2017 LOWER DESCHUTES RIVER WATER QUALITY STUDY RESULTS

DESCHUTES RIVER ALLIANCE

Prepared for Deschutes River Alliance
June 2018

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INTRODUCTION

The effect of the Selective Water Withdrawal (SWW) tower on water quality in the 100 miles of the Deschutes River downstream from the Pelton Round Butte dam complex has been an ongoing concern since the SWW tower became operational in December 2009. A thorough discussion of the tower's construction and operation was covered in the Deschutes River Alliance's 2016 water quality report (DRA 2017). The operation of the tower and release of surface water from Lake Billy Chinook (LBC), the reservoir behind Round Butte Dam, has continued with only minor operational changes throughout 2017. As in previous years, 100% surface water was released from early November 2016 through mid-June 2017. From mid-June through the end of October various blends of surface and bottom water were mixed and released downstream from LBC. It is important to note that water (surface or any blend of surface and bottom water) is released only during periods of power production at the Round Butte dam. When turbines at the dam are not running no water is released from LBC. Near constant streamflow in the lower Deschutes River is maintained by releasing a continuous flow of water from the reregulation reservoir located behind the Reregulating Dam, the third and most downstream dam of the three-dam complex. Pelton Dam and Lake Simtustus make up the middle dam and reservoir (Figure 1).

The Deschutes River Alliance (DRA) has described in detail in previous reports how the three tributaries entering LBC have different temperature and water quality characteristics (DRA 2017, 2016). The Crooked River is the warmest and most nutrient laden, while the Metolius is the coldest and has the lowest nutrient concentration. Because of the temperature differences between the tributaries, the warmer water of the Crooked River remains at the surface of LBC, while the colder water of the Metolius sinks to the bottom. As a result, when surface water is released from LBC the Pelton Round Butte complex is releasing the warmer, more polluted Crooked River water downstream into the lower Deschutes River. The water quality data collected by the DRA in 2017 and 2016 show how this change in the quality of water released from LBC is impacting the water quality in the lower Deschutes River.

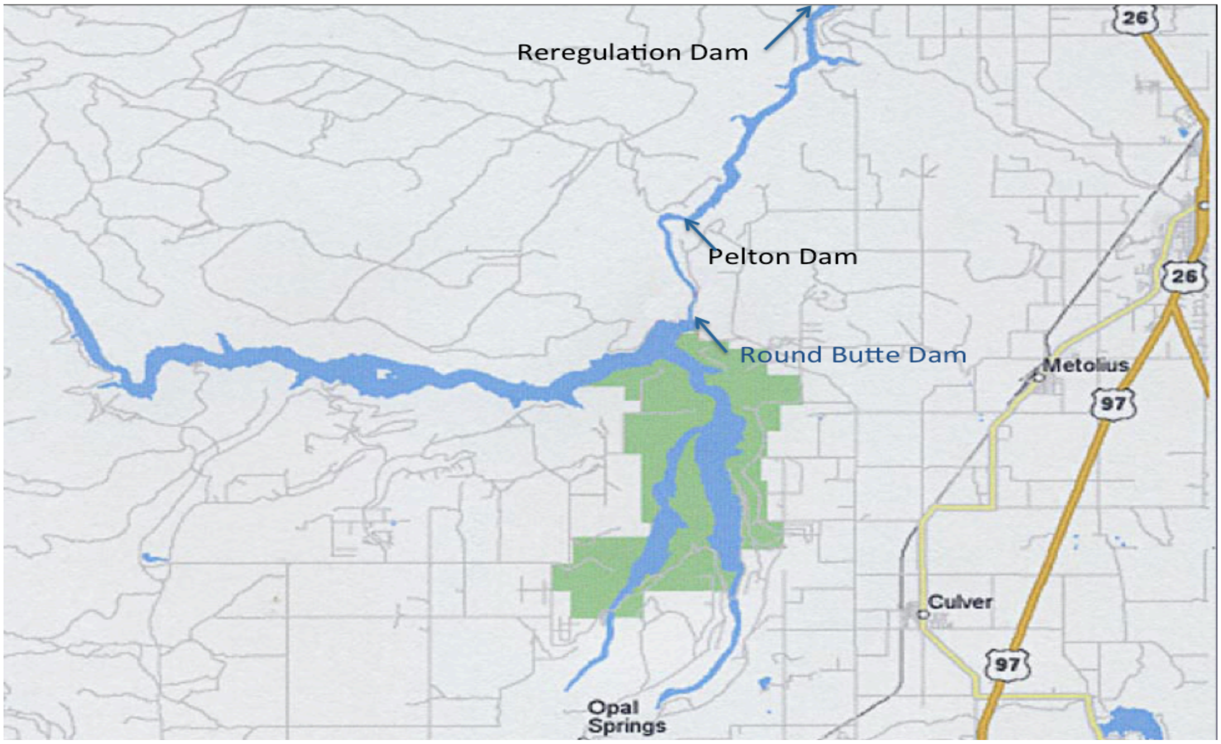

Figure 1. The three dams jointly owned and operated by PGE and CTWS: Round Butte Dam (creates Lake Billy Chinook reservoir), Pelton Dam (creates Lake Simtustus reservoir), and the Reregulating Dam (creates the reregulation reservoir).

OBJECTIVES AND KEY QUESTIONS

In 2017 the DRA continued to monitor water quality in the lower Deschutes River at river mile 99 (one mile below the Reregulating Dam tailrace), the same location sampled in 2016. Hourly data for six water quality parameters (temperature, pH, dissolved oxygen, chlorophyll-a, turbidity, and conductivity) were collected from April 6 through September 21. The monitoring objectives in 2017 remained unchanged from 2016:

1. How does water quality for the key parameters of temperature, pH, and dissolved oxygen change on an hourly basis?
2. Which, if any, of these parameters exceed Oregon's water quality standards for the Deschutes Basin and, if so, how frequently?
3. Is the water released from the Pelton Round Butte (PRB) complex through the SWW tower contributing to violations of water quality standards in the lower Deschutes River?

To answer these questions a YSI Model 6600 V2 data sonde was installed at river mile 99 (see methods section for details). This location is close enough to the Reregulating Dam tailrace to rule out other potential influences on water quality in the lower river, but far enough downstream to allow the river time to show a response to water released from the Pelton-Round Butte Dam (PRB) complex. Besides providing an excellent place to assess the effects of water released from the PRB complex on the lower Deschutes River, the sample site also includes spawning habitat actively used by trout and salmon.

A notable difference between 2016 and 2017 was the late winter and spring weather and its effects on snowpack and streamflow. In 2016 warm weather from late March through April resulted in lower overall late season snowpack and early snowmelt. On April 28, 2016 snowpack in the Upper Deschutes-Crooked River basin was 72% of normal (NRCS SNOWTEL basin reports). Weather conditions in 2017 were nearly the exact opposite, with colder and wetter than normal weather throughout the late winter and spring. This resulted in a snowpack on May 1, 2017 in the Upper Deschutes-Crooked River basin of 133% of normal. These differences had a direct affect on streamflow in the lower Deschutes River. Table 1 shows how streamflows differed between 2016 and 2017 at the Madras streamflow gauge (just below the PRB complex) and at the Moody gauge (mouth of the Deschutes River). These two years provide a unique opportunity to see how water quality in the lower Deschutes River differed between a low water year and a high water year.

Table 1. Comparison of stream discharge (cfs) in 2016 vs. 2017 in the lower Deschutes River.

Gauge Location Year	March 1st	April 1st	May 1st	Peak Flow
Madras Gauge 2016	5,000	5,000	4,100	6,500 on Mar 10
Madras Gauge 2017	5,600	8,000	5,300	10,000 on Mar 18
Moody Gauge 2016	6,900	6,500	4,800	9,000 on March 13
Moody Gauge 2017	7,000	11,500	8,000	13,800 on Mar 20

SAMPLING METHODS

Water quality data in 2017 was again sampled with a YSI 6600 V2 data sonde with 4 optical ports. It collected hourly water quality data for pH, dissolved oxygen, percent oxygen saturation, temperature, conductivity, turbidity, and chlorophyll-a (Figure 2). Probes include self-cleaning optical sensors to avoid inaccurate results due to bio-fouling. More complete information about this YSI data sonde can be found at: https://www.ysi.com/6600-v2-4

Figure 2. YSI 6600 V2 data sonde.

The YSI data sonde was calibrated against lab standards for all parameters before being deployed in the field, and it was programmed to record hourly readings for each parameter. Field installation occurred on April 6, 2017, at RM 99, one mile below the Reregulating Dam tailrace. The data sonde was placed in an area of laminar flow near the east bank in three feet of water. The probes were positioned four to six inches above the stream bottom. Following field installation, field audits for all parameters except chlorophyll-a were completed monthly to ensure that the data sonde continued to collect accurate results (Appendix A).

No malfunctions of the data sonde were noted during its deployment, and based on the field audit checks, the data quality remained high throughout the sample period. The data sonde was removed from the river at 1200 hours on September 21, 2017. Data downloads were made during several field audits. The final data download was completed after the data sonde was removed from the river. Quality control and assurance procedures were followed throughout the study (Appendix B).

RESULTS

Temperature:

Hourly temperature readings from April 7, 2017 through September 20, 2017 are shown in Figure 3. The width of the line shows the range in temperatures over a 24-hr period. The difference between the daily minimum (occurs just before sunrise) and daily maximum (typically around 3pm) was around 0.5 °C in early April. The difference in diel minimum and maximum temperature gradually increases as the days grow longer and warm. The maximum diel fluctuation occurs in the middle of the summer when the daily range increased to just over 1.5 °C (~3.0 °F). Diel fluctuations decline again in the fall as the days grow shorter and the weather cools.

