus-rich volcanic rock in the watershed.

- Chloride fluoride, and sulfate concentrations were within EPA guidance levels..

- Between 2021 and 2023, monthly maximums of total coliform ranged greatly from 15.8 to the upper quantification limit of 2,419 MPN/100 mL in the Deschutes River and 9.8 to 1203 MPN/mL in Tumalo Creek with the lowest monthly maximums observed in January and the highest monthly maximums routinely observed during summer months.

- There were no exceedances of the 90-day geometric mean of 126 *E. coli* organisms/100 mL or single sample of 406 *E. coli* organisms/100 at Deschutes River or Tumalo Creek sites from 2021 through 2023.

- There has been interest internally as well as from the public advisory group to further investigate potential harmful algae blooms (HABs) and the conditions that could trigger a bloom in the Deschutes River. Generally, HABs are more common in slow moving water and less common in higher velocity areas. At this time, the City will follow the lead of federal agencies in the area that routinely monitor HABs. If observations increase, then the City will consider implementing more rigorous testing for total nitrogen (which is a limiting nutrient in the Deschutes) and chlorophyll a.

Recommendations.

Comprehensive water quality monitoring programs such as the one that the City of Bend implements provide an extensive amount information which can be difficult to present to interested stakeholders and residents. An interactive online map, for example an ESRI Story Map, is recommended as a platform to present technical information in a stream-lined, easy to understand environment to better connect the watershed-users with the natural resource they interact with on a daily basis.

We recommended that City of Bend data available from the entire period of record be incorporated into a comprehensive water quality database and interactive map. This data base will streamline data quality assurance, increase data transparency, and promote data sharing though online maps or similar interfaces. The database should include a data qualifier library. This should include parameter-specific data qualifying codes which allows the flexibility to review each parameter independently. Additionally, data should not be omitted be from the water quality database. With the utilization of data qualifiers, data users should be able to include/exclude data based upon the type of analysis completed.

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Appendix A:
City of Bend Water Quality Monitoring Plan

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