SHASTA RIVER MONITORING REPORT
AGREEMENT NO. F17AC00348

ANNUAL MONITORING REPORT FOR 2019

PREPARED AND SUBMITTED BY

Shasta Valley Resource Conservation District

December, 2019

RCD
SHASTA VALLEY
RESOURCE CONSERVATION DISTRICT

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EXECUTIVE SUMMARY

This Monitoring Report addresses all monitoring parameters and expectations as required in the Project Monitoring Plan, some of which are addressed only in this Executive Summary (No's. 1, 2, 6, 7 and 8), including:

1. Final Engineered Stamped Construction Designs: in accordance with CDFW and NOAA-NMFS fish passage standards and protocols.
    - Completed and submitted in 2019.
2. Pre and Post Project Photo- Points: Photo monitoring will provide qualitative documentation of project progress from pre- project, during construction and post-project.
    - Pre- and post-project photo points will be taken in 2020
3. Water Temperature Continuous Monitoring: General water quality in the Shasta River using Onset HOBO temperature probes.
    - See attached Shasta River Monitoring Report for 2019.
4. Dissolved Oxygen will be measured using optical probes (D-Opto loggers): The probes will be deployed at one location below the weir and one location upstream of this location. In addition, results from the Shasta River Monitoring Network (22 sites) maintained by the SVRCD are included in the attached Monitoring Report.
    - See attached Shasta River Monitoring Report for 2019.
5. Summary of Findings
    - See attached Shasta River Monitoring Report for 2019.
6. Identification and discussion of problems with achieving performance standards
    - Project was extended to accommodate design completion 2019.
7. PROPOSED CORRECTIVE MEASURES
    - Project was extended to accommodate construction in 2020.
8. MONITORING DATA
    - All Monitoring data will be shared in the Final Monitoring Report. Data will be shared with CEDEN and the Klamath Basin Monitoring Program as applicable. Information about the project and monitoring results may be shared at local or regional conferences.

INTRODUCTION

The Shasta River was designated an impaired water body by the North Coast Regional Water Quality Control Board for dissolved oxygen and temperature with a TMDL also adopted in January 2007 by the Environmental Protection Agency (NCRWQCB 2007). Furthermore, the Southern Oregon/Northern California Coho has been listed as threatened both state and federally.

The NOAA Southern Oregon Northern California Coast Coho Recovery plan indicates that impaired water quality (temperature, DO, flow) and altered hydrologic function are the limiting stressors for the Shasta River coho salmon population (Weeder 2014). Further, poor water quality and stressful conditions encountered during hot, dry summer rearing months create challenging physiological conditions for over-summering juvenile coho. The California Department of Fish and Wildlife's Shasta River Juvenile Coho Habitat & Migration Study (2009) confirmed that many coho salmon tracked in the upper Shasta River spawned in the river reach that the Watermaster's Weir Modification: Weir Retrofit and Barrier Removal Project (herein referred to as "the Project) is in. The resulting cohort that emerges from the gravels in this reach and throughout the Shasta River are considered functionally blocked by this fish passage barrier (weir), and restricted from moving freely through this section of the river to find juvenile rearing refugia.

Under the protocols established in the Project Monitoring Plan, the SVRCD has monitored water quality in the Project area as part of a long-term monitoring network on the Shasta River and selected springs and tributaries. The goals of this monitoring effort were to establish pre-project conditions and assess progress in meeting Total Maximum Daily Load (TMDL) requirements (temperature and DO) by monitoring Shasta River water quality.

This report summarizes temperature and DO monitoring data from sites that included the Project site as well as upstream and downstream of the project site. In total, 22 sites on the Shasta River and tributaries Parks Creek and Yreka Creek were monitored and are reported in this comprehensive report. Project funding contributed to partial funding of the whole monitoring network, which also met or exceeded the requirements of the Monitoring Plan. Access to monitoring locations was acquired from private landowners through landowner agreements.

MONITORING LOCATIONS

Temperature and DO were measured from April 1st through October 1st, 2019 at 22 locations on the Shasta River and several tributaries and springs (Table 1). The study area spans approximately 40 river miles from Dwinnell Reservoir to the mouth of the Shasta River at its confluence with the Klamath River (Figure 1). Reach 3 of the Shasta River includes upstream and downstream locations in the Project area.

TABLE 1: REACH, SITE ID, RIVER MILE, EQUIPMENT DEPLOYED AND MEASURED METRICS DURING THE 2017 IRRIGATION SEASON (LISTED IN ORDER FROM UPSTREAM AT THE OUTLET OF DWINNELL RESERVOIR TO DOWNSTREAM AT THE MOUTH OF THE SHASTA RIVER). REACH 3 IN BOLD INCLUDES UPSTREAM AND DOWNSTREAM LOCATIONS IN THE PROJECT AREA.

Reach	Reach Description	Site ID	River Mile	Equipment	Measurement
6	Dwinnel Reservoir to Parks Creek	105SRHVRPOD	39.1	TidbiTs®	Temperature
		105SRHVSPL	38.1	TidbiTs®	Temperature
		105SRHVRALC	37.9	TidbiTs®	Temperature
		105SRU1DO	37.9	D-Opto	DO/Temperature
		105SRHVDSSPG	37.8	TidbiTs®	Temperature
		105SRU0IT	37.7	TidbiTs®	Temperature
		105SR7163DS	36.9	TidbiTs®	Temperature
		105SRHIGF	36.6	TidbiTs®	Temperature
Parks Creek	Parks Creek	(105SRP1DO)	SR 33.9 (PC 0.04)	D-Opto	DO/Temperature
	Parks Creek	(105PCFP)	SR 33.9 (PC 7.3)	TidbiTs®	Temperature
5	Parks Creek to Big Springs Creek	(105SRPCO)	SR 33.1 (PCO 0.04)	TidbiTs®	Temperature
4	Big Springs Creek to Willow Creek	105SRN1DO	30.9	D-Opto	DO/Temperature
		105SRV1DO	26.0	D-Opto	DO/Temperature
		105SRV4AT	25.2	TidbiTs®	Temperature
		105SRV4BT	24.3	TidbiTs®	Temperature
3	Willow Creek to Little Shasta River	**105SRT1DO**	23.0	D-Opto	DO/Temperature
		105SRM1DO	14.6	D-Opto	DO/Temperature
		105SR400T	12.3	TidbiTs®	Temperature
		105SRA1DO	11.8	D-Opto	DO/Temperature
		105SRA01T	10.2	TidbiTs®	Temperature
Yreka Creek	Yreka Creek	(105YCA01T)	SR 7.3 (YC 0.6)	TidbiTs®	Temperature
1	Yreka Creek to Shasta River Mouth	105SRL1DO	0.6	D-Opto	DO/Temperature

* Sites in parentheses indicate monitoring location is on a tributary of the Shasta River