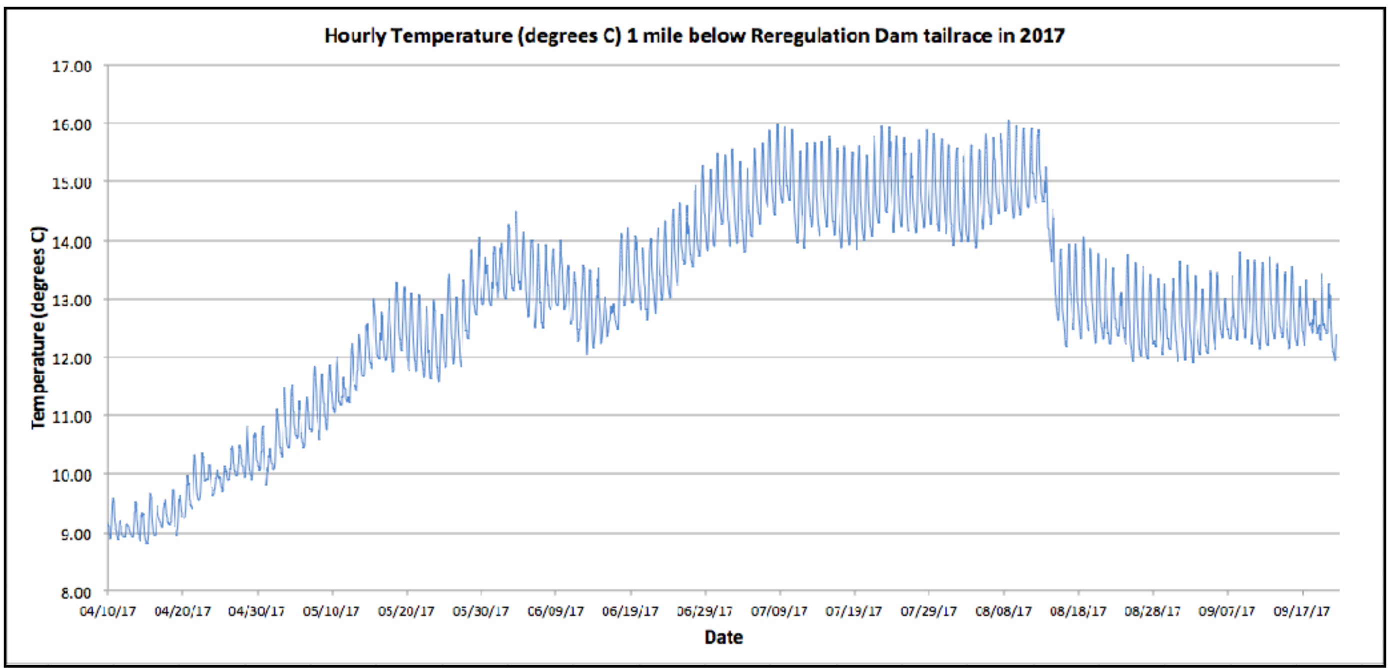

Figure 3. 2017 hourly water temperature at River Mile 99, one mile below Reregulating Dam tailrace.

The minimum recorded temperature at RM 99 during the monitoring season was 8.42 °C (47 °F), on April 8 at 0700 hours. The maximum water temperature was 15.99 °C (61 °F) recorded on July 8 at 1600 hours. Water temperature remained relatively constant between 14 and 16 °C throughout July and early August until a sudden drop in temperature occurred on August 14th.

This drop in temperature corresponded with a switch to 65% bottom withdrawal at the SWW tower on August 12. The shift to greater bottom withdrawal was reported by PGE to be due to cleaning debris from the tower intake. The increase in bottom water withdrawal is clearly visible in Figure 3, when the maximum water temperature rapidly dropped by 2 ^{o}C (3.5 ^{o}F).

Dissolved Oxygen:

Dissolved oxygen (DO) in water is measured and recorded in two ways: 1) as the concentration of dissolved oxygen in the water recorded in milligrams per liter (mg/L); and 2) as the percent of oxygen dissolved in the water (% saturation) given the temperature, elevation, and barometric pressure when the sample was collected. 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) is lower than the standard due to temperature, elevation, and barometric pressure conditions, but the saturation level is still high (e.g. >90%) it is the percent saturation of DO that is applied when evaluating whether DO water quality standards are being met.

Oregon's water quality standard for dissolved oxygen varies depending on the presence of spawning steelhead, salmon, or trout: the DO standard is higher when trout and/or salmon are spawning and their eggs and fry incubating, than when they are not. The DO standard currently being applied by ODEQ for the lower Deschutes River is 9.0 mg/L during spawning/incubation season and a lower, multiple standard of 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 must be met) during the period DEQ identifies as outside the spawning and incubation period. More explanation of Oregon's DO standard and its application to this Project is covered in the "**Discussion**" section of this report.

Figures 4 and 5 show the dissolved oxygen levels as mg/L and % saturation, respectively. These graphs show a clear diel change in DO: minimum concentrations occurred an hour or two before sunrise, while maximum

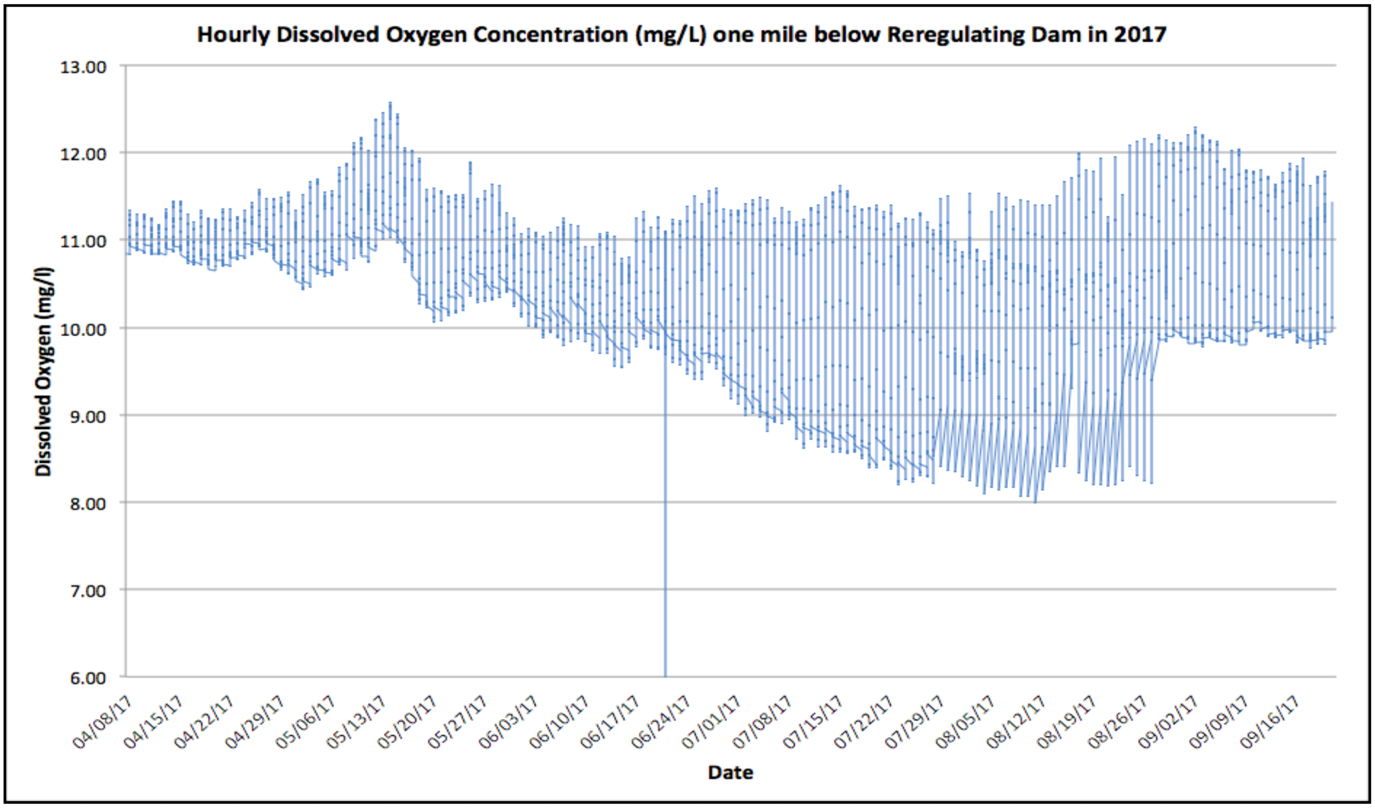

Figure 4. Hourly concentration of Dissolved Oxygen (mg/L) at River Mile 99, one mile below Reregulating Dam tailrace.

