CHERRY CREEK
BASIN WATER
QUALITY AUTHORITY

Cherry Creek Basin Water Quality Authority Monitoring Report

WATER YEAR 2024

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ACRONYMS/ABBREVIATIONS

Acronym	Definition
AF	Acre-feet
AOAC	Association of Official Analytical Chemists, now AOAC INTERNATIONAL
ASTM	American Society for Testing and Materials
Authority	Cherry Creek Basin Water Quality Authority
BMPs	Best Management Practices
CCBWQA	Cherry Creek Basin Water Quality Authority
CCR	Code of Colorado Regulations
CCSP	Cherry Creek State Park
CDPHE	Colorado Department of Public Health and Environment
Cells/mL	Cells per milliliter (phytoplankton)
CPW	Colorado Parks and Wildlife
CFR	Code of Federal Regulations
cfs	Cubic feet per second
chl α	Chlorophyll α
CM	Control Measures
CR72	Cherry Creek Reservoir Control Regulation 72
DM	Daily Maximum (for Temperature)
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
EPA	U. S. Environmental Protection Agency
IEH	IEH Laboratories
m	meters
mg/L	Milligrams per liter
mV	Millivolts
µg/L	Micrograms per liter
Mi	Mile
µm	Micrometers
µm^3/mL	Cubic micrometers per milliliter
µS/cm	Micro Siemens per centimeter
MS4	Municipal Separate Storm Sewer System
MWAT	Maximum Weekly Average Temperature
N	Nitrogen
N:P	Nitrogen to Phosphorus Ratio
NOAA	National Ocean and Atmospheric Administration

Acronym	Definition
ND	Non-detect
NH_3-N	Ammonia Nitrogen
NO_3+NO_2-N	Nitrate plus Nitrite Nitrogen
#/L	Number of animals per liter (zooplankton)
ORP	Oxidation Reduction Potential
%	Percent
POR	Period of record
PRF	Pollutant Reduction Facility
PRISM	Parameter-elevation Regression on Independent Slopes Model
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
Reg 31	WQCC Regulation No. 31
Reg 38	WQCC Regulation No. 38
SAP	Sampling and Analysis Plan
Reservoir	Cherry Creek Reservoir
SM	Standard Methods
SRP	Soluble Reactive Phosphorus
TDN	Total Dissolved Nitrogen
TOC	Total Organic Carbon
TN	Total Nitrogen
TDP	Total Dissolved Phosphorus
TP	Total Phosphorus
TSI	Trophic State Index
TSS	Total Suspended Solids
TVSS	Total Volatile Suspended Solids
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VSS	Volatile Suspended Solids
WY	Water Year
WQCC	Water Quality Control Commission
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

The Cherry Creek Basin Water Quality Monitoring Report – Water Year 2024 summarizes monitoring efforts conducted by the Cherry Creek Basin Water Quality Authority (CCBWQA) for the Cherry Creek Reservoir and its watershed from October 1, 2023, to September 30, 2024. These efforts, guided by the Cherry Creek Sampling and Analysis Plan (SAP), Quality Assurance Project Plan (QAPP), and regulatory requirements, assess compliance with the chlorophyll-α (chl α) standard and other water quality standards outlined in Cherry Creek Reservoir Control Regulation 72 (CR 72), as well as Water Quality Control Commission Regulations 31 and 38. The monitoring program includes regular evaluation of biological, physical, and chemical conditions in the Reservoir, its tributaries, precipitation, and groundwater. Key findings regarding water quality standards, beneficial uses, and other noteworthy details are summarized in this Executive Summary. Full data sets are available at the CCBWQA's portal at https://www.ccbwqportal.org/.

STANDARDS

Regulation 38 (Reg 38) assigns water quality standards for Cherry Creek Reservoir to protect aquatic life and other beneficial uses. Cherry Creek Reservoir met the chl α standard of 18 µg/L established in Reg 38 in WY 2024 (Figure ES-1). Cherry Creek Reservoir also met the standards for temperature, pH, and dissolved oxygen (DO), which are protective of the Class 1 Warm Water Aquatic Life use.

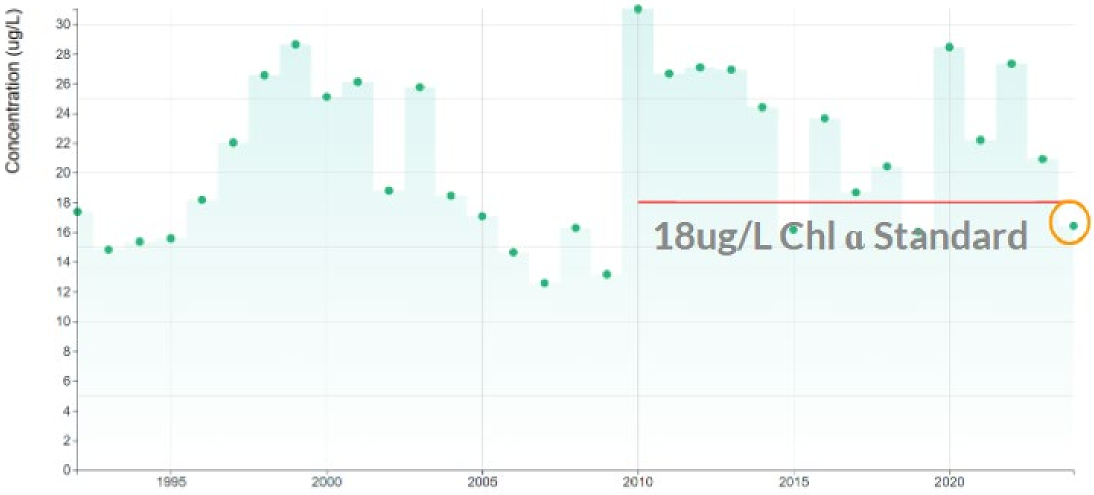

Figure ES- 1. Seasonal chl α concentrations in Cherry Creek Reservoir

RESERVOIR HIGHLIGHTS

The water quality in Cherry Creek Reservoir during WY 2024 was typical based on average flow, precipitation and weather patterns. During early 2024, the USACE conducted the first year of a pilot project to increase the storage in Cherry Creek Reservoir by one foot during open river conditions allowing for release during the month of July to benefit water quality.

Although the Reservoir met the DO standard, low DO concentrations were present at and near the bottom of the Reservoir during the warm summer months, increasing the potential for internal loading of phosphorus from the sediments due to anoxic conditions.

The seasonal phosphorus concentrations exceeded the interim nutrient criteria adopted by the WQCC in 2012 as well as the phosphorus standard that will be adopted statewide in lakes and reservoirs unless site-specific standards are adopted by 2027 (Figure ES-2). Although the seasonal nitrogen in the Reservoir was below the 2012 nutrient criteria, it exceeded the nitrogen standard that could be adopted in 2027 (see section 4.11).[1]

