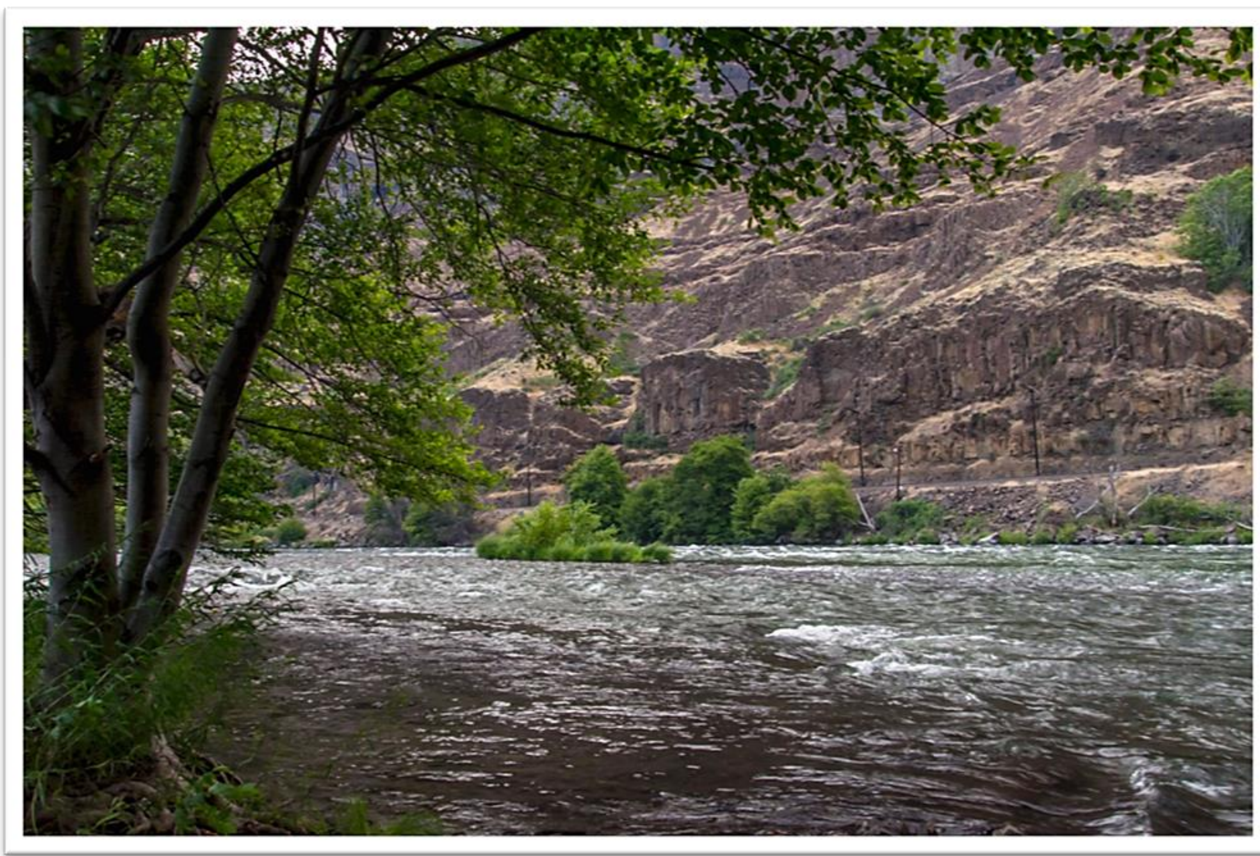
2021 LOWER DESCHUTES RIVER WATER QUALITY REPORT



Deschutes River Alliance
April, 2022

Purpose:

This report is a continuation of the Deschutes River Alliance's (DRA) annual water quality monitoring of the lower Deschutes River. It presents the known issues concerning unforeseen consequences affecting the lower Deschutes River following the installation and operation of the Selective Water Withdrawal (SWW) Tower at the Pelton-Round Butte Hydroelectric Project. As a consequence, the lower Deschutes has experienced an increase in water quality violations since the SWW Tower's installation and operation beginning in 2009.

The Deschutes River Alliance presents results from ongoing, annual water quality monitoring and explores how regional drought and low water flows from the Crooked River affect water quality in the lower Deschutes River. This report also emphasizes how small changes in operation practices at the SWW Tower could be used to mitigate known factors negatively influencing the lower Deschutes River's water quality, ecology, and local economies.

Objectives

The monitoring objectives of this study are:

1. To determine how SWW Tower operations affect the lower Deschutes River.
2. To determine how water quality parameters for temperature, pH, and DO change on an hourly and seasonal basis in the lower Deschutes River.
3. To determine if any of these parameters exceed Oregon's water quality standards for the Deschutes Basin and, if so, how frequently.
4. To assess how water quality varies seasonally and annually in the lower Deschutes River.
5. To explore plausible alternatives to the current operation practices of the SWW Tower and the Project.

Key Findings

- SWW Tower operations intentionally warm the lower Deschutes River during critical spawning and incubation periods for resident trout, spring Chinook, and steelhead.
- Drought conditions in the region promoted lower inflows of nitrogenous-based wastes from the Crooked River – resulting in a temporary improvement of water quality in the lower Deschutes River.
- Rapid increase of % bottom-draw at the SWW Tower can provide relief to fish and aquatic life by temporarily cooling the lower Deschutes River during periods of extremely high air-temperatures.
- Nutrient pollution in surface water released from Lake Billy Chinook continues to be the primary contributor to the declining health of the lower Deschutes River and is largely influenced by agricultural runoff in the Crooked River.
- High pH continued to exceed Oregon water quality standards throughout the monitoring period, but large, diel swings were less severe when compared to non-drought (wet) years and showed an immediate improvement with increased %bottom-draw.
- Dissolved oxygen concentration does not meet state standards set to protect incubating trout eggs and fry throughout observed spawning and incubation periods.
- Large diel swings in pH and dissolved oxygen indicate excess nutrients from the Crooked River and contribute to the well-documented nuisance algal growth and aquatic plant biomass accumulation in lower Deschutes River.
- Spawning redside trout were caught and released by hook-and-line anglers below Sherars Bridge on October 29, 2021.

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Acknowledgments

The Deschutes River Alliance welcomes Dan Ellis as president in 2021! It is with pleasure to say we look forward to your leadership and to share in your enduring passion for maintaining the health and preservation of the lower Deschutes River.

Thank you to Larry Marxer, Rick Hafele, and Steve Pribyl for their continued support with this year's data acquisition and analysis. A very special thanks goes to Greg McMillan - for all his hard work and perseverance with the DRA for the past nine years. You will be missed.

In addition, thank you to the organizations that have provided critical funding needed for this ongoing monitoring project: Patagonia, Clabough Foundation, Clark-Skamania Flyfishers, Jubitz Foundation, Maybelle Clark Macdonald Fund, American Fly Fishing Trade Association, and the Tualatin Valley Chapter of Trout Unlimited. As well as those not specifically listed.

Last, thanks to all those not mentioned here who care about the Deschutes River and have contributed hours of their time and money to better understand the river's changing ecology and protect its health. Many hundreds of people and numerous companies and foundations have made it possible to keep this work moving forward - THANK YOU.

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List of Abbreviations

CFS - Cubic Feet per Second

CTWSRO - Confederated Tribes of the Warm Springs Reservation of Oregon

DO - Dissolved Oxygen

DRA - Deschutes River Alliance

IGDO - Intergravel Dissolved Oxygen

OAR - Oregon Administrative Rules

ODEQ - Oregon Department of Environmental Quality

ODFW - Oregon Department of Fish and Wildlife

PGE – Portland General Electric

Project - Pelton Round Butte Hydroelectric Project

RM - River Mile

SWW Tower - Selective Water Withdrawal Tower / Tower

USBR - United States Bureau of Reclamation

USGS - United States Geological Survey

WQMMP - Water Quality Management and Monitoring Plan

7-DADM - 7-Day Average Daily Maximum

Background:

The lower Deschutes River, Pelton-Round Butte Hydroelectric Project, Licensees, and the Selective Water Withdrawal Tower:

The 252-mile-long Deschutes River runs south to north and is broken into three segments: the upper, middle, and lower Deschutes (Appendix D). The lower Deschutes River (LDR) begins in the tailrace of the downstream most dam of the Pelton-Round Butte Hydroelectric Project (Project), a three-dam complex (Figure 1) jointly owned by licensees Portland General Electric (PGE) and the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO). The LDR runs 100 miles north to where it (River Mile 0) converges with the Columbia River.

Start of lower Deschutes River (River Mile 100)

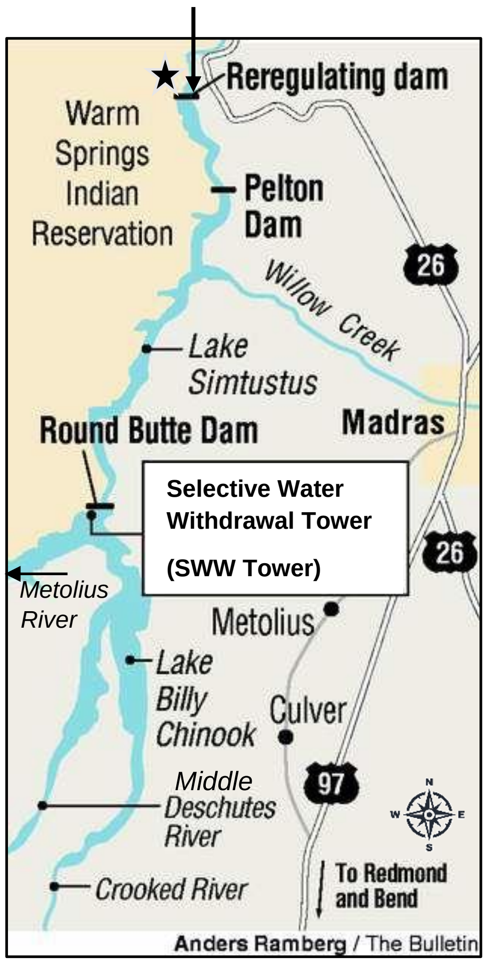

Figure 1. The Pelton-Round Butte Hydroelectric Project and Selective Water Withdrawal Tower owned by Portland General Electric and the Confederated Tribes of Warm Springs, Oregon. Round Butte Dam (creates Lake Billy Chinook reservoir), Pelton Dam (creates Lake Simtustus reservoir), and the Reregulating Dam (creates the Reregulating reservoir). The lower Deschutes River originates from the tailrace of the Reregulating Dam. Map adapted from original source.

In 2004, licensees PGE and the CTWSRO received a new operating license from the Federal Energy Regulatory Commission (FERC) allowing the generation of hydropower until 2054. Under the new FERC license, licensees were required, among other things to **1) reestablish both upstream and downstream passage of anadromous fish through**

the 3-dam Project, 2) improve water quality in both Lake Billy Chinook (LBC) and in the lower Deschutes River and 3) monitor and report a variety of water quality parameters on an annual basis to FERC, the Oregon Department of Environmental Quality (ODEQ), the Oregon Department of Fish and Wildlife (ODFW), the CTWSRO Water Control Board, and the Pelton-Round Butte Fish Committee (PGE et al. 2004).

To meet these requirements, PGE and the CTWSRO constructed the Selective Water Withdrawal (SWW) Tower in 2009 (Figure 1). A thorough discussion of the Tower's construction and operation is covered in the Deschutes River Alliance's 2016 water quality report (DRA 2017).

Relicensing Requirements: Anadromous fish passage, improved water quality, and impact monitoring:

1) Anadromous fish passage: During the spring and early summer the SWW Tower is operated to maximize surface draw in an attempt to create a surface current in LBC to help guide out-migrating juvenile salmonids through the reservoir to a collection facility at the SWW Tower (Figure 2). After capture, juveniles are trucked around the Project downstream and placed into the lower Deschutes River where they recover before being released to continue their migration to the ocean.

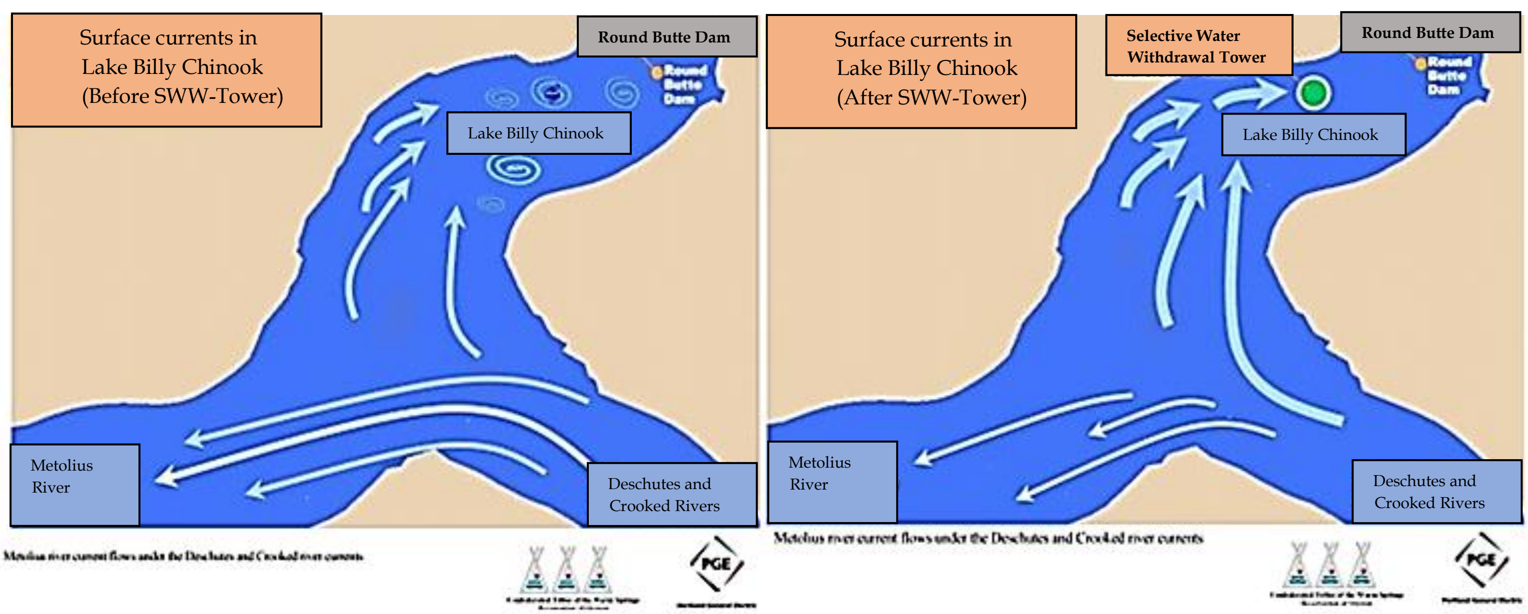

Figure 2. Currents in Lake Billy Chinook pre-and-post Tower. Taken from UO Blog "Dam Operator in 'HotWater' on Lower Deschutes" posted 05/08/2017.

Returning adults are captured at the Pelton Trap (located immediately downstream from the Reregulation Dam), trucked around the Project upstream, and released into the forebay of LBC. The expectation for these adults is that they will swim into one of the three tributaries entering LBC (the Crooked, Deschutes, or Metolius rivers) and hopefully spawn. It should be noted that this scheme does not meet any definition of volitional fish passage, as both juvenile and adult fish must be trapped and moved around the Project to complete their migration to and from the ocean.

2) Improved water quality in LBC and lower Deschutes River: To facilitate the downstream migration of anadromous juveniles, the SWW Tower draws and releases 100% surface water in an attempt to create a current (Figure 2) to help out-migrating smolts move through the reservoir to a collection facility at the SWW Tower. At times, when juveniles are not migrating, the SWW Tower can blend surface and bottom water in an effort to manage water temperature and water quality in the lower Deschutes River. The point of compliance for the license's water quality permit is where the water is released from the Reregulation Dam.

From approximately November 1st to June 15, 100% surface water is released from the SWW Tower. For the remainder of the year, "blended" water (a percent of surface water and up to 65% bottom-water) is released from Round Butte Dam. Blends are adjusted in an attempt to recreate a "Without Project Temperature (WPT)." The WPT is the Licensees' attempt to mimic a hypothesized pre-Project water temperature regime in the lower Deschutes River (i.e., as if the dams didn't exist). Models for these blends have changed multiple times since the construction of the SWW Tower in an effort to adequately manage water temperatures downstream. Unfortunately, the baseline conditions used in these models come from a sparse collection of data taken from a short window in the 1950's. Importantly, these data are thought to come from a period when historical accounts paint the Deschutes Basin in disarray due to high temperatures and poorer riverine conditions caused by over-grazing of riparian areas and proximal land use (East of the Cascades, A Peculiar River, Oregoncyclopedia.org).

After impoundment but prior to the construction of the SWW Tower (from 1964 to 2009), water released from LBC through Round Butte Dam consisted solely of cold hypolimnetic water from the bottom of the reservoir. As a result, water released pre-Tower was lower in nutrients and was colder than water now released through the SWW Tower (Figure 3). One justification for current water release practices is to increase downstream water temperatures during the winter through early summer, in order to "save cooler water for release in the fall" (Figure 3) (PGE, Monitoring Water Quality).

Water temperature data from 2006-2009 (pre-SWW Tower) at RM 100.1 shows that pre-Tower water temperatures peaked in early September (Figure 3). However, from 2016-2020 water temperatures peaked in late June-early July following PGE's attempt to follow the latest modeled blend to mimic without project temperatures (DRA 2017; DRA 2018; DRA 2019c). Current modeling of pre-Project temperatures takes the 7-day maximum average temperatures of the three tributaries (weighted by flow) entering Lake Billy Chinook to calculate maximum effluent temperatures. This has led to a sustained increase in water temperatures from the Project that do not reflect the natural daily temperature fluctuations of the tributaries entering the Project. Effects from this shift in peak annual water temperature have led to earlier emergence (four to six weeks) of most major insect hatches on the river. Changes in trout spawning have also been observed and documented by the DRA, but currently there are no studies underway to discover the effects early hatching of aquatic insects has on the resident trout population. While serious and alarming, the further effects of this shift in the lower Deschutes' temperature regime on other species and the larger river ecology are poorly documented or understood.