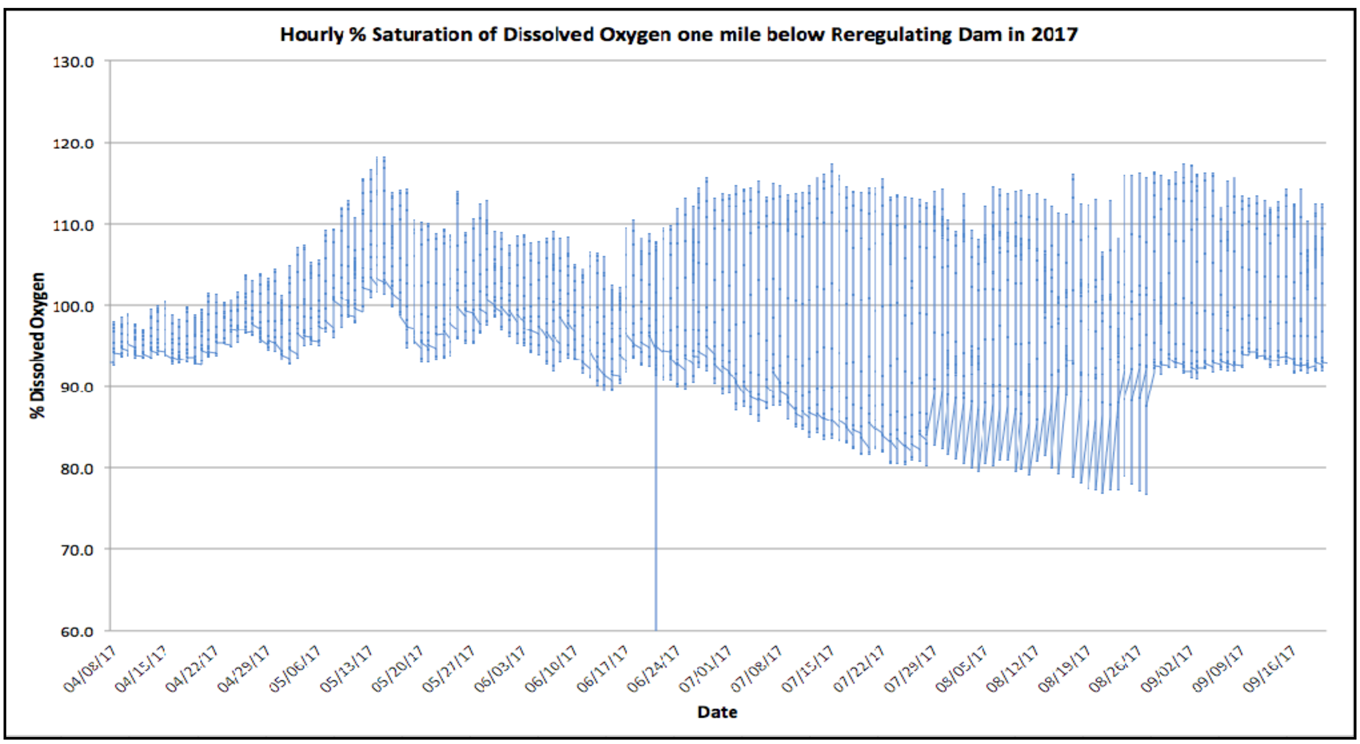

Figure 5. Hourly saturation levels of Dissolved Oxygen (% saturation) at River Mile 99, one mile below Reregulating Dam tailrace.

concentrations were measured mid-afternoon. The greatest range from daily low to daily high occurred during the summer months. These daily changes are driven by biological activity in the water. During daylight hours photosynthesis by algae and aquatic plants produces oxygen, increasing the DO levels. At night, when photosynthesis stops, respiration by plants and animals uses up the oxygen dissolved in the water, causing a decrease in DO concentration. The large difference between the daily low and daily high DO concentration during the summer months (indicated by the wider line on the graphs), reflects a higher level of photosynthetic activity (and hence oxygen production) due to a greater biomass of algae and longer days with more sunlight exposure. The effect of high algal biomass is clearly shown by the large swings in the daily DO concentration levels throughout July and August (Figure 4). In addition, DO saturation well above 100% was recorded from late June through early September (Figure 5). These changes in DO saturation - large diel swings and supersaturation - often occur in response to nutrient enrichment problems (EPA 2013, Hynes 1972).

Results for DO in 2017 look very similar to those recorded in 2016 (Figure 6). However, in 2017 maximum daily DO concentrations remained above 11mg/L, and daily minimums stayed just above 8mg/L, throughout most of the season (Figure 5), while in 2016 DO concentrations from July through August never rose above 11mg/L and often dropped below 8mg/L (Figure 6). The slightly higher DO levels during the summer in 2017 are likely due to differences in streamflow and weather conditions between the two years.

In both years minimum daily DO concentrations dropped below 9mg/L in late June or early July and continued to drop below 9mg/L on a daily basis until early September. Because trout spawning continues until at least the end of July or early August, and thus intergravel egg/fry incubation occurs until early September (Zimmerman & Reeves 1995), any DO concentration below 9mg/L during this time period is a violation of the basin water quality standards for salmonid spawning and incubation (Oregon Administrative Rules 340-041-0016).

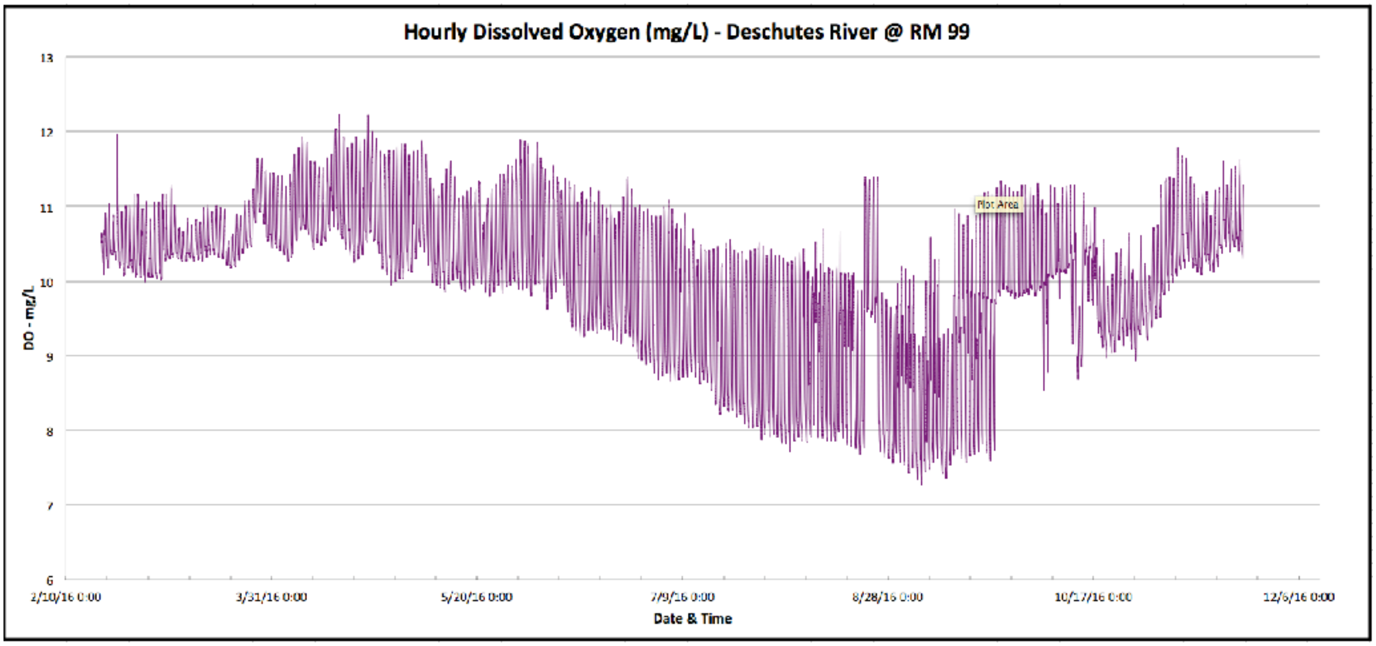

Figure 6. Hourly dissolved oxygen concentrations at River Mile 99, one mile below Reregulating Dam tailrace in 2016.

pH:

Figure 7 shows the hourly pH measurements recorded from mid-February to the end of November. As with temperature and DO, the width of the line shows the difference in pH over a 24-hour period. Daily changes in pH are driven by the photosynthetic activity of aquatic plants and algae: pH rises with increased photosynthesis and drops when photosynthesis declines. As a result, maximum daily pH levels typically occur mid-afternoon between 1400 and 1600 hours, while minimum pH occurs early in the morning, generally just before sunrise. An increase in the range of pH between early morning and mid-day (shown by the width of the line) indicates greater algal biomass and sunlight, which results in more photosynthesis. Because pH changes in response to algal density, high pH levels are also a useful indicator of nutrient enrichment (EPA 2013).

Oregon's water quality standard for pH in the Deschutes Basin is a pH between 6.5-8.5 standard units (Oregon Division 41 Water Quality Standards 2016). Like other water quality standards, this standard was set to protect aquatic life. While a pH just above 8.5 is not lethal to aquatic life, pH levels above the standard does not provide adequate protection (Robertson-Bryan 2004), and also indicates excessive algal growth.

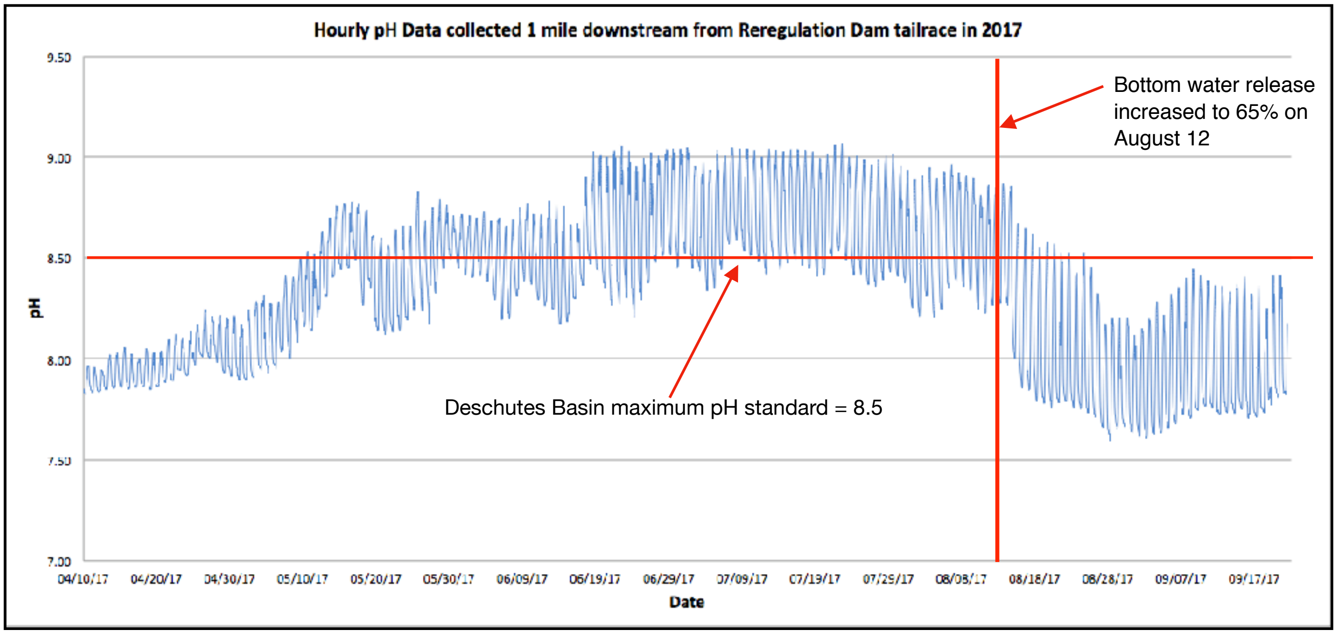

Figure 7. Hourly pH levels at River Mile 99, one mile below Reregulating Dam tailrace.