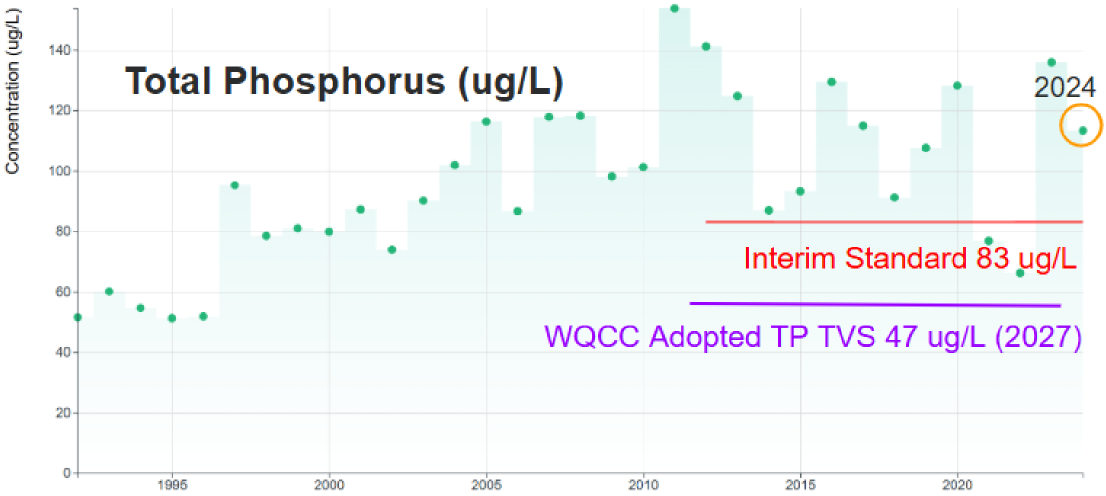

Figure ES- 2. Seasonal Total Phosphorus concentrations in Cherry Creek Reservoir

The Trophic State Index (TSI) is a relative expression of the biological productivity of a lake using total phosphorus (TP), chl α, and transparency. The WY 2024 TSI for Cherry Creek Reservoir indicates that Cherry Creek Reservoir continues to be classified as eutrophic based on water transparency and chl α concentrations and hypereutrophic based on TP concentrations (Figure ES-3). Eutrophic and hypereutrophic conditions indicate elevated nutrient concentrations and often excessive productivity with increased probabilities of encountering nuisance algal blooms. Although there has been some fluctuation of the historical trophic state, Cherry Creek Reservoir has remained in the eutrophic to hypereutrophic range for over 20 years.

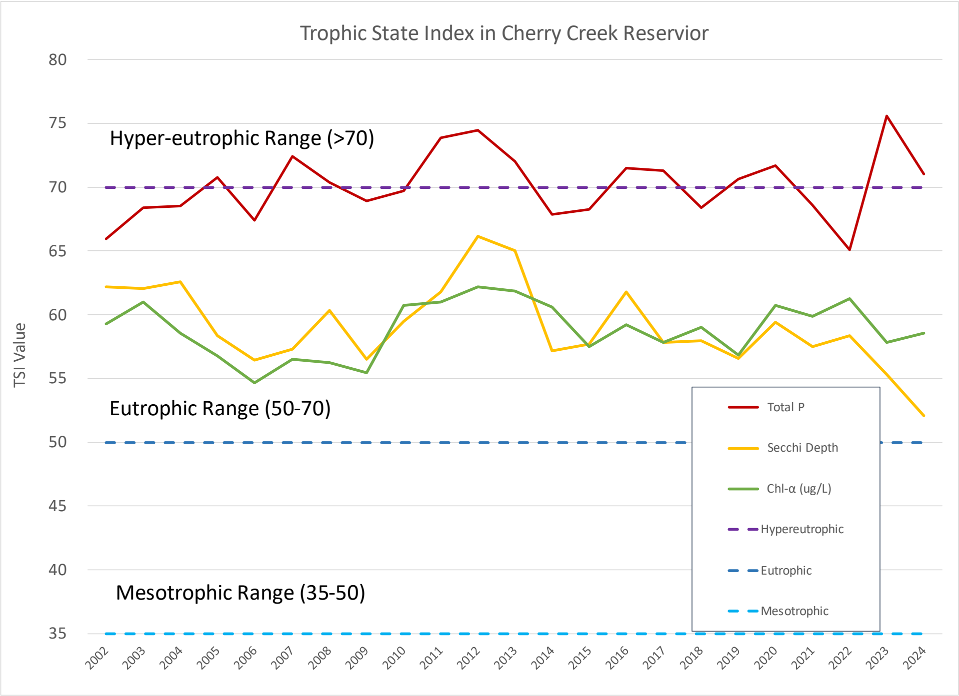

Figure ES- 3. Trophic State in Cherry Creek Reservoir

In mid-July, a cyanobacteria bloom prompted Colorado Parks and Wildlife to post “Caution” signs to inform the public of the potential recreational risk. Ongoing monitoring detected toxin concentrations above the

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[1] CCBWQA plans to propose site-specific standards for the Reservoir that differ from the statewide standards.

recreational threshold and a closure was implemented on July 28th in the area of the bloom and “Danger” signs were posted. Less than a week later, toxin levels had decreased to below the recreational threshold and the closure was lifted on August 4th, and by mid-August the bloom had dissipated.

WATERSHED HIGHLIGHTS

In WY 2024, the Cherry Creek State Park (CCSP) meteorological station measured a total of 9.7 inches of precipitation. NOAA’s Centennial Airport weather station KAPA site measured 13.4 inches, which is 92% of the historical average precipitation. NOAA’s Centennial Airport weather station KAPA site measured 13.4 inches, which is 92% of the historical average.

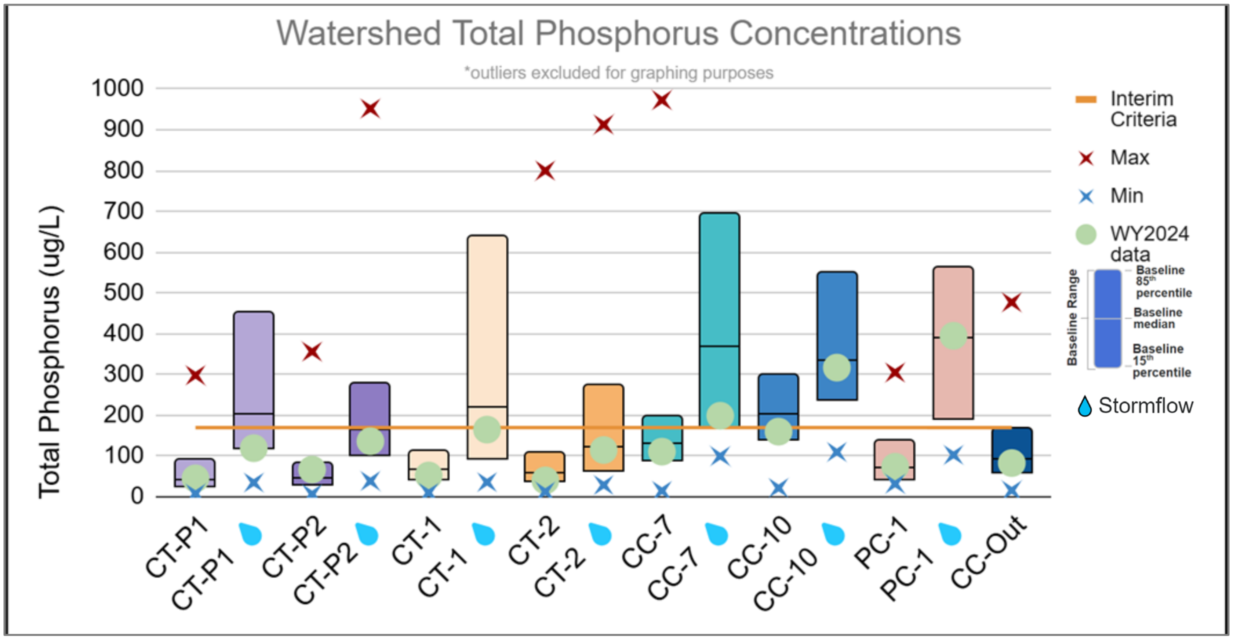

Figure ES- 4. Watershed Total Phosphorus Concentrations in base and storm flow conditions.