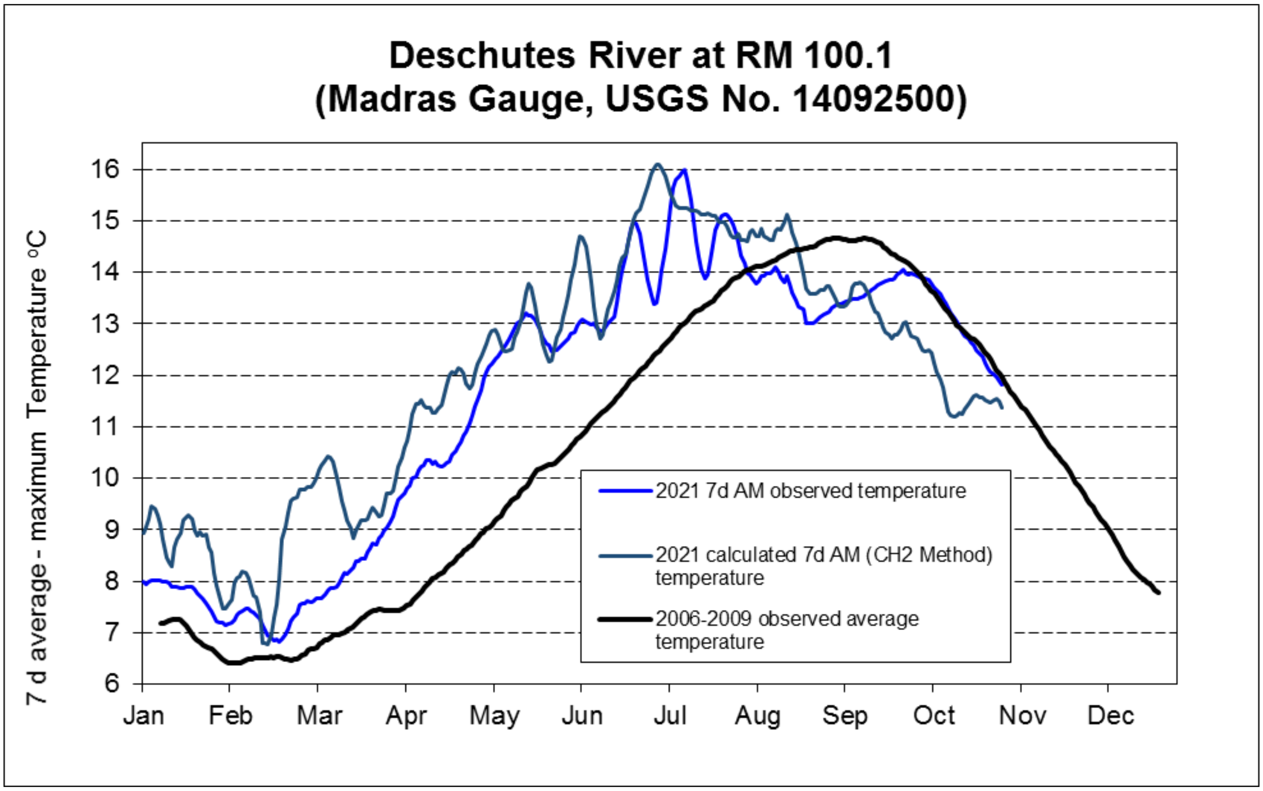

Figure 3. Intentional shift in water temperatures of the lower Deschutes River as a result of SWW Tower operations (taken from PGE's annual Water Quality Monitoring Reports).

3) Annual water quality monitoring and reporting: As part of the Project's Clean Water Act Section 401 permit required by Oregon and FERC to operate the project, the Oregon Department of Environmental Quality mandated that Licensees follow a Water Quality Management and Monitoring Plan (WQMMP) to continually monitor the impact(s) SWW Tower operation may have on the lower Deschutes River.

To comply, PGE submits monthly water monitoring data to DEQ, and releases an annual report on their findings. Additionally, PGE engaged with MaxDepth Aquatics, Inc. to help determine the effects of the SWW Tower on water quality and the ecology of LBC and the lower Deschutes River. From 2015-2017, MaxDepth Aquatics collected data from the three tributaries entering Lake Billy Chinook, the three reservoirs (Lake Billy Chinook, Lake Simtustus, and Regulating reservoirs) formed by the Project, and from multiple locations throughout the lower Deschutes River. Their final report - *Water*

Quality Study for the Pelton Round Butte Project and the Lower Deschutes River: Monitoring & Modeling, (hereinafter: PGE Water Quality Study) was released in June 2019 by Joseph Eilers and Kellie Vache of MaxDepth Aquatics, Inc. but has since been modified and rereleased as of March 2021. Their post-Tower ecological assessment documents extensive changes in the lower Deschutes' water temperature, water quality, and the benthic algal community as the result of SWW Tower operations. This report is discussed in depth on our website and in subsequent sections of this report.

Established Findings

The following is a brief summary of established findings consistent among three independent monitoring entities: PGE's annual WQMMP's data & reports, conclusions from Max Depth Aquatics Inc.'s report discussed above, and the ongoing Deschutes River Alliance's annual water quality monitoring program:

1. Water released from the SWW Tower discharges a disproportionate amount of surface water from Lake Billy Chinook from winter through early summer relative to historical conditions.

2. Current operation of the SWW Tower intentionally warms the lower Deschutes River winter through summer compared to pre-SWW Tower temperatures.

3. Surface water in Lake Billy Chinook is comprised primarily of lower quality water from the Crooked River[1] as a result of regional land uses (municipalities and agriculture) in the Crooked River Basin.[2] Nutrient pollution from the Crooked River in Lake Billy Chinook is higher for nitrates (NO3) compared to the nitrate contributions from the Metolius and Deschutes rivers.[3] Agricultural pollutants, including the pesticide chlorpyrifos, have been reported in the lower Deschutes River by ODEQ at levels that exceed the toxicity limits for fish, other aquatic life forms, and humans set by the Environmental Protection Agency.[4]

4. After construction of the dams and before SWW Tower installation, water released from LBC was 100% bottom water, which is comprised almost entirely of the colder, cleaner Metolius River water. Historically, the lower Deschutes River was a blend of nearly equal amounts of Crooked River water and Metolius River water (the middle Deschutes River contributed a minor amount of water) prior to dam construction in 1964.

5. High daytime pH and large diel swings in both pH and dissolved oxygen (DO) concentrations indicate that the lower Deschutes River has become eutrophic.[5]

6. Operations at the SWW Tower release planktonic, free-floating algae and cyanobacteria (not commonly found in natural, free-flowing streams) from the surface of Lake Billy Chinook into the lower Deschutes River; causing, among other things like further nutrient transfer, a murky appearance in the lower Deschutes River (Eilers & Vache 2019).

[1] Deschutes Basin Water Quality Status and Action Plan—Summary 2011 (ODEQ 2012)
[2] DRA Water Quality and Land Use Report (DRA 2019b)
[3] DRA Lake Billy Chinook Water Quality Study Results (DRA 2016)
[4] 2018/2020 Integrated Report (ODEQ 2018/2020)
[5] DRA Lower Deschutes River Water Quality Reports (DRA 2015, 2017, 2018, 2019c)

7. Both increased water temperature and nutrient pollution from Lake Billy Chinook cause excessive algal growth including both green algae (mainly *Cladophora*) and nuisance diatom species forming felt-like mats of algae on stream substrate in the lower Deschutes River.[6]

[6] Lower Deschutes River Macroinvertebrate Hatch Activity Survey Results (Hafele 2014)

Introduction

SWW Tower:

The DRA believes that construction and operation of the SWW Tower in 2009 is undoubtedly one of the greatest anthropogenic changes imposed on the lower Deschutes River since the initial completion of the Pelton Round Butte Hydroelectric Project in 1964. The SWW Tower allows operators to release up to 100% surface water from Lake Billy Chinook at any time and any duration. Water (surface or a blend of surface and bottom water) is only released from LBC (via Round Butte Dam) during periods of power production at the Round Butte Dam. When the turbines in the dam are not running, water is not released from Lake Billy Chinook. The Project is managed to reflect a run-of-the-river system, meaning that the flows entering Lake Billy Chinook must eventually equal the flows exiting the Project (within 10%). Constant streamflow in the lower Deschutes River is maintained by the continued release of water from the Reregulation Dam (the third and most downstream dam of the three-dam complex) (Figure 1).

Prior to the construction of the SWW Tower in Lake Billy Chinook, all water released from Round Butte Dam was 100% bottom-draw. Upon installation of the SWW Tower, all water released from Lake Billy Chinook passes through the SWW Tower (unless it is spilled for flood control). It should be noted that there appear to be constraints at the SWW Tower that restrict it from releasing more than 60-to-65% bottom-draw. Reasons for these constraints have not been publicized; yet we surmise that 100% bottom draw is no longer possible since that has never been reported by PGE since operation of the SWW Tower started and no explanation has been given. This constraint appears to be the result of some unforeseen engineering or construction failure.

SWW Tower operation:

PGE has regularly experimented with blending changes at the SWW Tower to meet requirements of relicensing agreements for discharge temperature, among other things. One potential blending model discussed in the PGE Water Quality Study that DRA believes could improve conditions in the lower Deschutes is a scenario called the "Night blend[7]." The "Night blend" draws and releases 100% surface water at night from March through June 15th to utilize the nocturnal migration behavior of juvenile anadromous fish and to help them navigate through Lake Billy Chinook to the collection facility at the SWW Tower (PGE: Our Story…) in hopes of improving in-reservoir passage of juvenile salmonids.

[7] To attract smolts to the Tower's fish trap 100% surface water is released from the Tower to create attractive surface currents. However, water is only released from LBC when water is run through the dam's turbines to produce electricity, and power production only occurs during part of the day. The use of the "night blend" approach means all of the surface water released from the Tower takes place at night, and that power production also occurs at night.

The modeling from the PGE Water Quality Study indicates that the "Night Blend" provides slight improvements to multiple water quality parameters in the lower Deschutes in addition to the enhanced capture rate of out-migrating juvenile anadromous fish (Eilers & Vache 2019), two things we support and believe are achievable.

Lake Billy Chinook:

Temperature stratification of Lake Billy Chinook occurs each year and generally follows the same pattern demonstrated at other lakes at similar latitudes. In the case of Lake Billy Chinook, thermal stratification means that surface water is composed primarily of warmer, nutrient-laden water from the Crooked River, which carries a higher concentration of nutrients and other pollutants. These surface nutrients, however, are in a dynamic relationship with algal growth and density. When algal blooms occur during the summer, most of the nutrients are consumed resulting in dense populations of algae and diatoms. Yet, with SWW Tower operation, these algae are now released downstream (as seston) into the lower Deschutes where their cells breakdown either naturally or by being mechanically damaged in the power production turbines through which they much pass and release their nutrients back into the water. Prior to the release of surface water from the SWW Tower, Lake Billy Chinook acted as sequestration reservoir; where excessive nutrients were absorbed by algae, decomposed, and in effect, bioremediated in the 300' deep reservoir. Their release (or rather, lack of) from the bottom of Round Butte Dam had fewer negative effects on the lower Deschutes River and resulted in the less nutrient rich water in the lower Deschutes prior to the SWW Tower. Additionally, water released from at or near bottom of Lake Billy Chinook is comprised primarily of the much colder and cleaner Metolius River water due to reservoir geology and stratification dynamics resulting in not only cleaner but colder water being discharged into the lower Deschutes River.

DRA Position statement:

The DRA advocates for returning to the release of the maximum amount of bottom water from Lake Billy Chinook into the lower Deschutes River while still providing surface withdrawal during peak smolt migration. DRA has shown that releasing a higher percentage of bottom water for a longer duration could provide immediate relief to the declining water quality in the lower Deschutes River. The DRA also supports changes to anadromous fish capture-and-release practices at the Project to maximize the possible success of anadromous fish reintroduction above the Project. A complete position statement is available here on our website.

DRA believes that the available records support the concept that for the long-term health of the entire basin, the water quality and quantity from the lower Crooked River ultimately needs improvement. By virtue of the location of the Crooked River as it enters Lake Billy Chinook and thermal stratification there for long periods of the year, the majority of surface water in Lake Billy Chinook is comprised of the Crooked River and is subsequently released directly into the lower Deschutes River through the SWW Tower. Unfortunately, even under the most optimistic scenarios, large-scale improvements to the Crooked River watershed will take decades to significantly improve water quality. The DRA's monitoring work in the lower Crooked River is presented in a separate report found here: 2020 Crooked River Water Quality Report. See also DRA's Crooked River Basin GIS water quality report (Mapping Water Quality and Land Use in the Crooked River Basin).

Based on the data presented in the PGE Water Quality Study, results from PGE's annual water quality monitoring reports, and annual water quality monitoring by the DRA, we believe that the installation and operation of the SWW Tower has resulted in numerous unintended consequences that negatively impact the lower Deschutes River. These consequences include but are not limited to degraded water quality, harmful impacts to resident and anadromous fish, and negative effects on the river ecology by releasing warmer, nutrient-laden water from the surface of Lake Billy Chinook (LBC) from winter through early summer.

DRA has implemented several studies independent of those by PGE in order to assess the impacts of the Tower on aquatic life and water quality. Results of these studies are published in annual reports and are available to the public on our website. This report presents the results from our continued water quality monitoring of the lower Deschutes River for the 2021 monitoring season and continues to advocate for changes in SWW Tower operations that could immediately improve water quality and benefit the health of the lower Deschutes River.

Sampling Methods and Procedures

Annual Water Quality Monitoring

We continued our commitment to monitor water quality at river mile (RM) 99 of the lower Deschutes River in 2021 (Figure 5). However, due to accessibility limitations at the historical monitoring location in 2021, the DRA relocated its monitoring site slightly upriver, a change we believe did not affect results or observations compared to previous monitoring years.

One multi-parameter YSI 6600 V2 data sonde (Figure 4) was used to collect hourly measurements for dissolved oxygen, pH, temperature, and turbidity in 2021. Sonde maintenance and supply chain issues prevented the initial deployment of the YSI EXO2 sonde used in previous years (2016-2020).

Before deployment, the YSI 6600 V2 was tested and calibrated to lab standards and programmed to record hourly readings of the following water quality parameters: temperature, DO, pH, conductivity, and turbidity. Each probe had individual self-cleaning wipers to eliminate inaccurate results caused by biofouling (Figure 4).

Figure 4. YSI 6600 V2 multi-parameter data sonde (left) and YSI 650 MDS Handheld (right).

From May 08, 2021, 1100 hours through December 6, 2021, 1400 hours a single multiparameter YSI 6600 V2 data sonde (Figure 4) was deployed using the YSI 650 MDS Handheld at the new DRA monitoring site below the Reregulating Dam tailrace in RM 99 of the lower Deschutes River (Figure 5). This monitoring site is close enough to the Reregulating Dam tailrace to eliminate external influences on water quality, yet far enough downstream to allow the river to stabilize after its release from the Project. The data sonde was deployed in three feet of laminar flow with probes positioned four to six inches above the stream bottom, a commonly desired positioning to achieve consistent and accurate measurements.

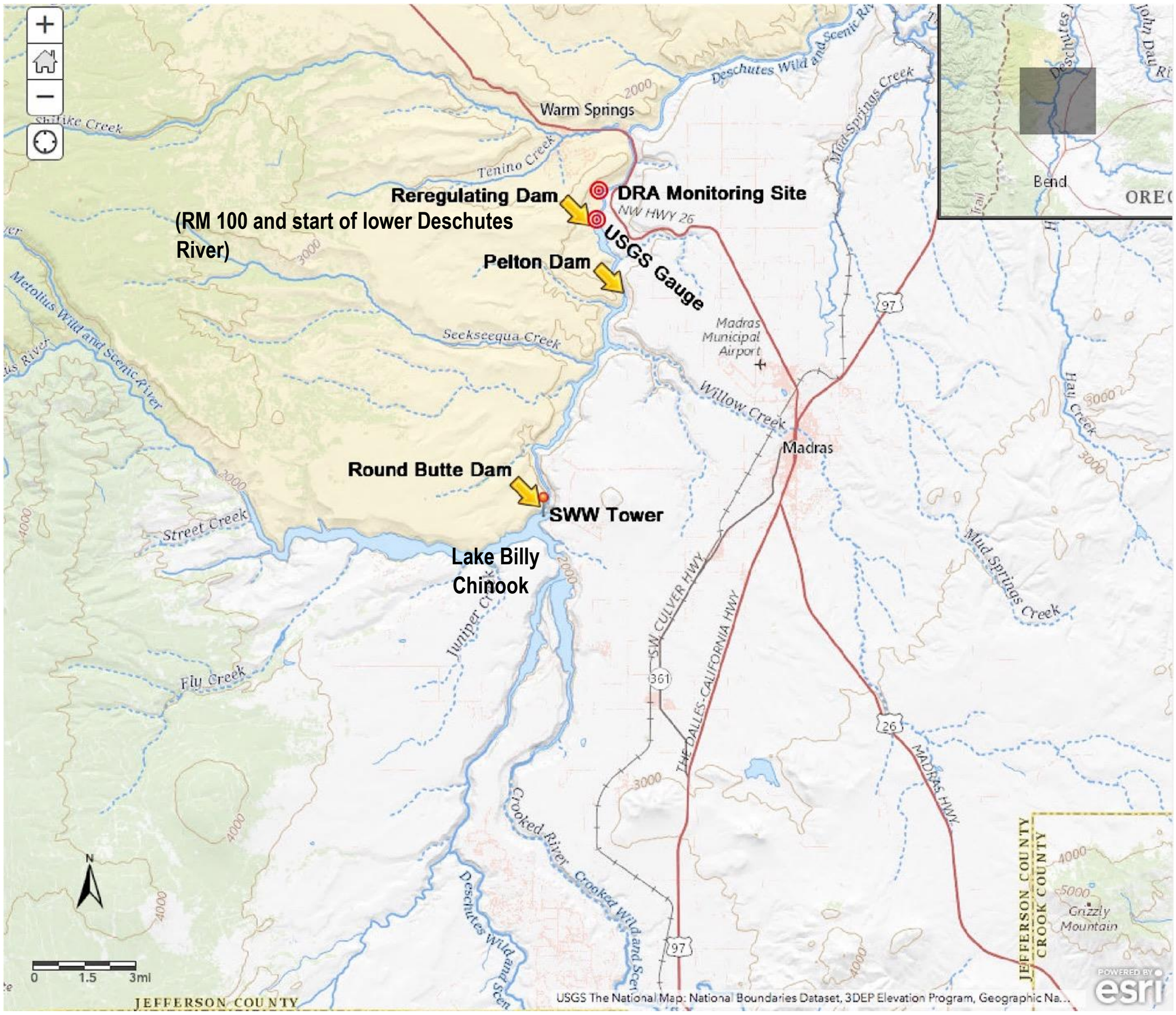

Figure 5. Topographical view of the Project with approximate placements of USGS Madras gauging station and DRA monitoring site(s) located downstream of the Reregulating Dam in RM

Data audits of the sonde sensors were conducted at the time of initial deployment and repeated during monthly field audits. Field probes independent of the data sonde were used to compare accuracy of deployed sonde sensors throughout the season (Appendix A). Data downloads were made during several field audits and batteries were replaced as needed. The final field audit and data downloads were completed when the sonde was removed from the river on December 6, 2021, at 1400 hours. Quality control and assurance procedures were followed throughout the study (Appendix B).

In addition to monitoring water quality, the DRA collected weather data from The Dalles Municipal Airport, from the National Oceanic and Atmospheric Administration Climate Charts database for Redmond, OR, and from the University of Nebraska-Lincoln to determine differences in annual precipitation and air temperature in the Deschutes Basin (Appendix C). Furthermore, the DRA monitors and uses data from the USGS National Water Information System: Web Interface water resources page to report on annual flow rates and water temperature changes from the origin of the lower Deschutes (RM 99, Madras Gauge) to its mouth (RM 1, Moody Gauge).

Results

Temperature:

Hourly temperature measurements from May 08 to December 06, 2021, are shown in Figure 6. The graph shows the seasonal changes and daily ranges. The average difference between the daily minimum (occurs just before sunrise) and daily maximum (typically around 3pm) was 0.67°C (~1.2°F). The maximum daily temperature range was 2.59°C (4.66°F) on August 16 and the minimum daily temperature range was 0.07°C (0.13°F) on November 2. The maximum daily recorded temperature reached 16.08°C (60.98 °F) on July 7th.