The first recorded pH above 8.5 was on May 10, at 1400 hours (pH of 8.53). From that date forward pH exceeded the Deschutes Basin maximum pH standard every day until late August. pH levels above 9.0 are further indication of excessive algal growth. Peak daily pH levels exceeded 9.0 starting in mid June and continued to exceed 9.0 most days until the end of July. The maximum pH recorded during 2017 was 9.06 on July 22, at 1300 hours.

Overall, pH levels were lower in 2017 compared to 2016 (Figure 8), with no pH levels measured above 9.5 in 2017, and a shorter period of time with daily peak pH levels above 9.0. These differences are likely due to the higher stream flows and different weather conditions in 2017 compared to 2016. Even with these higher spring flows and cooler weather however, the pH measured in 2017 still far exceeded the Deschutes Basin water quality standards continuously for nearly four months (early May through late August), and routinely reached a pH of 9.0 or above from mid June until late July. Such high pH is a strong indicator of excessive algal growth and nutrient enrichment problems in the lower Deschutes River.

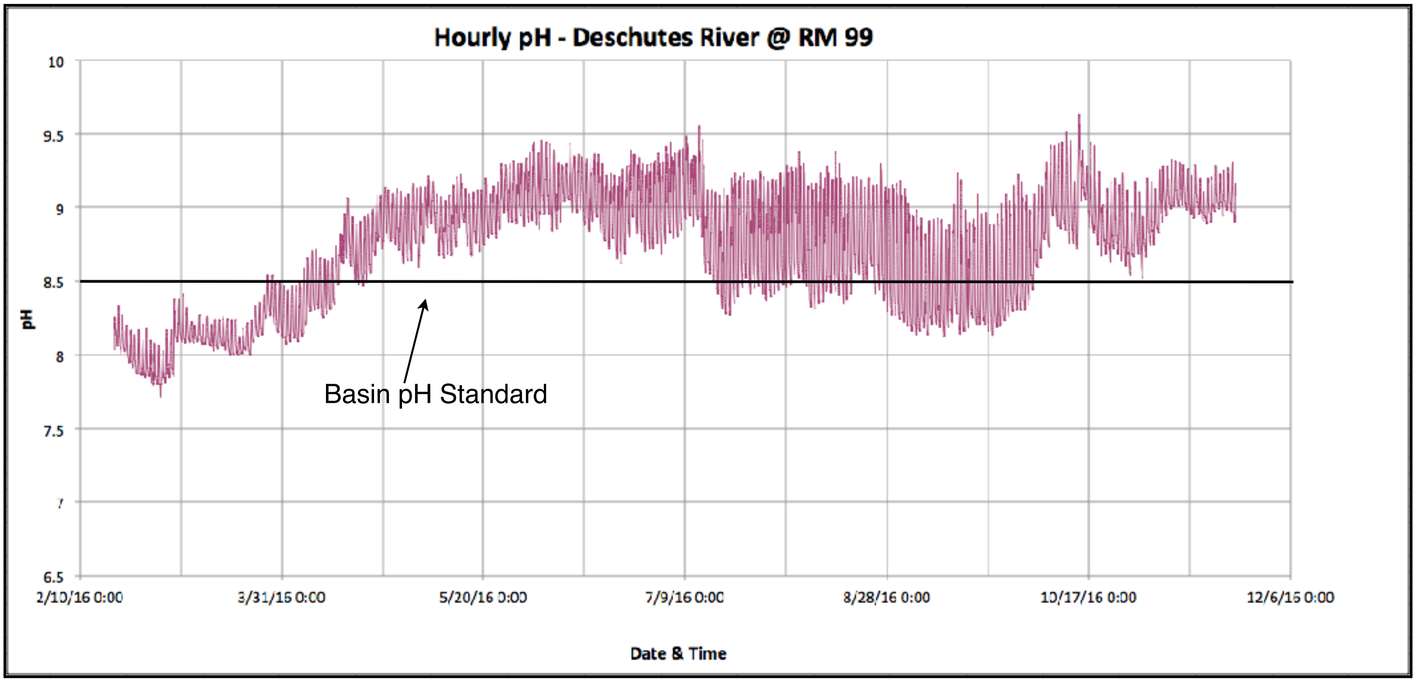

Figure 8. Hourly pH measurements at River Mile 99, one mile below Reregulating Dam tailrace in 2016.

Note: The early results of pH data collected in March and April of 2018 show higher pH than was recorded in 2017, with pH over 8.5 first measured on March 20th and pH above 9.0 recorded on April 8. These results indicate that 2018 will likely experience the higher pH levels recorded in 2016 rather than the slightly lower, but still problematic levels, recorded in 2017.

DISCUSSION

Temperature:

Temperature management has been cited as one of the key objectives of the SWW tower, and one of the main reasons for releasing surface water from LBC (Water Quality Management & Monitoring Plan 2002). Specific temperature requirements for the Project have been set out in the Water Quality Management & Monitoring Plan (WQMMP). This document describes how water quality is to be managed as part of the Project's water quality permit (§ 401 Certification).The method 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), and 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*. DRA believes that this equation does not provide a sound biological basis for temperature management at the PRB complex. The water temperature used in the equation is the 7-day rolling average of the **maximum daily temperature** of the three tributaries entering LBC. The DRA submits that using only the maximum temperature of the three tributaries does not, and cannot, result in, quoting from the WQMMP: *conditions that would exist as if the dams were not present*.

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 mid-afternoon high to a late night/early morning low. This daily range in temperature in the Deschutes River at RM 99, is shown by the width of the graph line in Figure 3. A model that accurately predicts water temperature below the dams *as if the dams didn't exist*, should take into account the natural diel temperature range of the three tributaries entering LBC. Using only the maximum tributary temperatures, as is currently done, cannot mimic a natural temperature regime.

Figure 9 shows the result of the current temperature management scheme. In this graph the actual 7-day average maximum temperature at the Reregulating Dam tailrace, the calculated or modeled 7-day average maximum temperature,

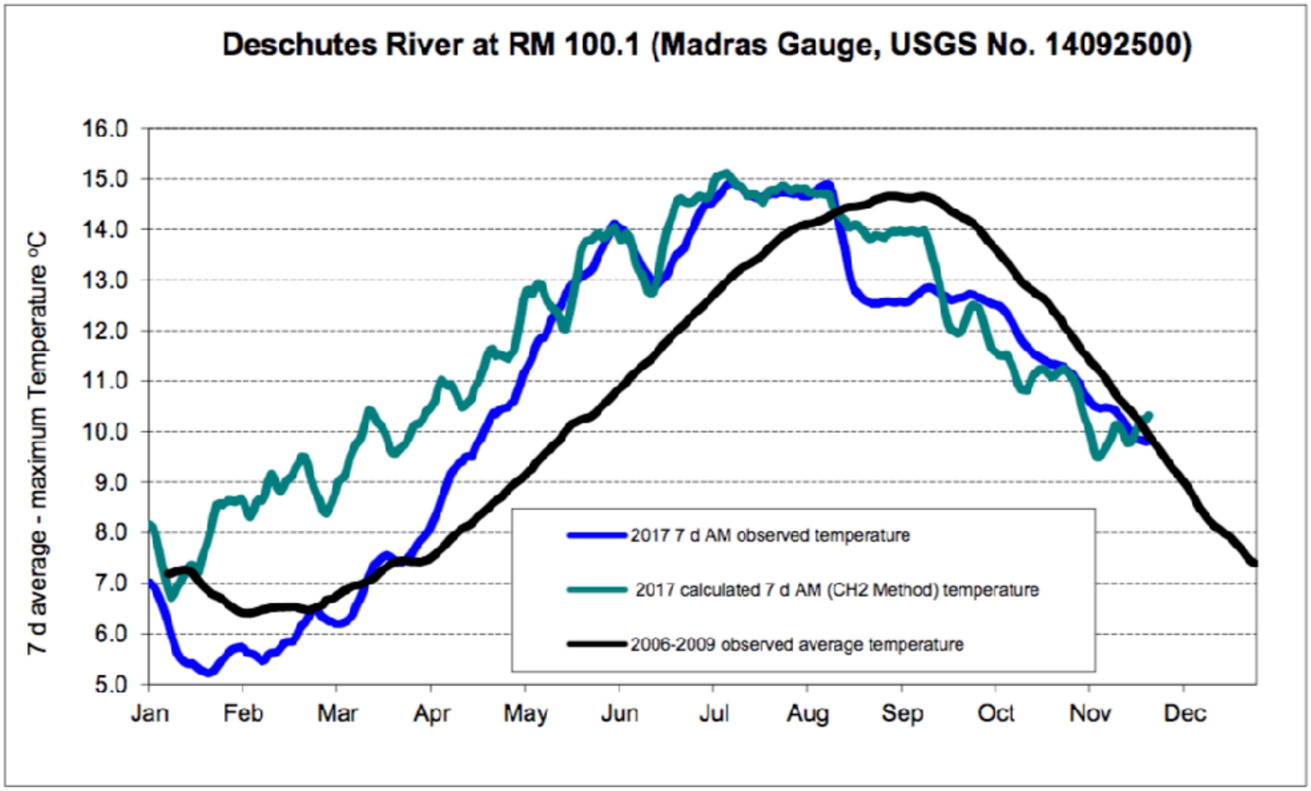

Figure 9. Comparison of the observed, modeled and pre-tower water temperature at the Reregulating Dam tailrace in 2017. (From PGE 2017 water temperature data report).

and the pre-SWW tower 7-day average maximum temperature averaged for the years 2006-2009 are compared. Comparing the actual observed temperature at the Reregulating Dam to the average maximum temperature for 2006-2009, shows that surface water releases resulted in an increase in water temperature throughout the spring and early summer. In 2016, a low-water year with lower streamflow in the spring, water temperatures in the lower Deschutes were elevated above pre-tower temperatures from February through June (Figure 10).