Although only a few storm samples were collected in WY 2024, median TP concentrations followed the usual pattern which is notably higher in storm flows than baseflows. The box plots in **Error! Reference source not found.** depict the baseline 85th/15th percentile ranges of concentrations in base flows and storm flows (💧) at each of the main sites (See Figure 2) during the historical period of record (Table 1) . Median TP instream concentrations were similar to the long-term baseline median at Cottonwood and Piney Creek sites under both baseflow and storm flow conditions and at Cherry Creek under baseflow conditions. For sites on Cherry Creek, WY 2024 TP concentrations were higher than the historic baseline median during storm conditions, likely due to significant erosion on Cherry Creek during major storm events.

In contrast to TP, higher total nitrogen (TN) concentrations were not consistently observed during storm events. The WY 2024 median TN concentrations were higher than the baseline median at three sites on Cottonwood Creek (CT-P1, CT-1, and CT-2) during baseflows and during storm events at CT-2. The WY 2024 median TN concentrations on Cherry Creek were also higher than the baseline median during baseflows and during storm events at CC-10 and the outlet to the Reservoir (CC-0).

POLLUTION REDUCTION FACILITIES (PRF) HIGHLIGHTS

The Pollution Reduction Facilities (PRFs) in the watershed are monitored on an ongoing basis to determine the effectiveness of water quality benefits upstream to downstream annually and over time.

Based on the water quality concentrations in baseflow and stormflow events during WY 2024 and the last 10 years, the Cottonwood Creek PRF ponds and treatment train as a whole reduced phosphorus and suspended sediment in downstream stormflows. During WY 2024, the Cottonwood Treatment Train showed statistically significant removal of TP, total suspended solids (TSS) and volatile suspended solid (VSS) upstream to downstream during storm flows, which is also true when evaluating the trend over the last 10 years. Both forms of suspended solids were also significantly lower in baseflow during WY 2024 through the whole treatment train. Peoria Pond and the Perimeter Pond both showed significant removal of TP and TSS upstream to downstream during stormflow conditions over the same period. The Perimeter Pond PRF also demonstrated significant reductions in TP and TSS concentrations in base flow conditions. The McMurdo Gulch upstream to downstream concentration analysis also demonstrated a statistically significant reduction of all nutrients in WY 2024.

Table ES- 1 Summary of Reductions in Nutrient and Suspended Solids in CCBWQA PRFs, WY 2024 and 2015-2024.

PRF	**Cottonwood Treatment Train**		**Peoria Pond**		**Perimeter Pond**		**Cottonwood Creek btw Ponds**		**McMurdo Gulch**
Analyte	Base	Storm	Base	Storm	Base	Storm	Base	Storm	Base
Nitrate+ Nitrite			●		○				●
Ammonia					●				●
Nitrogen, Total			●		●				●
Phosphorus, Soluble Reactive					●				●
Phosphorus, Dissolved									▨
Phosphorus, Total		▨		▨	●	▨			●
Total Suspended Solids		▨		▨	●	▨			
Volatile Suspended Solids	▨	▨		▨	▨	▨	○		

**Legend: ○ significant reduction of upstream to downstream medians in WY 2024, ▨ significant reductions of upstream to downstream medians (2014-2024), ● significant reduction of upstream to downstream medians in WY 2024 and 2014-2024, blank cells indicate no significant reduction or an increase upstream to downstream.*

GROUNDWATER HIGHLIGHTS

Groundwater and alluvium in the Cherry Creek watershed influence nutrient dynamics as water flows into the Reservoir. Long-term groundwater phosphorus trends are evaluated using total dissolved phosphorus (TDP) and soluble reactive phosphorus (SRP), the primary forms of phosphorus found in groundwater. Mann-Kendall trend analysis indicates a significant increase in TDP and SRP at monitoring well MW-9, located upstream of the Reservoir, while no significant trends are observed at upstream wells MW-1 and MW-5. Additionally, groundwater conductivity shows a statistically significant increase from upstream (MW-1) to downstream (MW-9) near the Reservoir. Groundwater conductivity shows a statistically significant increase from upstream (MW-1) to downstream (MW-9) near the Reservoir.

PLANKTON HIGHLIGHTS

Phytoplankton

In Cherry Creek Reservoir, phytoplankton (algae) serve as the primary producers and are responsible for chlorophyll-a (chl α) concentrations. Key phytoplankton highlights include:

- **Primary Producers:** Phytoplankton are essential to the aquatic food web, serving as a food source for zooplankton and herbivorous fish.
- **Species Diversity:** Cherry Creek Reservoir supported an average of 23 phytoplankton species per sampling date, slightly lower than in recent years (26-40 species). Diversity was highest during cooler spring and fall months, while nutrient availability in summer favored fewer species.
- **Cyanobacteria Dominance:** Cyanobacteria (blue-green algae) made up 64% of annual phytoplankton counts, maintaining dominance in cell counts but contributing less to total biovolume compared to other algal groups. Key cyanobacteria species observed included *Dolichospermum sp.*, *Eucapsis sp.*, and *Microcystis aeruginosa*, with blooms prompting a brief reservoir closure in late July due to toxin presence.
- **Notable Blooms:** The toxic cyanobacteria bloom which required closure in July 2024 resulted in elevated biovolume and visible nuisance conditions. Diatom blooms were prominent in spring and early summer, contributing to 89% of the annual phytoplankton biovolume. A significant diatom bloom on July 25th marked the highest biovolume observed since 2014.
- **Balanced Community:** Other algal groups, including green algae, diatoms, and golden algae (*Chrysochromulina parva*), were present at lower frequencies, contributing to a relatively balanced ecosystem outside bloom events (Figure ES-6).
- **Nutrient Influence:** Excess nutrients, particularly during summer, provided a competitive advantage to cyanobacteria and diatoms, which thrive in the warm, nutrient-rich, and low N:P ratio conditions of Cherry Creek Reservoir.

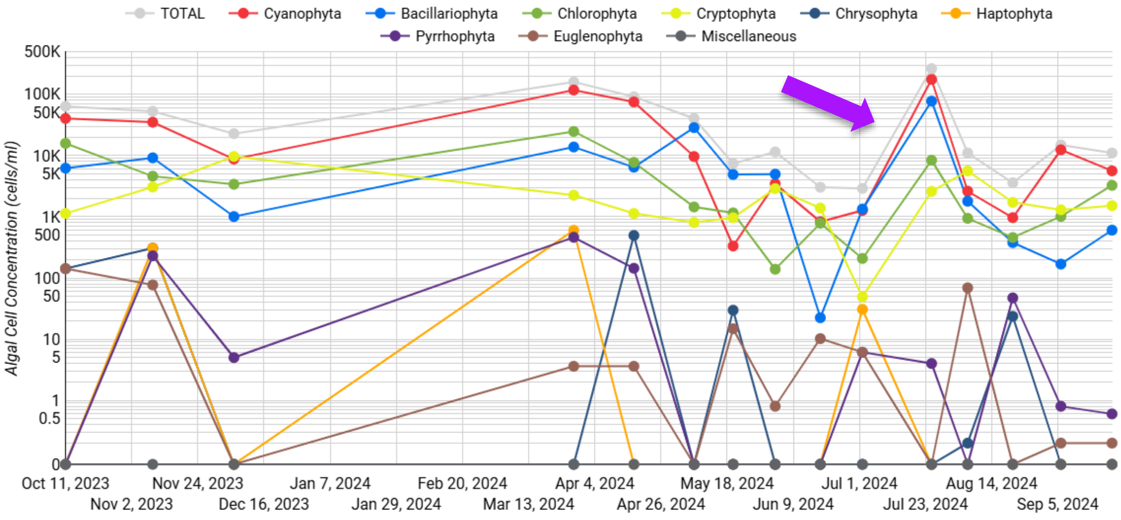

Figure ES- 5. Phytoplankton Dynamics in CCR during WY 2024.

