Morro Bay Watershed Creek Health Memo
For Water Year 2023

Date Range: Water Year 2023 (October 1, 2022 to September 30, 2023)
Analytes: Temperature, Nitrate as nitrogen (NO_3-N), Orthophosphate as phosphorus (PO_4-P), Dissolved Oxygen, pH

1. Background

The Morro Bay National Estuary Program (Estuary Program) conducts monitoring in the Morro Bay estuary and surrounding watershed to track ambient water quality trends and to assess the impacts of specific implementation projects.

Estuary Program staff and volunteers collect data under the guidance of a Quality Assurance Project Plan (QAPP) which is reviewed and approved by EPA and the Central Coast Regional Water Quality Control Board (CCRWQCB). This QAPP document contains the monitoring locations, protocols, equipment specifications, and other details that allow users to assess the quality of the collected data. The full QAPP document is available at https://www.mbnep.org/qapp/.

2. Water Temperature

Water temperature plays a critical role in the regulation of aquatic ecosystems. For sensitive wildlife like South-Central California Coast steelhead (*Oncorhynchus mykiss*), temperature has a direct impact on growth, reproduction, and survival potential. Elevated temperatures, especially those that are sustained for long periods of time, may impede the ability of *O. mykiss* to complete their lifecycle.

The Estuary Program monitors continuous water temperature in the Chorro Creek subwatershed to assess how frequently water temperature conditions are supportive of *O. mykiss*.

2.1 Equipment Specifications

The Estuary Program deploys HOBO TidbiT MX 2203 temperature data loggers at sites throughout the watershed (Section 2.2). These loggers monitor daily fluctuations and seasonal trends of creek water temperature. Loggers are deployed year-round and are programmed to collect readings at 30-minute intervals.

Specifications for the TidbiT temperature loggers are as follows:

Specification	Value
Measurement/Operating Range	-20° to 70°C in air -20° to 50°C in water
Accuracy	±0.25°C from -20° to 0°C ±0.2°C from 0° to 70°C
Resolution	0.01°C

While the TidbiT temperature loggers do not require calibration, staff collect independent temperature measurements from a secondary meter during deployment and retrieval. Additional measurements are collected periodically throughout deployments for quality assurance.

2.2 Monitoring Locations

The Estuary Program monitored continuous temperature at six sites in the Chorro Creek subwatershed (Figure 1) during WY2023. Three of the six monitoring sites are located along the mainstem of Chorro Creek, which is known to support *O. mykiss*. Historic data indicates elevated temperatures on Chorro Creek, above levels preferred by these sensitive fish. The remaining sites were chosen along tributaries to Chorro Creek: Pennington Creek, San Luisito Creek, and Dairy Creek. These tributaries have historically provided spawning ground for *O. mykiss*.

Continuous Temperature Monitoring Sites for WY2023

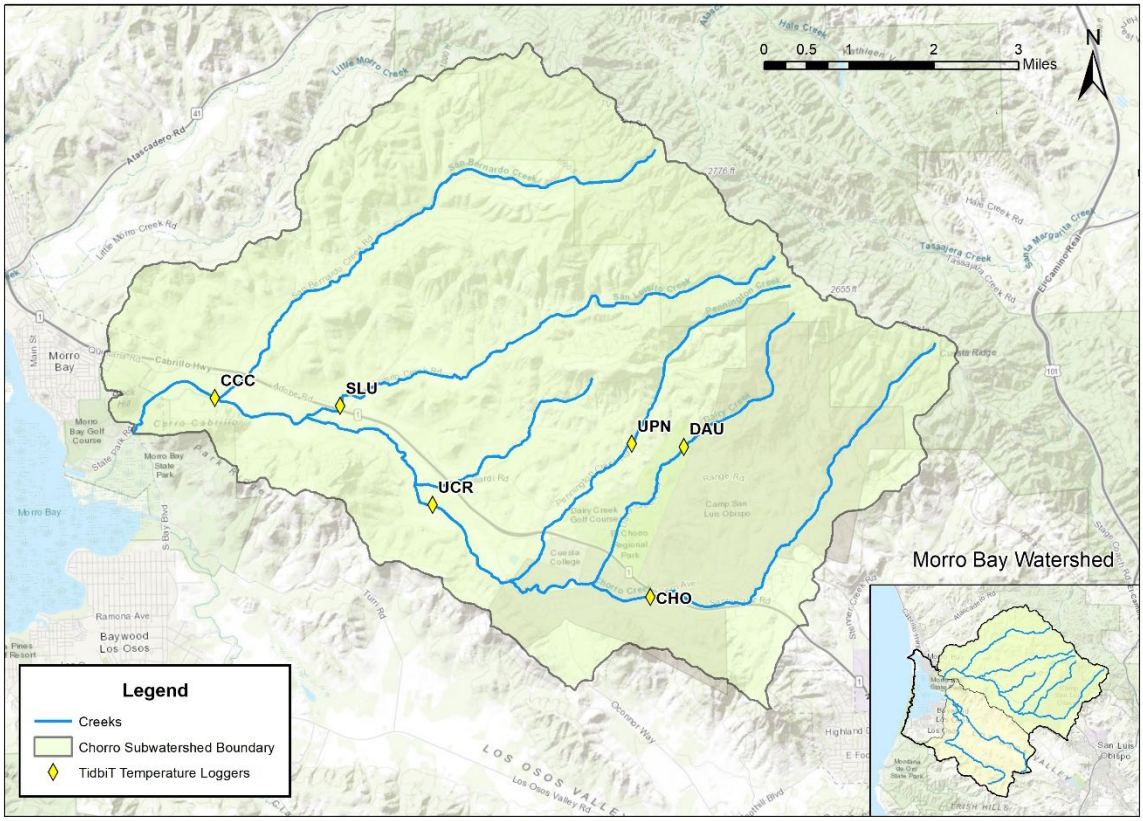

Figure 1: *Continuous temperature monitoring sites in the Chorro Creek subwatershed during WY2023.*

2.3 Results

Research has shown that prolonged exposure to temperatures above 18°C can negatively impact *O. mykiss* reproduction, growth, migration timing, stress levels, and survival (Moyle 2002). This 18°C temperature threshold was selected based on research that identified the optimal temperature range for *O. mykiss* as between 13 and 21°C.

The following graphs illustrate water temperatures for the entire water year, color coded by season[1]. The multi-colored line indicates water temperature in degrees Celsius (°C) recorded at 30-minute intervals, and the horizontal red line indicates an 18°C threshold protective of sensitive species.

Chorro Creek

Water temperature data was collected at three sites along Chorro Creek:

- Chorro Creek at Camp San Luis Obispo (CHO): this is the uppermost monitoring site is located at Camp San Luis Obispo at the Highway 1 bridge.
- Chorro Creek at Upper Chorro Reserve (UCR): this site is downstream of the California Men's Colony wastewater treatment plant outfall and just upstream of the Chorro Creek Ecological Reserve.
- Chorro Creek at Chorro Creek Road (CCC): this is the furthest downstream site located upstream of Chorro Flats. It is above the zone of tidal influence from the bay.

Camp San Luis Obispo (CHO)

The following graph (Figure 2) shows water temperatures at Chorro Creek near Camp San Luis Obispo (CHO). The temperature logger at CHO was deployed from the start of WY2023 (October 1, 2022) until December 14, 2022. Late fall and early winter data is not available due to a large storm that pushed the logger out of the water. The logger was placed back in the water on February 28, 2023 and was active until July 7, 2023, when technical issues prevented further data collection.

Fortunately, an InSitu Level TROLL 700 pressure transducer had been installed on site in June 2023. Because the equipment specifications met the need of the project[2], temperature was collected using the pressure transducer through the end of WY2023 (September 30, 2023). A month of overlapping readings between the two loggers was used to verify that the temperature results were significantly similar before combining the two datasets. The overlapping readings were significantly correlated ($p<0.001$) and exhibited an average relative percent difference of less than 2% between the sensors.

[1] Dates used to define the WY2023 seasons can be found in Appendix B.

[2] The InSitu Level TROLL 700 has a temperature accuracy of ±0.1°C and a resolution of 0.01°C, while the TidbiT MX2203 loggers have a temperature accuracy of ±0.2°C and a resolution of 0.01°C.