By implementing the new temperature management approach, the maximum annual temperature now occurs about four to six weeks earlier (early to mid July) than when 100% bottom water was released. However, while the annual peak temperatures occur earlier in the summer (one of the goals of the SWW tower), they are no cooler than pre-tower maximum temperatures. In addition, the higher temperatures in the late winter through early summer have had several negative affects on the river as described below.

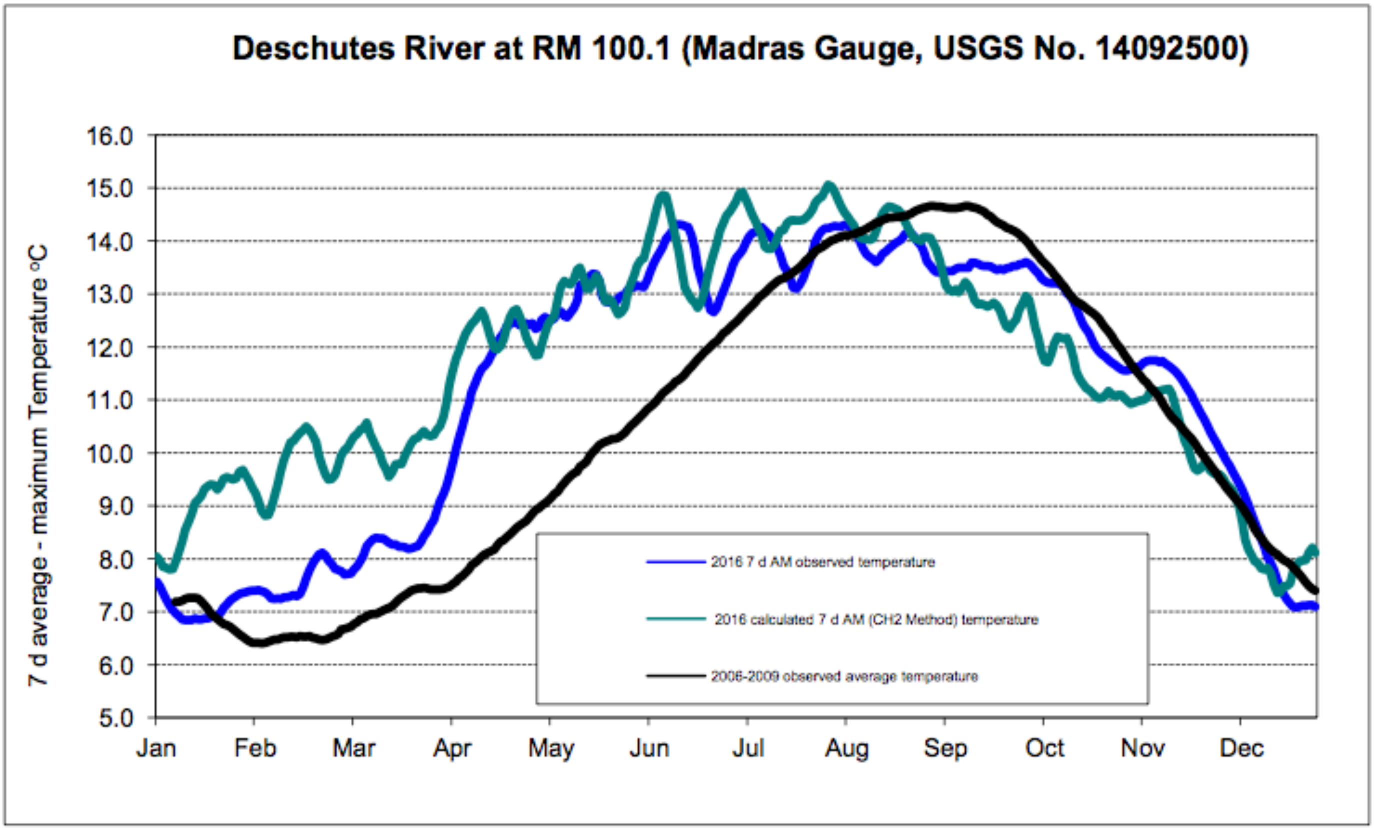

Figure 10. Comparison of the observed, modeled and pre-tower water temperature at the Reregulating Dam tailrace in 2016. (From PGE 2016 water temperature data report)

1. Increased water temperature can affect aquatic invertebrates in several ways: 1) changes in egg development, 2) faster larval growth, 3) earlier adult emergence, and 4) smaller adults due to faster larval development and earlier emergence, which has been correlated with a decline in insect fecundity (Ward 1992). DRA's guide hatch surveys have confirmed earlier emergence of the major insect hatches, and consistently low to moderate abundance of adult insects (Hafele 2014, 2015, 2016, 2018).

2. Algal growth is accelerated by higher water temperature (Bellinger & Sigee 2010), which, along with greater nutrients released with surface water, has resulted in nuisance levels of algae including two species that reduce suitable habitat for aquatic insect larvae. As discussed below, the increased algal growth negatively affects pH and dissolved oxygen concentrations in the river downstream from the Project.

3. Warmer water (and higher nutrients) has led to a shift in the aquatic invertebrate community with an increase in more pollution tolerant species (primarily worms and snails) and a decline in pollution sensitive species (mostly mayflies and stoneflies) (Edwards 2018). In addition there has been a dramatic increase in the polychaete worm *Manayunkia speciosa*. *M. speciosa* is the intermediate host of *Ceratonova shasta*, a serious parasite of Chinook salmon. *C. shasta* infects both juvenile and adult Chinook salmon with up to 90% mortality rates of infected fish (ODFW 2016: click here for online report). New studies have confirmed troubling levels of mortality of juvenile and adult Chinook salmon in the lower Deschutes River since the tower began operation (Connolly & McLean 2016: click here for online report).

4. The current temperature conditions with surface water releases, while different than pre-tower conditions, are still not "natural." Just as releasing 100% bottom water failed to release water with a temperature that would occur if no dams were present, the surface water released now is warmer than would occur without the dams instead of colder. Particularly in light of increasing concerns over warmer water temperature due to climate change, there is no justification to further warm a salmon and trout stream.

5. The Deschutes Basin temperature standard during salmon and steelhead spawning is a 7-day average maximum of 13°C (Oregon Administrative Rules, 340-041-0028). In 2017 the 7-day average maximum water temperature exceeded 13°C from mid-May through June 15th (Figure 11).

6. Figure 11 also shows the effect of increasing bottom water releases on water temperature in the lower Deschutes River. Based on PGE's water quality reports, bottom water releases increased from 30% on August 10, to 65% on August 12, apparently in order to clean debris from the surface water intake. By releasing more bottom water, the water temperature in the lower river one mile downstream quickly dropped by just over 2°C.

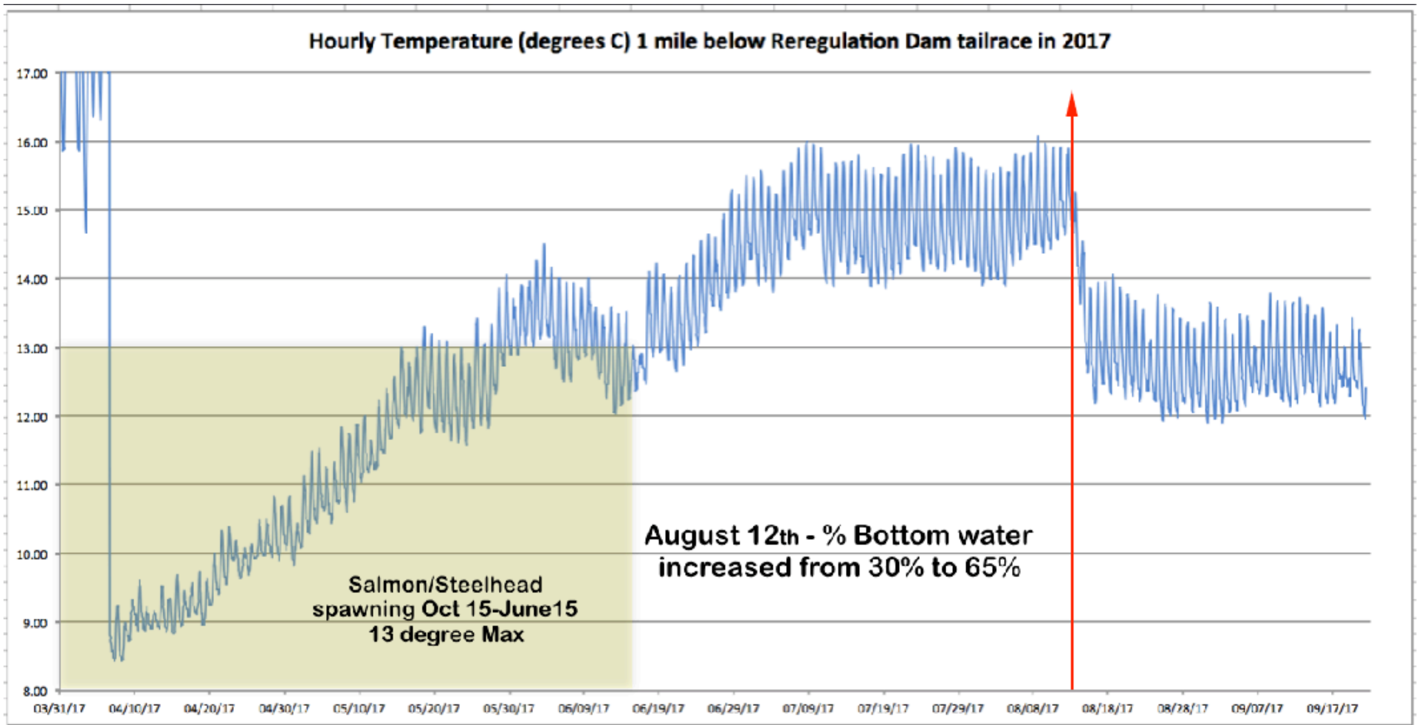

Figure 11. 2017 hourly water temperature at RM 99.