Zooplankton

Zooplankton, microscopic animals that feed on algae and bacteria, are crucial for regulating phytoplankton populations and supporting the aquatic food web. In Cherry Creek Reservoir, zooplankton diversity and numbers vary seasonally, influenced by temperature, food supply, and environmental factors.

Zooplankton highlights for WY 2024:

- **Role in Ecosystem:** Zooplankton consume algae and bacteria, influencing algal populations through grazing while serving as a food source for larger aquatic organisms.
- **Above-Average Diversity:** Cherry Creek Reservoir supported diverse zooplankton populations (~12 species per event), including copepods, cladocerans, rotifers, and occasional ostracods.
- **Population Trends**: Copepods dominated numerically, representing 43% of the annual population (Figure ES- 6. Zooplankton Population Diversity in WY2024Figure ES- 6). Cladocerans comprised 32% of the population and contributed most to biomass during warmer months (May-July). One cladoceran, the large bodied *Daphnia geleata*, were observed from March to September, peaking in biomass on June 3rd which is not commonly observed in Chery Creek Reservoir.
- **Notable Bloom:** A zooplankton bloom in mid-June 2024 was visually observed in the marina, coinciding with elevated cladoceran biomass. Unusual carp feeding behavior on zooplankton at the surface was documented.
- **Daphnia Presence:** Large-bodied Daphnia, including *Daphnia geleata*, were observed from March to September, peaking in biomass on June 3rd.
- **Influence of Gizzard Shad:** Lower abundance of larger zooplankton may relate to predation by gizzard shad, which are key prey for walleye in the reservoir but effective zooplankton grazers, particularly in their larval stage.
- **Plankton Dynamics**: High zooplankton numbers and biomass in mid June coincided with very low phytoplankton abundance and biovolume. Conversely, reduced zooplankton populations in late July coincided with peak phytoplankton counts and biovolume, supporting the observation that zooplankton grazing impacts phytoplankton abundance in Cherry Creek Reservoir.

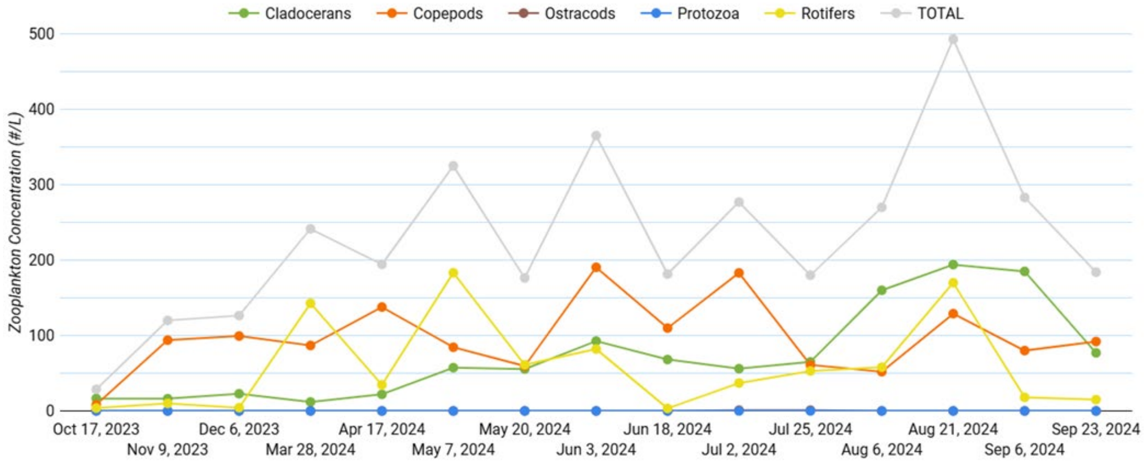

Figure ES- 6. Zooplankton Population Diversity in WY2024

WATER BALANCE HIGHLIGHTS

The annual water balance for Cherry Creek Reservoir is calculated to support nutrient storage assessments. Inflows include contributions from surface water, groundwater, and precipitation. Specific sources are direct precipitation, alluvial groundwater, surface flows from Cherry and Cottonwood Creeks, and ungauged flows. Outflows consist of evaporation, groundwater seepage, and releases from the reservoir outlet.

In Water Year (WY) 2024, the reservoir experienced a net loss of 1,013 acre-feet (AF). A summary of the WY 2024 water balance is presented in Table ES- 2.

Table ES- 2. WY 2024 Water Balance

Water Source	Water Volume (AF)	
Inflows	**Unadjusted**	**Adjusted**
Cherry Creek (CC-10)	14,296	14,511
Cottonwood Creek (CT-2)	5,839	5,927
Precipitation	704	704
Alluvial groundwater	2,200	2,200
Total Inflows	**23,040**	**23,342**
Outflows		
Evaporation	-3,751	-3,751
Reservoir releases	-20,605	-20,605
Total Outflows	**-24,355**	**-24,355**
Net Ungauged Flows		
Calculation	**300**	**Apportioned**
WY 2024 Change in Storage	-1,013	

**values rounded to the nearest AF. Adjusted water volumes are based on apportioned ungauged flows.*

The storms in 2023 damaged the monitoring equipment at the site historically used to calculate inflow from Cherry Creek into Cherry Creek Reservoir. As an alternative and similar to WY 2023, the inflow values provided by the USACE, precipitation, and groundwater were used to estimate surface water inflow based on the mean five-year relative contributions: 71% for Cherry Creek and 29% for Cottonwood Creek. This method appears to be representative based on the information available.

Net ungauged flows were calculated using USACE storage data, inflow estimates, and outflow data from the USGS monitoring station downstream of the reservoir. An ungauged flow volume of 300 AF was apportioned between Cherry Creek and Cottonwood Creek using their relative contributions to complete the water balance.

These adjusted daily inflow estimates were then used to calculate nutrient loading, as detailed in the following section.

NUTRIENT BALANCE HIGHLIGHTS

The nutrient concentrations of the inflows and the outflow of Cherry Creek Reservoir are used to calculate mass storage on an annual basis. The flow-weighted influent phosphorus goal, derived as part of the 2009 Regulation 38 rulemaking process, to achieve the 18 µg/L chl α standard, is 200 µg/L. The WY 2024 flow-weighted concentrations based on the median values and relative inflows are summarized in Table ES- 3.

Table ES- 3. Flow-weighted Nutrient Concentrations for all Sources to Cherry Creek Reservoir WY 2024.*

	Nutrient	Cherry Creek	Cottonwood Creek	Alluvial Groundwater	Precipitation	Weighted Total
Flow-weighted Inflow Concentration	Total Phosphorus	*115*	*13*	*18*	*4*	**149**
	Total Nitrogen	*863*	*609*	*96*	*60*	**1,626**