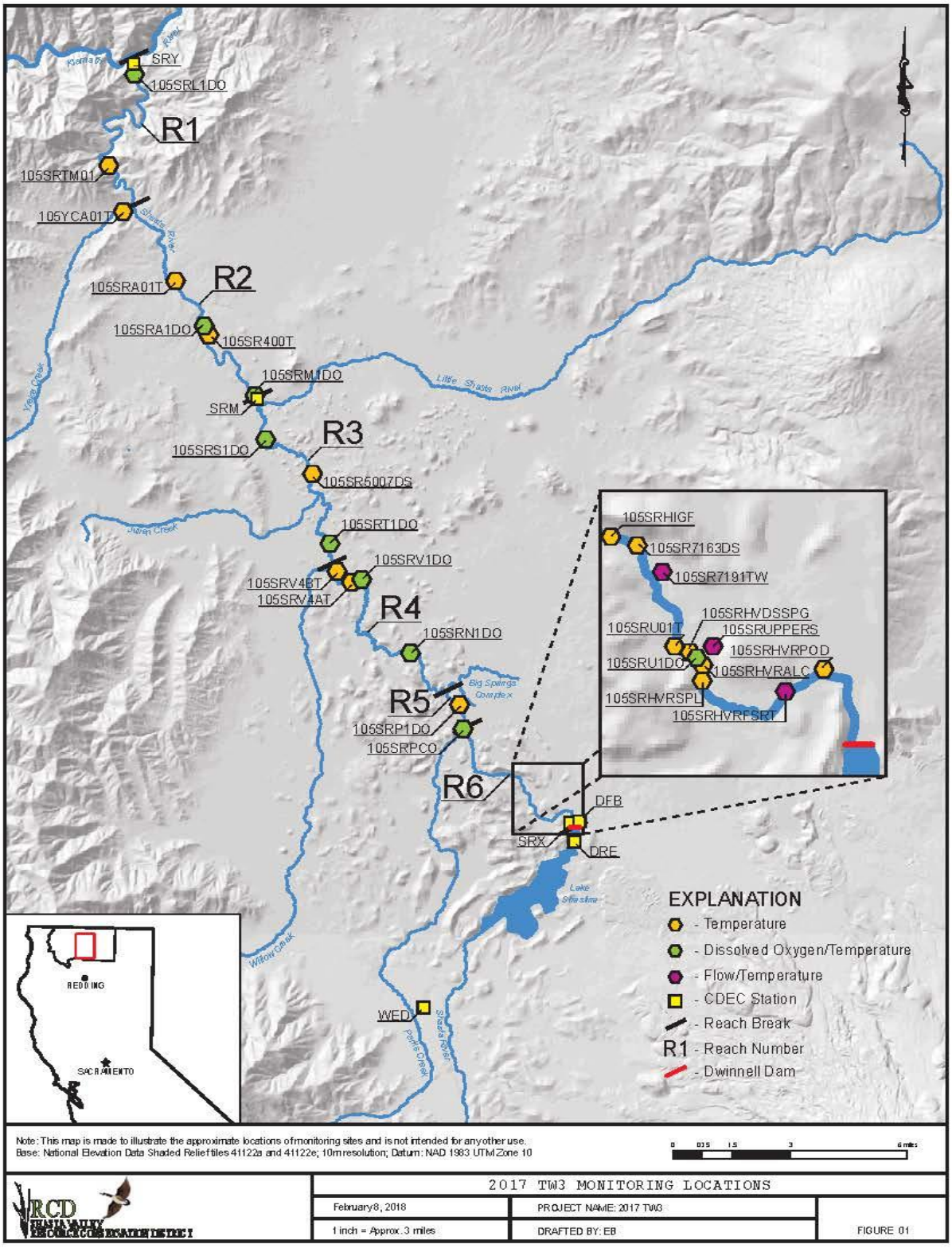

FIGURE 1. MAP OF 2019 TEMPERATURE, DO, FLOW AND CDEC MONITORING LOCATIONS. SOME SITES WERE NOT OCCUPIED IN 2019

METHODS

Dissolved oxygen (w/Temperature) Sampling

Dissolved Oxygen (DO) and temperature were measured at eight sites (Table 1; Figure 1) with ZebraTech D-Opto Loggers, which use optical fluorescence sensing elements to measure DO in liquids. These DO loggers were housed in custom made canisters designed to suspend the logger above sediment in the benthic zone, and to maintain a stationary position in the river in high flow.

Where possible, DO loggers were placed in runs or pool tail-outs and within the thalweg or deepest part of the cross-section. D-opto loggers were downloaded, cleaned of bio-fouling and re-calibrated per manufacturer specifications every three weeks. Intervals of more than three weeks may have increased the risk of optical lens bio-fouling that may have caused the logger to record inaccurate measurements.

Temperature Sampling

Temperature loggers were deployed at 14 sites in the Shasta River in sets of two (paired for quality control) and housed in custom made canisters to protect them from direct sunlight. Where possible, temperature loggers were placed in runs or pool tail-outs and within the thalweg or deepest part of the cross-section.

In 2019, temperatures were recorded at 15-minute increments (D-Opto loggers and Onset® Tidbits®) at temperature monitoring locations as identified in Table 1 and on Figure 1. The 7-day average daily maximums (7-DAD Max) were calculated as the 7-day running average of daily maximum temperatures. Dates reported correspond with the last date of this running average.

In addition to the 7-DAD Maximum temperature graphs are an analysis of the Maximum Weekly Average Temperatures (MWAT) and Maximum Weekly Maximum Temperatures (MWMT) for each site. The use of MWAT values was first proposed by the National Academy of Sciences (NAS) in 1972 as a long-term standard for preventing chronic sub-lethal effects for a variety of fish species. However, the MWAT is not calculated consistently by all researchers and agencies. The MWAT, as reported by Carter (2005), is the highest single value of the seven-day moving average temperature. Likewise, the MWMT is the highest seasonal or yearly value of the daily maximum temperatures over a running seven-day consecutive period. This methodology for calculating MWAT and MWMT was followed in this report and calculated for the entire irrigation season. Additionally, the absolute maximum is calculated as the highest daily maximum temperature for the entire irrigation season.

The objective of the MWAT index is to provide an upper temperature standard that is protective of juvenile salmonids during the summer rearing period. The MWAT is a common measure of chronic (i.e. sub-lethal) exposure, the absolute maximum is a measure of acute (i.e. lethal) exposure, and the MWMT is a common measure of both chronic and acute effects (Carter 2005). The MWMT describes the maximum temperatures in a stream, but the value is not overly influenced by the maximum temperature of a single day. Table 2 describes the MWMT for the Shasta River during various life stages of coho salmon (Carter 2005). Refer to Carter (2005) for additional information regarding temperature effects on various life stages of Chinook and steelhead salmonids.

TABLE 2. MWMT FOR DIFFERENT LIFE STAGES OF COHO SALMON (REPRODUCED FROM CARTER 2005).

Coho Life Cycle						
	Adult Migration	**Spawning**	**Egg Incubation**	**Fry Emergence**	**Juvenile Rearing**	**Juvenile Out-migration**
Coho Periodicity	Sept 15 – Jan 31	Nov 1 – Jan 31	Nov 1 – Mar 31	Feb 1 – Apr 15	Jan 1 – Dec 31	Feb 15 – July 15
MWMT Criterion (°C)	20	13	13	13	18	18

In addition to water temperature collection, ambient air temperature (as well as rainfall and solar radiation) data were retrieved from Weed Airport (CDEC Station ID-WED) to inform water temperature and DO results in this study.

RESULTS AND DISCUSSION

TEMPERATURE RESULTS

Temperature was measured at 22 sites on the Shasta River and its tributaries in 2019. Temperatures in the Shasta River and its tributaries fluctuate daily and are moderated in comparison to air temperatures due to the high specific heat capacity of water.

Please refer to the Shasta River Watershed Stewardship Report for a comprehensive year-to-year comparison of temperatures and DO at all sites.

Table 3 includes seasonal MWMT, MWAT, Annual Maximum Temperature and percentage of days each site exceeded the TMDL of 18 °C in 2019.

TABLE 3. 2019 SHASTA RIVER MWAT, MWMT, ANNUAL MAXIMUM TEMPERATURE AND PERCENTAGE OF DAYS TMDL WAS EXCEEDED. SITES IN BOLD TYPE ARE IN THE PROJECT REACH.

Site ID	Reach	MWMT (°C)	MWAT (°C)	Max Temp (°C)	% Days Exceeded TMDL
105SRHVRPOD	6	22.01	19.74	23.14	43
105SRHVRSPL	6	22.39	18.83	24.17	40
105SRHVRALC	6	13.70	13.29	13.83	0
105SRU1DO	6	21.68	18.46	22.67	47
105SRDSSPG	6	19.78	17.32	20.58	45
105SRU0IT	6	20.30	17.61	21.10	49
105SR7163DS	6	21.56	18.43	22.54	57
105SRHIGF	6	21.79	18.78	22.71	58
105SRPCFP	5 (Parks Ck)	28.77	22.56	30.07	79
105SRP1DO	5 (Parks Ck)	25.51	21.88	26.68	77
105SRPCO	5 (Parks Ck)	28.64	23.24	29.34	81
105SRN1DO	4	21.06	17.77	21.74	70
105SRV1DO	4	19.85	18.93	20.50	42
105SRV4AT	4	19.85	19.27	20.48	46
105SRV4BT	4	21.01	19.58	21.58	49
105SRT1DO	**3**	**21.91**	**19.75**	**22.31**	**54**
105SRM1DO	**3**	**24.23**	**21.80**	**25.01**	**68**
105SR400T	**3**	**25.21**	**22.58**	**25.79**	**74**
105SRA1DO	**3**	**25.14**	**22.74**	**25.66**	**75**
105SRA01T	2	25.79	23.10	26.72	73
105YCA01T	2 (Yreka Ck)	21.06	19.19	21.58	49
105SRL1DO	1	26.85	23.93	27.97	71

REACH 1 TEMPERATURE RESULTS

Figure 2 displays MWMT criterion for juvenile coho salmon rearing and 7-DAD Max water temperatures at a site within the tributary Yreka Creek (105YCA01T) and sites downstream of the confluence of Yreka Creek within Shasta River Reach 1. 7-DAD Maximum temperatures at Yreka Creek are consistently cooler than all other sites within Reach 1 throughout the monitored period. The temperature difference between Yreka Creek and the Shasta River in Reach 1 widens substantially from mid-June through mid-August when Reach 1 7-DAD Maximum temperatures reach their maximums. Despite the cool water input from Yreka Creek, its flows are minimal, ranging from 2-5 cfs during the summer. 7-DAD Maximum temperatures throughout Reach 1 are generally consistent with each other, increasing only slightly in the downstream direction. In general, Reach 1 is the warmest reach in the Shasta River due to lack of shade and typically stable summer atmospheric conditions that result in consistently high solar irradiance and absorption, increasing temperatures in the downstream direction. In addition, warm tailwater returns may contribute to downstream warming.