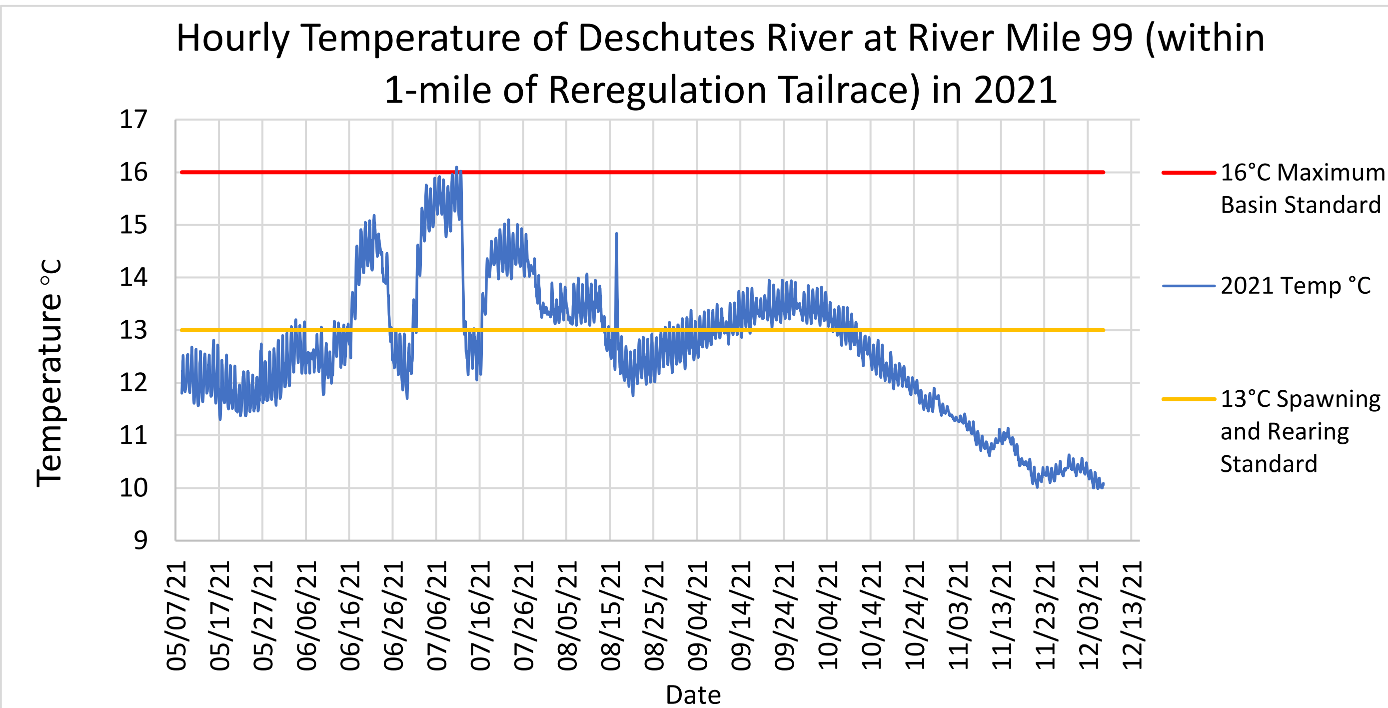

Figure 6. 2021 Hourly water temperature at River Mile 99 of the lower Deschutes River with the basin core-cold water habitat maximum temperature standard (16°C) shown with a red line. Maximum temperature during spawning periods (January 1st – June 15th for salmon and steelhead), is shown with a yellow line.

7-Day Average Daily Maximum Temperature:

Oregon's maximum water temperature standard is based on a 7-day moving average of the daily maximum water temperatures or "7-DADM." The standard applied in the lower Deschutes River from below the Project downstream to the confluence with the Warm Springs River is 16°C (60.8°F) for core cold-water habitat use (see red line in Figure 3; Appenxid D for maps and criteria). A lower water temperature standard (13°C; 55.4°F) is applied during periods identified as having salmon and steelhead spawning use. Figure 7 shows the 7-day average daily maximum temperature (7-DADM) at the DRA monitoring site in 2021. Orange highlight shows the salmon and steelhead spawning/incubation period, and the green highlight shows the actual resident trout spawning/incubation period continuing until at least early September (Zimmerman & Reeves 2000). The 13°C maximum temperature standard (OAR 340-041-0028) applies until the end of the salmon and steelhead spawning/incubation period on June 15. In 2021, the 7-DADM exceeded the applicable basin standard for salmon and steelhead spawning from June 2nd - June 5th, June 9th, and from June 12th until October 12th except for a brief period from August 17th-26th. While Oregon's 13°C maximum temperature standard does not currently apply to resident trout spawning/incubation, it is widely documented that cooler water temperatures during this time period are thought to provide better survival of resident trout eggs and fry.

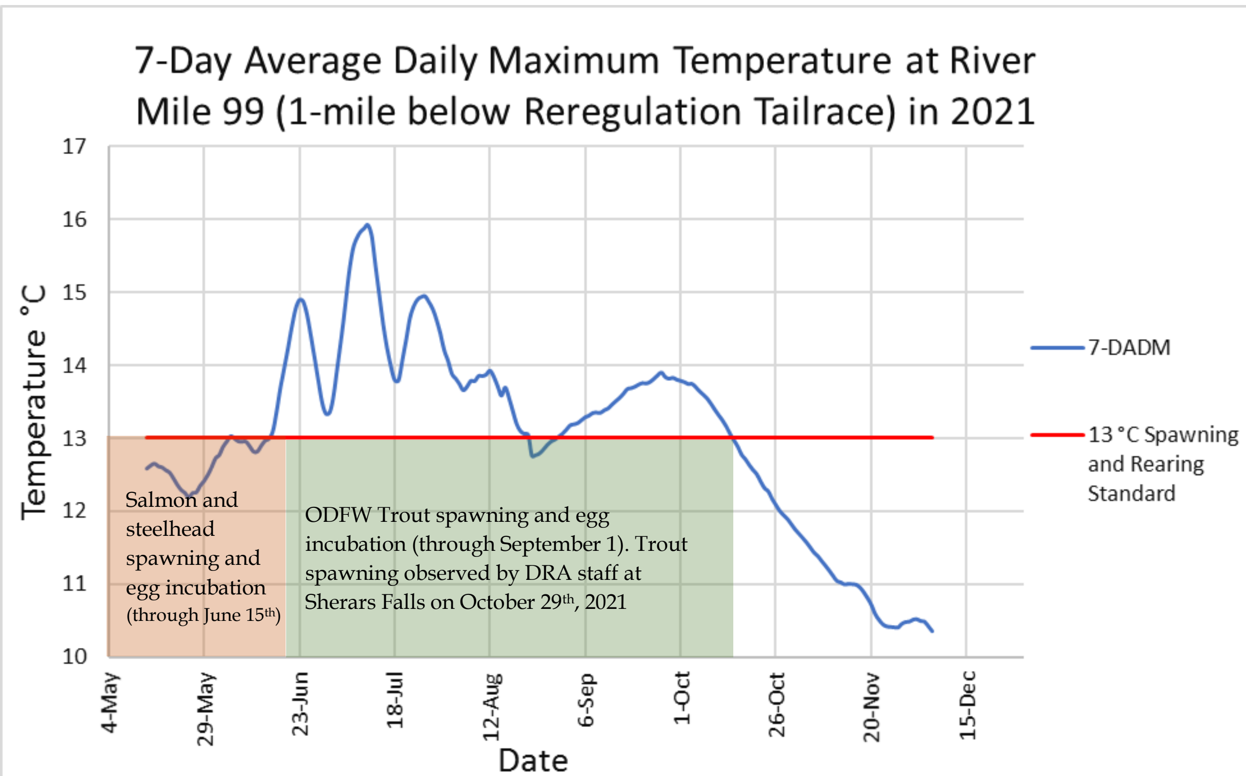

Figure 7. 2021 7-DADM water temperature at River Mile 99 of the lower Deschutes River with the maximum temperature standard during spawning and rearing times (January 1st – June 15th for salmon and steelhead) show with a red line (13°C).

Dissolved Oxygen:

Dissolved oxygen (DO) is measured and recorded in two ways: 1) the concentration in milligrams per liter (mg/L), and 2) the percent of oxygen dissolved in the water (% saturation) based on where the sample was collected (i.e., temperature, elevation, and barometric pressure). In most cases it is the concentration (mg/L) of DO that is applied to water quality standards. However, when the DO concentration (mg/L) standard cannot be achieved due to temperature, elevation, and barometric pressure conditions, the % saturation criteria is applied when evaluating whether DO water quality standards are met.

Oregon's water quality standard for DO is higher during the salmonid spawning and incubation season than during salmonid rearing season. The DO standard applied by ODEQ for the lower Deschutes River during steelhead and salmon spawning (currently designated as October 15 - June 15 at the monitoring site) is a minimum of 11.0 mg/L with a lower acceptable limit of 9.0 mg/L when adequate intergravel dissolved oxygen (IGDO) is available. This same standard also applies during resident trout spawning through incubation, which is believed to take place as early as February and as late as December in the lower Deschutes. A three-way DO minimum standard is applied by ODEQ to days outside the designated salmon/steelhead spawning period (October 15-June 15): a 30-day mean minimum of 8.0 mg/L, a 7-day minimum mean of 6.5 mg/L, and a 6.0 mg/L absolute minimum value (Appendix D). ODEQ's current application of the DO standard in the lower Deschutes does not protect resident trout spawning/incubation as required in Oregon's water quality standards. Further explanation of Oregon's DO standard and its application to the lower Deschutes River below the Project is covered in the Discussion.

Figures 8 and 9 show the daily DO levels as mg/L and % saturation, respectively, from May 08 to December 06, 2021. The red and yellow lines in Figure 9 show the DO criteria and standards applied during salmon and steelhead spawning. The area highlighted in pink indicates the designated salmon and steelhead spawning period, and the area highlighted in blue indicates trout spawning through fry emergence.

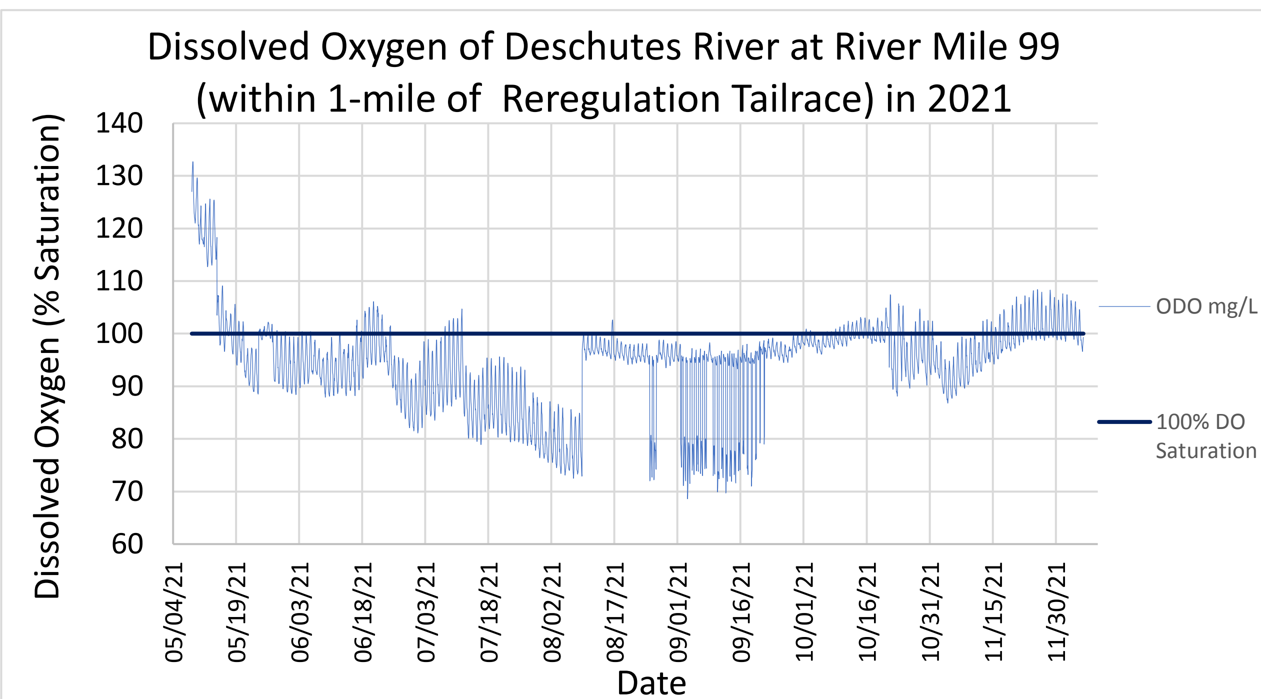

Figure 8. 2021 Hourly dissolved oxygen percent saturation (%Sat) at River Mile 99 of the lower Deschutes River. 100% saturation is shown with a dark-blue, horizontal line for reference.

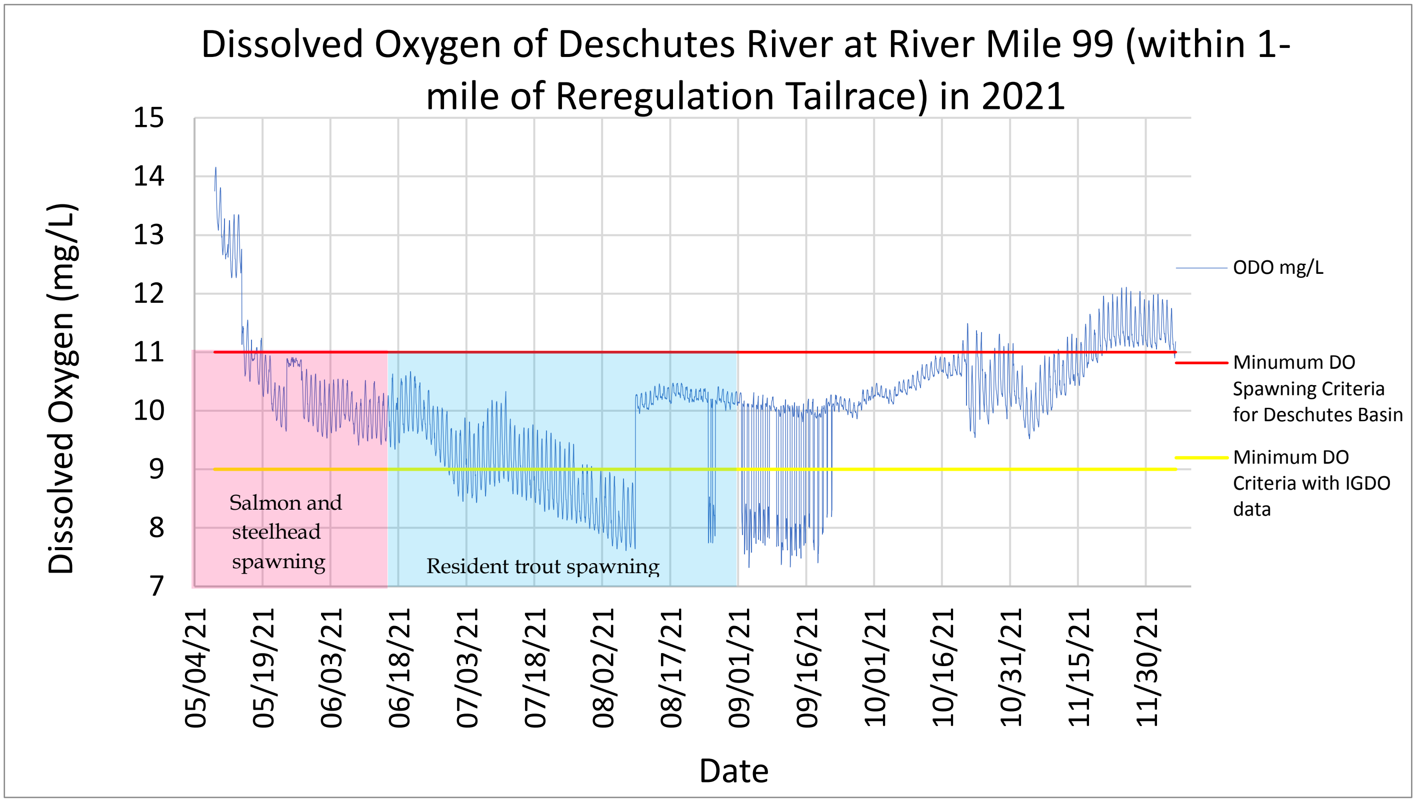

Figure 9. 2021 Hourly dissolved oxygen concentration (mg/L) at River Mile 99 of the lower Deschutes River. The red and yellow lines show the minimum dissolved oxygen basin standards based on two separate criteria. Designated salmon and steelhead spawning period highlighted in pink until June 15th, with residential trout spawning highlighted through September 1st in blue.

DO % saturation was primarily within 90-110% from mid-May to late-June 2021 (Figure 8). The daily maximum dissolved oxygen % saturation fell below 100% first on May 23, and then consistently declined after June 25 until August 10. Minimum daily DO levels fell to a low of 67.7% on September 11, 2021. Large diel swings were seen for both DO concentration (mg/L) and in DO % saturation (range: 70-100%) from July-September 23 except for August 10-26. Such large daily swings are indicative of excessive algal growth due to nutrient enrichment. From September 25 through December 06, DO % saturation was within a range of approximately 90-105%.

pH:

Figure 10 shows the hourly pH measurements recorded from May 08 - December 06, 2021. As with temperature and DO, the amplitude of the line shows the daily swing in pH over a 24-hour period. The red line shows the basin standard upper limit (8.5 standard units). Maximum daily pH levels typically occur mid-afternoon between 1400 and 1600 hours, while minimum pH occurs early in the morning (just before sunrise) due to daily changes in photosynthetic activity of aquatic plants and algae: pH rises with increased photosynthesis and drops when photosynthesis declines. An increase in the range of pH between early morning and mid-day (shown by the amplitude of the line) indicates greater plant biomass and sunlight exposure, resulting in more photosynthesis.