Dissolved Oxygen (DO):

Aquatic animals require adequate oxygen to survive, but the amount of dissolved oxygen in water is affected by several factors. For example, cold water can hold more dissolved oxygen than warmer water. Also, when water and air mix due to turbulence (think waterfalls, white water river sections, or spill from dams) oxygen from the air will be absorbed by the water increasing its concentration. Last, photosynthetic activity from aquatic plants and algae add oxygen to the water.

The concentration of dissolved oxygen needed to support the range of life functions - feeding, spawning, predator avoidance, etc. - varies with different 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 dissolved oxygen (Willers 1991). In addition, the oxygen requirements for developing salmonid eggs and fry are greater than for adults. For these reasons, Oregon's water quality standards for dissolved oxygen are set to protect salmon and trout, with higher standards applied during spawning and egg incubation periods than during non-spawning and incubation periods. Oregon's DO criteria for the Deschutes Basin are described in Table 2.

Table 2. State of Oregon's dissolved oxygen criteria for the lower Deschutes River.

Beneficial Use	Dissolved Oxygen Criteria
Salmonid Spawning, including where and when resident trout spawn.	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 DEQ determines *adequate data for DO exists, DEQ 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. It is a violation if any one of the three are not met. * No definition for what constitutes "adequate" data is given.

The criterion applied during spawning periods depends on intergravel DO levels. Intergravel dissolved oxygen (IGDO) is the amount of oxygen dissolved in the water that flows within the stream substrate. Adequate oxygen within streambed gravels is critical for developing salmon and trout eggs and incubating fry. When IGDO data are not available, or IGDO levels are less than 8 mg/L, the water column DO requirement of 11.0 mg/L is applied. However, if IGDO data have been collected and show adequate oxygen within the substrate (>8.0 mg/L) then the water column criterion is lowered to 9.0 mg/L.

The spawning/incubation season dates for salmon and steelhead are identified in maps that were developed with input from the Oregon Department of Fish & Wildlife (ODFW). These maps identify the location and time of year salmon and steelhead spawning occurs for the different river basins in Oregon. Figure 12 shows the map taken from OARs that defines the area and time of year for salmon and steelhead spawning in the Deschutes Basin. The spawning season for the reach from the Reregulating Dam to Warm Springs River (RM 84) (shown in yellow) is October 15 - June 15, while the spawning period from Warm Springs River to the mouth of the Deschutes at the Columbia River (shown in orange) is October 15 - May 15.

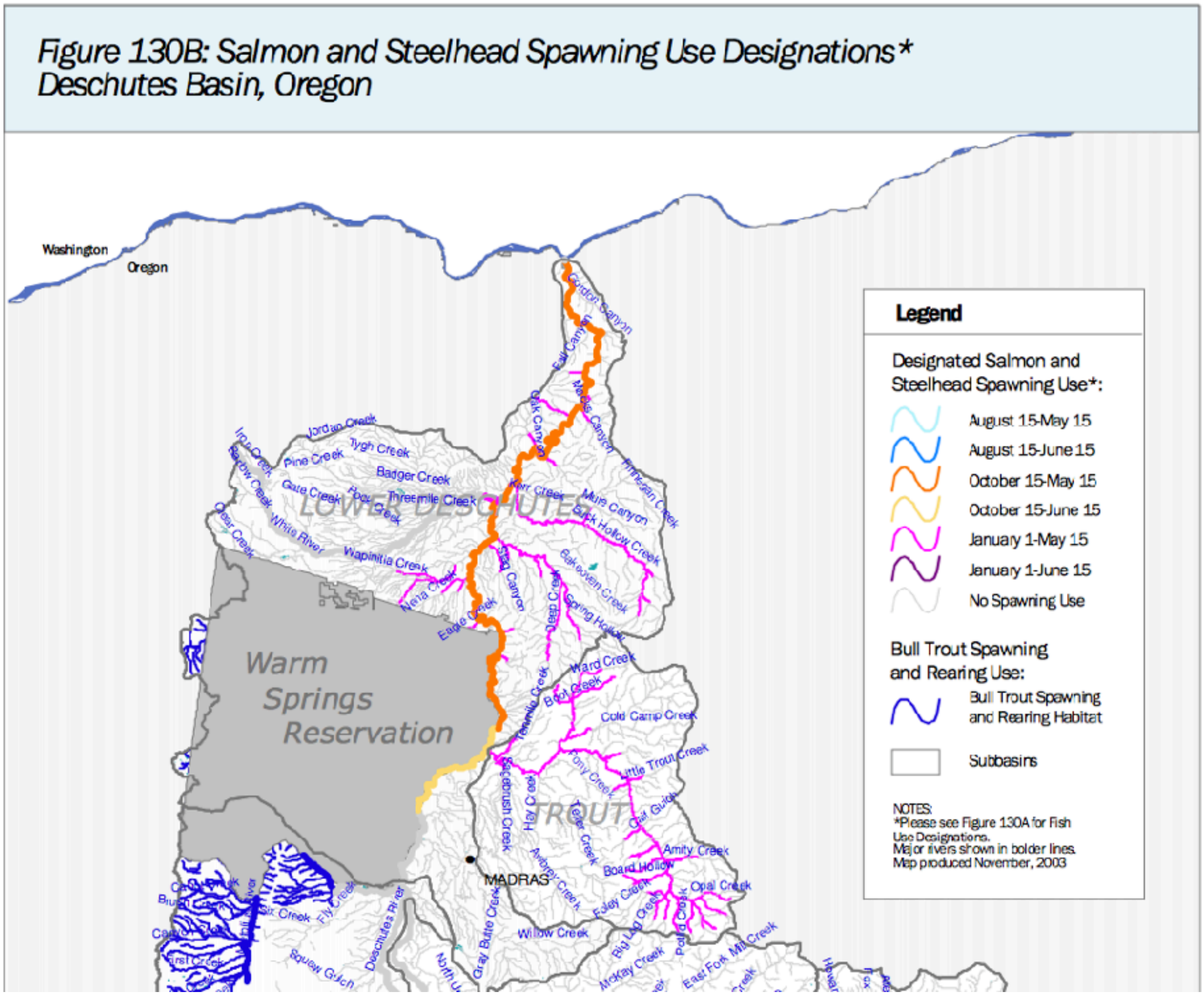

Figure 12. Map showing designated spawning periods for salmon and steelhead in Deschutes Basin. (Taken from Oregon OAR's section 340-041-0016)

It is important to note that this map identifies the time and place of spawning for only salmon and steelhead (and bull trout in some watersheds), but not where and when resident trout spawn. However, 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 incorporated as well. OAR 340-041-0016 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 (bold added for emphasis). In other words, Oregon's DO standard requires that the higher DO standard must be applied not just in the identified salmon and steelhead spawning time and place, but also during resident trout spawning through fry emergence.

Studies have documented trout spawning in the lower Deschutes River until the end of July (Zimmerman & Reeves 1995). DRA volunteers have also made first-hand observations at RM 99 of resident trout spawning in late July. As a result, the spawning/incubation criteria of 9.0 mg/L (11.0 mg/L if IGDO falls below 8.0 mg/L) is applicable until late August or early September to take into account all salmonid egg incubation through fry emergence, which continues for weeks after spawning is completed.

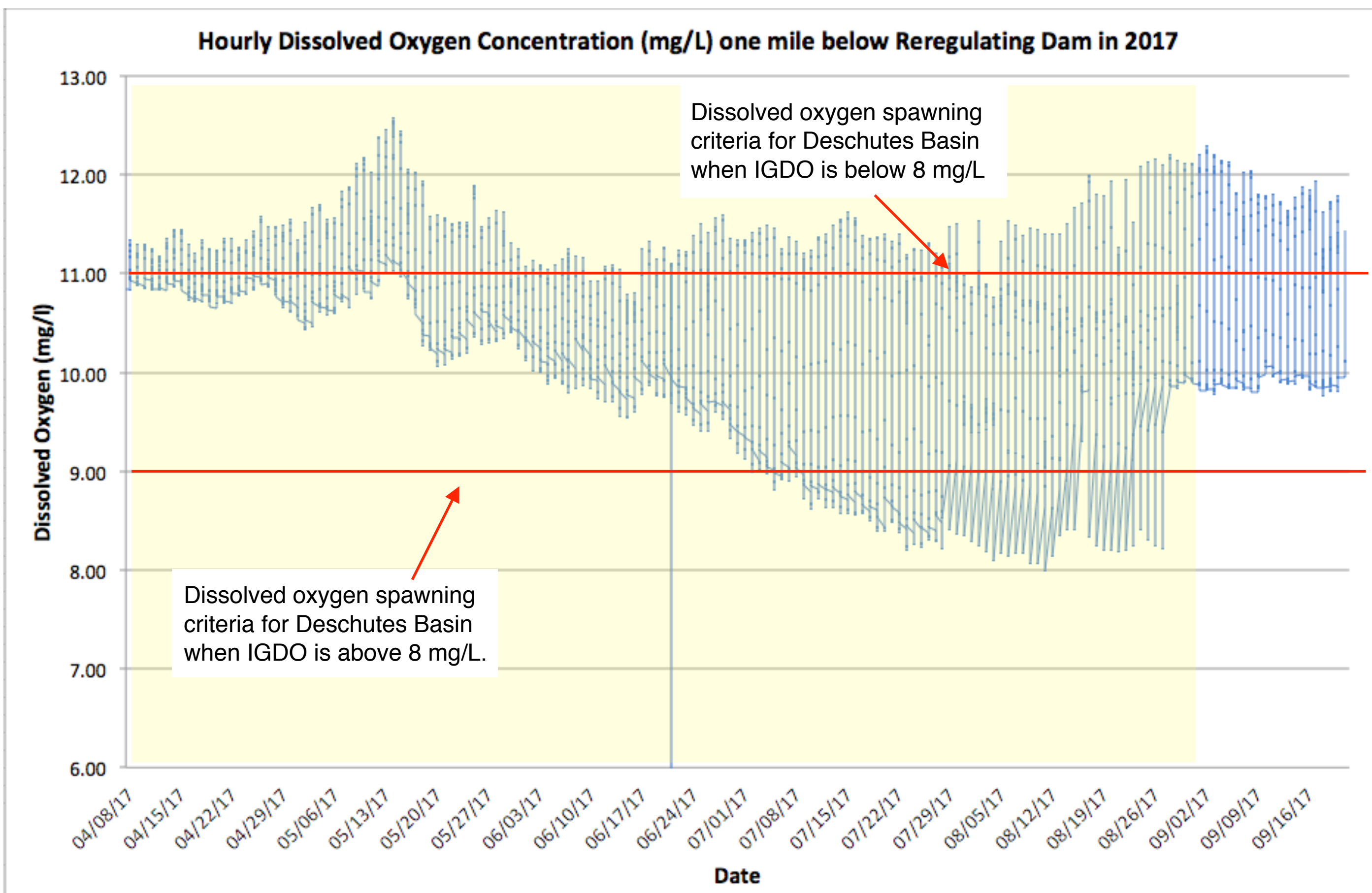

Figure 13. Hourly dissolved oxygen concentrations at River Mile 99, one mile below Reregulating Dam tailrace in 2017. **Shaded area shows spawning/incubation season for salmon, steelhead, & trout.**