(µg/L)						
% of Inflow		62%	26%	9%	3%	**100%**

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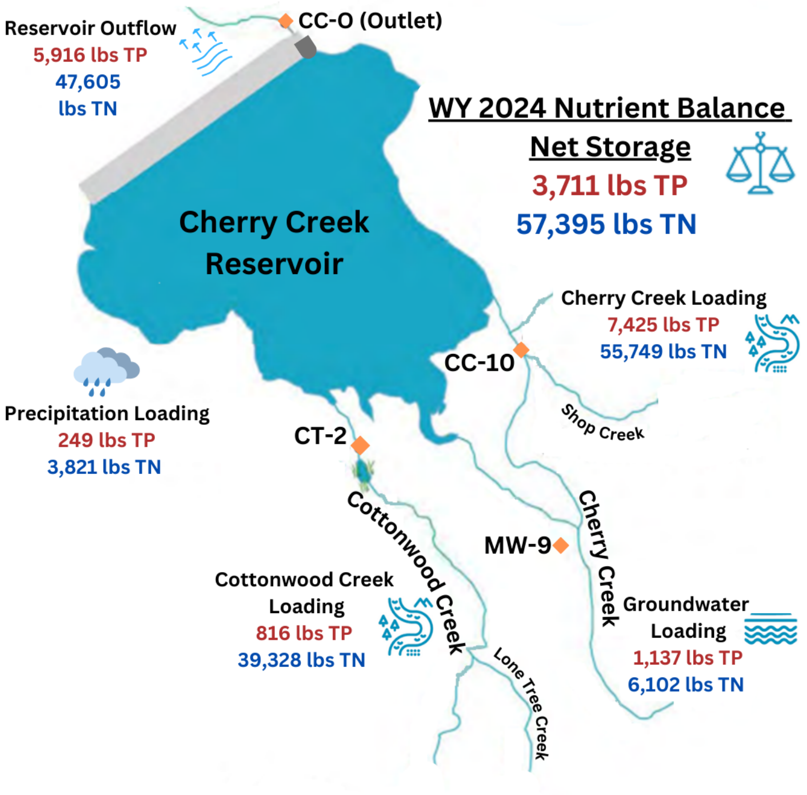

Figure ES- 7. Nutrient Loading and Storage in Cherry Creek Reservoir during WY 2024

WY 2024 nutrient balances for TP and TN for Cherry Creek Reservoir were calculated based on the nutrient calculations for inflows and releases and the mass balances are represented in Figure ES- 7.

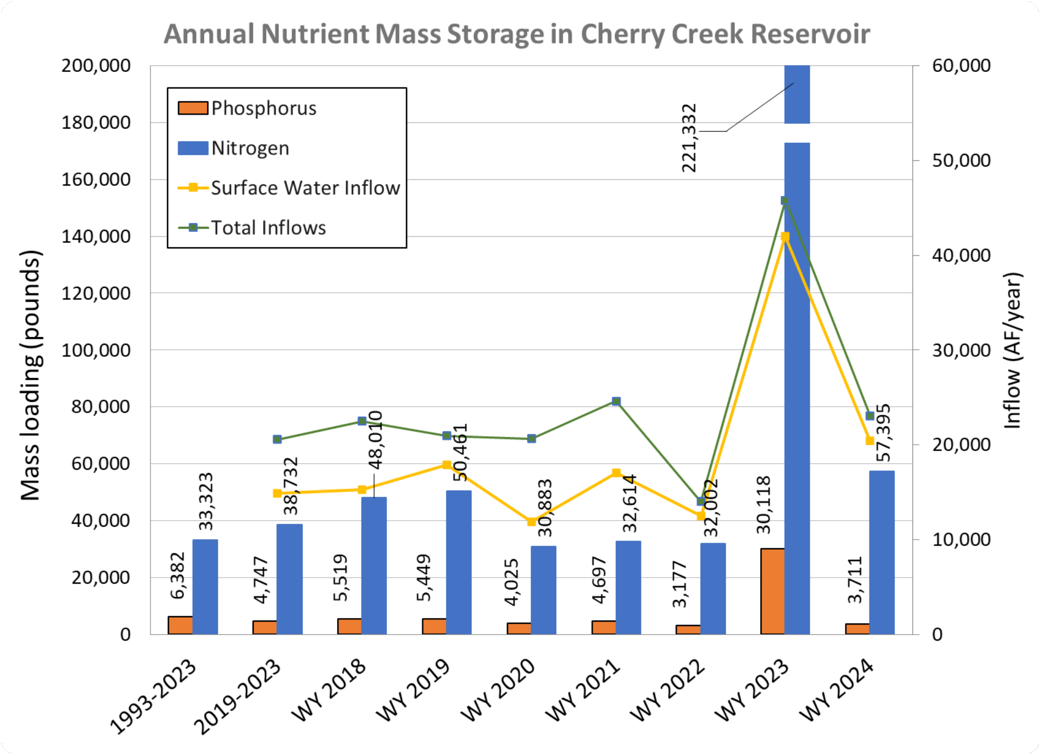

Figure ES- 8. Annual Mass Storage in Cherry Creek Reservoir.

The WY2024 total phosphorus mass storage calculated in Cherry Creek Reservoir and the historical five years and short and long term means are depicted in Figure ES- 8. WY 2024 was closer to a “typical” year in relation to nutrient storage when WY2023 was well above average due to the significant storm events.

WY 2024 KEY FINDINGS

The results obtained from the CCBWQA’s comprehensive monitoring program documents water quality within the watershed over time. Key findings from monitoring conducted during WY 2024 include:

- **Standards Met:** Cherry Creek Reservoir met the chl α seasonal standard and Regulation 38 standards for temperature, pH, and dissolved oxygen, supporting the Class 1 Warm Water Aquatic Life classification.
- **Water Quality Challenges:** The reservoir remains eutrophic to hypereutrophic with high total phosphorus and limited transparency. A toxic cyanobacteria bloom in July 2024 led to temporary recreational closures.
- **Nutrient Sources:** Surface water flows are the primary contributors to nutrient loading, with weather and precipitation significantly influencing inflows and reservoir dynamics.
- **Stream Variability:** Cherry Creek has higher phosphorus levels, while Cottonwood Creek shows higher nitrogen concentrations.
- **Trends:** Increasing stream and groundwater conductivity has the potential to impact reservoir water quality and aquatic life and will continue to be observed by CCBWQA.
- **PRF Effectiveness:** The pond PRFs on Cottonwood Creek and McMurdo Gulch continue to effectively reduce phosphorus and suspended solids, especially during stormflows.
- **Nutrient Storage:** WY 2024 nutrient storage was within the historical range, contrasting with elevated loading and storage during WY 2023 due to high-flow storm events.

1.0 INTRODUCTION

The mission of the Cherry Creek Basin Water Quality Authority (CCBWQA) is to benefit the public by improving, protecting, and preserving water quality in Cherry Creek and Cherry Creek Reservoir (Reservoir) for recreation, fisheries, and other warm water aquatic life, water supplies, and agriculture. CCBWQA works to achieve and maintain current water quality standards to support these beneficial uses. The CCBWQA also supports efforts by partner counties, municipalities, special districts, and landowners within the basin providing for the protection of water quality, ensuring that new developments and construction activities pay their equitable share of costs for water quality preservation and facilities, and promoting public health, safety, and welfare.

The CCBWQA was formally created by statute in 1988 by the Colorado State Legislature. The CCBWQA Board consists of representatives from two counties and eight cities, along with one representative from each of the seven special districts that provide water and wastewater treatment in the basin, and seven public representatives appointed by the Governor.

The Cherry Creek Basin watershed includes over 386 square miles and 600 miles of creeks and streams (Figure 1). The U.S. Army Corps of Engineers (USACE) states that Cherry Creek Reservoir has a maximum surface area of 850 surface acres at an operating pool elevation of 5550 ft. The Reservoir is located near the base of the watershed, south of I-225 and west of Parker Rd., in Cherry Creek State Park (CCSP or the Park). The Park covers approximately 4,000 acres and is one of the most productive fisheries and widely enjoyed recreational areas in Colorado. The Park has miles of trails to view birds and wildlife with scenic views of the Rocky Mountains in the background.

USACE constructed the Reservoir between 1948 and 1950 for flood control. In 1951, the State Park Board leased Cherry Creek recreation area from the USACE and created Colorado’s first state park, which was opened in 1959. In addition to providing flood control, the Reservoir is a recreational and aquatic life amenity, and water released from the Reservoir supports downstream agriculture and water supply uses. The Reservoir is not a direct use water supply.