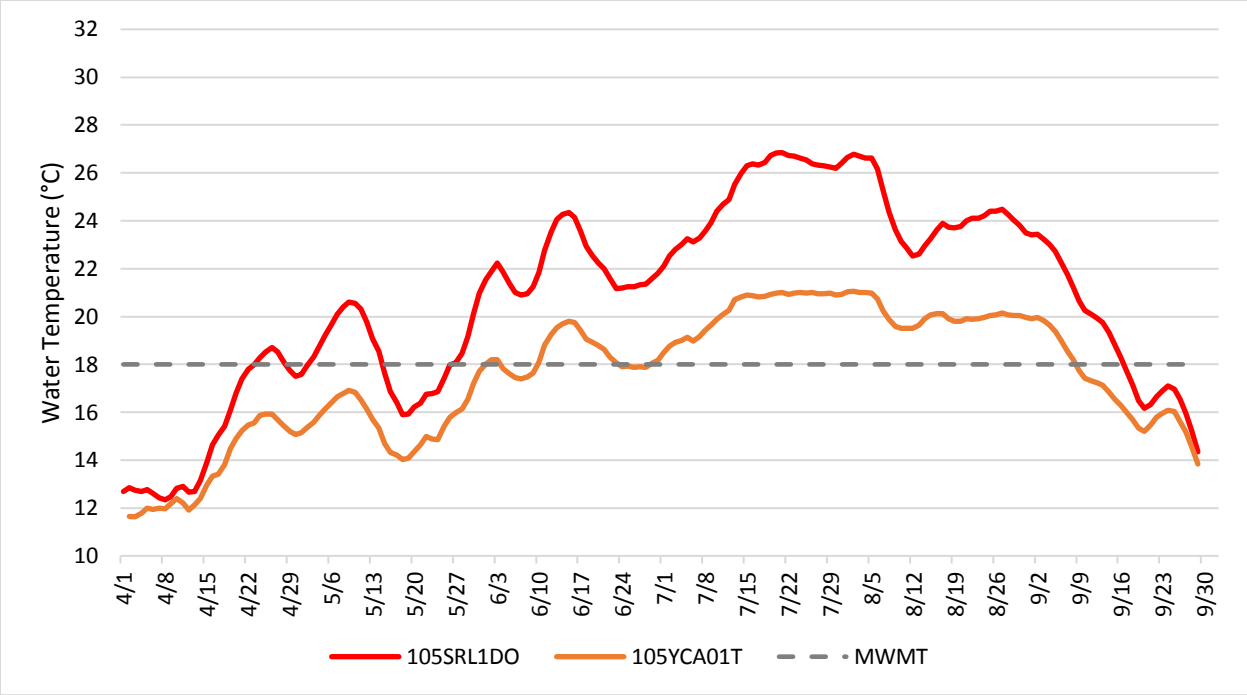

FIGURE 2. 2019 7-DAD MAXIMUM TEMPERATURES AT REACH 1 (SHASTA RIVER AND YREKA CREEK SITES).

REACH 2

Figure 3 displays MWMT criterion for juvenile coho salmon rearing and 7-DAD Maximum water temperatures at sites within Shasta River Reach 2. These sites are located downstream of the USGS operated Montague Weir. 7-DAD Maximum temperatures at all sites within Reach 2 are generally consistent with one another with 7-DAD Maximum temperatures increasing in the downstream direction.

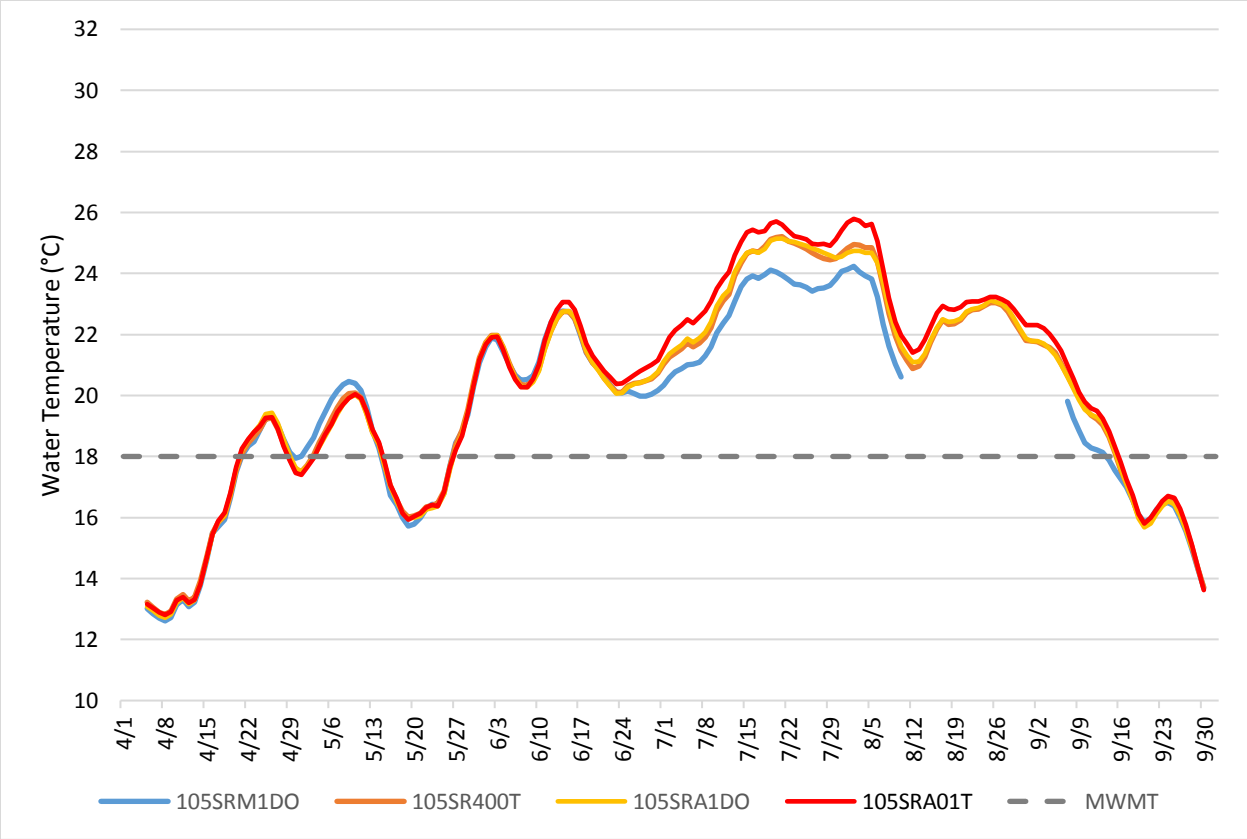

FIGURE 3. 2019 7-DAD MAXIMUM TEMPERATURES FOR REACH 2, SHASTA RIVER.

REACH 3

Figure 4 displays MWMT criterion for juvenile coho salmon rearing and 7-DAD Maximum river temperatures at sites within Shasta River Reach 3. In 2019, two temperature monitoring sites (105SRSR1DO and 105SR5007DS) were not occupied due to lack of funding and equipment availability.

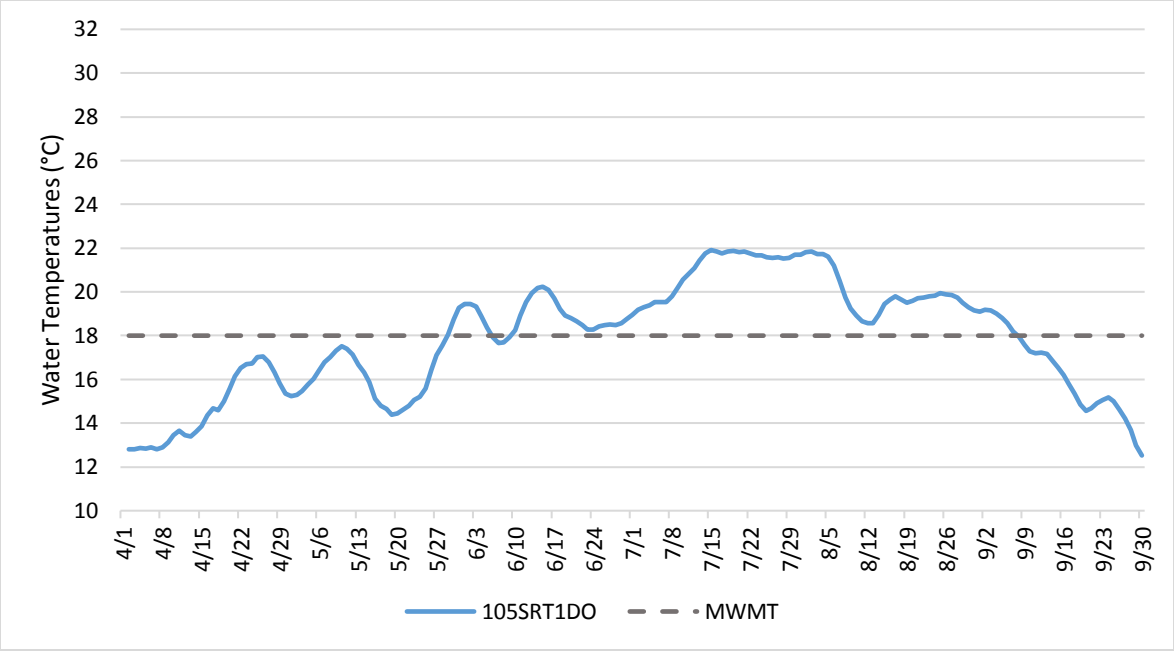

FIGURE 4. 2019 7-DAD MAX TEMPERATURES FOR SHASTA RIVER, REACH 3.