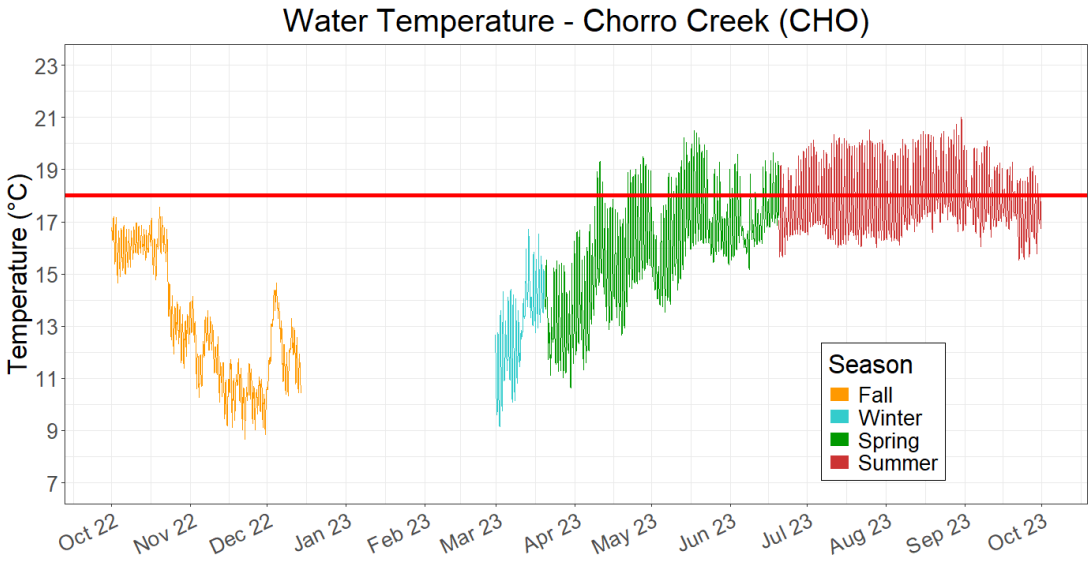

Figure 2: *Water temperature at Chorro Creek (CHO) during WY2023, colored by season. Data was not available from December 14, 2022 to February 28, 2023 and was supplemented with data from an InSitu Level TROLL 700 pressure transducer located at the same site from July 7, 2023 through the end of WY2023.*

Upper Chorro Reserve (UCR)

The following graph (Figure 3) shows water temperatures at Chorro Creek upstream of the Chorro Creek Ecological Reserve (UCR). The temperature logger at UCR experienced two interruptions in data collection. The battery died and the logger was inactive from October 19, 2022 to October 26, 2023 and large winter storms washed the logger away on December 14, 2022. It was replaced on March 23, 2023 and was active until the end of WY2023 (September 30, 2023).

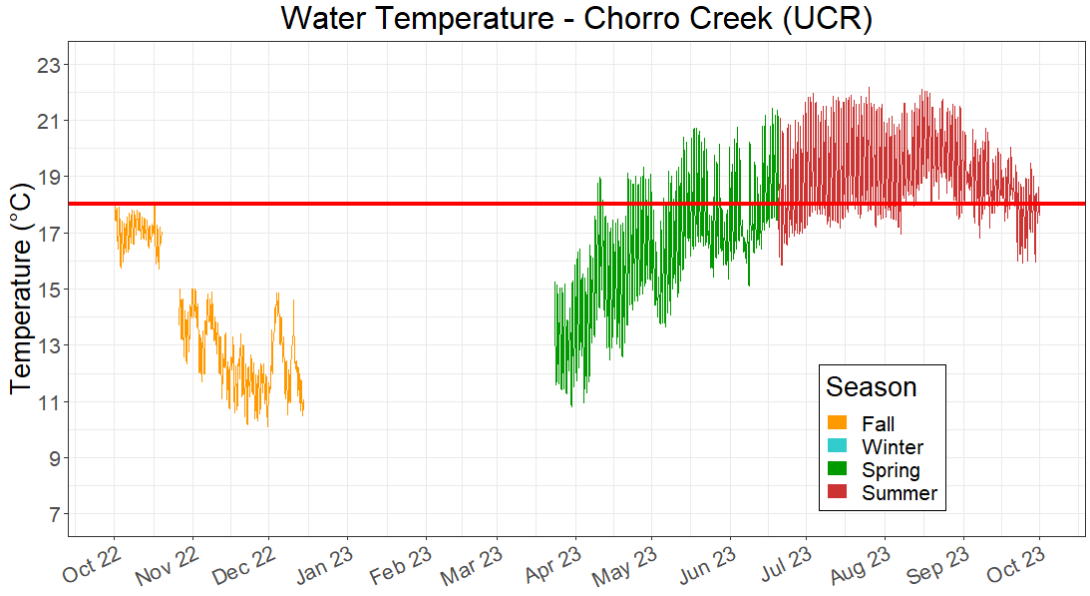

Figure 3: *Water temperature at Chorro Creek (UCR) during WY2023, colored by season. Data was not available from October 19, 2022 to October 26, 2022 and from December 14, 2022 to March 23, 2023.*

Chorro Creek Road (CCC)

The following graph (Figure 4) shows water temperatures at Chorro Creek near Chorro Creek Road (CCC). The temperature logger at CCC was deployed from the start of WY2023 (October 1, 2022) until December 14, 2022. Due to a large storm that washed the logger away, late fall and early winter data is not available. The logger was replaced on March 24, 2023 and was active until the end of WY2023 (September 30, 2023).

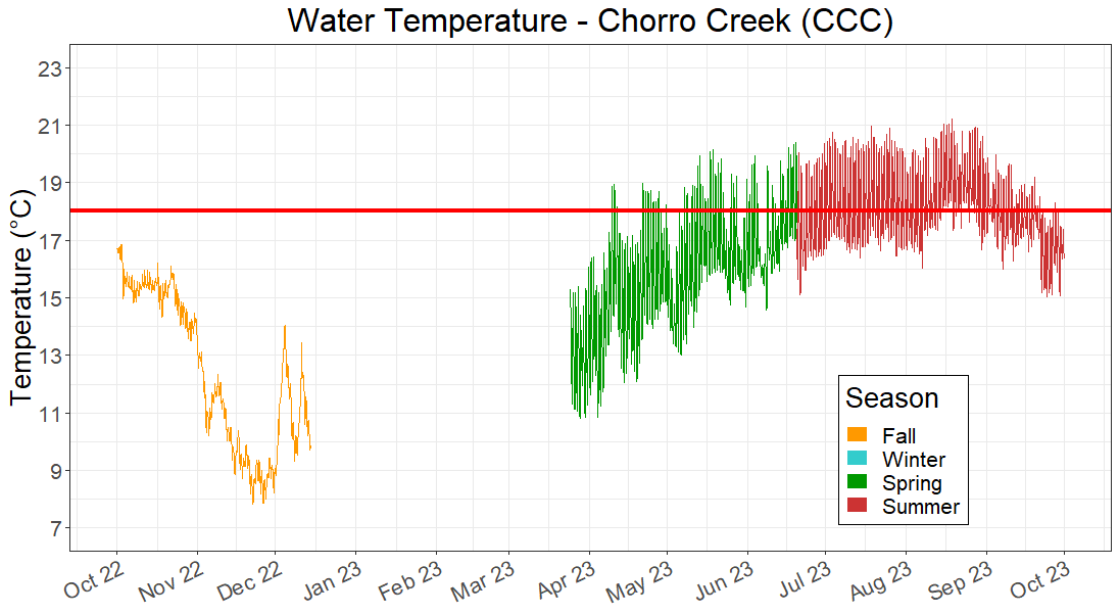

Figure 4: *Water temperature at Chorro Creek (CCC) during WY2023, colored by season. Data was not available from December 14, 2022 to March 23, 2024.*

Chorro Creek Tributaries

Water temperature data was collected from three tributaries to Chorro Creek:

- San Luisito Creek (SLU): this site is located on Adobe Road, about 0.5 miles upstream of the confluence with Chorro Creek.
- Pennington Creek (UPN): located about 2.5 miles upstream of the confluence with Chorro Creek, upstream of the former Rancho El Chorro Outdoor School campus and near the Cal Poly Beef Center at Escuela Ranch.
- Dairy Creek (DAU): located within El Chorro Regional Park, approximately 2 miles upstream of the confluence of Dairy and Chorro Creek.

San Luisito Creek (SLU)

The following graph (Figure 5) shows water temperatures at San Luisito Creek at Adobe Road (SLU) during WY2023. The temperature logger at SLU was deployed from the start of WY2023 (October 1, 2022) until December 14, 2022. Due to a large storm that washed the logger away, late fall and early winter data is not available. The logger was replaced on March 24, 2023 and was active until the end of WY2023 (September 30, 2023).

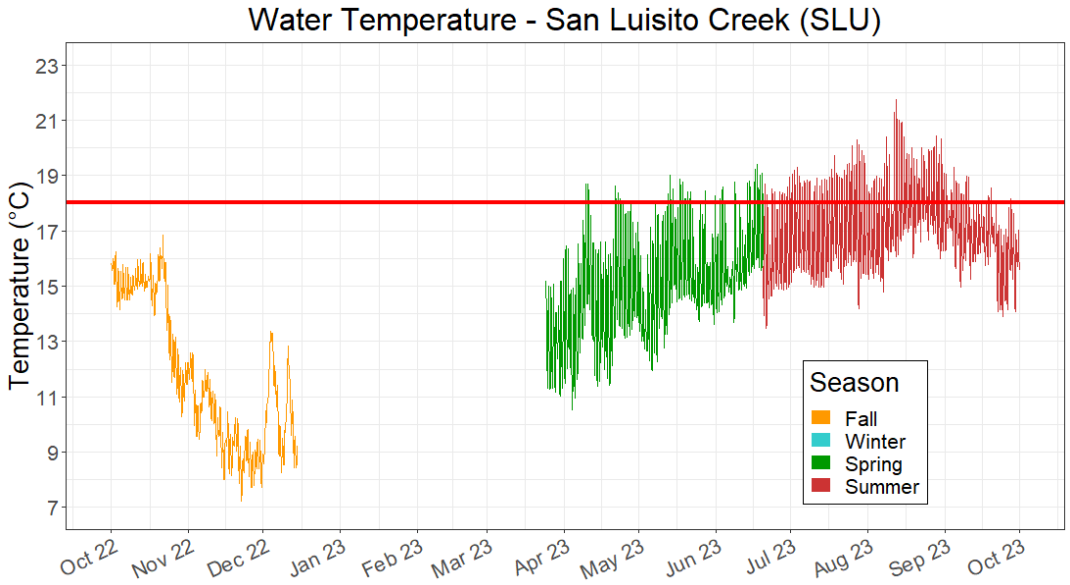

Figure 5: *Water temperature at San Luisito Creek (SLU) during WY2023, colored by season. Data was not available from December 14, 2022 to March 24, 2023.*

Pennington Creek (UPN)

The following graph (Figure 6) shows water temperatures at Pennington Creek on Escuela Ranch (UPN) during WY2023. The temperature logger at UPN was deployed from the start of WY2023 (October 1, 2022) until December 14, 2022. Due to a large storm that washed the logger away, late fall and early winter data is not available. The logger was replaced on March 24, 2023, and was active until the end of WY2023 (September 30, 2023).