The Water Quality Control Commission (WQCC) adopted use classifications and water quality standards for the Reservoir and watershed, most recently effective August 30, 2023. These numeric standards, as specified in Regulation No. 38 (5 CCR 1002-38) (Reg 38), include the mainstem of Cherry Creek to the inlet of the Reservoir and from the outlet to the confluence with the South Platte River, Cherry Creek Reservoir, Cottonwood Creek, and other tributaries, lakes, and reservoirs within the watershed. These standards are set to protect recreation, aquatic life, agriculture, and water supply uses. The CCBWQA focuses on improving, protecting, and preserving the water quality of Cherry Creek and Cherry Creek Reservoir, and on achieving and maintaining the existing water quality standards.

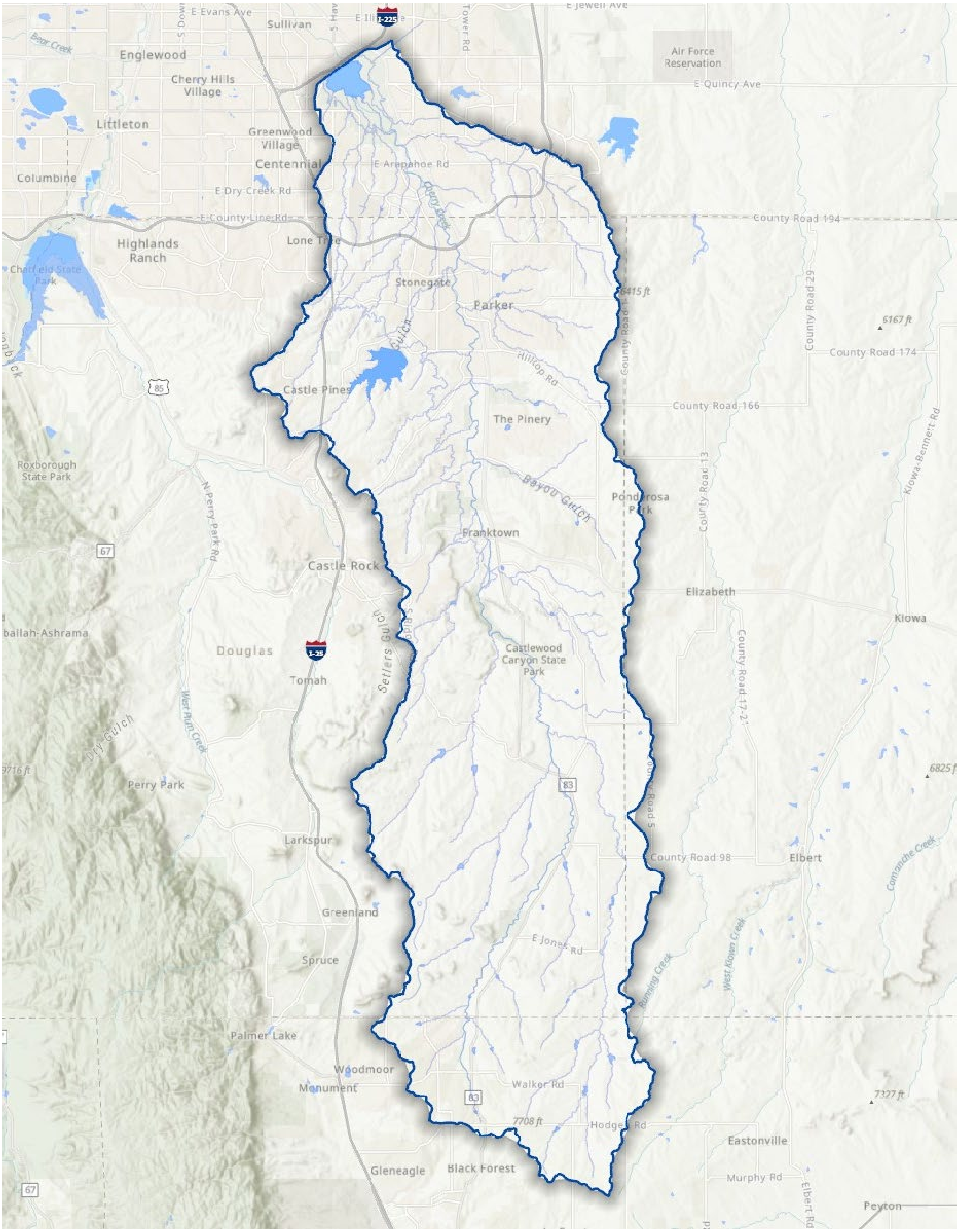

Figure 1. Cherry Creek Reservoir Basin.

2.0 MONITORING PROGRAM

The WQCC's Cherry Creek Reservoir Control Regulation No. 72 (5 CCR 1002-72), (CR 72), requires that the CCBWQA execute a water quality monitoring program of the Cherry Creek watershed and Reservoir for water quality, inflow volumes, alluvial water quality, and non-point source flows. The program is implemented to determine total annual flow-weighted concentrations of nutrients to the Reservoir and to monitor the Pollutant Reduction Facilities (PRFs) to determine inflow and outflow nutrient concentrations. The sample collection and analysis provide data required to evaluate the nutrient sources and transport, characterize reductions in nutrient concentrations, and calculate and document compliance with associated water quality standards. In addition, these data are used to update the Reservoir and Watershed models.

The CCBWQA Sampling and Analysis Plan/Quality Assurance Project Plan (SAP/QAPP) provides the foundation for the sampling and analysis program, including sampling methods, QA/QC (quality assurance/quality control) and protocols. The monitoring program was designed to understand and quantify the relationships between nutrient loading and Reservoir productivity. The routine monitoring of surface water and groundwater was implemented to promote the concentration-based management strategy for phosphorus control in the basin, to determine the total annual flow-weighted concentration of nutrients to the Reservoir, to evaluate watershed nutrient sources and transport mechanisms, and to evaluate the effectiveness of PRFs including the cumulative effect of stormwater control measures (SCMs, also known as BMPs) implemented in the basin.

All monitoring activities and analytical work are performed in accordance with the SAP/QAPP, which includes details of the current monitoring program (monitoring locations, frequency, parameters analyzed, etc.) and can be found on the CCBWQA website, https://www.cherrycreekbasin.org/plans. The monitoring sites and details regarding station type, monitoring frequency, event types, and telemetry are shown in Figure 2.

This WY 2024 Monitoring Report summarizes data collected during the 2024 water year and includes an assessment and evaluation of data and results from the Reservoir and watershed sampling and analysis, including water quality and quantity of surface water, groundwater, stormwater, and the effectiveness of PRFs. The water quality data and results described herein are available on the CCBWQA's Data Portal, http://www.ccbwqportal.org.