REACH 4

Figure 5 displays 7-DAD Maximum water temperatures at sites within Shasta River Reach 4 and MWMT criterion for juvenile coho salmon rearing. These sites are located downstream of the Big Springs Creek confluence, which adds a large volume (53 cfs average during July and August) of cold water to the Shasta River (Nichols et al. 2010). Consequently, 7-DAD Maximum water temperatures within this reach are consistently cooler throughout irrigation season than in all other reaches within the Shasta River. Although 105SRN1DO has the highest 7-DAD Maximum temperatures in Reach 4, it has a greater diel variation in temperatures than other sites, and this results in the lowest MWAT in the reach. The upstream section of Reach 4 represented by 105SRN1DO also has some of the best habitat potential and available spawning gravels in the Shasta River.

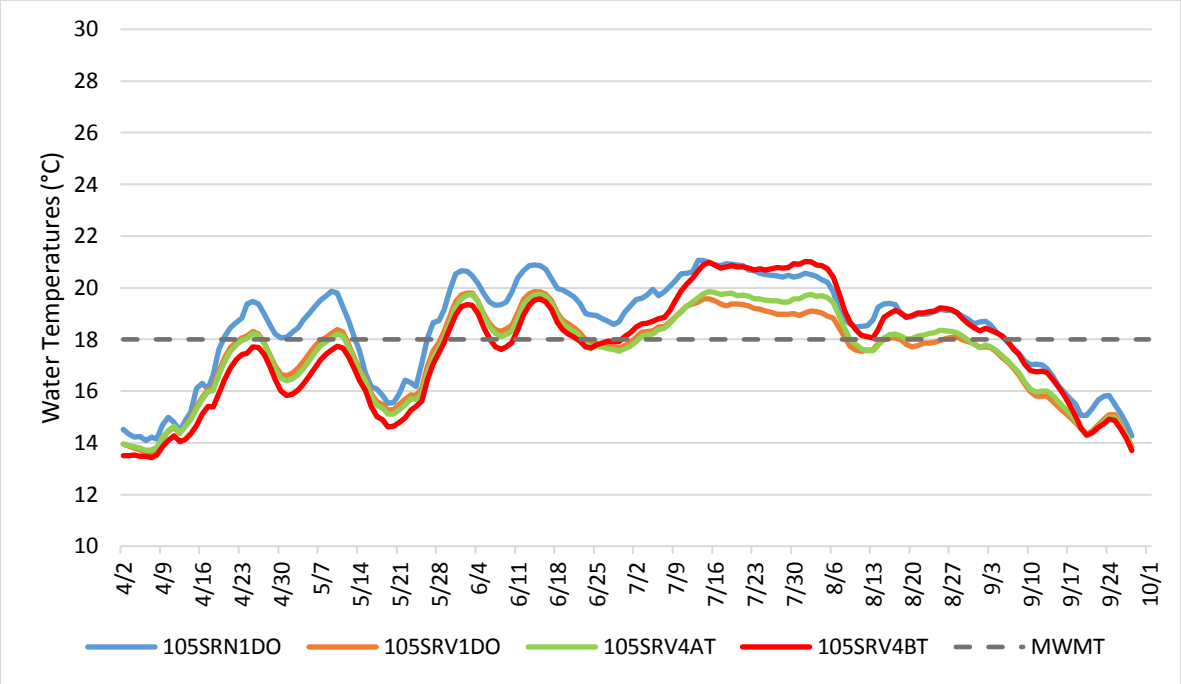

FIGURE 5. 2019 7-DAD MAX TEMPERATURES FOR SHASTA RIVER, REACH 4.

REACH 5

In Reach 5, the Shasta River is supplemented by flows from Parks Creek (105SRP1DO), Hole in the Ground Creek (not measured) and Parks Creek overflow (105SRPCO). Coho salmon utilize Parks Creek for migration, spawning and juvenile rearing (Chesney et al. 2009). Parks Creek overflow is the historic Parks Creek channel, which primarily collects a mix of tailwater from one ranch and small ephemeral spring water inputs. The overflow is only connected to Parks Creek during high flow events, usually winter or early spring. This flow enters the Shasta River just north (downstream) of the Parks Creek confluence with the Shasta River. During irrigation season, Parks Creek overflow discharges up to 5 cfs into the Shasta River.

7-DAD Maximum temperatures from Parks Creek were typically 2-3°C warmer than upstream Shasta River sites. Depending on flow rates, these warm inflows may increase water temperatures in the Shasta River. Inflow from Big Springs Creek reduces temperatures considerably at the bottom of Reach 5 (Figure 6).

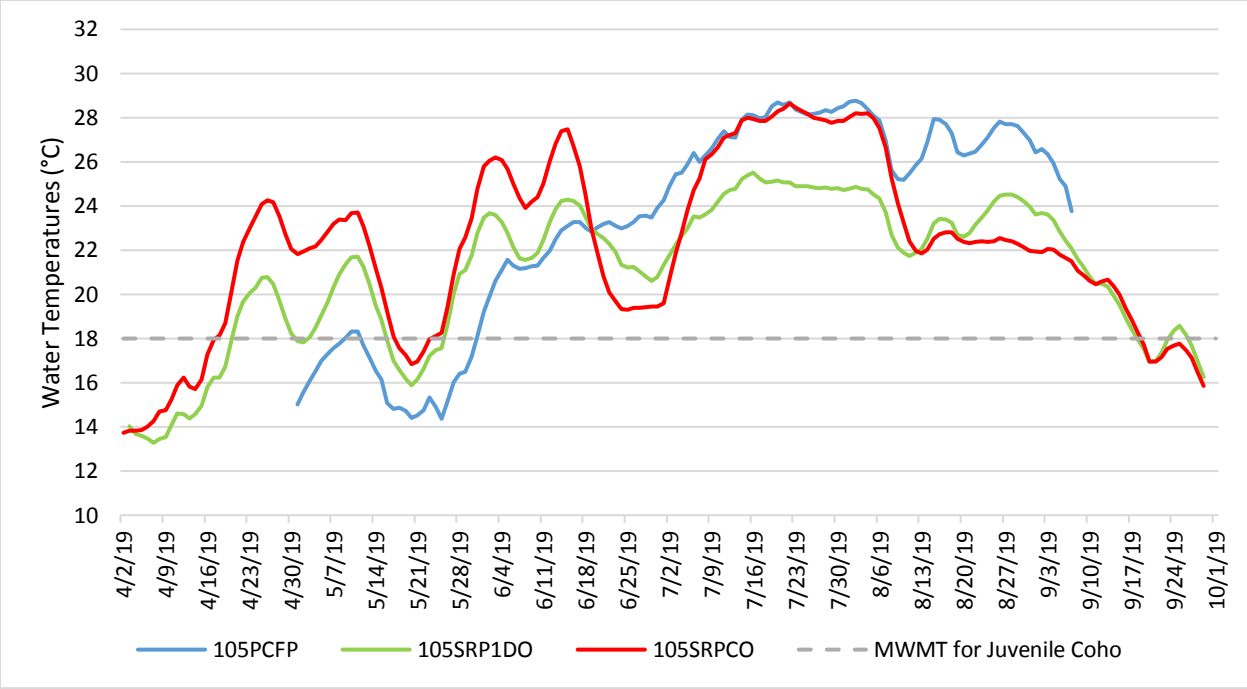

FIGURE 6. 2019 7-DAD MAX TEMPERATURES AT SHASTA RIVER REACH 5. ALL SITES ARE ON PARKS CREEK, TRIBUTARY OF SHASTA RIVER.

REACH 6

In 2019, cold spring water conveyed directly into the Shasta River as part of the 2017 Cold Water Exchange Project contributed to reducing river temperatures up to 2.2 °C for more than 1.6 miles from the pipeline outlet (Figure 7 and Figure 8).

105SRHVRPOD appears to have much cooler temperatures than other sites, especially early in the season. However, the positioning of this temperature logger in a deep, pooled area underneath a large amount of aquatic macrophytes and occasionally embedded in a silty stream bed provides a poor representation of overall stratified temperatures at this location. SVRCD technicians will work to reposition the sensor at this site to better represent the average temperature at this location in 2020.