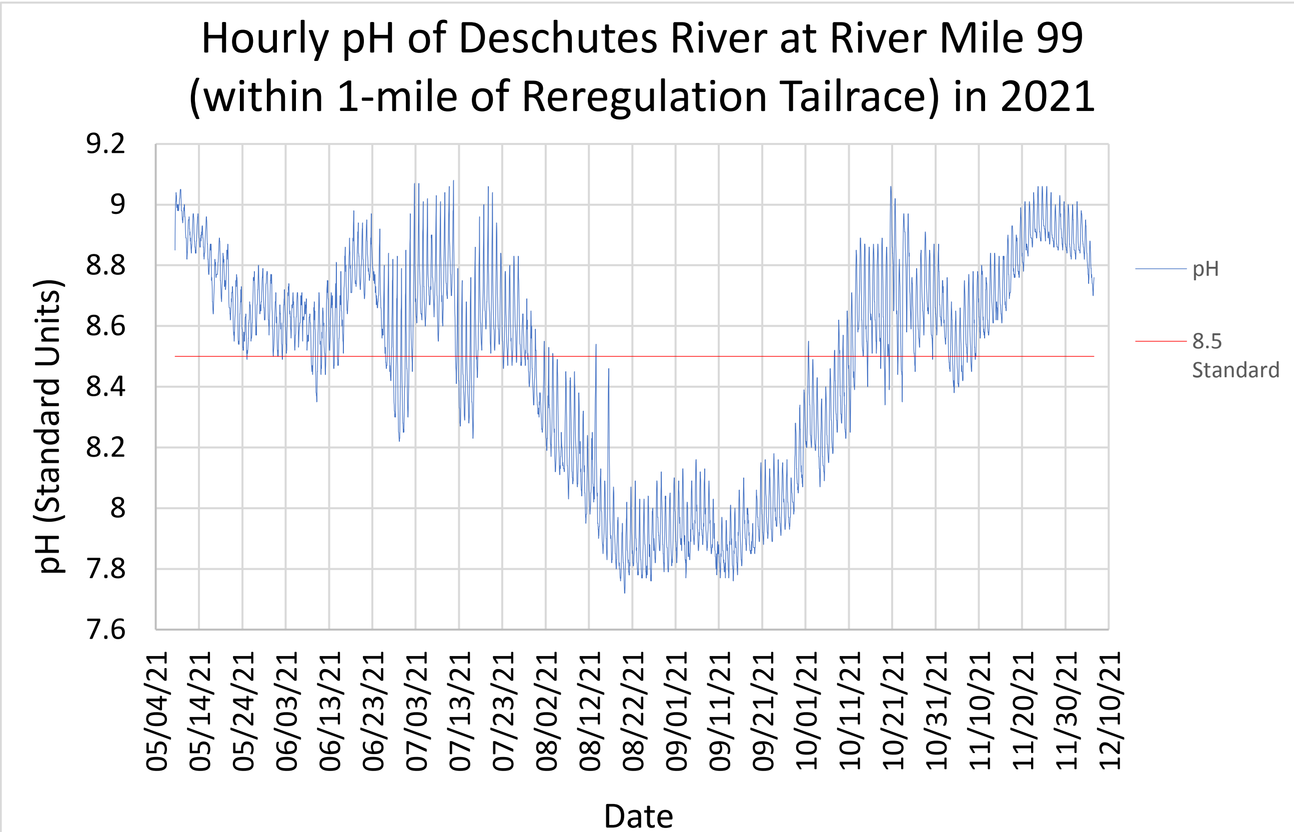

Figure 10. 2021 Hourly pH (standard units) at River Mile 99 of the lower Deschutes River with basin upper limit of 8.5 standard units shown with a red line**.**

From initial deployment on May 08, pH exceeded the basin pH standard consistently until August 01 (Figure 10). The maximum recorded pH was 9.08 on July 11, 2021, at 1800 hours and the lowest recorded pH was 7.72 on August 20, 2021 at 1500 hours. pH adhered to the basin standard from August 04 to October 07, 2021 (except for two daily maximums) until it again consistently exceeded the 8.5 standard each day until the end of the monitoring period on December 06, 2021. Figure 11 contains the recorded daily maximum pH in 2021 and outlines a dramatic drop in pH following a significant increase in % bottom-draw that occurred on July 10. This large drop in pH is explored in greater detail in the discussion section.

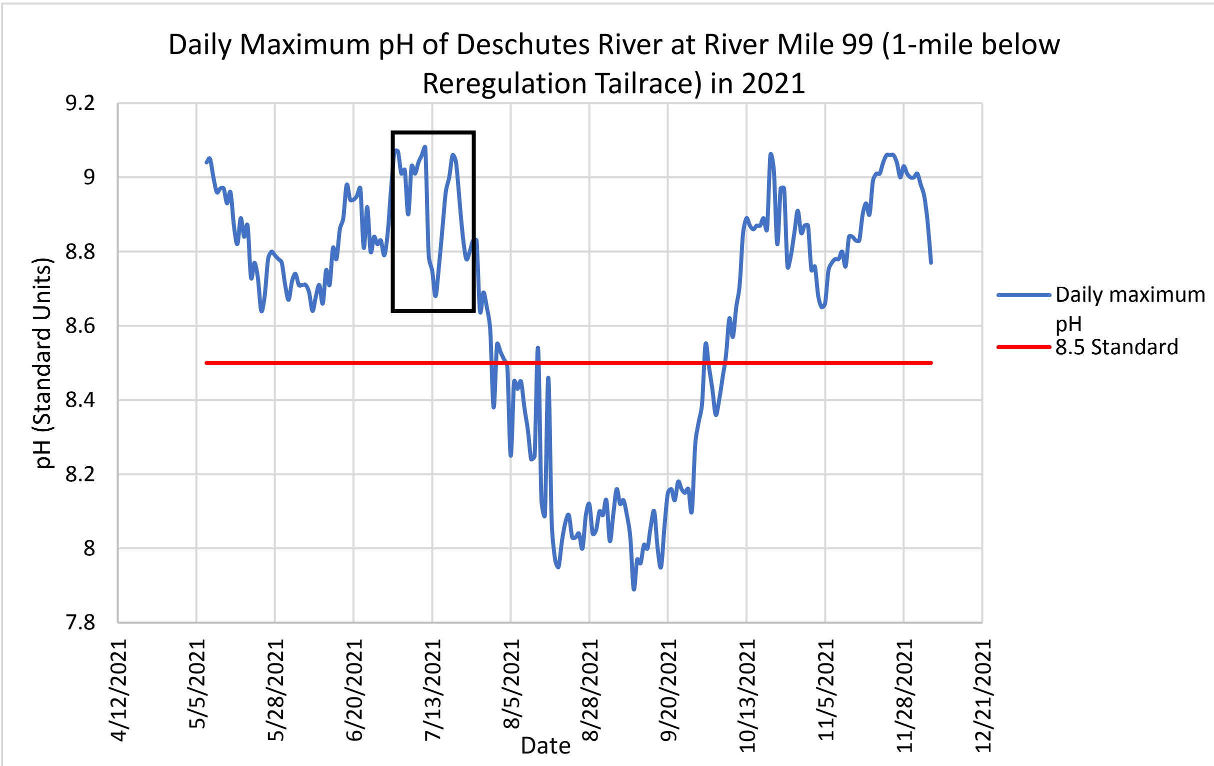

Figure 11. 2021 Hourly daily maximum pH at RM 99 with basin standard in red. Black box emphasizes the drop in daily maximum pH values following the abrupt increase in % bottom-draw at the SWW Tower.

Regional drought and streamflow:

The DRA has observed changes in water quality as a result of regional weather and climate. Winter snowpack and drought conditions in the basin contribute to the water quality and quantity entering the lower Deschutes River. Overall, lower flows in the Crooked River have resulted in lower over-land nutrient loads entering LBC. Thus, the DRA has observed temporary improvements to water quality in the lower Deschutes River in drought years.

Table 1 shows differences in streamflow of the lower Deschutes River from 2016 to 2021. The Madras streamflow gauge (RM 100) is located just below the Reregulating Dam tailrace and measures the flow released from the Project forming the lower Deschutes River (USGS Gauge, Figure 4). The Moody streamflow gauge (RM 1) is located at the mouth of the Deschutes River before its confluence with the Columbia River (RM 0). Peak flow in the lower Deschutes River was highest in 2019 (25,100 cfs at RM 1 on April 09) compared to years 2016-2021. Monthly spring flows in 2021 followed the same low-flow trajectory as observed in 2020. Overall, monthly peak flows were less in 2021 than in 2020 but on January 14th 2021 (the highest flow event) surpassed the highest flow event of 2020.

Max Daily Stream Discharge—cubic feet per second (cfs)					
Gauge Location	**Study Year**	March 1st	April 1st	May 1st	Peak Flow
Madras Gauge (RM 100)	**2016**	5,280	5,200	4,150	6,580 on Mar. 10
	2017	5,580	8,640	5,510	9,970 on Mar. 20
	2018	4,560	4,930	4,180	5,060 on Apr. 9
	2019	4,740	4,480	4,700	11,600 on Apr. 9-10
	2020	4,250	4,280	4,280	5,040 on Dec. 21
	2021	4,030	4,100	4,200	5480 on Jan. 14
Moody Gauge (RM 1)	**2016**	6,900	6,560 Apr. 2nd	4,860	9,380 on Jan. 20
	2017	7,140	12,000	7,770	13,700 on Mar. 19
	2018	5,710	6,240	5,330	7,370 on Apr. 9
	2019	5,330	6,110	7,150	25,100 on Apr. 9
	2020	5,140	5,070	5,530	6,980 on Feb. 8
	2021	5,100	5,000	5,440	10,000 on Jan. 14

Table 1. Lower Deschutes River max daily stream discharge 2016-2021 (Source: USGS).

Figure 12 shows the summer-through-fall hydrograph of the lower Crooked River in consecutive "wet" years (2016 & 2017) versus consecutive "drought" years (2020 & 2021) (Figure 12). Flow from the Crooked River affects the quantity of water entering Lake Billy Chinook and the quality of water (i.e., nutrient loads) entering LBC and in the lower Deschutes River as a result of surface draw at the SWW Tower. Effects from drought on the lower Deschutes are discussed further in the pH section of the Discussion.

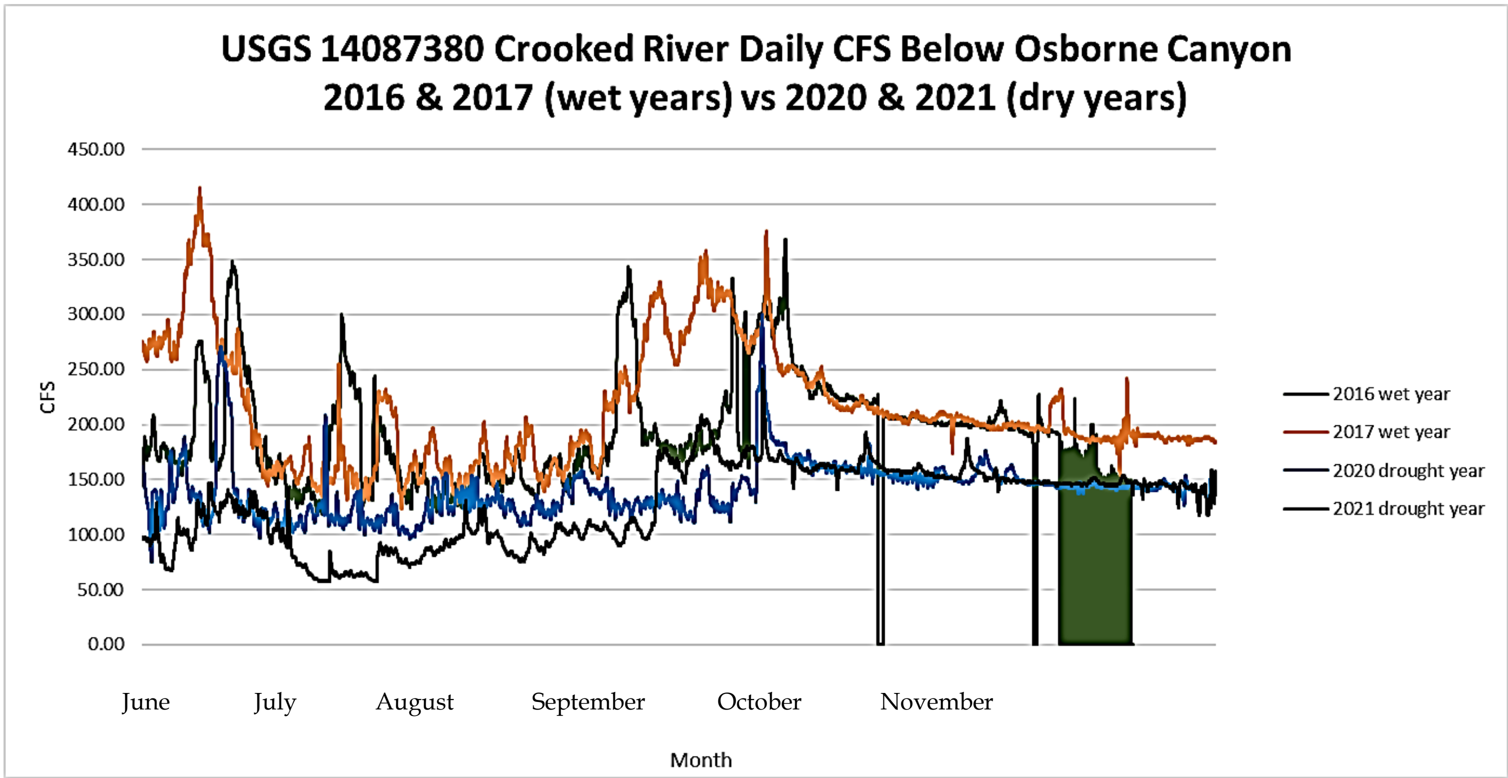

Figure 12. 2016,2017, 2020, 2021 Crooked River hydrograph measured below Osborne Canyon. (Source: USBR).

Figure 13 shows the drought maps for Oregon (central Oregon in particular) in consecutive "wet" years (2016-2017) and in "drought" years (2020-2021) (Appendix C). Drought years in the region prohibit farmers from maximizing land use, as water is scarce enough to prevent full-season irrigation of croplands. The 2021 drought also led to fewer runoff events, reducing nitrogenous-waste runoff from the Crooked River Basin and from the North Unit Irrigation District. The effects of reduced runoff from the Crooked River are further discussed in the pH section of the Discussion.

Drought Maps 2016, 2017, 2021, 2020

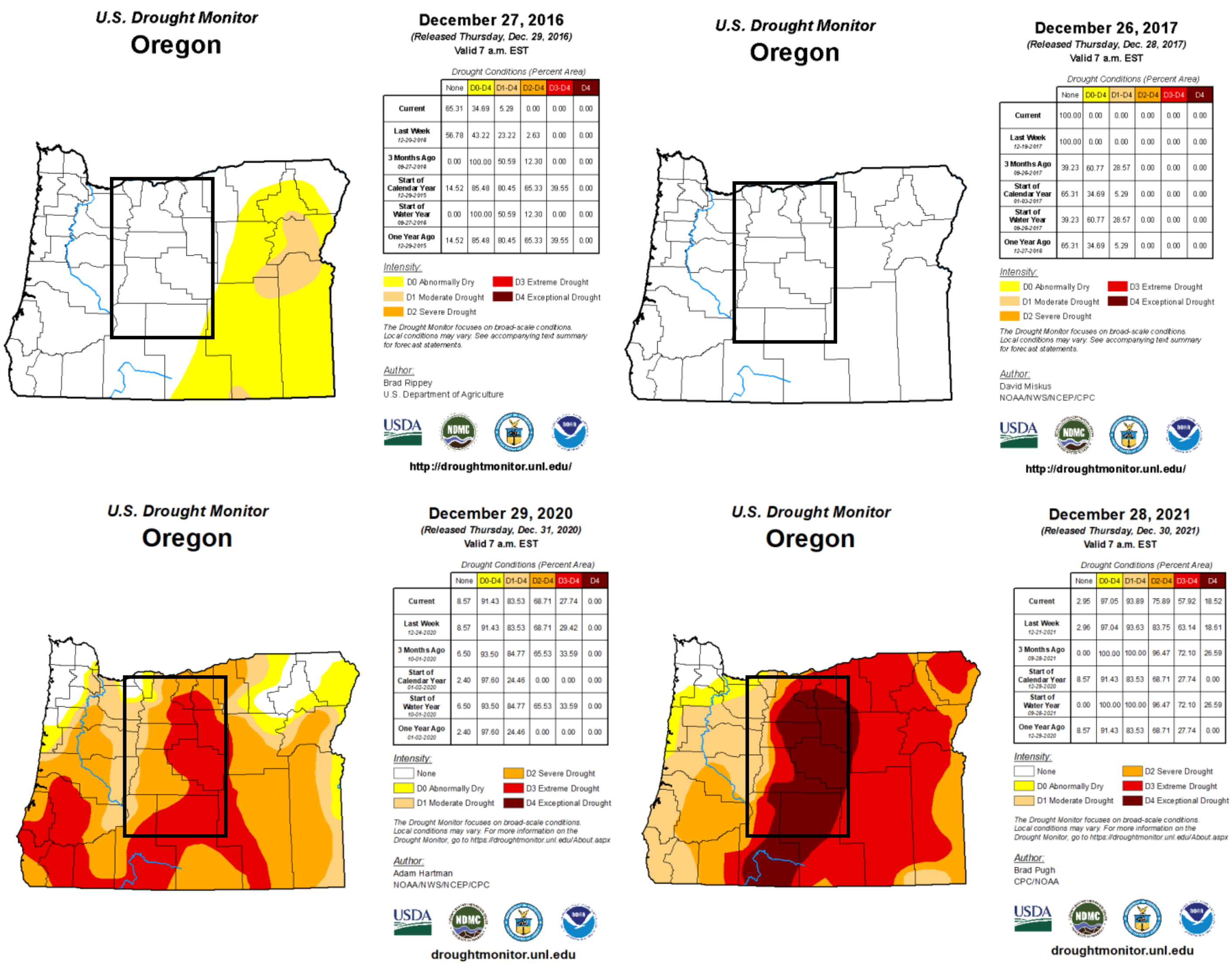

Figure 13. Drought monitoring maps for "wet" (2016-2017) and "drought" (2020-2021) years (Appendix C).

Discussion

SWW Tower operations (blending and unexpected increases in % bottom-draw):

Changing the operation practices of the SWW Tower is the primary way Licensees can improve water quality in the lower Deschutes River. This hypothesis is supported by the models developed in the PGE Water Quality Study and in the annual water quality monitoring conducted by PGE (Eilers & Vache 2019, PGE Annual WQMMP). In 2017, Licensees experimented by releasing surface water at night in order to increase smolt capture at the SWW Tower. This minor modification of Project operations not only increased smolt capture, but also provided slight improvements to water temperatures in the lower Deschutes, as the surface water of Lake Billy Chinook is cooler at night.

While iterations of nighttime operations did show signs of improvement to water temperatures in the lower Deschutes River, a much more significant impact to water temperatures and other water quality parameters in the lower Deschutes River can come from simply sustaining the increase in the % bottom-draw throughout the year. The following subsections present the effects from changes made to the blend ratios at the SWW Tower, and how they affected water quality parameters.

The cold-water flush:

Changes to percent %bottom-draw through the SWW tower are submitted periodically throughout the year by Licensees in their reports to FERC. A review of the % bottom-draw record submitted by Licensees allows for a look at the possibility of executing a "cold flush" in order to temporarily cool the lower Deschutes River during periods of extreme heat.

Figure 14 shows an increase in % bottom-draw (a 25% increase over 6 days) that occurred in July of 2015, alongside the recorded water temperatures at the Moody Gauge (RM 1) and ambient air temperatures taken from the Dalles Municipal Airport 15 helicopter miles away. Percent bottom draw increased from 35% to 60% from July 8th to July 13th and remained at its maximum (~60%) until July 19th when %bottom-draw began to decrease. When paired with the water temperature data taken from the Moody Gauge (RM 1), and air temperature data taken from the Dalles Municipal Airport (15 helicopter-miles from the Moody Gauge) the results clearly show that releasing more cold water from bottom water at the tower improves water temperature all the way to the mouth of the Deschutes even when air temperatures are increasing (Figure 14). Increasing the %bottom-draw cooled water down to the mouth of the Deschutes River (RM 1), and the "canyon effect" did not "mute" the cooling as is often claimed.