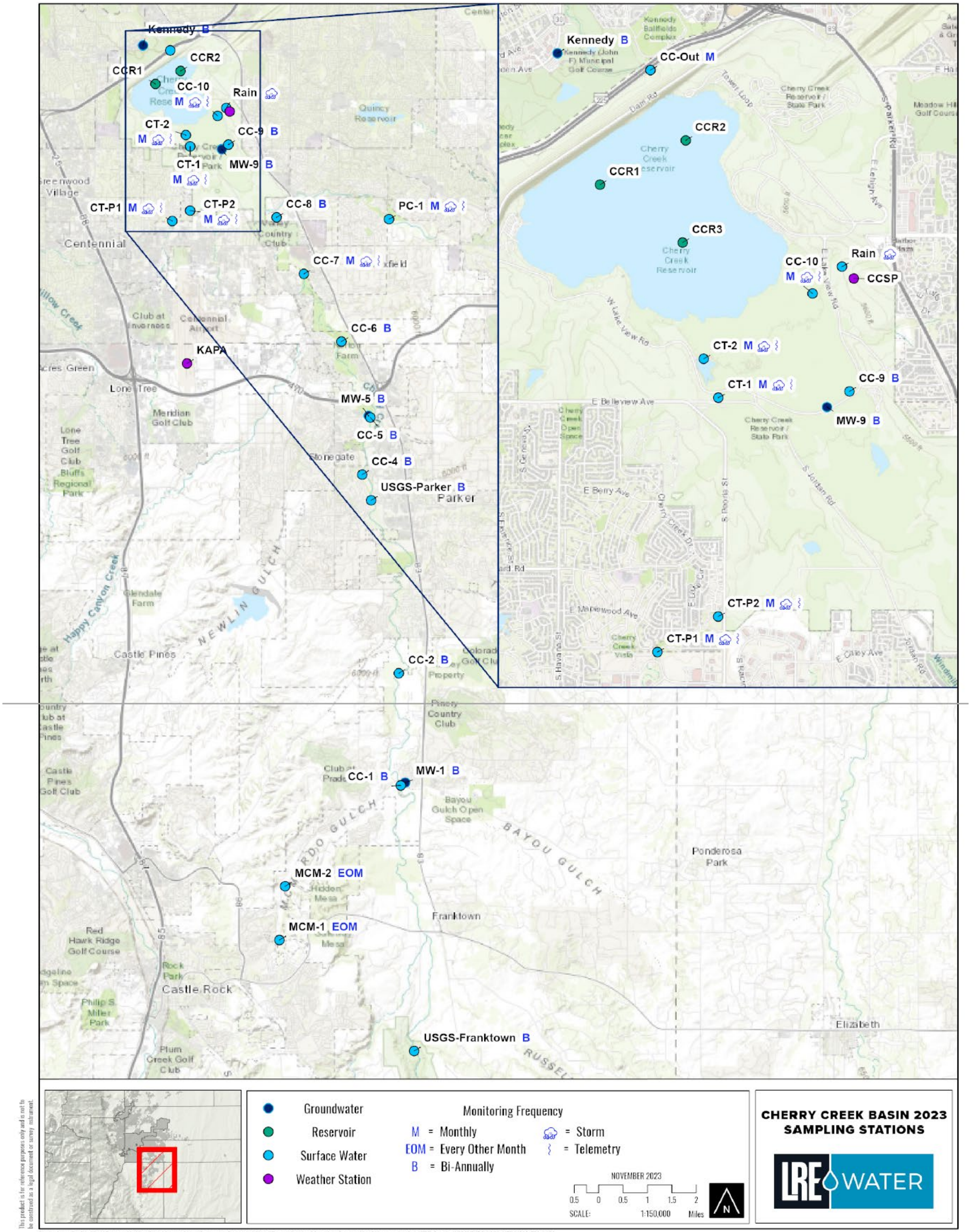

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Figure 2. CCBWQA Monitoring Sites and Details

2.1 MONITORING METHODS AND ANALYTE DESCRIPTIONS

The monitoring program evaluates several water quality parameters to help determine if the Reservoir meets standards designed to protect aquatic life and recreation. The parameters also play a critical role in defining the Reservoir's trophic state—a measure of its overall health that reflects interactions between chemical and biological components within the aquatic ecosystem. While additional water quality standards exist for parameters like metals and fecal indicator bacteria, these are not included in the scope of the annual monitoring program.

All analyses performed adhere to approved methods outlined by the U.S. Environmental Protection Agency (EPA) or Standard Methods for the Examination of Water and Wastewater, as detailed in the project's Sampling and Analysis Plan/Quality Assurance Project Plan (SAP/QAPP).

A summary of the key parameters and metrics analyzed in this report is provided below.

pH

pH is a measure of how acidic or basic water is, expressed on a scale from 0 to 14. On this scale, a pH of 7 is neutral, values below 7 are acidic, and values above 7 are basic (or alkaline). Regulation 38 specifies that the acceptable pH range for the reservoir is 6.5 to 9.0 to ensure the protection of aquatic life.

pH is measured on a logarithmic scale, meaning each 1-unit change corresponds to a tenfold difference in hydrogen ion concentration. For example, water with a pH of 6 is 10 times more acidic than water with a pH of 7 and 100 times more acidic than water with a pH of 8. For context, the pH of normal rainwater, unaffected by pollutants, is approximately 5.6 due to the natural presence of carbon dioxide, which forms carbonic acid when dissolved in water.

Oxidation Reduction Potential

Oxidation reduction potential (ORP) measures the ability of a water body to breakdown contaminants or waste in the water. The value quantifies the exchange of electrons during chemical reactions in which the oxidation states of atoms are changed, also known as redox or oxidation-reduction reactions, or electrical activity. ORP is reported in millivolts (mV) and is measured in addition to dissolved oxygen since it provides additional information on water quality or pollution.

At the water/sediment boundary layer, microbial organisms mediate chemical reactions but do not directly oxidize or reduce most compounds. Instead, they create conditions that facilitate redox reactions, which provide energy for microbial cells to carry out their metabolic processes (Wetzel 2001). The combination of microbial activity and redox processes is responsible for the breakdown of organic matter and the development of anoxic conditions near the sediment boundary in reservoirs during the summer. Higher ORP values indicate an oxidizing environment, with a higher potential for organic matter breakdown in the water. Conversely, low or negative ORP values indicate a reducing environment, typically associated with lower dissolved oxygen concentrations and higher microbial decomposition activity, especially in deeper sites and sediments of lakes.

Conductivity

Conductivity (specific conductance) is the ability of water to conduct an electrical current and is based on the dissolved inorganic solids (positive and negative ions) present. Conductivity is a useful general measure of water quality since values increase with salinity and can be an indicator of dissolved solids that can be considered “pollutants” in the water. The geology of the area, water source, and watershed affect conductivity. Conductivity values of 50-1500 µS/cm are typical for surface water. Conductivity also varies in direct proportion with temperature with higher temperature increasing the conductivity. Thus, to allow direct comparison of samples collected at different temperatures, conductivity is typically corrected to 25 ^{o}C and reported as specific conductance (µmhos/cm @ 25 ^{o}C). For the sake of simplicity, specific conductance is referred to as "conductivity" in this report.

Dissolved Oxygen

Dissolved oxygen (DO) refers to the amount of oxygen gas dissolved in the water column that is available for aquatic organisms. Oxygen enters the water primarily through direct diffusion at the air-water interface and as a byproduct of photosynthesis by aquatic plants and algae. Turbulent water bodies, such as rivers and streams, typically have higher DO concentrations due to increased aeration, while stagnant water bodies, like lakes or ponds, tend to have lower concentrations.

DO saturation is closely tied to temperature; as water temperature increases, its capacity to hold oxygen decreases. Gradients in DO levels within a lake or reservoir can provide insights into mixing patterns and the effectiveness of physical mixing processes. DO levels also influence the physical-chemical properties of lakes and significantly affect the composition of aquatic biota.

Lakes with high sediment loads often experience low DO levels. Suspended particles increase turbidity, which reduces light penetration and limits photosynthesis, further lowering DO production. Additionally, the decomposition of organic matter consumes large amounts of oxygen, further depleting DO concentrations.

Regulation 38 specifies a minimum DO standard of 5.0 mg/L to protect warm-water fish species in Cherry Creek Reservoir. If DO concentrations fall below this level in one area or depth of the reservoir, adequate refuges must exist at other depths or locations where DO concentrations are above 5.0 mg/L to ensure the survival of aquatic life.

Temperature

Water temperature affects the DO concentration of the water, the rate of photosynthesis, rates of chemical reactions, metabolic rates of aquatic organisms, and the sensitivity of organisms to toxins, parasites, and disease. All aquatic organisms are dependent on certain temperature ranges for optimal health. If temperatures are outside of this optimal range for a prolonged period of time, the organisms become stressed and can die. Water temperature generally increases with turbidity; as the particles absorb heat, the DO levels are reduced. Temperature is primarily controlled by climatic conditions but can also be impacted by human activities.