Figure 13 shows that DO levels began dropping below the 9.0 mg/L minimum concentration on July 4, and continued to fall below 9.0 mg/L daily until August 27. Because trout spawning and incubation are occurring during this time, on each of these days DO concentration fell below the applicable basin standard. Plus, if IGDO levels are not in fact above 8 mg/L, then DO should not fall below 11 mg/L. If the 11 mg/L standard were applied, the DO was below the standard for almost the entire spawning season (Figure 13).

This failure to protect trout spawning and incubation is a violation of Oregon's water quality standards that should not be allowed and can be corrected by spilling water from the Reregulating Dam instead of passing it all through the power generation turbines.

pH:

Oregon's water quality standard for pH in the Deschutes Basin is a minimum of 6.5 and maximum of 8.5 standard units. The pH standard is designed to protect aquatic life from the harmful effects of water that is too acidic or too alkaline. Like temperature and DO, pH shows a daily range, with minimum values typically occurring just before sunrise, and maximum values reached in the mid to late afternoon. The mid-day peak in pH is the result of increased photosynthetic activity by algae and aquatic plants due to maximum sunlight exposure. Photosynthesis lowers the dissolved CO_2 concentration in the water, which in turn reduces the carbonic acid concentration, which raises pH. At night photosynthesis stops while respiration continues, so that CO_2 levels increase — causing increased carbonic acid production and a decline in pH. As algal biomass increases, the difference between the daily minimum and maximum pH also increases as evidenced by the large swings in daily pH noted in our data (Figure 7).

Because both low (acid) and high (alkaline) pH levels are harmful to aquatic life, the water quality standard includes both a minimum and a maximum pH value. Since high pH levels (>8.5) are often the result of increased photosynthetic activity, pH is also a useful indicator of excessive algal growth and nutrient enrichment in freshwater (EPA 2013).

The hourly pH data collected at RM 99 showed that pH first exceeded the basin standard of 8.5 on May 10, and continued to exceed the upper standard of 8.5 until August 23 (Figure 7). The fact that pH levels were elevated above the 8.5 standard from May through August is a strong indication of excessive algal growth caused by nutrient enrichment. An example of the typical algal growth on the substrate at RM 99 is shown in Figure 14. Such a high level of sustained pH poses definite stress and health risks to aquatic life including salmon, steehead, and resident native trout (Robertson-Bryan 2004).

Figure 14. Algae and diatom growth on bottom substrate at Riffle Ranch (one mile below Reregulating Dam) on July 19, 2016.

Violations of the Deschutes Basin pH standard were known to occur before the SWW tower went into operation. An important question, then, is whether surface water withdrawal has made the pH problem worse. Figure 15 shows pH data collected by ODEQ at the Warm Springs Highway 26 bridge from January, 2005 through November, 2015. The vertical blue line indicates the beginning of surface water withdrawal in late December, 2009. These data demonstrate an immediate increase in pH levels when the SWW tower went into operation, and frequent violations of the basin standard in the years following. This clearly indicates that surface water releases through the SWW tower from LBC had a rapid and negative impact on water quality in the lower Deschutes River.

The sudden increase in pH seen in Figure 15 indicates a substantial increase in the growth of periphyton algae that was triggered by an increase in nutrients with the release of surface water from LBC. The statement below from the 1997 Final Report on Lower Deschutes Water Quality Study for Pelton Round Butte Hydroelectric Project raises a warning for just such an impact:

The lower Deschutes River periphyton exhibits mixed characteristics. Many of the species present are characteristic of cool, high elevation streams, while others are found in more nutrient enriched conditions. ***This may reflect the unique nature of the river and its hydrology. It may also indicate that the river will be susceptible to relatively small changes in nutrient input*** (from page 25, paragraph 2, in Raymond et al. 1998) (bold added for emphasis).

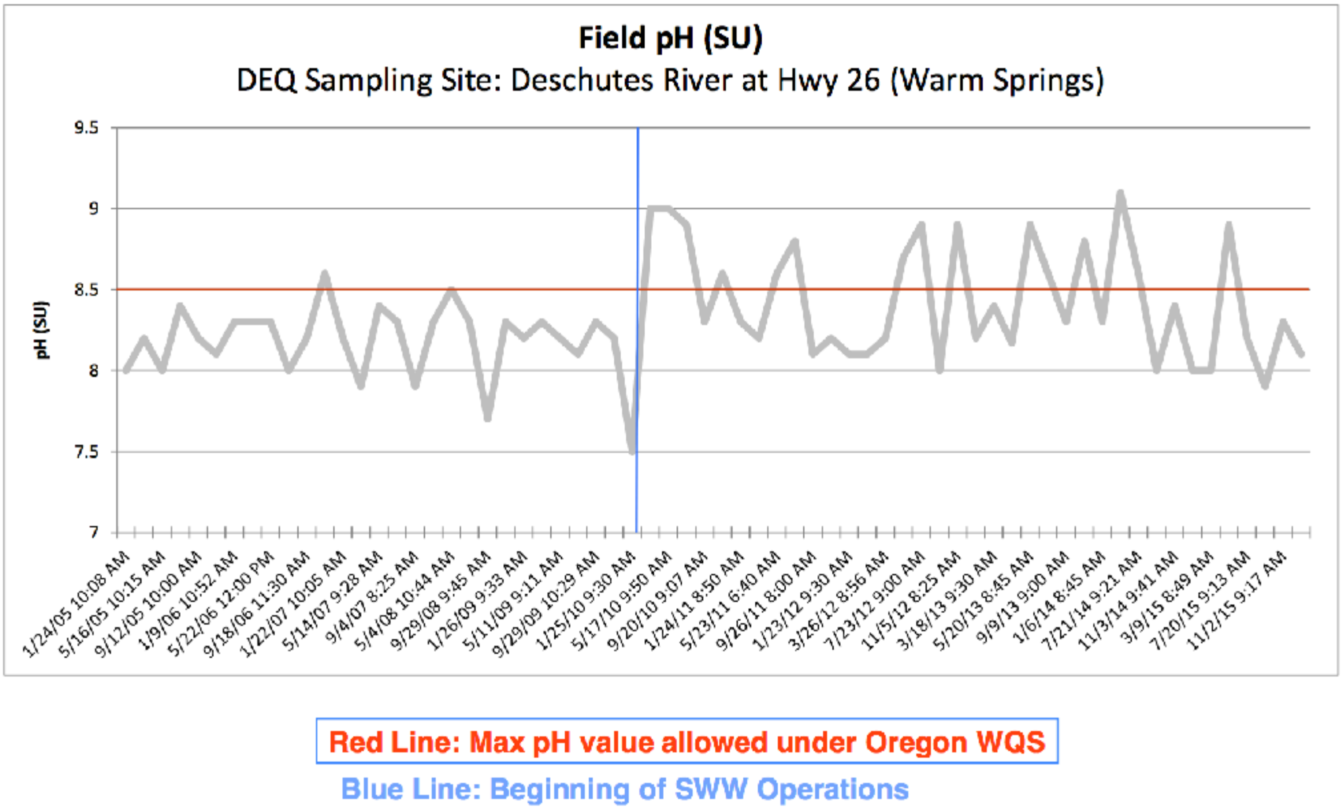

Figure 15. pH measurements collected by Oregon DEQ at the Warm Springs Hwy 26 bridge every other month from January 2005 through November 2015.

Finally, Figure 7 shows that a noticeable drop in pH at RM 99 occurred in mid August shortly after the amount of bottom water was increased to 65% of the total blend in order to clean debris from the upper intake (PGE 2017 water quality report). This provides more evidence that surface water releases from the SWW tower negatively impacts pH in the lower Deschutes River, and that the violations of the pH standard in the lower river can be reduced simply by releasing more bottom water from Lake Billy Chinook.

CONCLUSIONS

Cold, wet weather in the late winter and early spring in 2017 resulted in peak spring streamflows in the lower Deschutes River that were 35% higher in 2017 compared to 2016. More water generally means better water quality. And in fact the 2017 water quality results do show fewer and less extreme pH violations in 2017 compared to 2016. However, the water quality data collected and analyzed by the Deschutes River Alliance in 2017 again shows serious violations of water quality standards throughout the spring and summer months that continue to raise questions about water quality management in the lower Deschutes River. Based on the results of our data in both 2016 and 2017, plus data collected by PGE that shows numerous violations of the Project's water quality certification, the DRA believes it is of utmost importance to the health of the lower Deschutes River's aquatic ecosystem, to say nothing of the people who recreate and make their living from the river, to manage water releases from the SWW tower so that water quality standards are met to the fullest extent possible. The WQMMP established clear management guidelines and water quality requirements for temperature, pH and dissolved oxygen. These requirements were established to adequately protect the aquatic life in the lower Deschutes River.