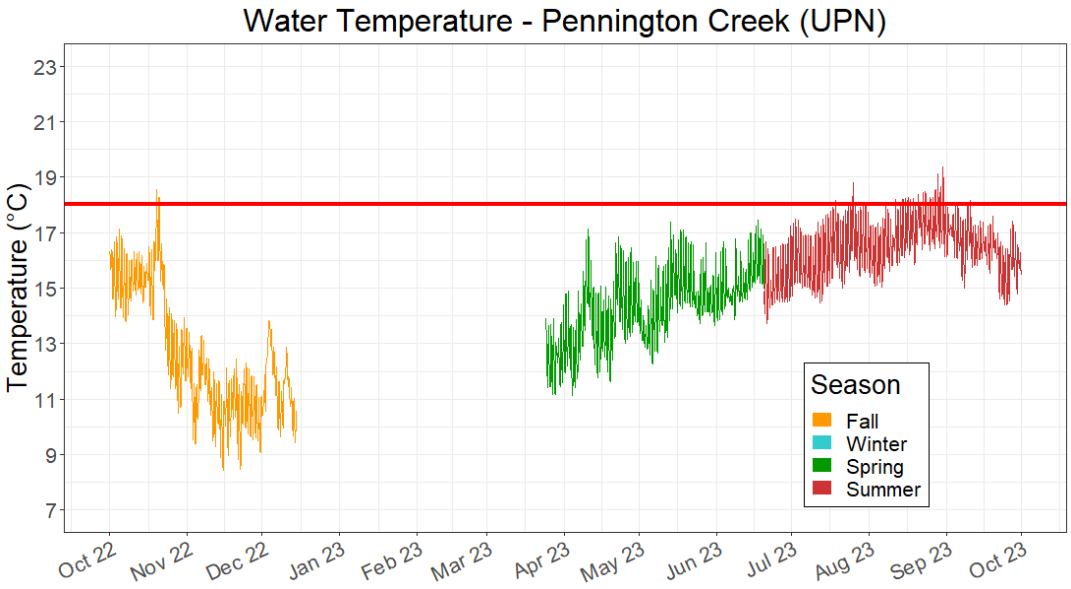

Figure 6*: Water temperature at Pennington Creek (UPN) during WY2023, colored by season. Data was not available from December 14, 2022 to March 24, 2023.*

Dairy Creek (DAU)

The following graph (Figure 7) shows water temperatures at upper Dairy Creek above El Chorro Regional Park (DAU) during WY2023. The site was dry at the start of WY2023, so the temperature logger at DAU was deployed on December 12, 2022 after flows resumed. Issues with a faulty battery led to subsequent data gaps from December 18, 2022 to March 8, 2023 and from March 11, 2023 to March 28, 2023. Once the issue was resolved, the logger was active until the end of WY2023 (September 30, 2023).

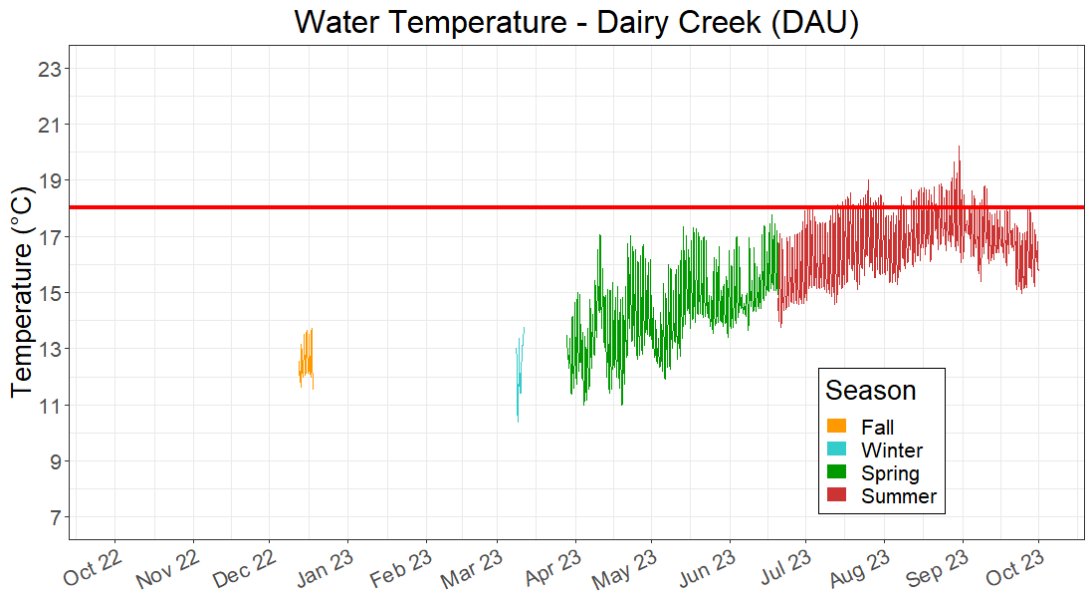

Figure 7: *Water temperatures at Dairy Creek (DAU) during WY2023, colored by season. Data is not available before December 12, 2022 due to lack of surface flows. Data is also not available from December 18, 2022 to March 8, 2023 and from March 11, 2023 to March 28, 2023 due to battery issues.*

2.4 Discussion

Water temperatures during WY2023 were analyzed using a variety of metrics. First, percent exceedance was calculated to see how frequently sites had water temperatures higher than 18°C. Exceedance was calculated for the entire deployment period of the logger, which varied by site, and on a seasonal basis (Table 1). Because deployment periods for each logger varied, percent exceedance for each site cannot be directly compared between sites. Deployment periods for each temperature logger are outlined in Appendix A.

Table 1: *Percent exceedance of the 18°C threshold for sensitive species at each monitoring site for WY2023. The deployment periods vary based on site locations.*

Timeframe	CHO	UCR	CCC	UPN	DAU	SLU
Full Deployment Period	17.7%	37.7%	23.3%	1.9%	5.8%	10.4%
Fall	0.0%	0.1%	0.0%	0.6%	0.0%	0.0%
Winter	0.0%	-	-	-	0.0%	-

Spring	14.7%	19.9%	12.8%	0.0%	0.0%	5.1%
Summer	36.6%	77.8%	49.2%	4.5%	11.0%	22.5%
Total days deployed in WY2023	290[3]	261	266	266	199	266

The U.S. Environmental Protection Agency (EPA) set forth water temperature criteria in the 1986 Quality Criteria for Water (also known as the "Gold Book"), where it recommends the use of a maximum weekly average temperature (MWAT) as an index for assigning protective temperature standards for fisheries. The MWAT is the highest single temperature value of the seven-day moving average. This index is calculated relative to an upper limit, such as the 18°C threshold mentioned previously.

Despite being a standard outlined by the EPA, several case studies have found the MWAT to be inadequately protective (McCullough, 2010). Because high daily maximum temperatures are often accompanied by low daily minimums, averages may remain relatively constant even if the daily maxima are much higher than ideal (Beschta et al. 1987). For a more protective metric, the maximum weekly maximum temperature (MWMT), also known as the seven-day average of the daily maximum temperatures (7-DADM), has been adopted more recently in some watersheds for assessing temperature regimes. The MWMT is defined as the maximum seasonal or yearly value of the daily maximum temperatures over a running seven-day consecutive period (Welsh et al., 2001).

In addition to percent exceedance of the 18°C threshold, both MWAT and MWMT were calculated monthly to further assess thermal suitability for sensitive species. These values were compared to thermal thresholds for salmon and trout life stages, as designated by the EPA (Table 2).

[3] The logger at CHO experienced technical issues in the summer and was supplemented with data from a pressure transducer located at the same site from July 7, 2023, through September 30, 2023, making up 83 of the 290 days reported in the table below. For more details, see Appendix A.