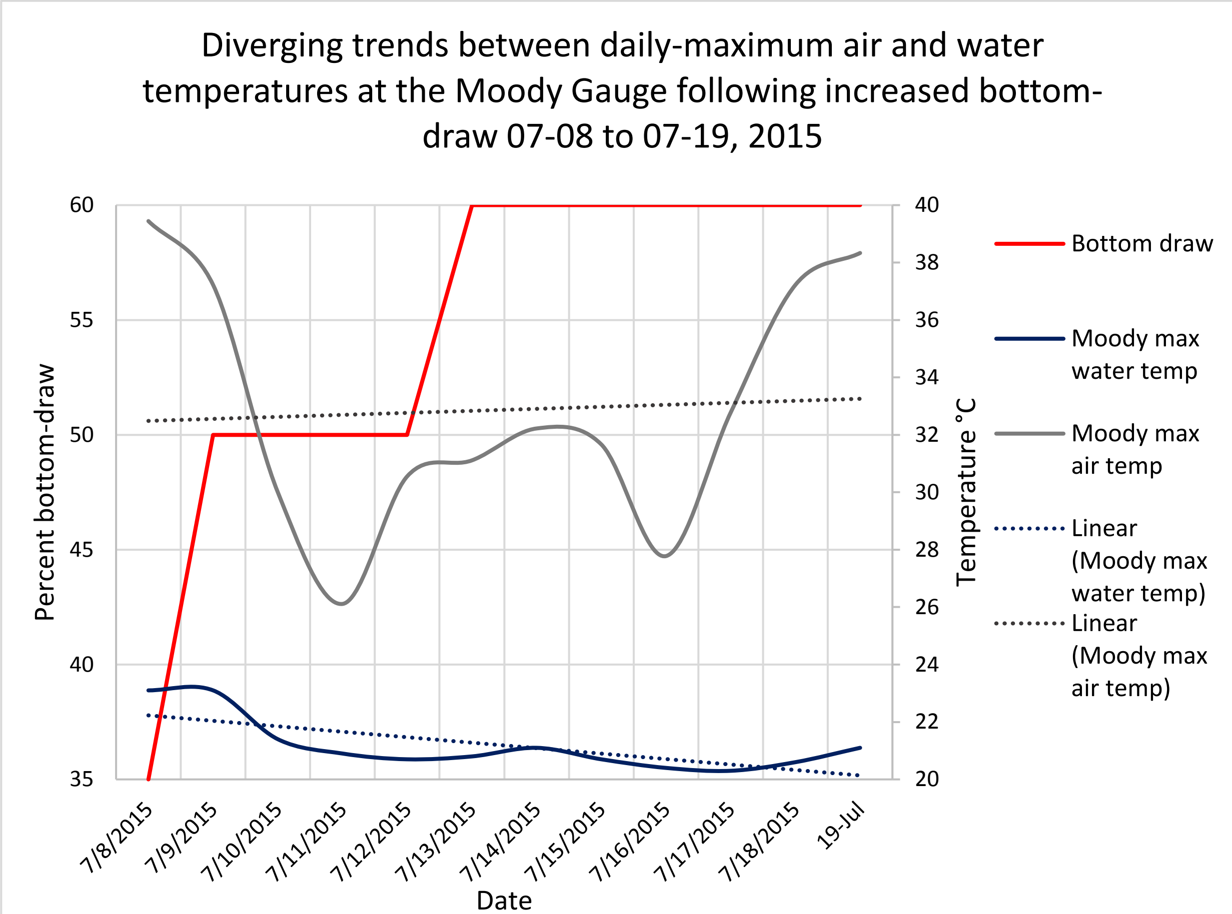

Figure 14. Diverging temperature trends between water and air temperatures in the lower Deschutes River (RM 99) following a 25% increase in %bottom-draw.

The following table consists of the % bottom-draw records submitted by PGE in July 2015:

Date	% Bottom-draw	Date	% Bottom-draw	Date	% Bottom-draw
4-July, 2015	25	13-July, 2015	60	22-July, 2015	55
5-July, 2015	25	14-July, 2015	60	23-July, 2015	55
6-July, 2015	25	15-July, 2015	60	24-July, 2015	55
7-July, 2015	35	16-July, 2015	60	25-July, 2015	55
8-July, 2015	35	17-July, 2015	60	26-July ,2015	55
9-July, 2015	50	18-July, 2015	60	27-July, 2015	50
10-July, 2015	50	19-July, 2015	60	28-July, 2015	50
11-July, 2015	50	20-July, 2015	55	29-July, 2015	50
12-July, 2015	50	21-July, 2015	55	30-July, 2015	50

Table 2. Bottom-draw records (% bottom-draw at the SWW Tower) in July, 2015 submitted by Licensees.

Temperature:

As the daily air temperatures climb from spring through the summer, Licensees typically respond by increasing the % bottom-draw at the SWW Tower (Figure 16) to meet their modeled temperatures. This is a common operation practice that occurs every year, but it should be noted that the modeling used by Licensees is flawed, and does not represent the natural thermal regime of the lower Deschutes River and its tributaries.[8]

In 2021, ambient air temperatures climbed at a steady rate from February and peaked by the end of July (Figure 15). As with the cold-water release in July 2015, another cold-water release event happened unexpectedly in July 2021. From July 10 to 13, 2021, the % bottom-draw was rapidly increased at the SWW Tower to remove debris from the intake, resulting in a fortuitous cooling event in the lower Deschutes River following peak recoded temperatures (Figure 17).

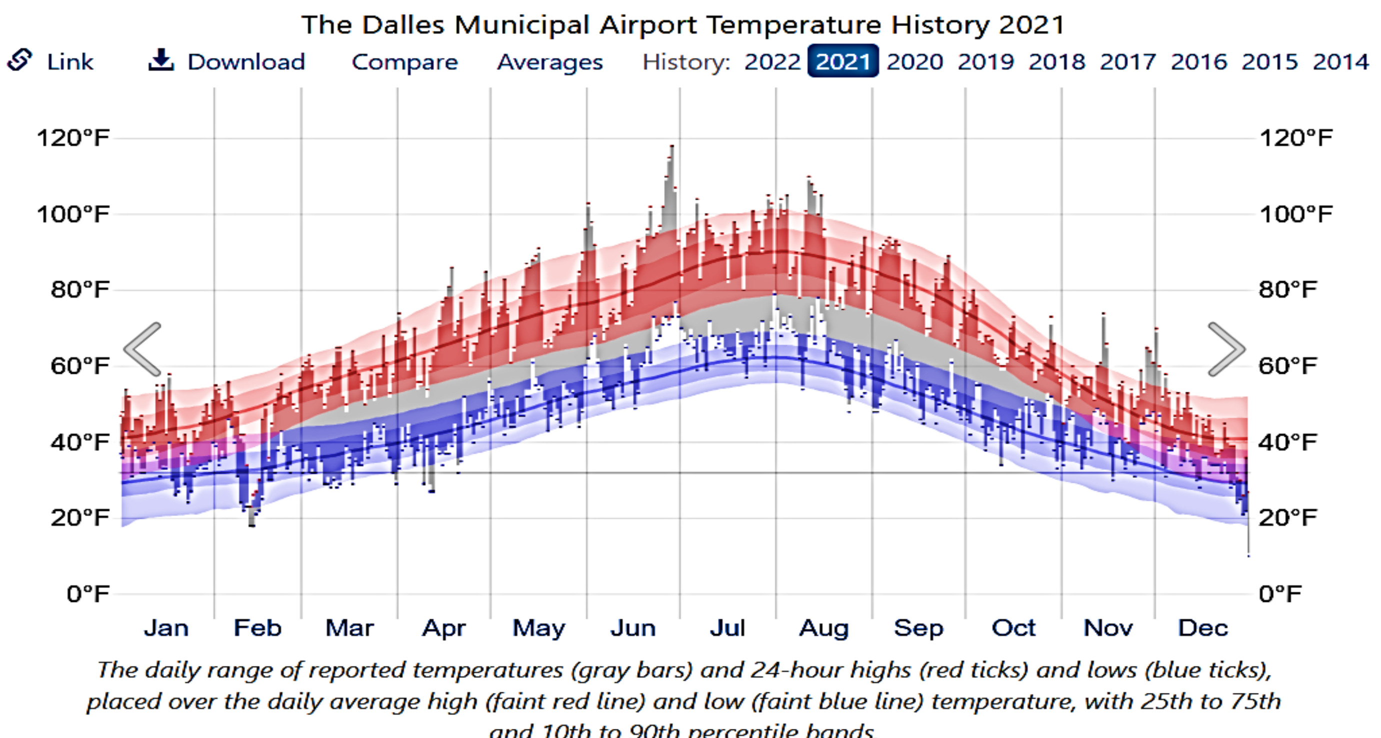

Figure 15. Daily air temperatures at the Dalles Municipal Airport, 2021

[8] The modeling used to calculate the effluent temperature at the reregulation dam is based on the 7-day (weighted) average of the maximum water temperatures of the three tributaries entering Lake Billy Chinook. This allows Licensees to constantly release water based on the highest recorded temperatures of the tributaries entering LBC, and therefore negates the natural cooling process that occurs in rivers from early evening through the early morning.

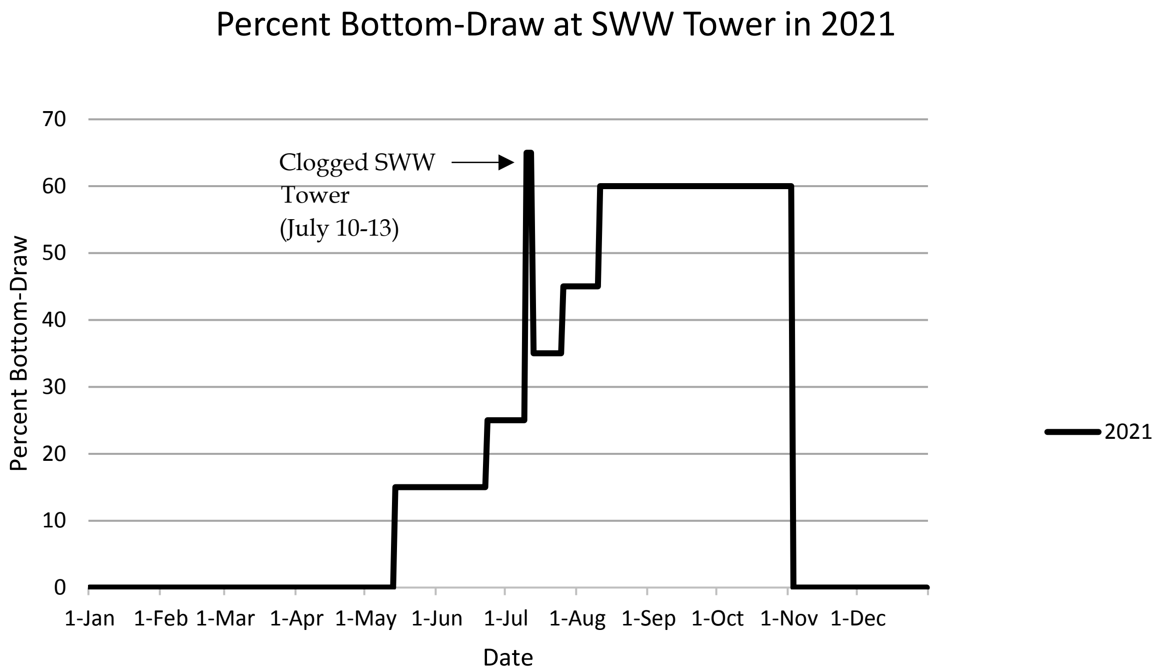

Figure 16. Percent (%) bottom-draw at the Selective Water Withdrawal Tower in 2021. (Source: adapted from PGE report to ODEQ 2021). Maximum bottom draw is ~ 60-65%.

On July 10th 2021, Licensees increased % bottom-draw from 25% to its maximum output of 65% bottom-draw following a clogging of debris at the intake of the SWW Tower (Figure 16). By July 13th, the debris had been removed and the SWW Tower resumed target operations (and % bottom-draw was reduced to 35%).

Of particular interest is the measured response in temperature of the lower Deschutes River to this abrupt change in % bottom-draw. Figure 17 shows the recorded water temperatures of the lower Deschutes River at the Madras (RM 100) and Moody (RM 1) gauges following this abrupt change in % bottom-draw. As one might expect, a dramatic drop in the daily-maximum temperatures was observed following the increase in % bottom-draw. Response at the Moody Gauge (RM 01) is delayed due to the travel time of the colder water from the Madras Gauge (RM 99).

Although these changes did not persist because of the return to warmer surface water withdrawal at the SWW Tower, they do reflect the ability to influence water temperatures for the entirety of the lower Deschutes following an increase in %-bottom draw from the SWW Tower.

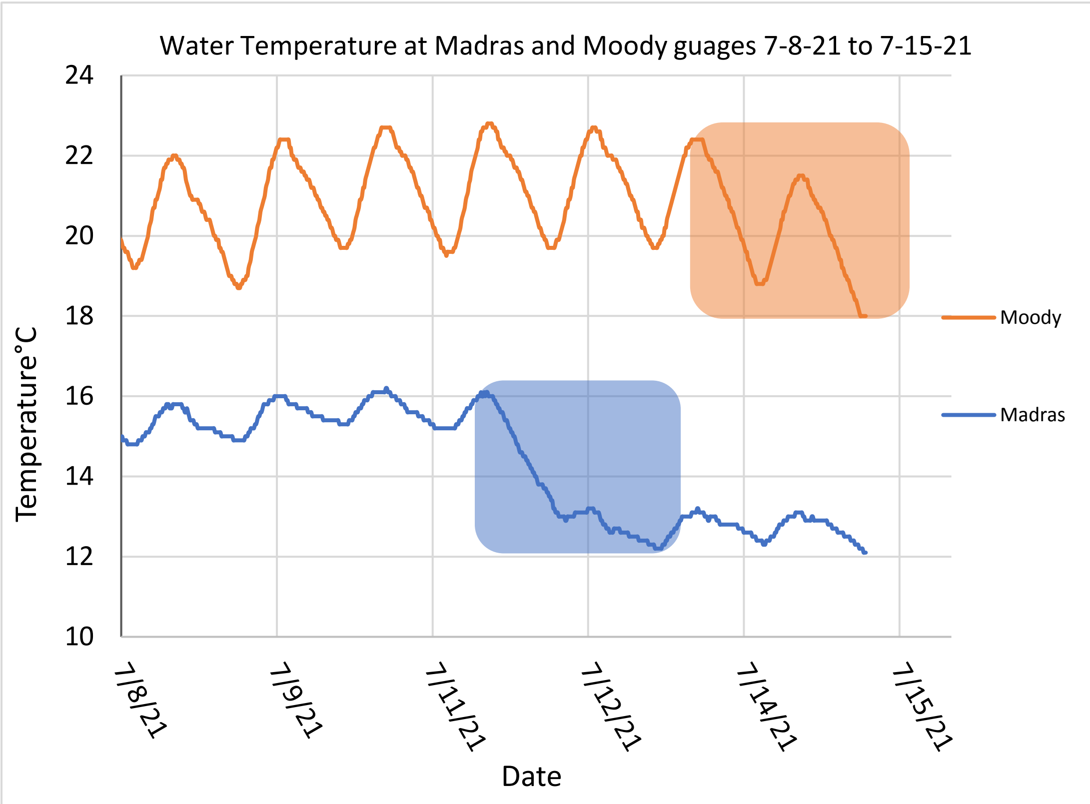

Figure 17. Decreasing water temperatures (°C) at the Madras (RM 100) and Moody (RM 1) gauges in the lower Deschutes River. Shaded areas highlight the decline in water temperatures in response to an abrupt increase in % bottom-draw from July 10th to July 13th, 2021.

pH:

Oregon's water quality standard for pH in the Deschutes Basin is between a minimum of 6.5 and maximum of 8.5 standard units (OAR 340-041-0135). The pH standard is designed to protect aquatic life from the harmful effects of water that is too acidic or too alkaline. Exceedances of the Deschutes Basin upper pH limit were known to occur before the SWW Tower went into operation. However, surface water withdrawal has made the pH problem significantly worse. Bi-monthly water quality data collected by ODEQ at the Warm Springs bridge during similar times of day and month show that pH above 8.5 occurred in ~4% of measurements (n=28) from 2005-2009 (pre-SWW Tower) compared to 38% of measurements (n=58) above 8.5 from 2010-2019 (post-SWW Tower; DRA 2019c) (Figure 18). Such a significant increase in pH seen in ODEQ's pre- & post-tower data clearly demonstrates the negative effect the Tower has had on water quality in the lower Deschutes River (Figure 18).

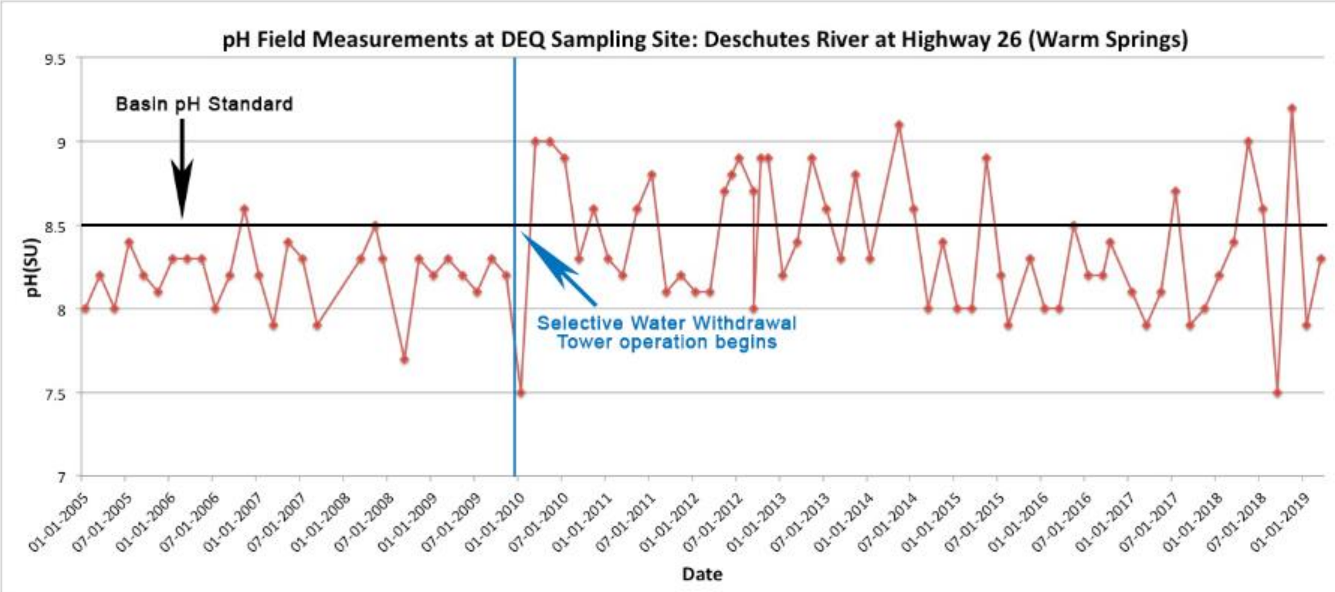

Figure 18. pH measurements taken from similar times of day and month from 2005-2019 (pre- and post-SWW Tower). pH above 8.5 occurred in ~4% of measurements (n=28) from 2005-2009 (pre-SWW Tower) compared to 38% of measurements (n=58) from 2010-2019 (post-SWW Tower).