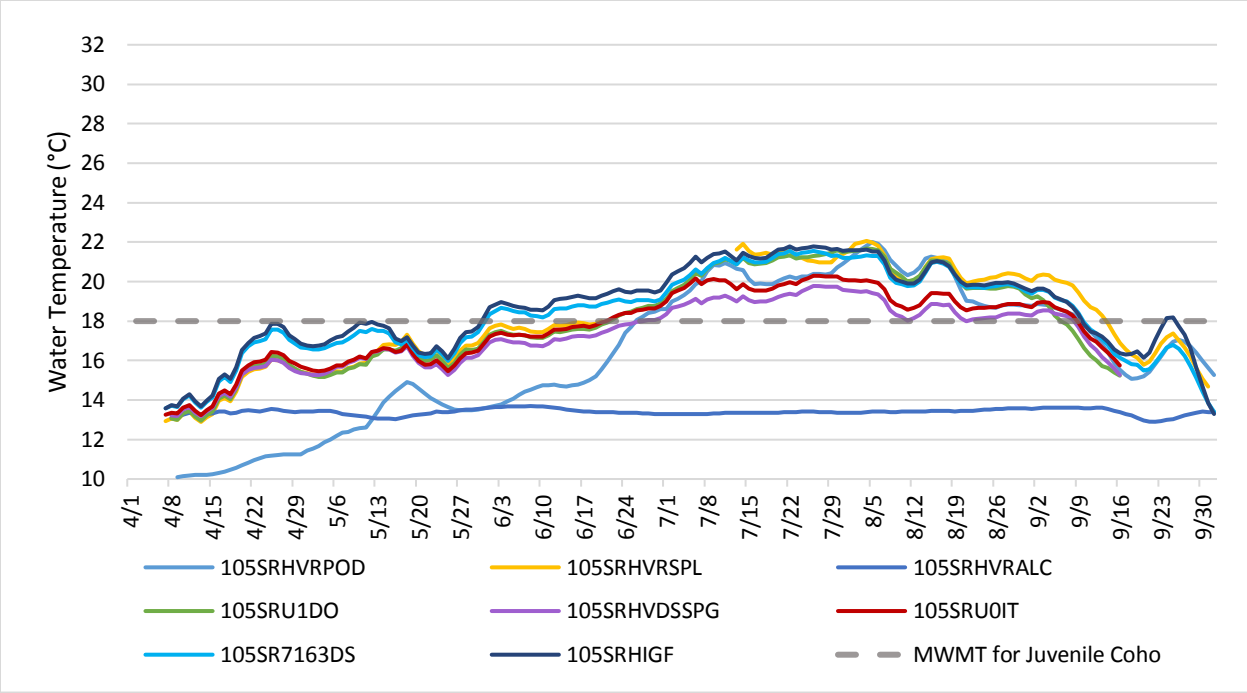

FIGURE 7. 2019 7-DAD MAX TEMPERATURES AT MONITORING LOCATIONS IN THE SHASTA RIVER AT REACH 6.

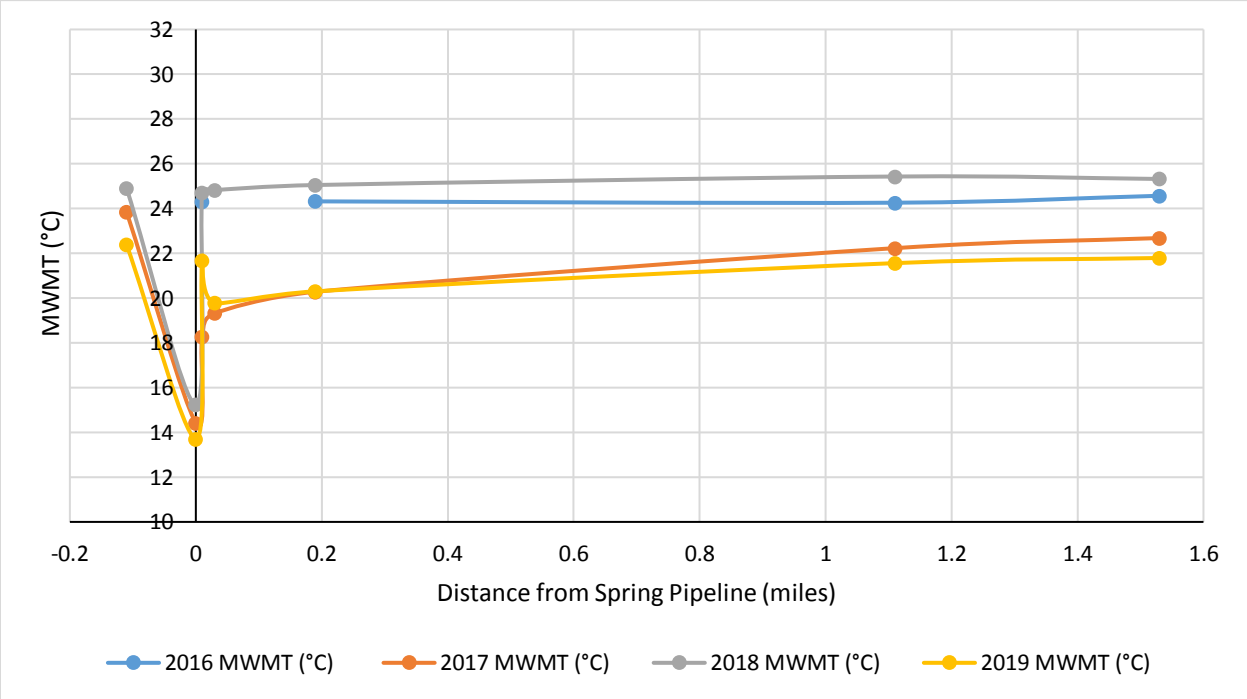

FIGURE 8. TEMPERATURE IN RELATION TO DISTANCE FROM THE SPRING PIPELINE OUTLET IN REACH 6, 2016-2019. PIPELINE CONVEYED COLD (~14°C) SPRING WATER TO THE SHASTA RIVER IN 2017 AND 2019.

DISSOLVED OXYGEN

Dissolved oxygen (DO) levels in surface waters are not constant, but change throughout the day as oxygen is added (by photosynthesis and reaeration) and removed (by carbonaceous and nitrogenous deoxygenation, sediment oxygen demand, and respiration) from the water. Salmonids such as coho and Chinook salmon are particularly sensitive to low DO concentrations as DO regulates metabolic activity in these and many fish species (Fry 1971). The 2015 North Coast Water Quality Control Plan states that the minimum dissolved oxygen concentration in the Shasta River should not fall below 6 mg/L.

Diurnal DO fluctuations were recorded at eight monitoring sites on the Shasta River and its tributaries. Lowest DO concentrations were between 23:00 and 7:00 when respiration occurs without photosynthesis, while the highest concentrations of DO were between 12:00 and 15:00 when peak photosynthesis occurs.

DISSOLVED OXYGEN RESULTS

Figure 9 displays 2019 daily minimum dissolved oxygen measurements at all sites on the Shasta River and Parks Creek. The general trend among all sites measured was a continuous reduction in the daily minimum DO from early April through late July due to seasonal warming, followed by increasing DO through early October due to cooling temperatures and increased production of instream vegetation (e.g., macrophytes).

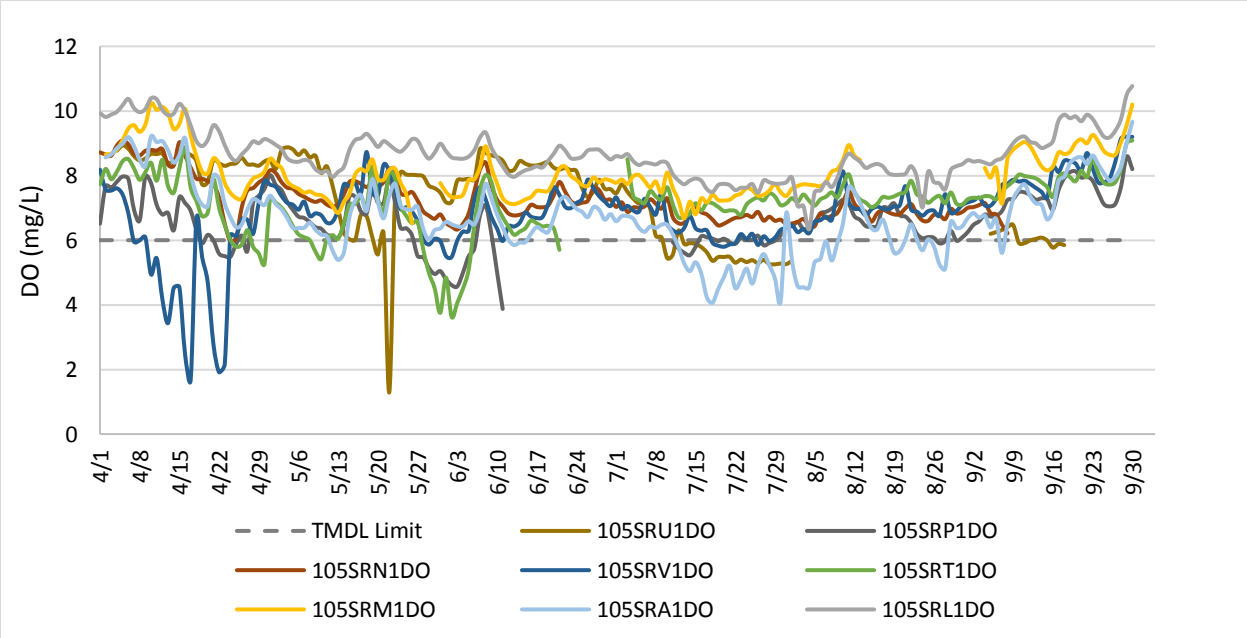

FIGURE 9. 2019 DO MINIMUM AT ALL SITES, SHASTA RIVER AND PARKS CREEK.