Table 2: *Maximum weekly average temperatures (MWAT) and maximum weekly maximum temperatures (MWMT) for monitoring sites during WY2023. Salmon and trout life stage thresholds adapted from EPA, 2003.*

Maximum Weekly Average Temperature (MWAT) - WY 2023												
Site	Oct '22	Nov '22	Dec '22	Jan '23	Feb '23	Mar '23	Apr '23	May '23	Jun '23	Jul '23	Aug '23	Sep '23
CHO	16.3	12.3	12.7	-	11.7	14.3	16.7	17.8	17.7	17.9	18.4	17.9
UCR	17.2	13.6	13.1	-	-	13.3	16.7	18.1	18.7	19.5	20.1	19.0
CCC	15.8	11.7	11.7	-	-	13.1	16.1	17.3	18.0	18.5	19.2	18.1
UPN	15.9	11.7	12.0	-	-	12.5	14.7	15.4	15.8	16.8	17.4	16.9
DAU	-	-	12.4	-	-	12.6	14.5	15.2	15.8	17.0	17.7	17.2
SLU	15.3	11.0	11.1	-	-	13.1	15.3	16.1	16.8	17.3	18.2	17.3

Maximum Weekly Maximum Temperature (MWMT) - WY 2023												
Site	Oct '22	Nov '22	Dec '22	Jan '23	Feb '23	Mar '23	Apr '23	May '23	Jun '23	Jul '23	Aug '23	Sep '23
CHO	16.9	13.1	13.4	-	12.7	15.9	19.1	20.1	19.2	20.1	20.4	19.8
UCR	17.7	14.4	13.7	-	-	15.0	19.0	20.4	20.9	21.8	21.9	20.4
CCC	16.1	12.2	12.2	-	-	15.2	18.6	19.5	19.8	20.5	20.9	19.5
UPN	17.0	12.6	12.6	-	-	13.7	16.4	16.9	17.0	18.1	18.6	17.8
DAU	-	-	13.2	-	-	13.7	16.6	17.1	17.3	18.5	19.2	18.4
SLU	16.0	11.7	11.7	-	-	14.9	18.1	18.4	18.8	19.8	20.7	18.8

- > 20°C, Exceeds EPA Threshold for Salmon/Trout Migration
- > 18°C, Exceeds EPA Threshold for Salmon/Trout Migration plus Non-Core Juvenile Rearing
- > 16°C, Exceeds EPA Threshold for Salmon/Trout "Core" Juvenile Rearing
- > 14°C, Exceeds EPA Threshold for Steelhead Smoltification
- > 13°C, Exceeds EPA Threshold of Salmon/Trout Spawning and Egg Incubation
- < 13°C, EPA Optimal Range for Salmon/Trout Egg Incubation
- - = insufficient data

Table 2 illustrates how MWMT is a more protective metric than the MWAT. All temperature monitoring sites show elevated summer temperatures that exceeded a MWMT of 18°C, including the tributaries to Chorro Creek. The MWAT table similarly shows elevated temperatures during this time, however Chorro Creek at CCC never exceeded the 18°C threshold using this metric. This site is located the furthest downstream of the Chorro mainstem sites and is directly below the confluence of San Bernardo Creek and Chorro Creek. During the winter months, the MWAT table shows tributary temperatures that could support all salmonid life stages from December to February, while the MWMT table shows little sustained viability for salmonid egg incubation during the most crucial time of year.

The highest MWAT and MWMT values from WY2023 occurred on Chorro Creek at CHO (upstream of the CA Men's Colony wastewater treatment plant), followed by Chorro Creek at UCR, which is located approximately two miles downstream of CHO. Both sites have had frequent and sustained issues with elevated temperatures. CHO is the furthest upstream of the three mainstem sites. This site is more exposed to sunlight when compared to downstream sites and does not receive cooler incoming water from tributaries. Water temperatures at UCR could also be affected by incoming treated effluent from the wastewater treatment plant. Warmer temperatures are less frequent downstream at CCC, likely due to increased canopy cover and cooler water coming in from tributaries.

3. Bimonthly Nutrient Monitoring

Nutrient impairment can lead to degraded water quality conditions and eutrophication, which can harm aquatic life and compromise ecosystem function. The Estuary Program assesses ambient nutrient concentrations throughout the Morro Bay watershed to identify long-term trends and prioritize restoration and conservation efforts.

Estuary Program staff collect samples for laboratory analysis for nitrate as nitrogen and orthophosphate as phosphorus. Sites were initially visited on a quarterly basis, or four times each year. As of June 2019, sites are now visited on a bimonthly basis, or six times each year. As such, this effort was previously referred to as Quarterly Nutrient Monitoring (QNM) and is now referred to as Bimonthly Nutrient Monitoring (BNM).

3.1 Analytical Specifications

The Estuary Program collects samples using standard sampling techniques. The samples are stored in the dark on ice and then delivered by a courier to a certified laboratory for analysis within the specified hold time. The analysis specifications are as follows:

Nitrate as Nitrogen (NO_3-N, mg/L):

Specification	Value
Method Number	EPA 300.0
Minimum Detection Limit (MDL)	0.024 mg/L
Project Quantitation Limit (PQL)	0.10 mg/L
Hold Time	48 hours
Sample storage conditions	4°C in the dark

Orthophosphate as Phosphorus (PO_4-P, mg/L):

Specification	Value
Method Number	EPA 365.1
Minimum Detection Limit (MDL)	0.017 mg/L
Project Quantitation Limit (PQL)	0.050 mg/L
Hold Time	48 hours
Sample storage conditions	4°C in the dark

The laboratory occasionally dilutes the sample prior to analysis if the nutrient concentrations are elevated, which impacts the minimum detection limit and project quantitation limit for the results. For each result that is less than the Project Quantitation Limit (PQL), a random number between zero and the PQL is generated in R and used for analysis. This is the same method utilized by the CCRWQCB to manage non-detects in their own analysis.

3.2 Monitoring Locations

Eight sites were selected to represent Chorro and Los Osos Creeks and their respective tributaries (Figure 8). The sites include upper Chorro Creek (site code CHO), middle Chorro Creek (UCR), lower

Chorro Creek (TWB), middle Dairy Creek (DAM), Pennington Creek (UPN), San Luisito Creek (SLU), Warden Creek (TUR), and upper Los Osos Creek (CLV).

Morro Bay Watershed Bimonthly Nutrient Monitoring Sites

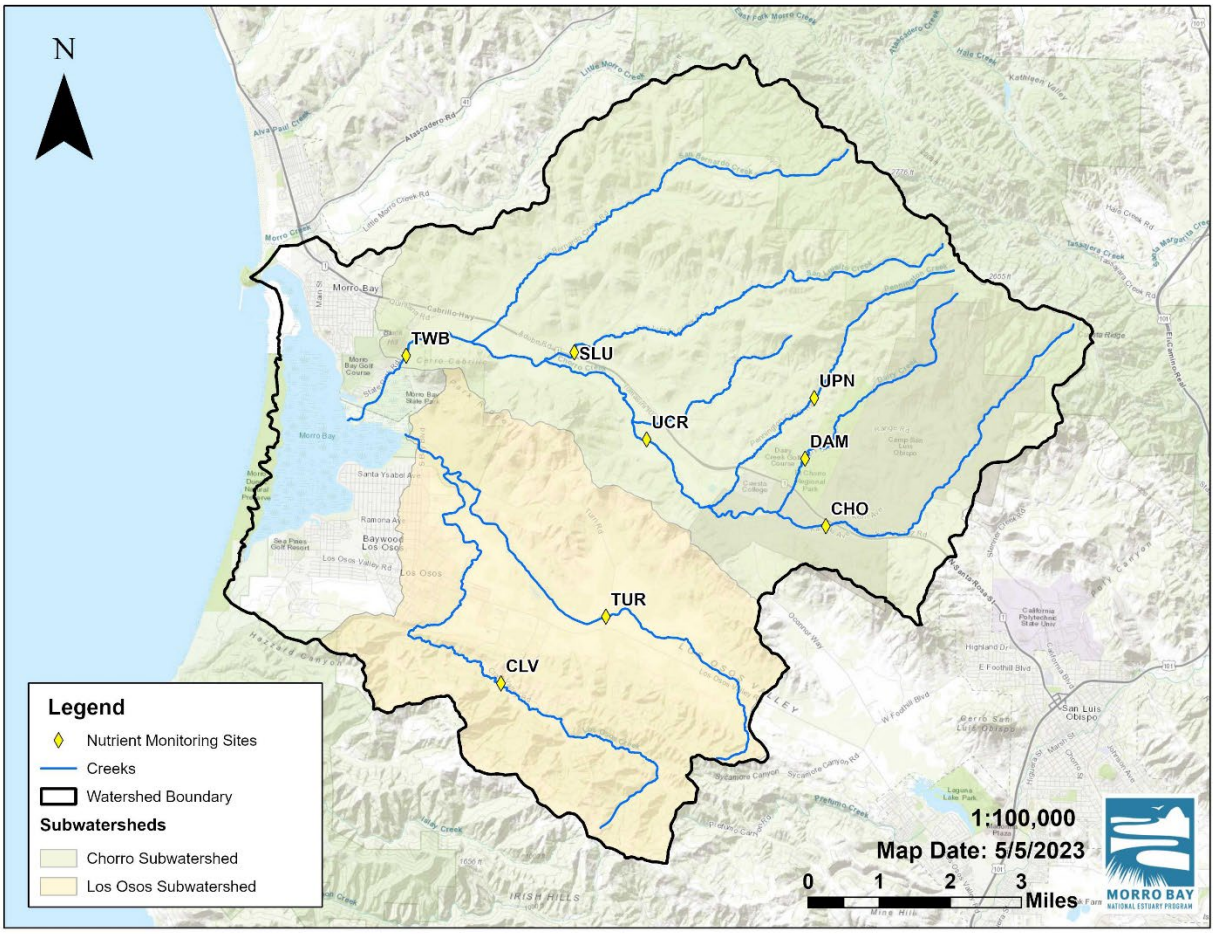

Figure 8: *Bimonthly nutrient monitoring locations in the Morro Bay watershed.*

3.3 Results

Nitrate as Nitrogen

Nitrate results are compared to two standards. In freshwater systems, a water body is considered to likely be impaired by nitrates if NO_3-N concentrations are greater than or equal to 1 mg/L as N and. This is a 303(d) Listing Guidance Value utilized by the CCRWQCB and others to assess potential impairment when accompanied by other signs of ecological impact, such as widespread algal growth and excessively low or high dissolved oxygen concentrations. The EPA has a maximum contaminant level (MCL) of 10 mg/L NO_3-N for drinking water for protection of human health.