The DRA continued to document violations of the pH standard throughout the monitoring period. Two trends are apparent from these data.

First, the unexpected increase in the % bottom-draw due to debris clogging the SWW Tower from July 10th - July 13th, 2021 (Figure 16) lowered the daily maximum pH values almost immediately (Figure 11, bold box). This illustrates how SWW Tower operations could be managed to meet pH standards in the lower Deschutes River.

Second, the daily swing in pH appears less severe in drought-years (2020 & 2021) when compared to wet-years (2016 & 2017). One hypothesis is that during drought years, less agricultural irrigation takes place due to the lack of water especially late in the growing season, and therefore far less nitrogenous- based waste runoff reaches Lake Billy Chinook. Figures 19 and 20 illustrate these smaller diel swings and generally lower pH values in wet (2016 & 2017) vs drought (2020 & 2021) years.

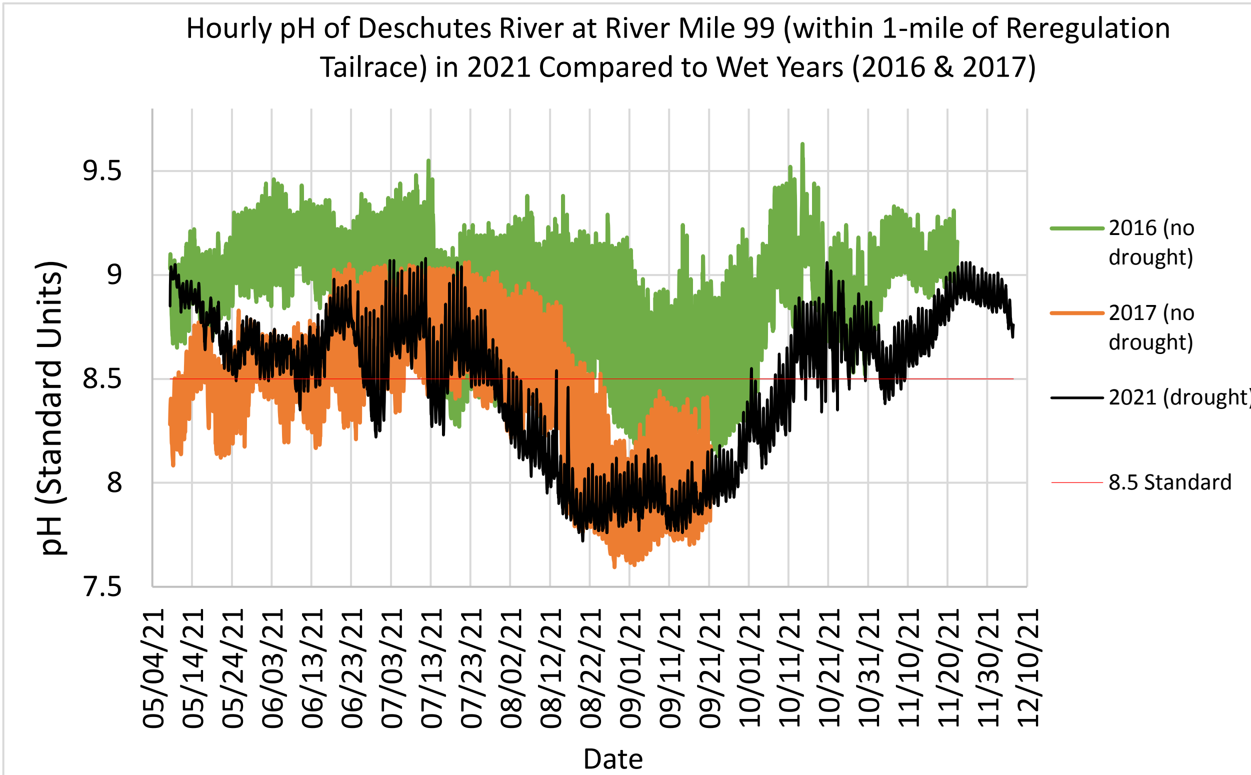

Figure 19. 2021 annual pH swing compared to wet years with pH standard shown with a red line.

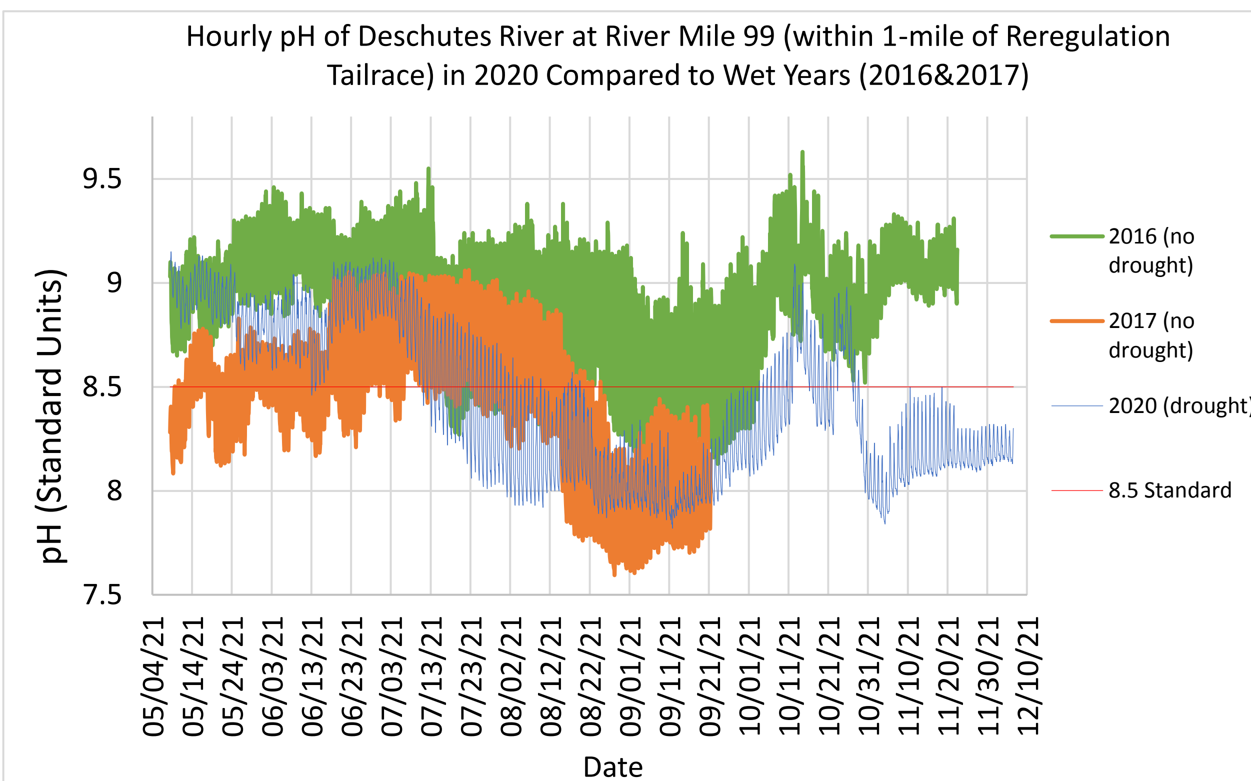

Figure 20. 2020 annual pH swing compared to wet years with pH standard shown with a red line.

Like temperature and DO, pH also shows a daily range with minimum values typically occurring just before sunrise, and maximum values reached in the mid to late afternoon. Mid-day peaks in pH are the result of increased photosynthetic activity by aquatic plants and algae due to maximum sunlight exposure. Photosynthesis lowers the dissolved CO2 concentration in the water, which in turn reduces the carbonic acid concentration and raises pH. At night, photosynthesis stops and respiration releases CO2 into the water. As a result, carbonic acid production increases and the pH drops. When algal biomass increases, the difference between the daily minimum and maximum pH increases and produces large diel swings in pH. Thus, large diel swings in pH are a useful indicator of excessive algal and plant growth stimulated by excess nutrients in polluted water (EPA 2014).

The DRA believes that results from DRA water quality reports (DRA 2015-2019c) and the existing data record clearly establish that surface water releases have had a rapid and negative impact on pH in the lower Deschutes River.

Dissolved Oxygen:

Aquatic animals require adequate dissolved oxygen to survive and the amount of available DO in water is affected by several factors, including water temperature, turbulence, and photosynthetic activity. In particular, cold water can physically hold more DO than warmer water. Also, when water and air mix due to turbulence (waterfalls, white water, spill from dams, etc.) oxygen from the air entrains in the water, increasing its concentration.

The concentration of DO necessary to support the life functions of fish— feeding, spawning, predator avoidance, etc.—varies among species and life stages. In cold water streams of North America, salmon and trout are typically the most sensitive and least tolerant species to low levels of DO (Willers 1991).

In addition, oxygen requirements for developing salmonid eggs are greater than for juveniles and adults (ODFW 2000). For these reasons, Oregon's water quality standards for DO are set to higher standards during the most sensitive times of year: salmonid spawning and egg incubation periods (Appendix D). Oregon's complete DO criteria for the Deschutes Basin are listed in Table 2.

Beneficial Use	Dissolved Oxygen Criteria
Salmonid Spawning, **including where and when resident trout spawn through fry emergence.**	1) Not less than 11.0 mg/L, or - 2) If intergravel DO (IGDO), as a spatial median, is 8.0 mg/L or greater, then DO criterion is not less than 9.0 mg/L
Cold-water Aquatic Life (includes salmon and trout rearing).	1) Not less than 8.0 mg/L. *If ODEQ determines adequate data for DO exists, ODEQ may allow: 2) 8.0 mg/L as a 30-day mean minimum, 6.5 mg/L as a 7-day minimum mean, and 6.0 mg/L as an absolute minimum. All three requirements must be met. *No definition for what constitutes "adequate" data is given.

Table 3. State of Oregon's dissolved oxygen criteria for the lower Deschutes River (OAR 340-041-0016).

In prior reports, the DRA expressed concerns about how the DO criterion is applied and how the designated spawning and incubation periods for species are covered (DO discussion section, DRA 2019c). In summary, Oregon's water quality standards for DO clearly mandate that when determining the DO standard for a particular water body, resident trout spawning must be included. Oregon Administrative Rules (OAR 340-041-016) states:

"The following criteria apply during the applicable spawning through fry emergence periods set forth in the tables and figures and, where resident trout spawning occurs, during the time trout spawning through fry emergence occurs."

In other words, Oregon's DO standard requires that the DO criteria of 11.0 mg/L (or 9.0 mg/L when IGDO is above 8.0 mg/L) minimum concentration must be applied not just in the identified salmon and steelhead spawning time and place, but also during resident trout spawning through fry emergence.

As the DRA has seen in prior years, DO fell below the 11.0 mg/L standard in May and continued to decline below the 9.0 mg/L standard starting in July (Figure 4). Because trout spawning and incubation continue until early September (and was observed and recorded by DRA staff on October 29th), the DO concentration fell below the applicable standard from early July through August. Additionally, if IGDO levels are not in fact above 8.0 mg/L, then DO should not fall below 11.0 mg/L. If the 11.0 mg/L standard were applied, then DO fell below the standard every day starting in early-May through the end of the monitoring period on December 06th, 2021. Project operations can easily correct this by spilling water over the Reregulating Dam to entrain oxygen as it is released into the lower Deschutes River as has been done many times in the past.

Conclusions

Water quality data collected and analyzed by the DRA in 2021 again document numerous and ongoing violations of Oregon's pH and DO water quality standards in the lower Deschutes River. The DRA believes that our investigations and the available record demonstrate that the SWW Tower plays a significant role in these violations. Violations to Oregon's water quality standards set to protect aquatic life have increased since the installation and operation of the SWW Tower (DRA Annual Water Quality Reports, Figure 18). The DRA believes it is of utmost importance to the health of the lower Deschutes River's aquatic ecosystem that operators begin to manage water released from the SWW Tower to ensure water quality standards are met to the fullest extent possible and thus, improve the health of the lower Deschutes River. The WQMMP established by the FERC designates clear management requirements for adhering to water quality standards for temperature, DO, and pH to adequately protect the aquatic life in the lower Deschutes River. These requirements are not being met under current SWW Tower operations.

Data collected by PGE, ODEQ, and the DRA are clear that violations of water quality standards are not due to climate change, nor do they reflect "inherent" water quality problems in the basin, but rather, operational practices at the SWW Tower. Solutions to improve water quality and protect aquatic life that do not hinder the reintroduction efforts of salmonids are readily available to manage water quality in the lower Deschutes River. In fact, as more data becomes available, improving lower Deschutes River water quality will be necessary for reintroduction efforts to succeed (e.g., *C. shasta* infection rates on salmonids; OSU 2019).

Below are the summarized water quality exceedances documented by the hourly water quality data collected by the DRA at RM 99 from 2016-2021 as well as from data reported in the PGE Water Quality Study (Eilers & Vache 2019).

Temperature:

The current water temperature management approach with the SWW Tower has several serious impacts on aquatic life in the lower Deschutes River:

1. The "Without Project Temperature" equation used to set the temperature goals in the lower Deschutes River is unacceptable and does not represent a scheme to protect and enhance aquatic life. Using the average of the 7-day **maximum temperatures** of the three tributaries entering Lake Billy Chinook, allows for the Project to constantly discharge the **maximum temperature** value from the three tributaries, albeit on a rolling 7-day average. This does not recreate true or natural thermal conditions in the lower river that existed pre-dam construction and must be changed to better reflect reality. Blending bottom water with surface water at the Tower is the primary means for the Project to meet temperature

management targets outlined in their WQMMP.[9] Streams in temperate regions of North America experience a natural diel or daily temperature flux (Hauer et al., 2006), meaning that water temperature changes over a 24-hour period from a midafternoon high to a late night/early morning low (see for example Figure 6). Using only the average of the maximum tributary temperatures, as is currently done, does not recognize the natural temperature regime and does not account for the diel temperature flux in the tributaries. There is no biological, or statistical justification for using maximum temperatures and does not mimic a "natural" temperature regime in the lower Deschutes River[10]

2. Releasing 100% surface water from Lake Billy Chinook from November through May (or June) each year raises the water temperature in the lower Deschutes River throughout the late winter, spring, and early summer. This surface water temperature is much warmer than the pre-SWW Tower temperatures released into the lower Deschutes and certainly alters aquatic insect life cycles and abundance as well as other aquatic biota. It is likely contributing to the widely observed earlier-in-the-year and more dense growth of nuisance algae and diatoms that has further impacted aquatic invertebrate populations in the lower river. This is well supported by DRA's independent statistical analysis of aquatic macroinvertebrate data collected by R2 Resource Consultants when their data showed significant increases in non-insect taxa (worms and snails), increases in pollution tolerant invertebrates, and declines in pollution sensitive taxa after the SWW Tower started operating (Edwards 2018).
3. Also of concern is the disturbing increase in abundance of the polychaete worm, *Manayunkia occidentallis,* that is the obligate intermediate host for the parasite *Ceratonova shasta* that infects young, ocean-bound as well as returning adult salmonids. DRA sampling of benthic invertebrates found over 8,000 *M. occidentallis* per square meter in September 2016 at RM 99 (DRA 2019d), and Oregon State University is conducting its own investigation on the prevalence of this devastating parasite in the lower Deschutes River. It is thought that an increase in water temperature and nutrient load favors *M. occidentallis* production and yields a higher incidence of *C. shasta*.
4. Project operations under the rubric of temperature management caused water temperatures to exceed the temperature standard for spawning salmon and

[9] The method outlined in the WQMMP for calculating the maximum temperature allowed for water released into the lower Deschutes River is based on a regression equation developed by Huntington et al. (1999). This equation is defined as *the flow- weighted, 7-day rolling average daily maximum temperatures of the three major tributaries to LBC, and the 7-day average daily air temperature at Redmond Airport*.

[10] See for example, DRA's blog post, "The Low Down on High Temperatures in the Lower Deschutes River" available: https://deschutesriveralliance.wordpress.com/2015/08/12/thelow-down-on-hightemperatures-in-the-lower-deschutes-river/

steelhead in June of 2020 & 2021 (7-day average daily maximum no greater than 13°C; Figure 12).

5. The increase in spring temperatures have resulted in Deschutes River water temperatures near the Columbia River reaching 60°F earlier than in previous years (Figure 3). The warmer water earlier in the year likely encouraged smallmouth bass to migrate from the Columbia River, where they are abundant, up the Deschutes, possibly in search food resources. The capture of smallmouth bass *Micopterus dolumieu* by steelhead anglers in the lower 40 miles of the Deschutes River during the summers of 2016 and 2017 exceeded anything in recent memory (S. Pribyl, pers. comm.) and remain seasonally very abundant. In 2017, walleye *Sander vitreus* were also caught in the lower Deschutes River near its mouth for the first time. Subsequent investigations by the Oregon Department of Fish & Wildlife confirmed smallmouth bass presence in numbers never previously observed by them (ODFW 2019). Conditions that triggered this increase are not completely clear, but higher water temperatures in the lower Deschutes River from April-July compared to pre-SWW Tower temperatures are one explanation. The impact of increased smallmouth bass numbers in the lower Deschutes River is currently unknown, but an increased predation of native fish is a likely possibility.
6. The lower Deschutes River is one of the more important cold-water refugium for Upper Columbia River Basin adult salmon and steelhead (Keefer et al. 2018). Increasing the water temperature in the lower Deschutes is counterproductive to larger management goals for salmonids in the Columbia River Basin and potentially eliminates or seriously degrades this important cold-water refugium.

Dissolved Oxygen:

Water with adequate dissolved oxygen is critical for the survival and reproduction of aquatic life. Incubating salmon and trout eggs and developing fry are the most sensitive life stages to inadequate DO concentrations. For this reason, water quality standards for DO are higher during salmonid egg incubation and fry development (Table 2). Life history studies of resident trout in the lower Deschutes River, photo documentation, and observation of trout spawning at RM 50 on October 29, 2021 all confirm that trout spawning continues through August (Zimmerman & Reeves 2000, Appendix D). Resident trout incubation through fry emergence continues for some time after spawning and the DO standards apply through that period, so the current DO standard as currently applied is completely inadequate for protection of this sensitive activity. Under current Oregon standards, a minimum DO concentration of 11.0 mg/L (lower minimum of 9.0 mg/L if IGDO data available and above 8.0 mg/L) should be extended to sufficiently support actual resident trout spawning and resulting incubation periods. From the middle of May until the end of the October in 2021, DO was below the 11.0

mg/L protective standard, and fell below the less protective standard of 9.0 mg/L from July to the middle of August, and again in September (Figure 9).

pH:

It is well established that pH can be an indicator of watersheds experiencing nutrient enrichment. High nutrient loads stimulate excessive algae and aquatic plant growth which in turn causes large diel swings in pH (EPA 2014). The pH levels measured at RM 99 in the lower Deschutes River in 2021 show significant water quality exceedances of the pH standard, which are largely due to the release of nutrient polluted surface water from LBC:

1. Hourly pH measurements exceeded the upper limit for the Deschutes Basin pH standard (8.5 s.u.) from the start of data collection on May 08 through the end of July. Measurements recorded between August and September showed improved pH within basin standards, but elevated pH measurements above the basin standard again occurred throughout October.
2. No management plan for lowering pH has been developed by PGE, even though it is required by the WQMMP when pH measurements from the Project discharge exceed the weighted average pH of inflows into Lake Billy Chinook (PGE & CTWSRO 2002).
3. Based on ODEQ data, pH in the lower Deschutes showed an immediate and sustained increase when SWW Tower operations began in 2009 (DRA 2019c). Yet, pH also showed a significant decrease following the abrupt increased % bottom-draw from the SWW Tower in July, suggesting a viable operational scenario to meet pH standards.
4. Diel swings in pH were smaller in drought years than those recorded in wet-years and reflect a lessened influx of nitrogenous-based waste from the Cooked River and regional land use during drought years.