Table 4 displays the percentage of days that each site fell below the TMDL (6 mg/L) during the 2019 irrigation season.

Upstream site 105SRU1DO experienced one of the highest percentages of days below the TMDL. However, frequent disruption in flow due to in-stream construction near this site may have impacted temperature, DO levels and sensor function. Moreover, the DO meter at this site is located in a mixing zone where cooler (but lower DO) spring water mixes with warmer (but higher DO) water from

upstream. Natural aeration and mixing eventually increase DO levels further downstream. Therefore, these results may not be an accurate representation of DO levels through the reach. This DO meter was removed on September 18, 2019 due to in-stream construction at the monitoring site.

105SRV1DO experienced an early season reduction in DO that can not be explained by water temperatures or other known variables including metrics measured at upstream and downstream DO locations. It is possible that the sensor was bio-fouled during this time, but it was reading accurately at the time of calibration on April 30th. DO level at this site remained above the TMDL for much of the remainder of the season.

The DO meter and canister at 105SRM1DO were unknowingly removed from the river by a vegetation clearing crew on approximately August 13, 2019. SVRCD technicians found the DO meter, re-calibrated it and re-deployed it on September 5.

105SRA1DO consistently ranks among the highest in percentage of days below the TMDL. More than a mile of livestock exclusion fencing was completed in the riparian zone through this reach in 2020, which will help to create a riparian buffer and increase shade that will reduce river temperatures and erosion, and increase DO levels.

TABLE 4. PERCENTAGE OF DAYS WHERE DO LEVELS FELL BELOW THE TMDL (6 MG/L). SITES IN BOLD TYPE ARE IN THE PROJECT REACH.

DO Monitoring Site	Reach	% Days Exceeded TMDL (6 mg/L)
105SRL1DO	1	0
105SRA1DO	2	23
105SRM1DO	**2**	**0**
105SRT1DO	**2**	**10.5**
105SRV1DO	4	15.5
105SRN1DO	4	1
105SRP1DO	5	22.1
105SRU1DO	6	23

REACH 1-6 DO CHARTS

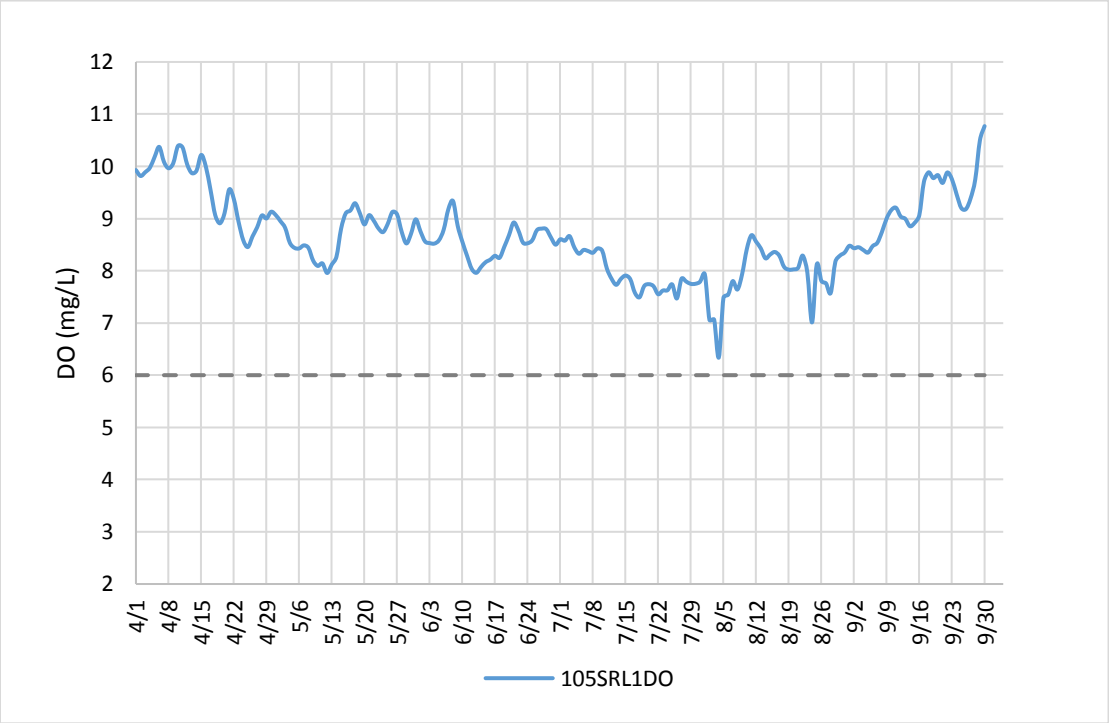

FIGURE 10. 2019 DO MINIMUM AT 105SRL1DO, SHASTA RIVER.

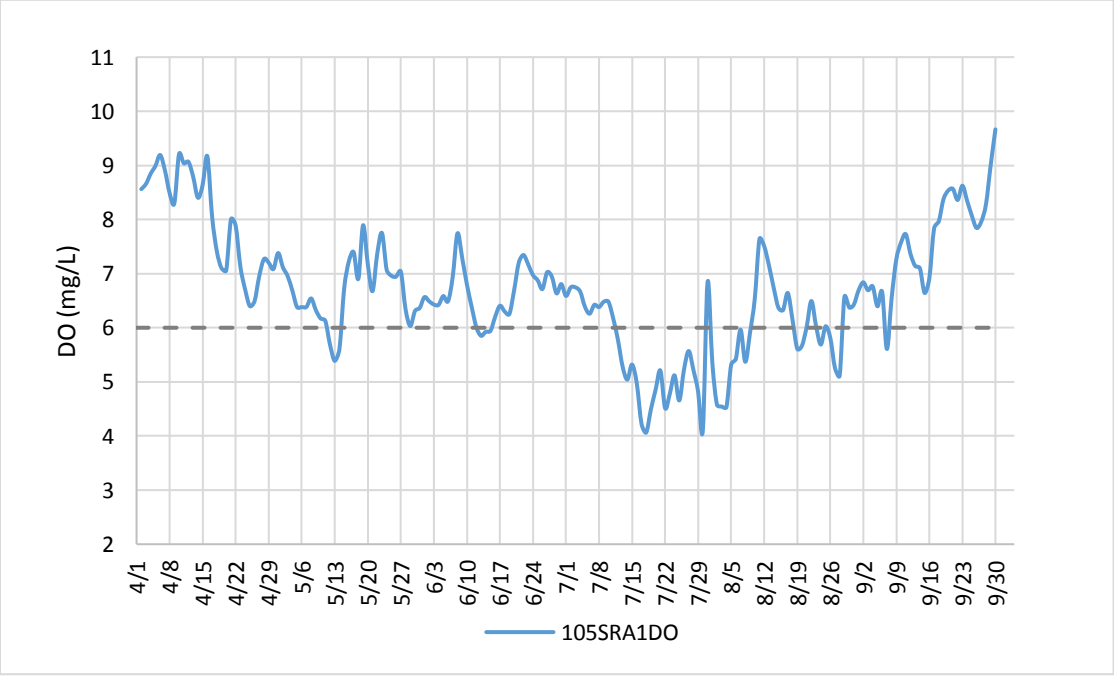

FIGURE 11. 2019 DO MINIMUM AT 105SRA1DO, SHASTA RIVER.