The Estuary Program assessment utilized the following scores:

Good	- for NO_3-N concentrations < 1 mg/L (protective of aquatic and human health)
Fair	- for NO_3-N concentrations ≥ 1 mg/L and < 10 mg/L
Poor	- for NO_3-N concentrations ≥ 10 mg/L (exceeds level protective of human health)

Figure 9 shows the average NO_3-N concentration for sites monitored in WY2023. The number of samples varies by site, as some sites go dry during the summer. For sites with year-round flow, this represents six readings.

Average Nitrate as Nitrogen (mg/L) Concentrations for WY2023

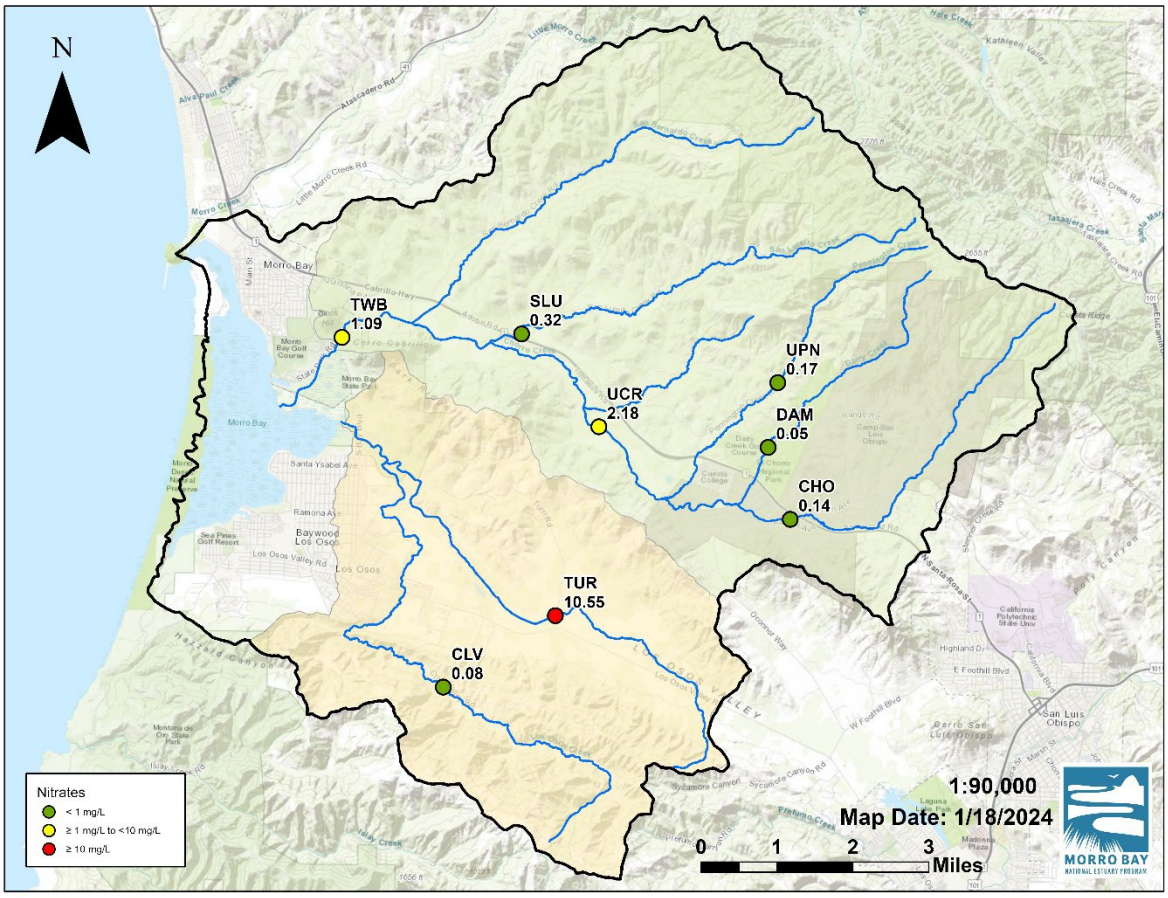

Figure 9: *Average NO_3-N concentrations for WY2023 at eight representative monitoring locations.*

Historical NO_3-N averages were compared to results from WY2023 (Table 3). Historic data includes nutrient monitoring data from WY2016 through WY2023. Values highlighted in green indicate concentrations which are protective of aquatic and human health (< 1 mg/L NO_3-N). Values highlighted in yellow indicate values that fall under the EPA MCL but are greater than CCRWQCB's level of protection of aquatic life (≥ 1 mg/L and < 10 mg/L NO_3-N). Values highlighted in red exceed the drinking water level protective of human health (≥ 10 mg/L NO_3-N). The relative percent difference (RPD) was then calculated to compare WY2023 data to historical data. Sites with higher RPDs indicate greater differences between WY2023 and historical data.

Table 3: *Historical NO3-N averages compared to WY2023 averages.*

Site Code	CHO	CLV	DAM	SLU	TUR	TWB	UCR	UPN
Historical Average, NO_3-N mg/L	0.11	0.08	0.06	0.09	12.43	0.68	2.08	0.06
WY2023 Average, NO_3-N mg/L	0.14	0.08	0.05	0.32	10.55	1.09	2.18	0.17
Relative Percent Difference (RPD)	21.5%	0.2%	26.4%	113.5%	16.3%	45.6%	4.9%	91.6%

Orthophosphate as Phosphorus

Orthophosphate as phosphorus (PO_4-P) results are compared to targets outlined in the Pajaro River nutrient objectives guidance document (Williamson, 1994). A value of 0.12 mg/L is used for comparison since freshwater systems with concentrations less than 0.12 mg/L are at low risk for eutrophication, although there is no established value for the Morro Bay watershed. To date, there is no standard protective of human health for orthophosphates.

The Estuary Program assessment utilized the following scores:

Good	- for PO_4-P concentrations < 0.12 mg/L
Fair	- for PO_4-P concentrations ≥ 0.12 mg/L

Figure 10 shows the average PO_4-P concentrations for sites monitored in WY2023. The number of samples varies by site, as some sites go dry during the summer. For sites with year-round flow, this represents six readings.

Average Orthophosphate as Phosphorus (mg/L) Concentrations for WY2023

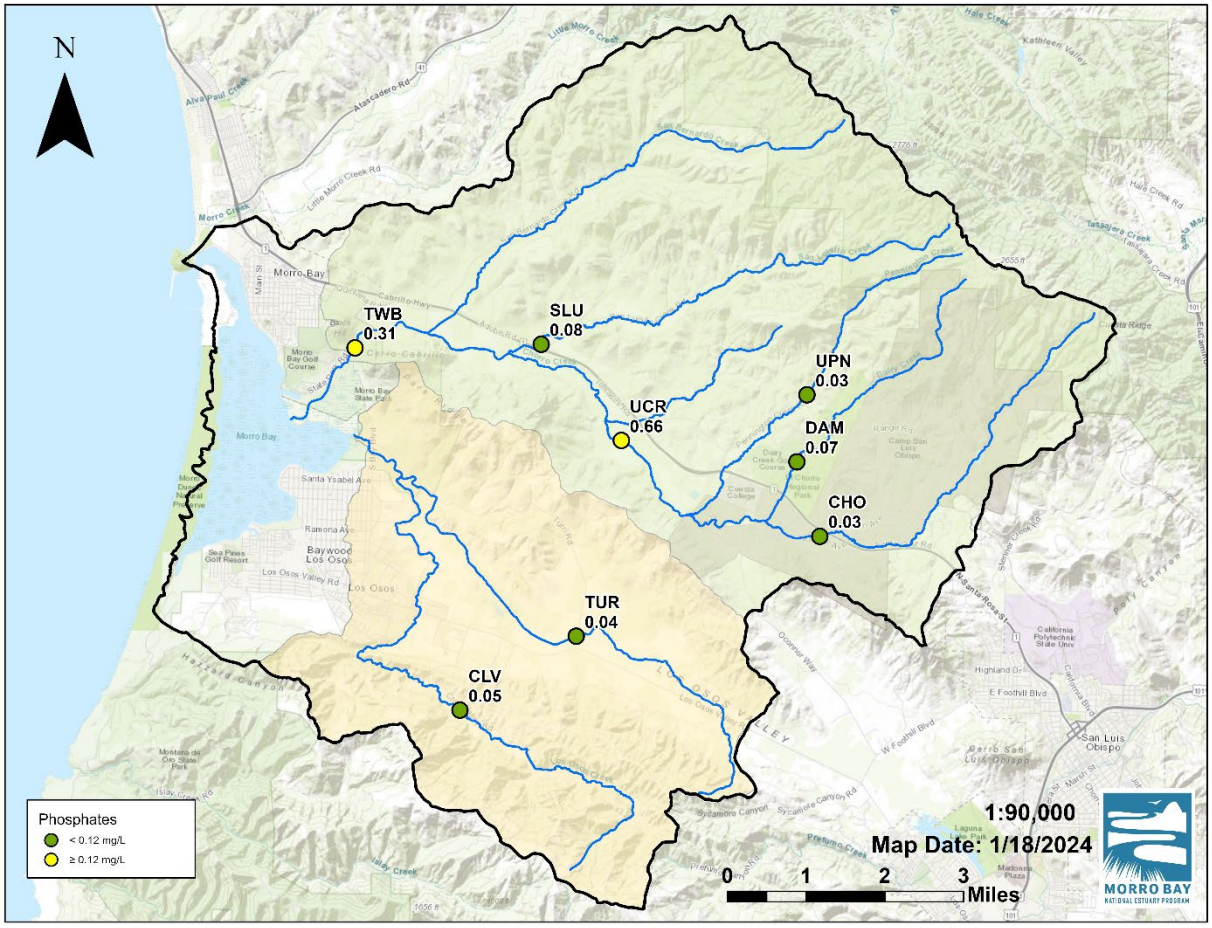

Figure 10: *Average PO_4-P concentrations for WY2023 at eight representative monitoring locations*

Historical PO_4-P averages were compared to results from WY2023 (Table 4). Historical data includes nutrient monitoring data from WY2016 through WY2023. Values highlighted in green indicate those that are at a low risk for eutrophication (< 0.12 mg/L PO_4-P). Values highlighted yellow are at a higher risk for eutrophication (≥ 0.12 mg/L PO_4-P). The relative percent difference (RPD) was then calculated to compare WY2023 data to historical data. Sites with higher RPDs indicate greater differences between WY2023 and historical data.