The available record from 2010-to-present clearly indicate that Project and SWW Tower operations have habitually contributed to the violations of Oregon's water quality standards for temperature, pH, and DO in the lower Deschutes River. When multiple standards are exceeded together - as often is the case for pH and DO - the negative effects on aquatic life increase substantially. It is unacceptable that multiple water quality standards are habitually violated for any given periods of time (days and weeks on end as documented in this and past studies) in the lower Deschutes River, given that standards have been in existence since the original completion of the Project in 1964.

Water quality standards are essential to protect the beneficial uses of Oregon's water. Yet, without enforcement of those water quality standards beneficial uses are not protected. The standards are the result of years of research and public process to ensure that the standards will adequately protect aquatic life in Oregon's waterways. Yet, without strict adherence to these standards, the efforts taken to maintain acceptable water quality and reintroduce anadromous salmonids to tributaries upstream of the project, and in particular the lower Crooked River, will be an up-hill battle and may even prove impossible in the long-term.

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Appendix A – 2021 Field Audit Data

Watershed Assessment Section Multiparameter Logger Monitoring Report

	SITENAME	FILENAME	CASE #
2021	VD2021 6600		

NOTE: GRADE F is a manual grade for "exceptional event" level data only (See DQM for further explanation). GRADE D is a manual grade for "missing" data. Grade E is data of an unknown quality or of known poor quality. **GRADES D, E AND F REQUIRE AN EXPLAINATION IN THE RUN COMMENTS SECTION**

ELEVATION (ft)

TEMPERATURE AUDIT RESULTS

#	*Audit*	*DS Value*		*Status*
1	11.9	11.7	0.20	A
2	12.1	11.96	0.14	A
3	14	13.94	0.06	A
4	13.6	13.46	0.14	A
5	13	12.88	0.12	A
6	13.6	13.49	0.11	A
7	11.5	11.39	0.11	A
8	10.3	10.1	0.20	A
9				

Criteria:

GRADE A	GRADE B	GRADE C
=<±1.5	=<±1.51 - 2.00	=>±2.01

pH AUDIT RESULTS

#	*Audit*	*DS Value*	*Abs. Difference*	*Status*
1	8.58	8.48	0.10	A
2	8.93	8.88	0.05	A
3	8.63	8.71	-0.08	A
4	8.34	8.34	0.00	A
5	8.01	7.99	0.02	A
6	8.17	8.05	0.12	A
7	8.69	8.7	-0.01	A
8	8.57	8.76	-0.19	A
9				

Criteria:

GRADE A	GRADE B	GRADE C
=<±0.3	=<±0.31-0.5	=>±0.5

DO AUDIT RESULTS

#	*Audit*	*DS Value*	*Abs. Difference*	*Status*
1	11.51	13.7	-2.19	C
2	11.55	12.79	-1.24	E
3	9.84	9.82	0.02	A
4	8.94	8.52	0.42	B
5	10.4	10.28	0.12	A
6	10.42	10.2	0.22	A
7	10.78	10.58	0.20	A
8	11.48	11.26	0.22	A
9				

Criteria: units in **mg/L**

GRADE A	GRADE B	GRADE E	GRADE C
(≤+ 0.3)	(≤+ 0.31-1.0)	(≤+1.01-2.0)	(?+ 2.01)

AUDIT RESULTS

DATE (mm/dd/yyyy)	TIME (hh:mm)	TEMP (deg C)	pH (SU)	DO (mg/L)
5/7/2021	10:39	11.9	8.58	11.51
5/14/2021	9:45	12.1	8.93	11.55
6/24/2021	10:40	14	8.63	9.84
8/3/2021	11:15	13.6	8.34	8.94
8/31/2021	12:50	13	8.01	10.4
9/27/2021	14:35	13.6	8.17	10.42
11/1/2021	13:35	11.5	8.69	10.78
12/6/2021	12:40	10.3	8.57	11.48

Appendix B- Water Quality Sampling Quality Assurance/Quality Control Program and Methods

Instrument Calibration:

All instruments were calibrated per manufacturer instructions. A log of calibrations has been kept on all instruments. Calibration and/or accuracy checks on handheld instruments were done within 24 hours of each use event. Calibration on in-dwelling instruments (YSI data sonde) was done prior to initial placement and again after battery replacement.

Instruments were calibrated using name brand pre-formulated calibration standard solutions.

Instrument Data Audits:

The YSI data sonde was audited as often as possible using handheld instruments to determine temperature, pH, dissolved oxygen, oxygen saturation and turbidity. Use of multiple measures was employed as described below.

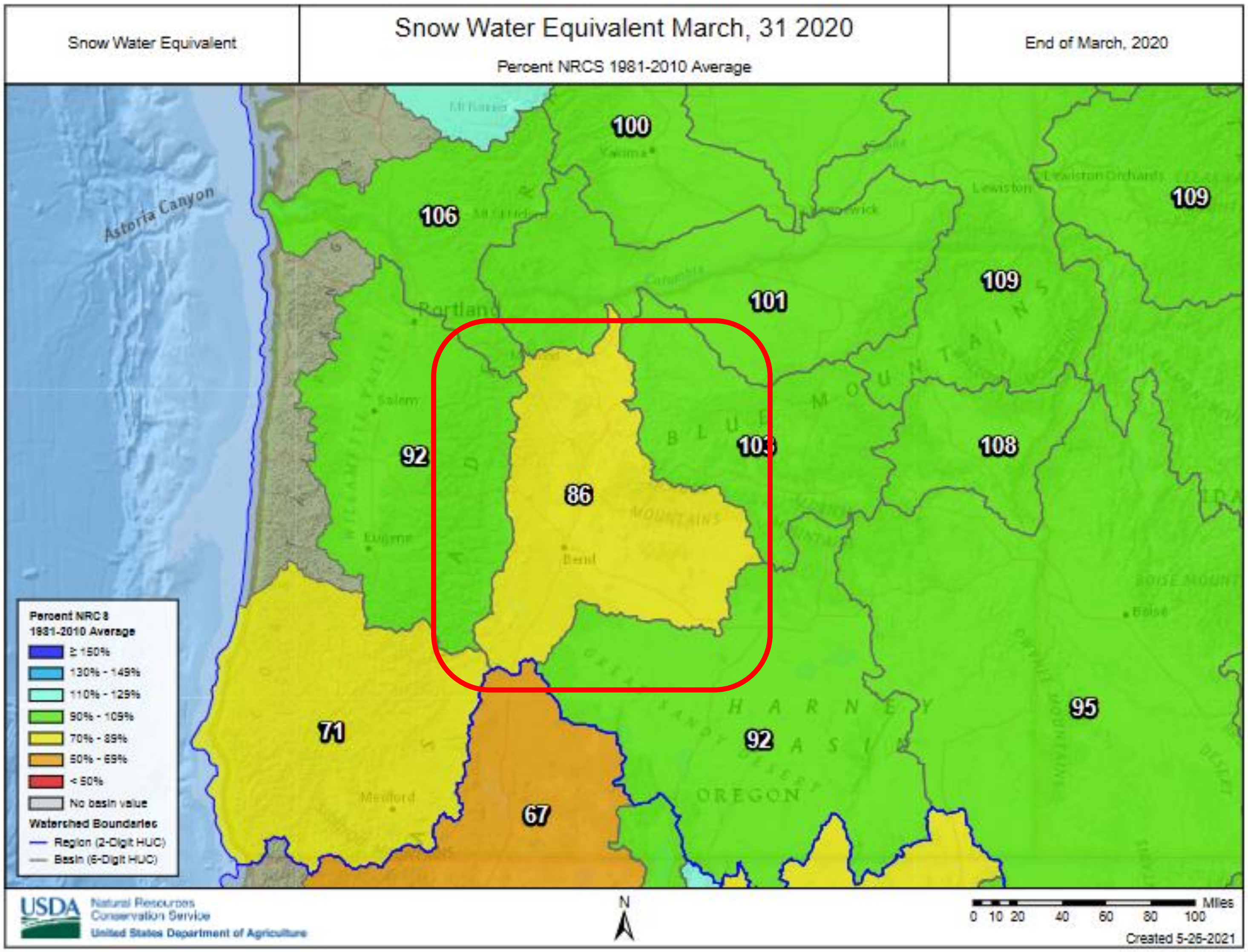
Use of Multiple Measures:

To ensure in-field accuracy, independent meters/instruments were used to measure temperature, pH and DO simultaneously with the YSI data sonde. Re-calibration and/or probe replacements were done when necessary.

Instrument Storage:

Instruments were stored in a secure and temperature-controlled environment when not in use.

Appendix C- Supplemental Figures



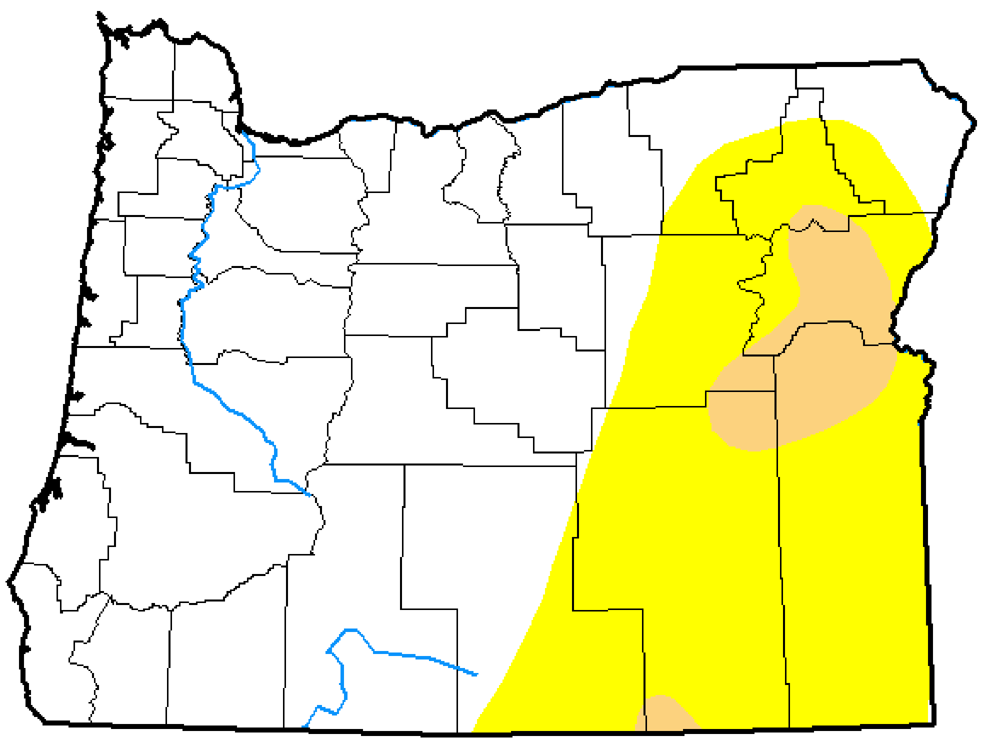
U.S. Drought Monitor

Oregon

December 27, 2016

(Released Thursday, Dec. 29, 2016)

Valid 7 a.m. EST



Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	65.31	34.69	5.29	0.00	0.00	0.00
Last Week *12-20-2016*	56.78	43.22	23.22	2.63	0.00	0.00
3 Months Ago *09-27-2016*	0.00	100.00	50.59	12.30	0.00	0.00
Start of Calendar Year *12-29-2015*	14.52	85.48	80.45	65.33	39.55	0.00
Start of Water Year *09-27-2016*	0.00	100.00	50.59	12.30	0.00	0.00
One Year Ago *12-29-2015*	14.52	85.48	80.45	65.33	39.55	0.00

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:

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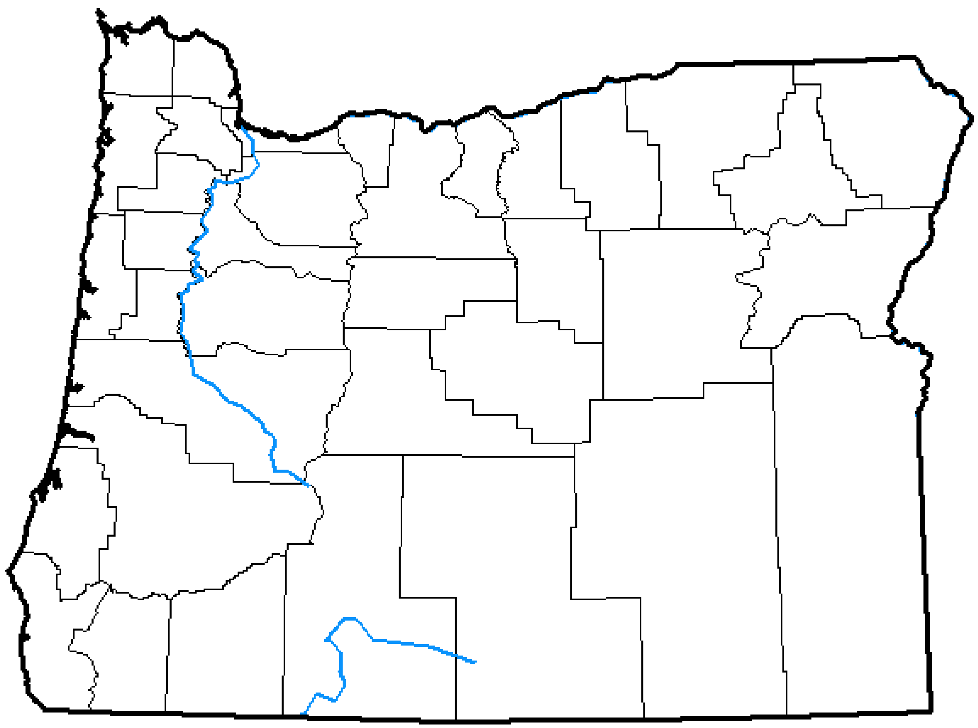
U.S. Department of Agriculture

http://droughtmonitor.unl.edu/

U.S. Drought Monitor

Oregon



December 26, 2017

(Released Thursday, Dec. 28, 2017)

Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	100.00	0.00	0.00	0.00	0.00	0.00
Last Week *12-19-2017*	100.00	0.00	0.00	0.00	0.00	0.00
3 Months Ago *09-26-2017*	39.23	60.77	28.57	0.00	0.00	0.00
Start of Calendar Year *01-03-2017*	65.31	34.69	5.29	0.00	0.00	0.00
Start of Water Year *09-26-2017*	39.23	60.77	28.57	0.00	0.00	0.00
One Year Ago *12-27-2016*	65.31	34.69	5.29	0.00	0.00	0.00

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

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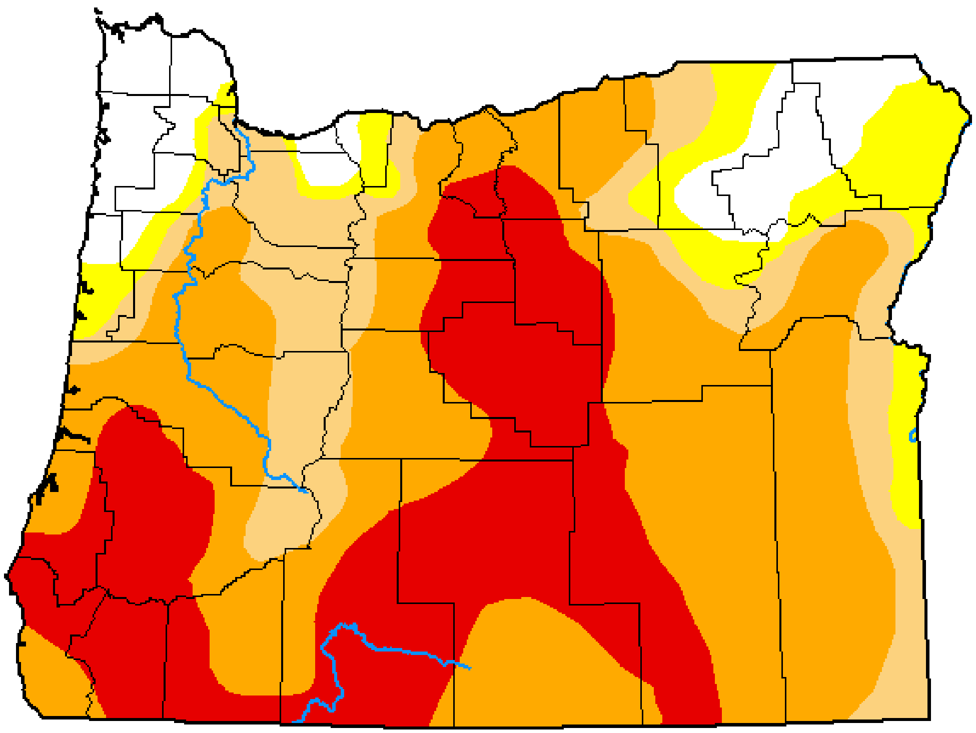
U.S. Drought Monitor

Oregon



December 29, 2020

(Released Thursday, Dec. 31, 2020)

Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	8.57	91.43	83.53	68.71	27.74	0.00
Last Week *12-24-2020*	8.57	91.43	83.53	68.71	29.42	0.00
3 Months Ago *10-01-2020*	6.50	93.50	84.77	65.53	33.59	0.00
Start of Calendar Year *01-02-2020*	2.40	97.60	24.46	0.00	0.00	0.00
Start of Water Year *10-01-2020*	6.50	93.50	84.77	65.53	33.59	0.00
One Year Ago *01-02-2020*	2.40	97.60	24.46	0.00	0.00	0.00

Intensity:

- None
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. For more information on the Drought Monitor, go to https://droughtmonitor.unl.edu/About.aspx