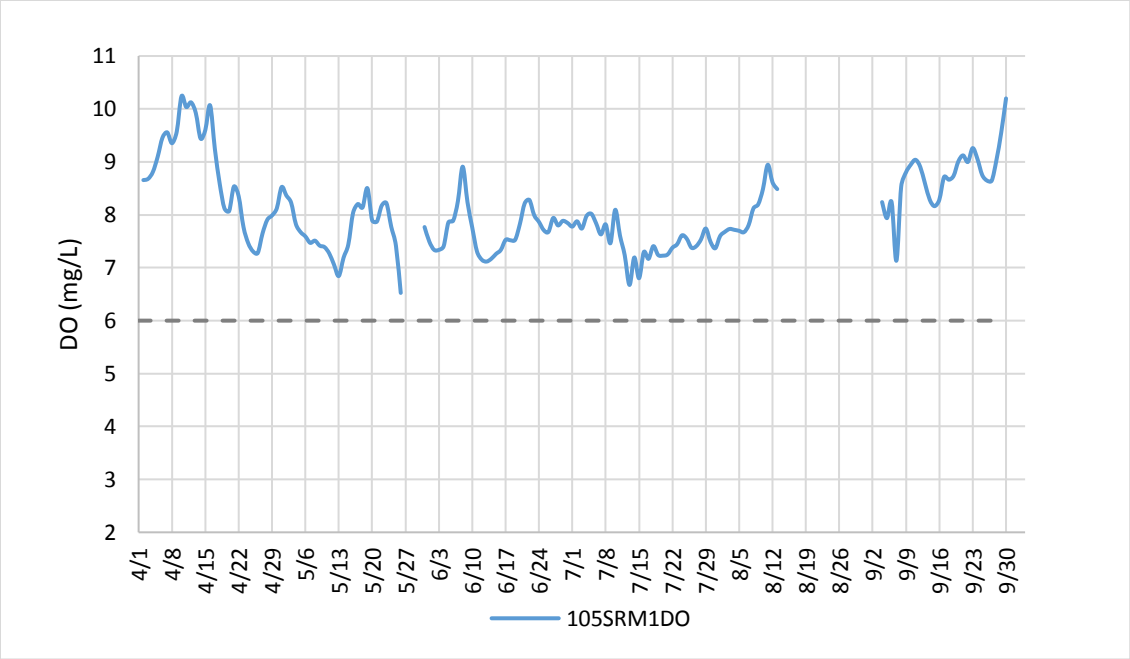

FIGURE 12. 2019 DO MINIMUM AT 105SRM1DO (AT THE PROJECT SITE), SHASTA RIVER. DATA MISSING DUE TO LOGGER BEING REMOVED FROM SITE BY 3RD PARTY.

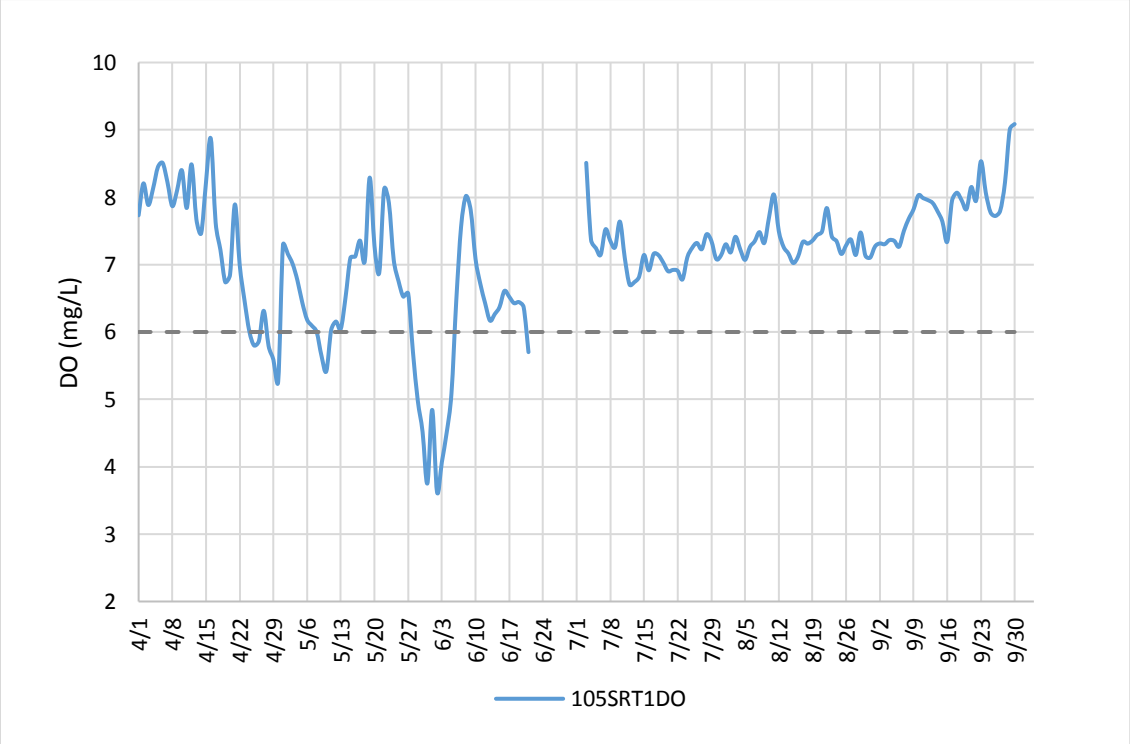

FIGURE 13. 2019 DO MINIMUM AT 105SRT1DO (UPSTREAM OF THE PROJECT SITE), SHASTA RIVER. DATA MISSING DUE TO SENSOR BIO-FOULING.

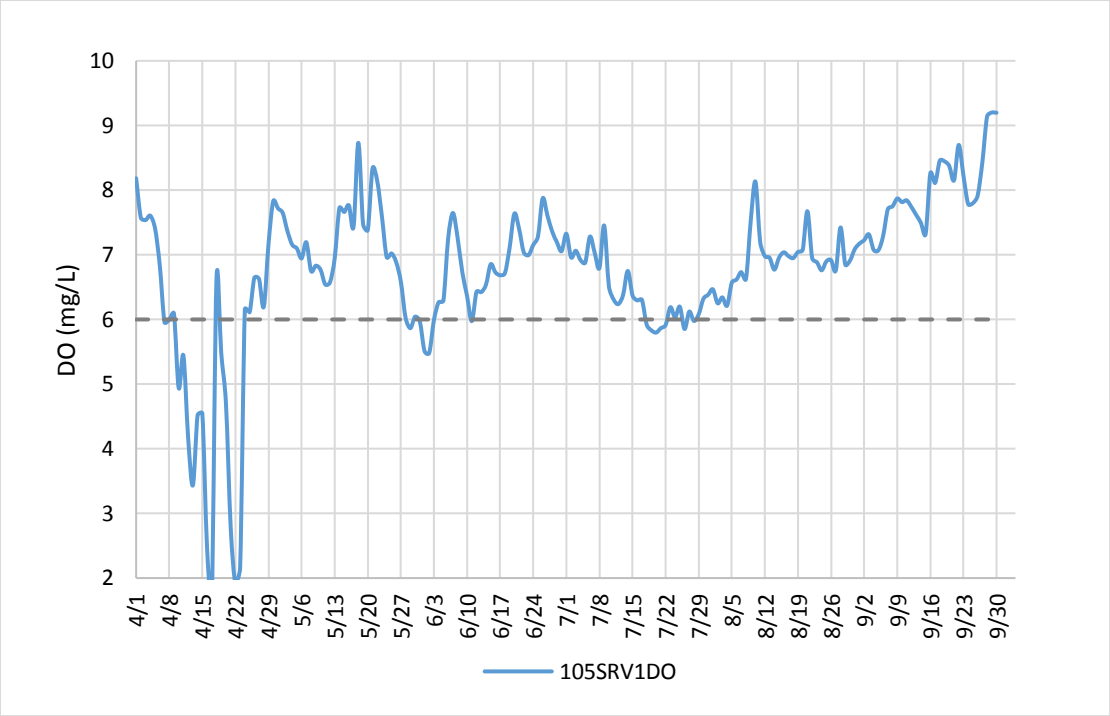

FIGURE 14. 2019 DO MINIMUM AT 105SRV1DO, SHASTA RIVER.