Table 4: *Historical PO_4-P averages compared to WY2023 averages.*

Site Code	CHO	CLV	DAM	SLU	TUR	TWB	UCR	UPN
Historical Average, PO_4-P mg/L	0.03	0.04	0.08	0.10	0.04	0.43	0.97	0.04
WY2023 Average, PO_4-P mg/L	0.03	0.05	0.07	0.08	0.04	0.31	0.66	0.03
Relative Percent Difference (RPD)	13.6%	23.2%	13.3%	31.8%	19.9%	32.1%	38.4%	40.8%

3.4 Discussion

Concentrations of PO_4-P are typically higher in the Chorro Creek subwatershed than in the Los Osos Creek subwatershed. Sites located along the mainstem of Chorro Creek, especially those downstream of the CA Men's Colony wastewater treatment plant, tend to track with higher PO_4-P concentrations than the surrounding tributaries. Chorro Creek at UCR, located approximately two miles downstream of the treatment plant, represents the higher end of PO_4-P concentrations in the watershed, followed by lower Chorro Creek at TWB.

The highest NO_3-N values in the Morro Bay watershed have consistently been detected on Warden Creek at TUR, which is heavily impacted by surrounding agricultural cropland. Elevated NO_3-N values at TUR have consistently exceeded the level of protection for both human and aquatic health (≥ 10 mg/L NO_3-N). Data collected from Chorro Creek at UCR and TWB have also indicated elevated NO_3-N concentrations relative to upstream and downstream levels. These concentrations have historically exceeded the level of protection for aquatic health (≥ 1.0 mg/L NO_3-N) but not the level of protection for human health (≥ 10 mg/L NO_3-N).

In WY2023, several sites within the Chorro Creek subwatershed experienced higher than normal average NO_3-N concentrations. San Luisito Creek at SLU and Pennington Creek at UPN saw the most significant increases from historical averages, with concentrations at SLU nearly four times higher than the historic average, and UPN about twice the historic average. This trend did not track as clearly in the Los Osos subwatershed, where upper Los Osos Creek at CLV remained on par with historic concentrations, and Warden Creek at TUR even showing improvement in average NO_3-N concentrations.

While the exact cause of the increased NO_3-N concentrations for San Luisito and Pennington Creeks is unknown, both tributaries that experienced significant stream bank erosion during the historic rainfall and peak flows of WY2023. Higher than normal NO_3-N concentrations at SLU and UPN may be attributed to soil erosion, leaching, and other natural nitrogen sources specific to each location. Heightened trends of NO_3-N may not have correlated with increases in PO_4-P concentrations in these systems due to the structure and solubility of NO_3-N, or perhaps due to biological uptake of PO_4-P by plants and algae.

4. Continuous Water Quality Monitoring

The Estuary Program collects continuous water quality data throughout the watershed using multiparameter sondes. The data collected provides insight into water quality trends and diurnal variations that may otherwise be missed with instantaneous measurements.

Starting in February 2023, routine deployments were conducted at two sites on Chorro Creek and two sites on Warden Creek (Figure 11). Sondes were deployed at each of the four sites for approximately one week each month between February 2023 and October 2023. The following data detail continuous water quality conditions during these eight deployment periods. The data presented is not meant to represent a continuous time series, but rather the results of these short-term deployments.

4.1 Equipment Specifications

The Estuary Program deploys YSI EXO3 multiparameter sondes that collect dissolved oxygen (DO), specific conductivity, water temperature, and pH at 15-minute intervals. A central wiper brush installed on the sonde cleans off the sensors between each interval, preventing sediment buildup and biofouling during deployments.

Specifications for the YSI EXO3 multiparameter sondes are as follows:

Specification	Value
Measurement/Operating Range	Dissolved Oxygen: 0 to 50 mg/L Specific Conductance: 0 to 100,000 µS/cm Temperature: -5 to 50°C pH: 0 to 14 units
Accuracy	Dissolved Oxygen: 0-20 mg/L: ±0.1 mg/L or 20-50 mg/L: ± 5% of reading Specific Conductance: ± 2 µS/cm Temperature: ± 0.2°C pH: ± 0.2 pH units
Resolution	Dissolved Oxygen: 0.01 mg/L Specific Conductance: 0.1 µS/cm Temperature: 0.001°C pH: 0.01 units

4.2 Monitoring Locations

The Estuary Program deployed EXO3 sondes at four sites during WY2023. Two sites were located along Chorro Creek, co-located with the CHO and UCR TidbiT deployment sites. The other two sondes were deployed along Warden Creek. The upstream sonde at Warden Creek (TUR) is located along a stretch of creek that is impacted by agricultural runoff and the downstream sonde is located within the Resource Conservation District property above the confluence of Warden Creek with Los Osos Creek (LWR) (Figure 11).

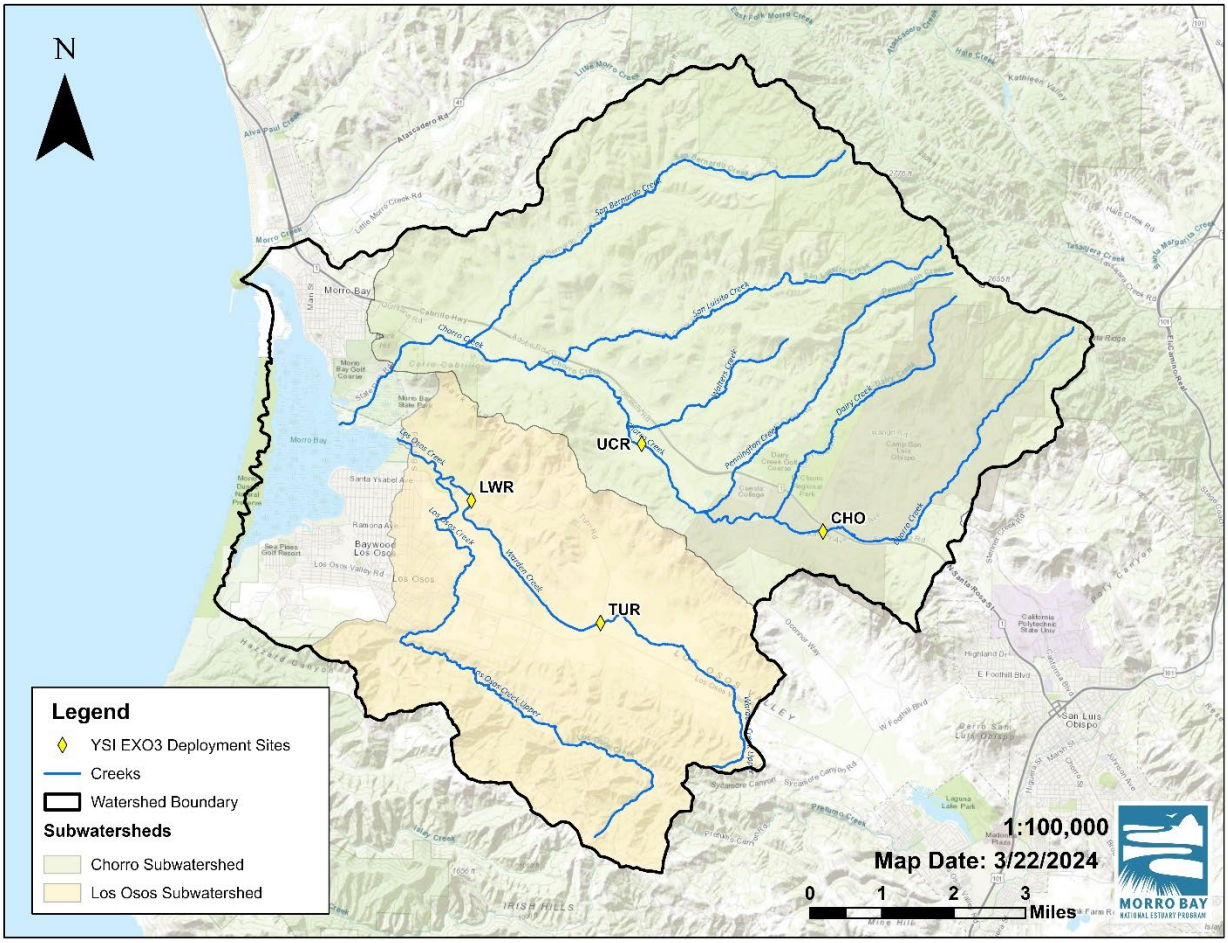

Figure 11: *YSI EXO3 multiparameter sonde deployment locations on Chorro Creek and Warden Creek during WY2023.*

4.3 Results

The CCRWQCB Basin Plan outlines water quality objectives that are considered necessary to protect designated beneficial uses. Chorro Creek and Los Osos Creeks support several beneficial uses including cold freshwater habitat (COLD) and fish spawning (SPWN). To be protective of these uses, dissolved oxygen concentrations should not drop below 7.0 mg/L at any time, and surface waters must not have pH values below 7.0 or above 8.5, with changes in ambient pH levels less than 0.5. Temperature results were compared to an 18°C threshold, as described in Section 2.4.