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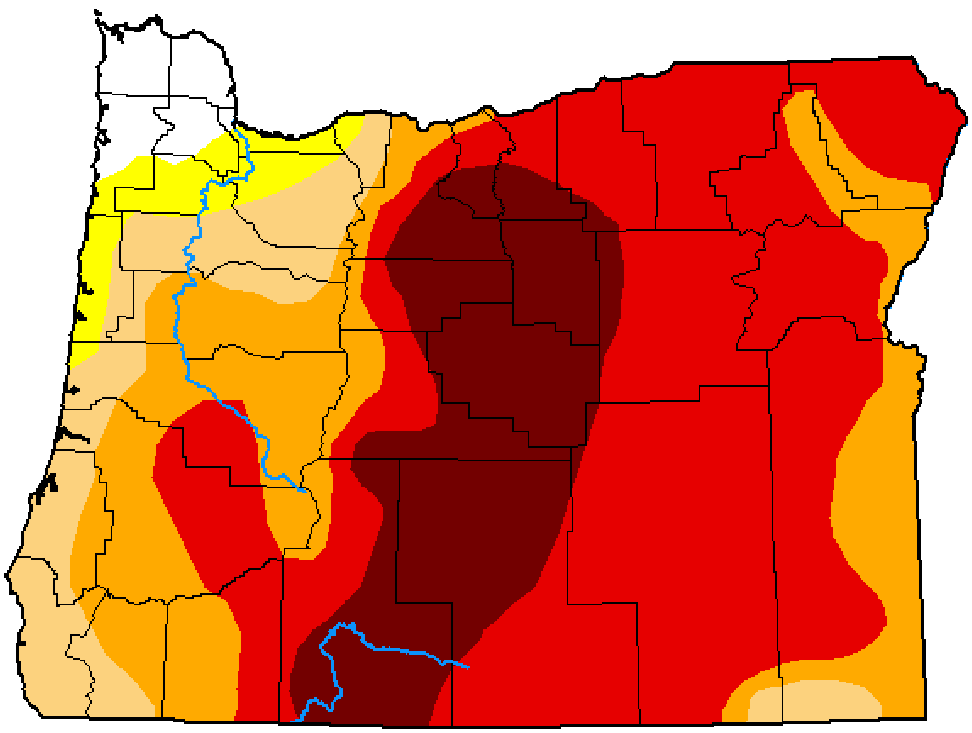
U.S. Drought Monitor
Oregon



December 21, 2021
(Released Thursday, Dec. 23, 2021)
Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	2.96	97.04	93.63	83.75	63.14	18.61
Last Week *12-14-2021*	1.39	98.61	96.78	90.05	66.97	20.35
3 Months Ago *09-21-2021*	0.00	100.00	100.00	96.47	72.10	26.59
Start of Calendar Year *12-29-2020*	8.57	91.43	83.53	68.71	27.74	0.00
Start of Water Year *09-28-2021*	0.00	100.00	100.00	96.47	72.10	26.59
One Year Ago *12-22-2020*	8.57	91.43	83.53	68.71	29.42	0.00

Intensity:

- None
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. For more information on the Drought Monitor, go to https://droughtmonitor.unl.edu/About.aspx

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Appendix D- Oregon Administrative Rules for Temperature & Maps

The seven-day-average maximum temperature of a stream identified as having salmon and steelhead spawning use on sub-basin maps and tables set out in OAR 340-041-0101 to 340-041-0340: Tables 101B, and 121B, and Figures 130B, 151B, 160B, 170B, 220B, 230B, 271B, 286B, 300B, 310B, 320B, and 340B, may not exceed 13.0 degrees Celsius (55.4 degrees Fahrenheit) at the times indicated on these maps and tables;

The seven-day-average maximum temperature of a stream identified as having core cold water habitat use on sub-basin maps set out in OAR 340-041-101 to 340-041-340: Figures 130A, 151A, 160A, 170A, 180A, 201A, 220A, 230A, 271A, 286A, 300A, 310A, 320A, and 340A, may not exceed 16.0 degrees Celsius (60.8 degrees Fahrenheit);

The seven-day-average maximum temperature of a stream identified as having salmon and trout rearing and migration use on sub-basin maps set out at OAR 340-041-0101 to 340-041-0340: Figures 130A, 151A, 160A, 170A, 220A, 230A, 271A, 286A, 300A, 310A, 320A, and 340A, may not exceed 18.0 degrees Celsius (64.4 degrees Fahrenheit)

*Figure 130A: Fish Use Designations**
Deschutes Basin, Oregon

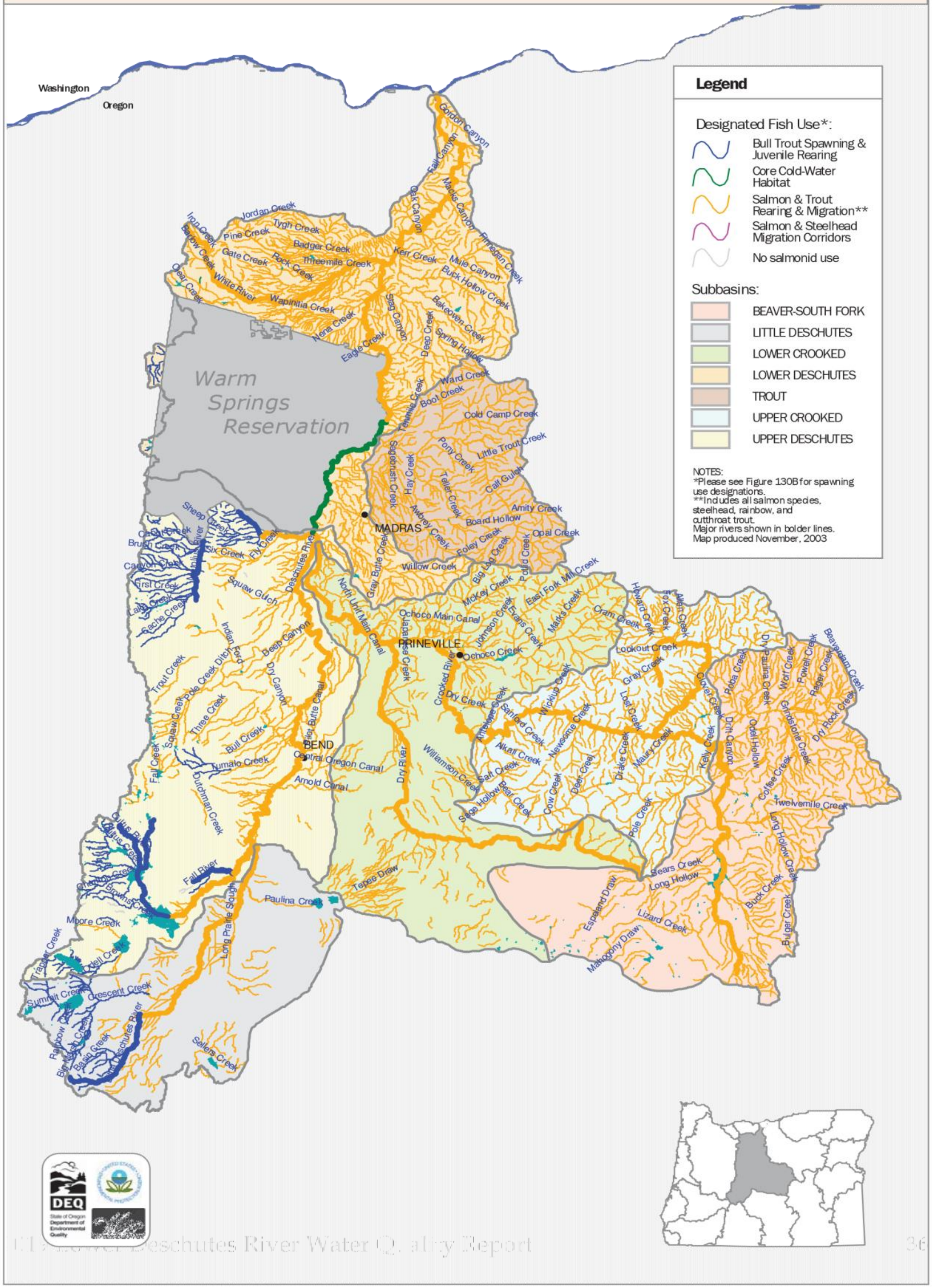
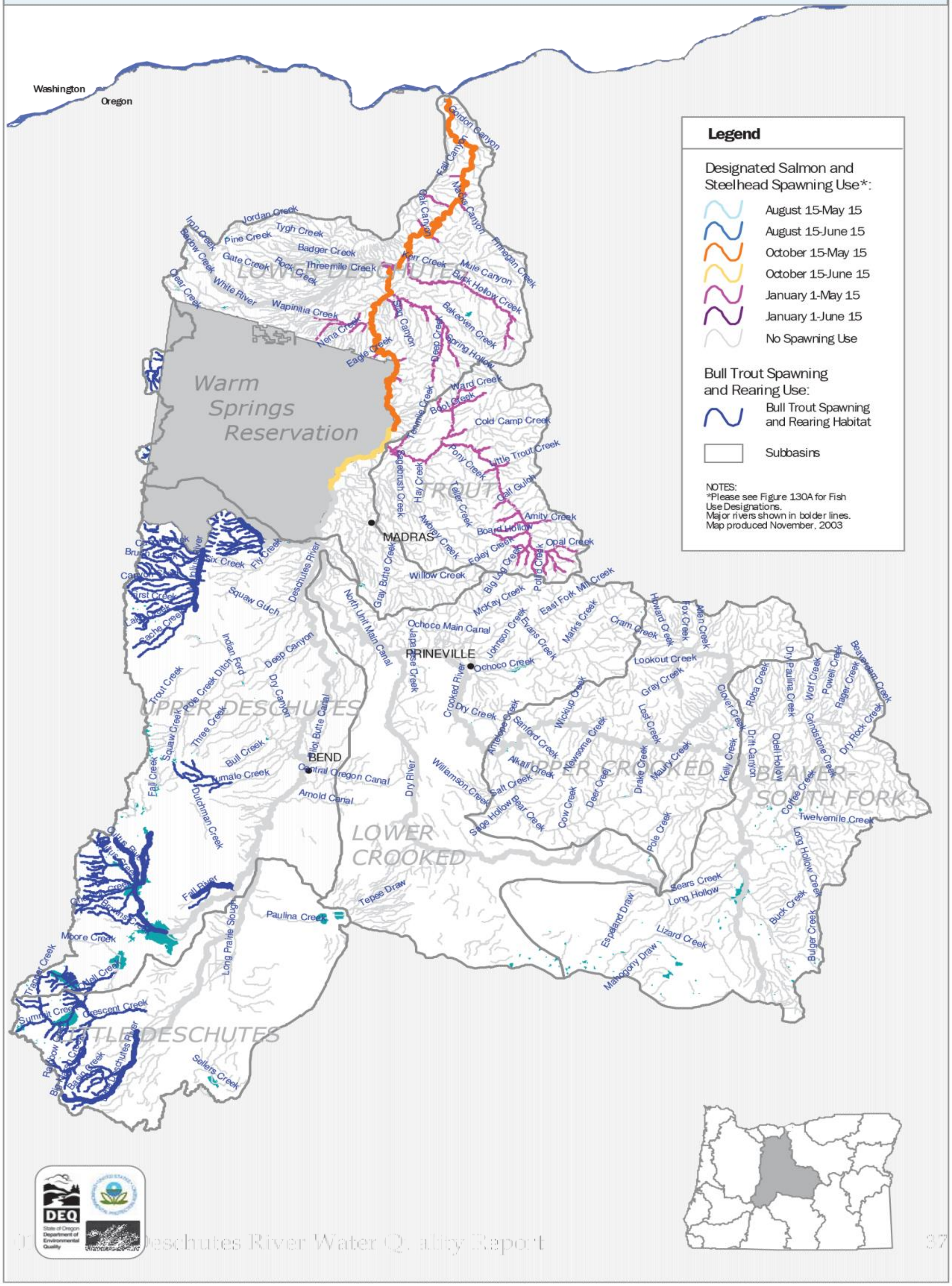
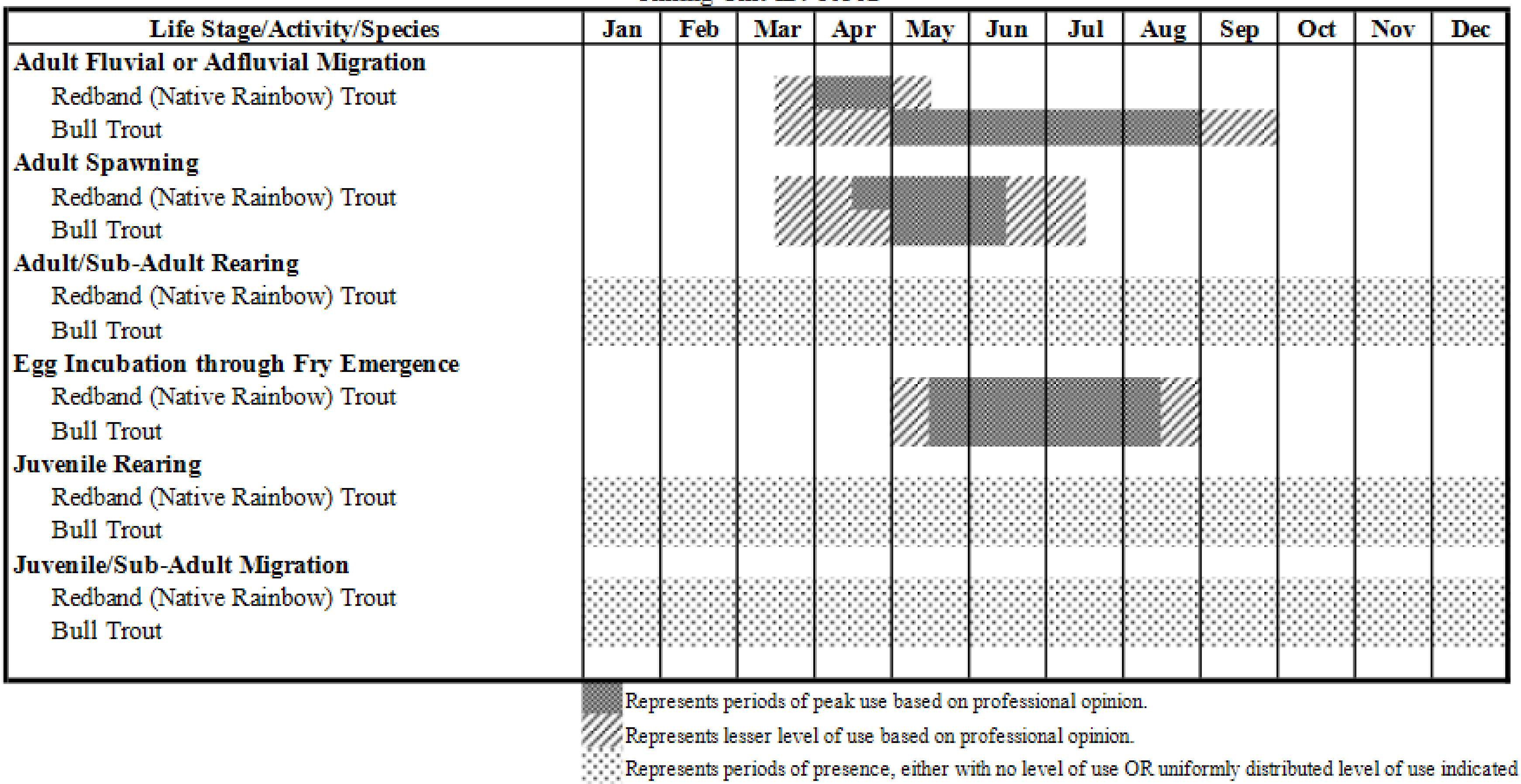


*Figure 130B: Salmon and Steelhead Spawning Use Designations**
Deschutes Basin, Oregon

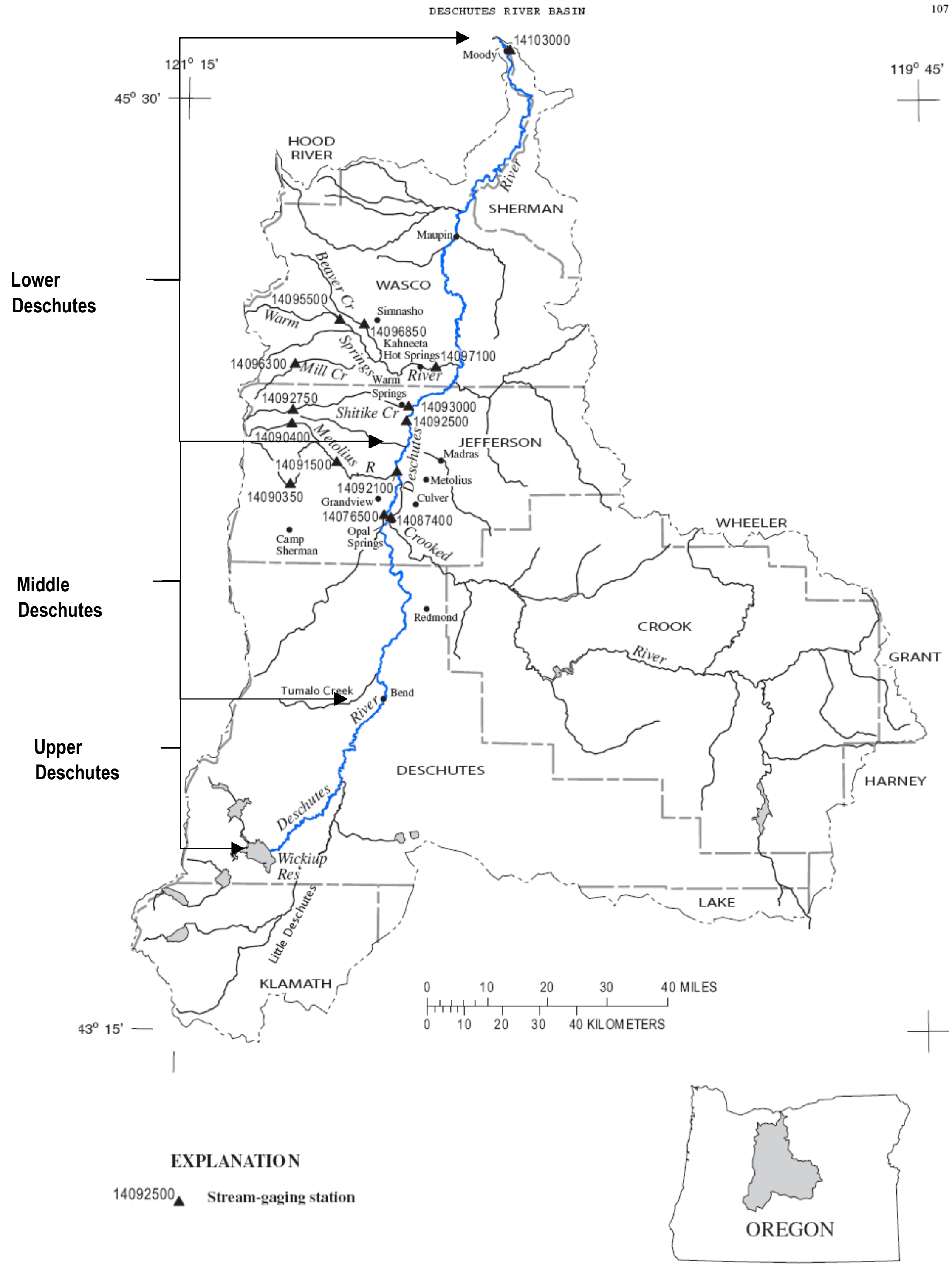


Deschutes R below Pelton Dam - Non-Anadromous Species

Timing Unit ID: 10362



Based on professional opinion, 90% of the life-stage activity occurs during the time frame shown as the peak use period.
Based on professional opinion, 10% of the life-stage activity occurs during the time frame shown as the lesser use period.



https://upload.wikimedia.org/wikipedia/commons/2/21/Usgs_deschutes_watershed.png