The water quality violations summarized below have been documented by the hourly water quality data collected by the DRA at RM 99 in both 2016 and 2017. The DRA believes the data clearly show that these problems are not due to climate change or reflect "regional" water quality problems. We also believe that solutions to improve water quality are readily available that would not negatively impact upstream salmonid reintroduction efforts. In fact, as more data becomes available (e.g. *C. shasta* infection rates) improving lower Deschutes River water quality will be necessary for the reintroduction effort to succeed.

Temperature:

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

1) The stated goal in the WQMMP of managing water temperature downstream from the Project, "as if the dams did not exist," may sound like a laudable idea. However, the equation being used to set the temperature targets in the lower Deschutes River is calculated using the 7-day **maximum** average temperatures of the three tributaries entering LBC. Project discharge targeting the level of the maximum temperatures from the three tributaries does not create the true and natural thermal conditions in the lower river that would exist if the Project did not exist.

2) Releasing 100% surface water from LBC from November through early June each year raises the temperature in the lower Deschutes River throughout the late winter, spring, and early summer above pre-SWW tower temperatures. This increase has altered aquatic insect life cycles and likely contributes to earlier growth of nuisance algae that has further impacted aquatic invertebrate populations in ways yet to be fully understood. However, a thorough and independent statistical analysis, commissioned by DRA, compared pre and post tower aquatic invertebrate data collected by R2 Consultants for PGE; it found significant increases in pollution tolerant invertebrates and declines in pollution sensitive taxa after the SWW tower started operating (Edwards 2018).

   One example is the disturbing increase in abundance of the polychaete worm, *Manayunkia speciosa*. The number of individuals per square meter of stream substrate of this species increased from zero before tower operation began to over 4,000 at some sites after the tower started operating (Nightengale et al. 2016). DRA sampling of benthic invertebrates found over 8,000 per square meter in 2016 at RM 99.

   This very small polychaete worm is the intermediate host of the salmonid parasite *Ceratanova shasta.* Recent studies in the lower Deschutes River have reported high infection rates of *C. shasta* in spring Chinook salmon juveniles, with subsequent high mortality rates (ODFW 2016 click here for ODFW report). These high infection and mortality rates coincide with a sudden and unexplained decrease in smolt to adult survival of both wild and hatchery origin spring Chinook to the Deschutes River. The overall impacts *C. shasta* might be having on salmonid populations in the lower Deschutes River are presently unknown. The dramatic increase in the host worm for *C. shasta* is likely the result of increased nutrient load and warmer temperature in the lower Deschutes River as a result of SWW tower operation.

3) Temperature management in 2017 allowed water temperatures to exceed the temperature standard for spawning salmon and steelhead (7-day maximum average no greater than 13 ^{o}C) from mid May through June 15 (Figure 8).

4) 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). In 2017 walleye were also caught in the lower Deschutes near its mouth for the first time. Subsequent investigations by ODFW confirmed smallmouth bass presence in numbers never previously observed by them (R. French pers. comm. to S. Pribyl). The conditions in the lower Deschutes River that triggered this increase are not completely clear, but Figures 9 & 10 clearly show higher water temperatures in the lower Deschutes River from April to July compared to pre-SWW tower temperatures. These increased spring temperatures are resulting in Deschutes River water temperatures near the Columbia River reaching 60°F earlier than in previous years. The warmer water, earlier in the year, likely encourage smallmouth bass to migrate up the Deschutes River from the Columbia River, where they are abundant, in search of the warm water they prefer. Most of the smallmouth bass appeared to leave the Deschutes River in September and October, likely from a downstream migration back to the now-warmer Columbia River. The impact of increased smallmouth bass numbers in the lower Deschutes River is currently unknown, but increased predation on native fishes is a definite possibility.

5) Increasing water temperature in the Deschutes, a large river that previously contributed important cold water to the Columbia River during summer

months—when fish managers throughout the Columbia River basin are looking for ways to keep the Columbia cooler—is counter-productive to these larger management goals, and eliminates one of the more important cold-water refuges for upstream migrating adult salmonids in the mid-Columbia region.

6) According to data reported to FERC by PGE, bottom water released from the SWW tower increased from 30% on August 10, to 65% on August 12, 2017. The increase in bottom water quickly lowered the water temperature in the lower Deschutes River one mile below the Reregulating Dam by 2^{o}C. This drop in temperature shows that increasing bottom water will quickly lower temperature in the lower river and improve water quality.

Dissolved Oxygen:

Water with adequate dissolved oxygen is critical for the survival 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). Dissolved oxygen is also affected by algae and plant growth. Dense growth of aquatic plants and algae produce high DO concentrations during the day and low levels late at night and early morning, resulting in large diel swings in DO. These large diel swings measured at RM 99 can be seen on Figure 13.

Life history studies of resident trout in the lower Deschutes, and direct observation of trout spawning at RM 99, confirms that trout spawning continues through the end of July. This means that resident trout incubation continues until the end of August or early September. Under current Oregon standards a minimum DO concentration of 9.0 mg/L is applicable throughout this resident trout spawning and incubation period (presuming that intergravel DO concentrations are above 8.0 mg/L). In 2017, violations of this DO standard for spawning trout occurred from July 4 through August 27.

pH:

Oregon's water quality standards for pH (6.5-8.5 for the Deschutes Basin) are set for one reason: **to protect aquatic life**. It is also well established that pH provides a useful indicator of nutrient enrichment problems, since high nutrient loads stimulate excessive algae and aquatic plant growth, which in turn causes pH levels to increase. The pH levels measured at the DRA study site in the lower Deschutes River in 2017 showed significant water quality violations of pH:

1) pH measurements exceeded the 8.5 pH standard for the Deschutes Basin from May 10th until August 23rd.

2) pH noticeably dropped when bottom water releases from LBC were increased to 65% on August 12th (Figure 7). This clearly illustrates that pH violations can be reduced by releasing more bottom water from the SWW tower.

3) No management plan for lowering pH has been developed by the Joint Applicants, as required in the WQMMP when pH measurements in Project discharge exceed the weighted average pH of inflows into LBC.

4) Based on ODEQ data, pH showed an immediate and sustained increase when SWW tower operations began (Figure 15).

The above results describe a river severely impacted by high pH caused by excessive algae and aquatic plant growth stimulated by an increased nutrient load and warmer water released from the SWW tower operation. Data collected by ODEQ show that this change in pH began immediately after the SWW tower began operation. Data from 2017 also show that pH can be quickly improved by releasing more bottom water from the SWW tower.

Project operations are regularly resulting in violations of Oregon's water quality standards for temperature, pH and DO, and are violating the water quality requirements laid out in the Project's § 401 Certification.

It is important to remember that water quality standards are set at levels deemed necessary to protect the beneficial uses of the waters in question. In the lower Deschutes River the most sensitive beneficial uses are salmon and trout spawning and egg incubation through fry emergence, and cold-water aquatic life such as juvenile salmon and trout rearing and aquatic invertebrates. Years of research, based on both laboratory and field studies, have been evaluated to determine safe levels for a wide range of parameters (EPA 1986). These levels are further evaluated by state water quality agencies before being adopted as state standards. As a result, Oregon's water quality standards have been set based on years of research and public process to ensure aquatic life is adequately protected.

While water quality standards are set for each parameter separately, interactions between parameters can increase their level of impact on aquatic life. For example, as water temperature increases the concentration of dissolved oxygen in water declines, while at the same time salmonid metabolism increases, thus elevating their oxygen demand. Changes in pH also affect the toxicity of other potentially toxic constituents in water. For example, the toxicity of ammonia is 10 times greater at a pH of 8.0 compared to a pH of 7.0. Therefore, whenever water quality standards are violated the potential for negative impacts from other parameters also increases. When multiple standards are exceeded at the same time over long periods of time - days and weeks - as we have seen in this study, the negative effects on aquatic life increase substantially.

The water quality data collected by this study clearly demonstrates extensive violations of Oregon's water quality standards and the requirements of the Project's CWA § 401 Certification for multiple parameters throughout most of the study period sampled.

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Appendix A - FIELD AUDIT RESULTS

Data Sonde Instantaneous Measurements

Date/Time	4-6-2017 1530	5-4-2017 1140	6-8-2017 1130	7-13-2017 1115	9-24-2017 1120
Temperature (C)	8.7C		13.3C	14.9C	12.5C
pH	7.82		8.7	8.95	8.20
Conductivity	0.143		0.126		0.123
Turbidity (NTU)	17		18	19	1.7
Chlorophyll-a	1.8		5.2	2.0	1.0
Dissolved Oxygen (mg/dl)	11.2		10.8	10.6	11.5
Oxygen Saturation (%)	96.3%		103%	105%	108%
Battery (volts)	11.7		10.8	10.6	9.6

Audit Data

Temperature (C)	10.2C	12.9C	13.4C	15.2C	12.8C
pH	8.05	8.32	8.72	8.95	8.29
Turbidity	5.99	4.64	1.82	1.65	1.36
Dissolved Oxygen	10.78	11.70	10.16	10.54	10.66
Oxygen Saturation	98.2%	113.9%	102%	109.2%	105.6%
Hach DO	10.9 10.5		10.00 10.20	10.6 10.3	1.0 9.8

Appendix B - QUALITY ASSURANCE/QUALITY CONTROL PROGAM & METHODS

Deschutes River Alliance

Water Quality Sampling Quality Assurance/Quality Control

Program and Methods

Instrument Calibration:

All instruments were calibrated per manufacturers instructions. A log of calibrations has been kept on all instruments. Calibration on handheld instruments was 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 monthly using handheld instruments to determine temperature, pH, dissolved oxygen, oxygen saturation and turbidity. The Winkler method of determining dissolved oxygen was utilized as a further confirmatory assay for dissolved oxygen. Use of multiple measures was employed as described below.

Use of Multiple Measures:

To ensure in-field accuracy, redundant multiple instruments were used simultaneously to measure temperature, pH and DO. Excessive variances led to repeat calibration as needed, or probe replacement.

Instrument Storage:

Instruments were stored in a secure and temperature controlled environment when not in use. During seasonal storage, calibrations were done every 30 days.