Analyte	Criteria	Source
Dissolved oxygen	< 7 mg/L (COLD, SPWN)	CCRWQCB Basin Plan Water Quality Objectives for Specific Beneficial Uses (Section 3.3.2.2)
Temperature	> 18°C	Moyle, 2002
pH	< 7.0 and > 8.5 (COLD, SPWN)	CCRWQCB Basin Plan Water Quality Objectives for

Analyte	Criteria	Source
		Specific Beneficial Uses (Section 3.3.2.2)

Dissolved Oxygen

The following figures describe the mean and standard deviation of DO concentrations during eight monthly deployments in WY2023. Each deployment lasted approximately seven days, and measurements were collected every 15 minutes. The red line on each graph indicates the CCRWQCB water quality objective for dissolved oxygen.

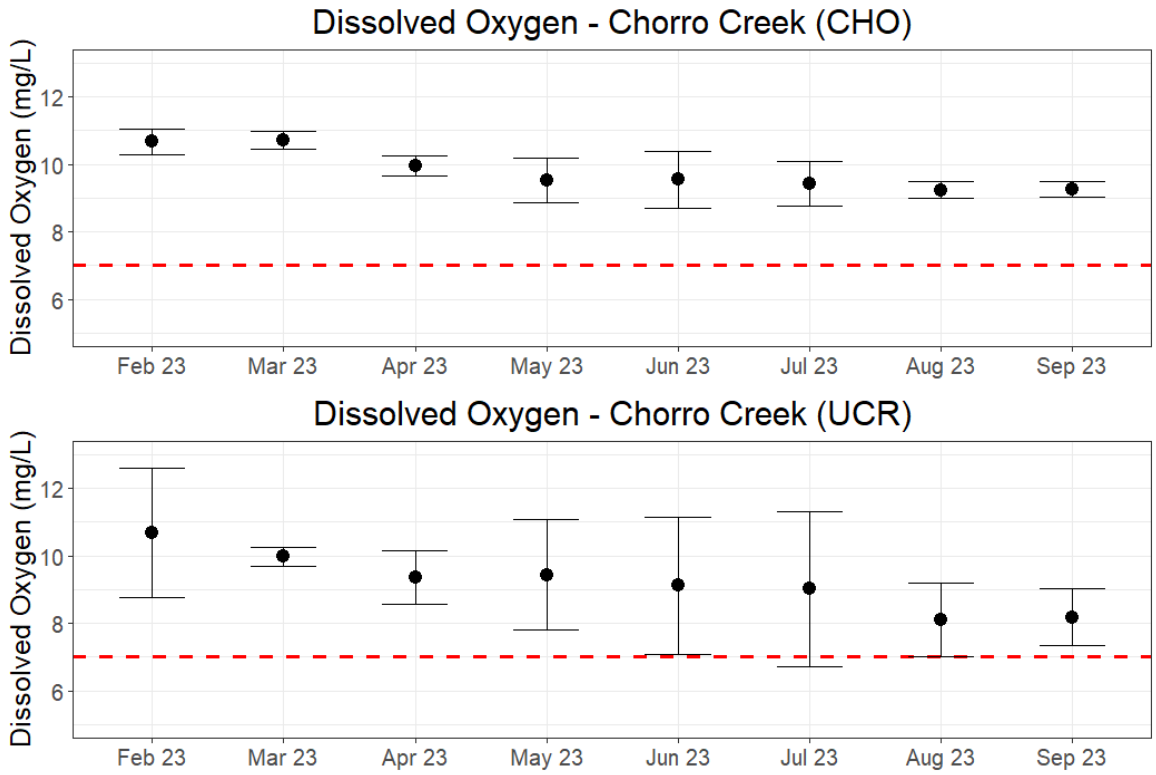

Figure 12: *Dissolved oxygen concentration (mg/L) from each deployment at two Chorro Creek sites (CHO, UCR) during WY2023. The horizontal red line represents the CCRWQCB Basin Plan objective (7 mg/L). Error bars represent one standard deviation of the mean. Typical deployments consisted of seven-day periods, however the March deployment at CHO was cut short at 15 hours due to an expired battery.*

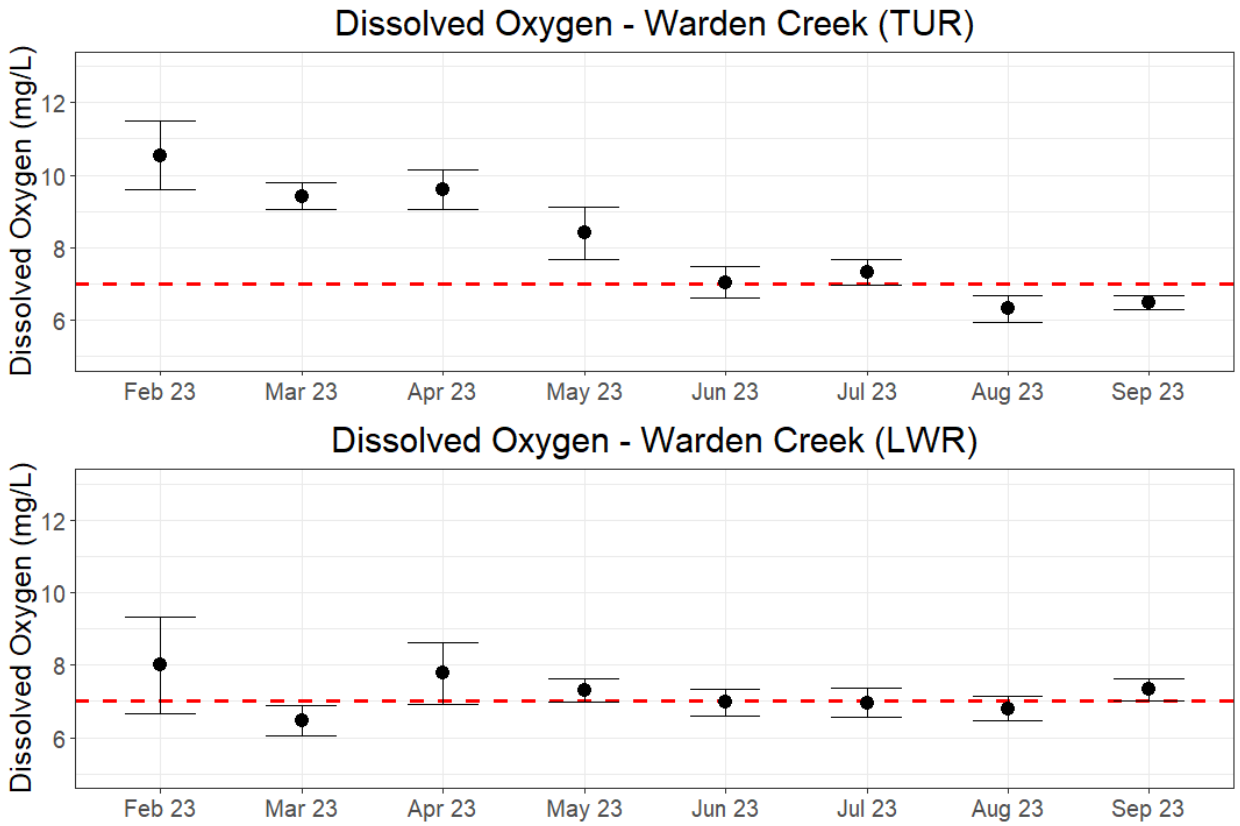

Figure 13: *Dissolved oxygen concentration (mg/L) from each deployment at two Warden Creek sites (TUR, LWR) during WY2023. The horizontal red line represents the CCRWQCB Basin Plan objective (7 mg/L). Error bars represent one standard deviation of the mean. Typical deployments consisted of seven-day periods.*

Temperature and pH

The following figures describe the monthly mean temperature and pH levels during eight monthly deployments in WY2023. Each deployment lasted approximately seven days, and measurements were collected every 15 minutes. The red line on the temperature graph indicates an 18°C threshold, as described in Section 2.4. The red line on the pH graph indicates the CCRWQCB water quality objective threshold.