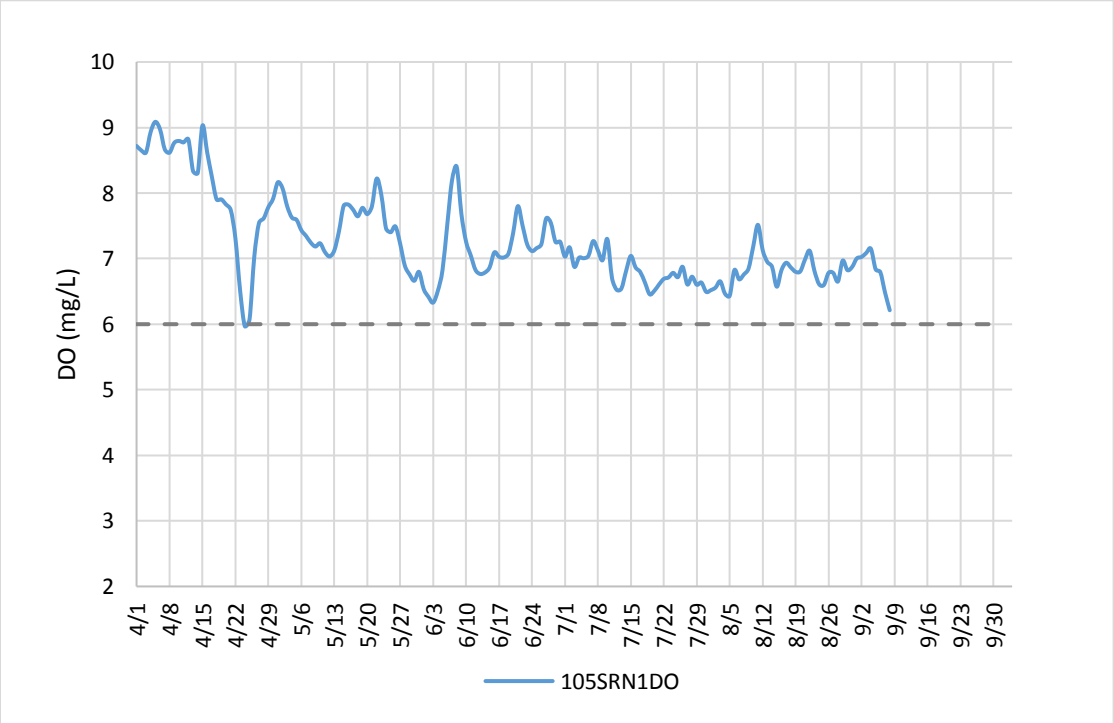

FIGURE 15. 2019 DO MINIMUM AT 105SRN1DO, SHASTA RIVER. DATA MISSING DUE TO SENSOR BIO-FOULING.

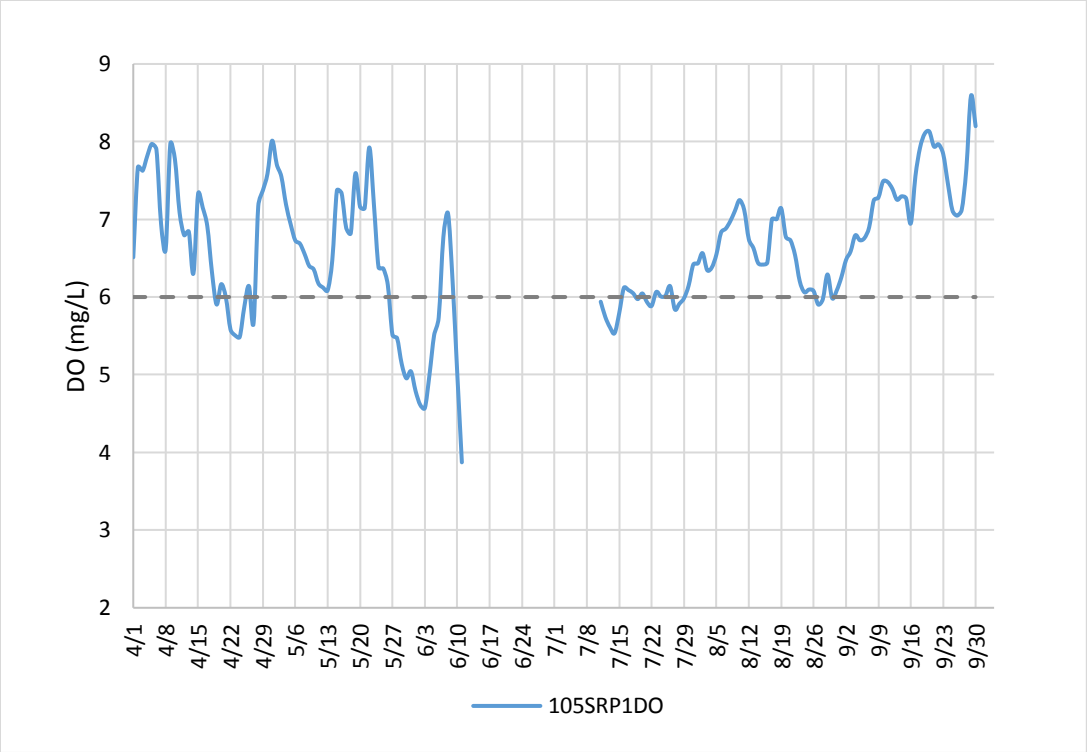

FIGURE 16. 2019 DO MINIMUM AT 105SRP1DO, SHASTA RIVER. DATA MISSING DUE TO SENSOR BIO-FOULING.

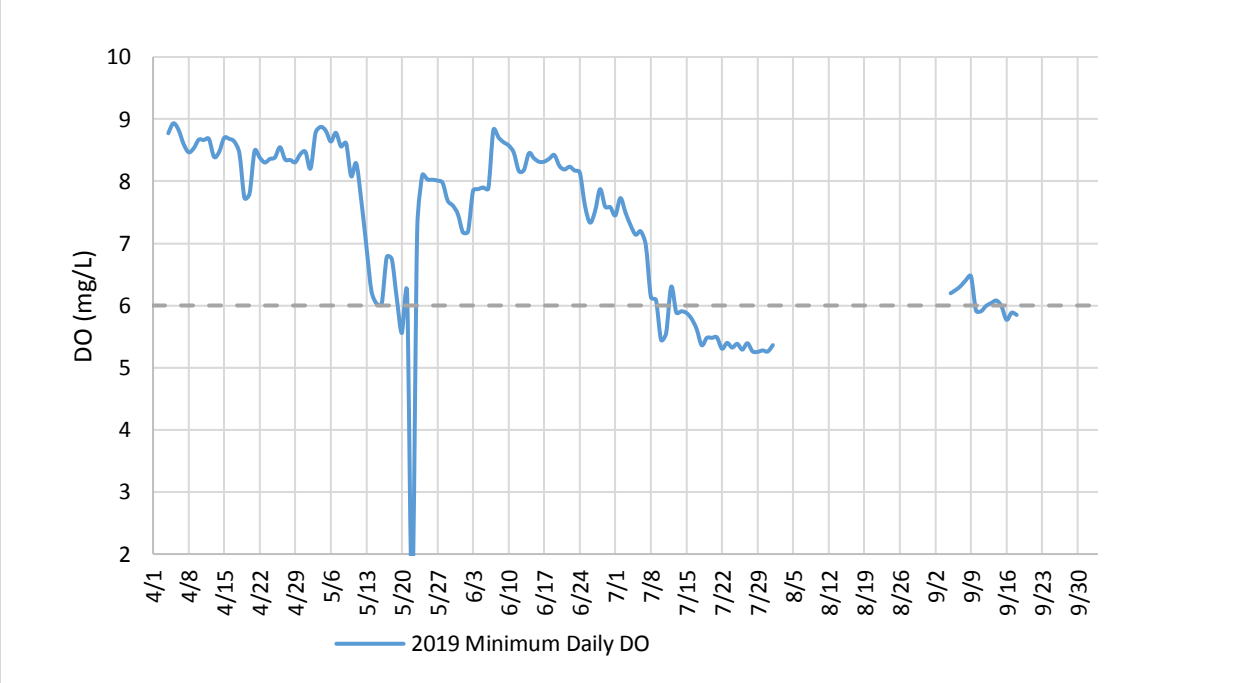

FIGURE 17. 2019 DO MINIMUM AT 105SRU1DO, SHASTA RIVER. DATA MISSING DUE TO SENSOR BIO-FOULING.

CONCLUSION

In general, temperatures on the Shasta River and through the Project area exceeded TMDL and MWMT objectives in 2019, while DO levels were above minimum objectives at most sites but fell below those objectives at others (DO at the project site remained above the TMDL requirement). These mixed results suggest that, in general, DO and especially temperature did not meet NCWQCP objectives in 2019, but long-term monitoring results have shown positive impacts of ongoing resource management and restoration projects on the Shasta River and its tributaries.

Moreover, riparian zone livestock exclusion fencing installed in Reach 2 in 2019 will help improve water quality and available fish habitat in this reach. Projects scheduled for 2020 include weir re-construction with an improved fish passage design at 105SRM1DO in Reach 3, and removal of a fish passage barrier at 105SRPCFP in Reach 5, Parks Creek.

The results from this annual monitoring report, as well as a multi-year analysis of temperatures and DO on the Shasta River that can be found in the 2018 Shasta River Watershed Stewardship Report, support continued efforts (e.g. riparian planting, tailwater reduction, spring-connection/enhancement projects, and impoundment removal) to decrease water temperatures and improve DO conditions in the Shasta River.

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Funding for this project has been provided in full or in part through an agreement with the U.S. Fish and Wildlife Service through the CFDA program. The contents of these documents do not necessarily reflect the views and policies of the U.S. Fish and Wildlife Service, nor does mention of the trade names or commercial products constitute endorsement or recommendation for use (Gov. Code 7550, 40 CFR 31.20).

The SVRCD would like to give sincere thanks to all landowners and agencies who provided access to the Shasta River and/or tributaries through their properties.