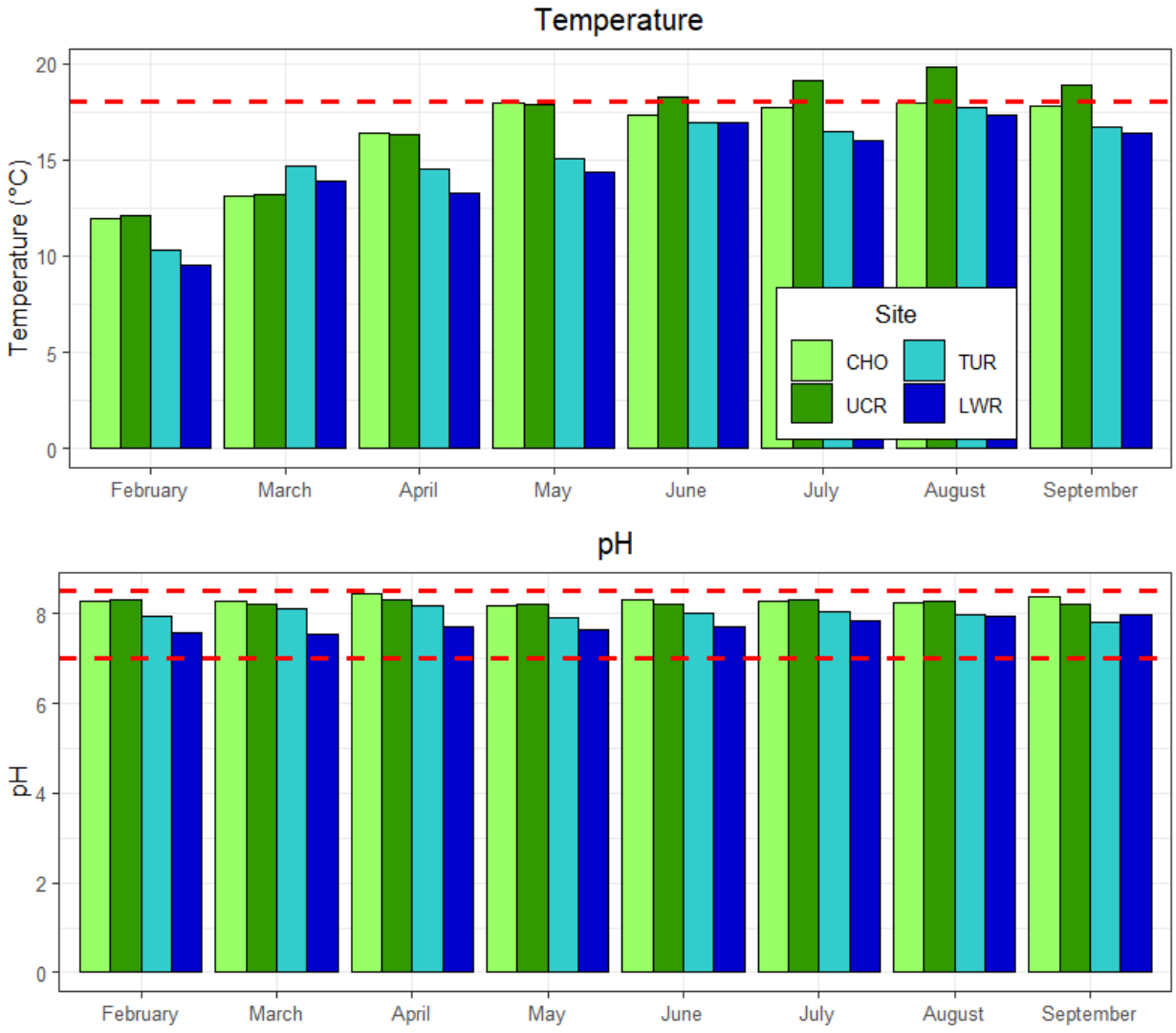

Figure 14: *Monthly mean water temperature (°C) and pH from two deployment locations in Chorro Creek (CHO, UCR), and two in Warden Creek (TUR, LWR) during WY2023. The horizontal red lines represent water quality objectives. For temperature, this represents an 18°C threshold (Moyle, 2002). For pH, this represents pH values of < 7.0 and > 8.5 (CCRWQCB, 2019).*

Water temperature trends on Chorro Creek at CHO and UCR followed the same trend observed in Sections 2.3 and 2.4. Chorro Creek at UCR experiences more frequent exceedances of the 18°C threshold than CHO. Throughout WY23, the Warden Creek sites were generally colder than the Chorro Creek sites. During their respective deployments, neither TUR nor LWR had an average deployment temperature over 18°C. Cooler temperatures along Warden Creek may be due to denser riparian cover and differences in ambient air temperature.

Average pH levels were within the CCRWQCB range for cold freshwater habitat (COLD) and fish spawning habitat (SPWN) in all deployments, however the Chorro Creek sites experienced brief exceedances of the upper threshold. Chorro Creek at CHO exceeded pH values of 8.5 for short periods in April and June, and Chorro Creek at UCR exceeded this threshold in February, June, and July.

4.4 Discussion

Dissolved oxygen (DO) concentrations in freshwater systems have immediate implications for the health of aquatic organisms. DO concentrations fluctuate throughout the day, making instantaneous measurements less effective at fully capturing oxygen dynamics in the creeks. Continuous deployments allow for a more complete characterization of oxygen availability and impacts to the biota.

Table 5: *Percentage of readings collected during each deployment that were outside of CCRWQCB Basin Plan objectives for dissolved oxygen concentration in WY2023.*

Percentage of Deployment Below 7 mg/L DO Concentration								
	February	March	April	May	June	July	August	September
CHO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UCR	0.0	0.0	0.0	0.0	2.4	25.7	0.0	0.0
TUR	0.0	0.0	0.0	0.0	49.4	30.8	100.0	99.7
LWR	27.7	94.5	21.2	19.6	62.0	63.0	73.1	16.5

The results from the WY2023 sonde deployments indicate that DO concentrations in Chorro and Warden Creeks are lowest in the summer, when the creeks are warmer, near stagnant, and influenced by algae impacts. The site along Warden Creek (LWR) experienced atypically low DO in February and March, most likely attributable to an influx of low-oxygen stormwater runoff during large rain events. This site is the shallowest of the four deployment locations and likely experienced a disproportionate effect from the addition of rainwater during these storms. In contrast, DO at the site at upper Chorro Creek (CHO) did not drop below 7 mg/L during any deployment, even in the summer months. The exact reason for the sustained adequate oxygen at CHO is unknown, however a combination of higher flow rates from an especially wet winter, average water temperature consistently below 18°C, and lower rates of nutrient loading than UCR likely played a role.

5. Data Availability

Bimonthly nutrient monitoring data is publicly available from the California Environmental Data Exchange Network (CEDEN), a State Water Resources Control Board managed data portal. For all continuous monitoring data, please contact the Estuary Program.

To retrieve nutrient data, visit www.CEDEN.org.

- Click on “Find Data”
- Choose the “CEDEN Query Tool”
- Under “Category,” select “Water Quality (Chemistry)”
- Under “Program,” select “Morro Bay National Estuary Program”
- Under “Analyte,” select “Orthophosphate as P, Dissolved” and/or “Nitrate as N, Dissolved”
- Under “FromDate” and “ToDate,” select the date range desired.
- Click on “Submit” to retrieve results.

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Appendix A. WY2023 TidbiT Deployment Timelines

Site	Deployments
CHO	10/1/2022 - 12/14/2022 and 2/28/2023 - 7/7/2023 *Pressure Transducer data used 7/7/2023 - 9/30/2023*
UCR	10/1/2022 - 10/19/2022 and 10/26/2022 - 12/14/2022 and 3/23/2023 - 9/30/2023
CCC	10/1/2022 - 12/14/2022 and 3/24/2023 - 9/30/2023
DAU	12/12/2022 - 12/18/2022 and 3/8/2023 - 3/11/2023 and 3/28/2023 - 9/30/2023
UPN	10/1/2022 - 12/14/2022 and 3/24/2023 - 9/30/2023
SLU	10/1/2022 - 12/14/2022 and 3/24/2023 - 9/30/2023

Appendix B. WY2023 Dates for Each Seasonal Period

Time Period	Start	End
Water Year 2023	10/1/2022	9/30/2023
Fall Season	10/1/2022	12/20/2022
Winter Season	12/21/2022	3/19/2023
Spring Season	3/20/2023	6/19/2023
Summer Season	6/20/2023	9/30/2023

Appendix C. WY2023 EXO3 Deployment Timelines

Sites	February	March	April	May	June	July	August	September
Chorro Creek (CHO and UCR)	2/15 - 2/22	3/23 - 3/27	4/20 - 4/25	5/18 - 5/24	6/22 - 6/27	7/7 - 7/14	8/9 - 8/16	9/6 - 9/12
Warden Creek (TUR and RCD)	2/22 - 3/1	3/16 - 3/21	4/5 - 4/11	5/4 - 5/11	6/15 - 6/20	7/20 - 7/26	8/17 - 8/24	9/13 - 9/21

**The March deployment at CHO was cut short at 15 hours due to an expired battery.*

List of Acronyms

Acronym	Definition
CCRWQCB	Central Coast Regional Water Quality Control Board
CEDEN	California Environmental Data Exchange Network
DO	Dissolved oxygen
EPA	Environmental Protection Agency
EXO3	YSI Multiparameter Sonde Model EXO3
MDL	Method Detection Limit
MWAT	Maximum Weekly Average Temperature
MWMT	Maximum Weekly Maximum Temperature
NO3-N	Nitrate as Nitrogen (dissolved)
O. mykiss	*Oncorhynchus mykiss*, rainbow trout (resident) or steelhead trout (anadromous)
PO4-P	Orthophosphate as Phosphorus (dissolved)
PQL	Project Quantitation Limit
RPD	Relative Percent Difference
SD	Standard deviation
WY	Water Year (Oct 1 to September 30; named for the year in which it ends)