Secchi Depth

The Secchi depth of a waterbody is a way to quantify turbidity or water clarity. It is measured with an 8" black and white disk which is slowly lowered into the water column and the depth at which it is no longer visible becomes the Secchi depth. The measurement is based on both light absorption and the amount of light scattered by particles in the water column. The Secchi depth is higher when there is greater clarity or fewer particles in the water and is usually a representation of productivity of the water. Secchi depths of less than 6.6 feet (2.0 meters) have traditionally been considered undesirable for recreational uses in natural lakes; however, lower clarity is usually tolerated in reservoirs.

Light Transmission

Light transmission is a measurement of light absorption in the water column. The depth at which 1% of the surface light penetrates is considered the lower limit of algal growth and is referred to as the photic zone (see below). The measurement of 1% light transmission is accomplished by using both an ambient and an underwater quantum sensor attached to a data logger. The ambient quantum sensor remains on the surface, while the underwater sensor is lowered into the water on the shady side of the boat. The underwater sensor is lowered until the value displayed on the data logger is 1% of the value of the ambient sensor, and the depth is recorded.

Photic Zone

The Photic Zone of an aquatic resource is calculated as the depth at which light can penetrate or the depth of the water column where phytoplankton could complete photosynthesis based on light availability. Samples in Cherry Creek Reservoir are collected as a composite from what represents the common photic zone based on conditions, typically from 0-3 m. See Light Transmission above.

Chlorophyll α

Chlorophyll is the pigment found in plants that provides a green color and helps absorb energy during photosynthesis. Chlorophyll α is the primary form found in algae and concentrations are an excellent indicator of water quality based on the presence and density of photosynthesizing phytoplankton responsible for algal blooms in a water body.

Cyanobacteria, commonly called blue-green algae, produce chlorophyll α, but can also produce toxins that are dangerous to other animals, including humans. Excess algae and cyanobacteria result in elevated chlorophyll α production and can result in undesirable conditions such as green water, floating mats, and even scums. When these blooms die and start to decay, they can produce bad odors and can reduce dissolved oxygen concentrations which can stress fish and lead to nutrient cycling from the reservoir sediments.

In surface water, lower chl α concentrations often (0-6 µg/L) correspond to oligotrophic or mesotrophic (low to medium nutrient concentrations) conditions, where higher concentrations indicate nutrient rich, or eutrophic (6-40 µg/L) conditions, or a hypereutrophic state with very nutrient enriched conditions (>40 µg/L).

Cherry Creek Reservoir's chlorophyll α levels are established by Regulation 38 which sets the standard of 18 µg/L. Maintaining chlorophyll α levels around or below this threshold is important to the overall health of Cherry Creek Reservoir and helps to maintain its beneficial uses.

Phosphorus

Phosphorus exists in several forms in freshwater systems, but the biologically available form that contributes to nuisance plant and algal growth is soluble inorganic orthophosphate, also known as soluble reactive phosphorus (SRP). Inorganic phosphates readily bind to soil particles and plant roots, so much of the phosphorus in aquatic systems is bound and transported as sediment. Organic phosphates, found in plant and organism cells, are not biologically available unless converted into inorganic forms.

Under anoxic (low oxygen) conditions, phosphorus bound to bottom sediments can be released, significantly increasing the concentration of biologically available orthophosphate in the water column. Sources of phosphorus in aquatic systems include soil erosion from steep slopes, disturbed ground, and stream channels, as well as surface runoff containing phosphorus from fertilizers, wastewater effluent, and decaying organic matter.

- **Total Phosphorus (TP)** measures all forms of phosphorus in a sample, including inorganic, oxidizable organic, and polyphosphates. It accounts for phosphorus that is readily available, has the potential to become available, and stable forms. In lakes and reservoirs:

  TP concentrations <12 µg/L indicate oligotrophic conditions (low productivity).
  TP concentrations of 12–24 µg/L indicate mesotrophic conditions (moderate productivity).
  TP concentrations of 25–96 µg/L indicate eutrophic conditions (high productivity).
  TP concentrations >96 µg/L indicate hypereutrophic conditions (excessive productivity).

- **Soluble Reactive Phosphorus (SRP)** is the measure of dissolved inorganic phosphorus (PO_4^{-3}, HPO_4^{-2}, $H_2PO_4^-$, and H_3PO_4). This form is readily available in the water column for phytoplankton growth in the water column.
- **Total Dissolved Phosphorus (TDP)** is a measure of all phosphorus forms (inorganic, organic, and polyphosphate) that are dissolved in water.

Nitrogen

Nitrogen exists in a variety of forms within aquatic systems, including organic, inorganic, particulate, gaseous, and soluble states. The soluble, inorganic oxidized forms of nitrogen are nitrate (NO_3^-) and nitrite (NO_2^-), which are typically found in surface water. The reduced inorganic form, ammonia (NH_3), is more common in low-oxygen environments. Among these, the inorganic forms—NO_3^-, NO_2^-, and NH_3—are the most readily available for primary productivity, such as algal growth.

Certain algae and cyanobacteria can also utilize atmospheric nitrogen (N_2) as a nutrient source through nitrogen fixation. Additionally, decomposition processes can produce various reduced forms of nitrogen. While particulate and dissolved organic nitrogen are not immediately available for algal uptake, they can be converted to ammonia by bacteria and fungi. This ammonia can then be oxidized to form nitrites and nitrates, completing part of the nitrogen cycle.

Surface runoff often contributes inorganic nitrogen from fertilizers and organic nitrogen from sources such as animal waste and wastewater, increasing nutrient loads in aquatic systems.

- **Total Nitrogen (TN)** represents the total quantity of all nitrogen in the water, calculated by adding the measured forms of organic nitrogen, nitrate, nitrite, and ammonia.
- **Nitrates and Nitrites ($NO_3^- + NO_2^-$)** are collectively referred to as total oxidized nitrogen and are readily available for algal uptake.
- **Ammonia (NH_3-N)** is a reduced form of dissolved nitrogen that is readily available for phytoplankton uptake. Ammonia is prevalent in low oxygen environments, such as the hypolimnion of a eutrophic lake, and is produced by bacteria as a byproduct of decomposition.

Nitrogen/Phosphorus Levels and Ratios

Phytoplankton growth depends on macronutrients such as phosphorus, nitrogen, and carbon, as well as trace nutrients like iron, manganese, and other essential minerals. Growth is limited by the nutrient present in the smallest quantity relative to the organism's needs, a principle known as Liebig's Law of the Minimum (Liebig, J von, 1840).

The ratio of total nitrogen (TN) to total phosphorus (TP) in a water body is a useful indicator of nutrient limitation. When nitrogen is limited, many harmful cyanobacteria (blue-green algae) gain a competitive advantage over beneficial green algae because they can fix atmospheric nitrogen. In phosphorus-rich, nitrogen-limited environments, this ability allows cyanobacteria to dominate, increasing the risk of harmful algal blooms.

Maintaining a molar TN:TP ratio greater than 16:1 (or approximately 7:1 by weight) promotes balanced phytoplankton diversity and reduces the likelihood of cyanobacteria dominance. In some cases, the ratio of total inorganic nitrogen (TIN)—which includes nitrate, nitrite, and ammonia—to soluble reactive phosphorus (SRP) provides a more direct measure of phytoplankton growth potential, as these forms are the most readily available in the water column.

Trophic State

The Trophic state as described by Vollenweider (1970) is used as a guideline for describing water quality as it relates to the trophic state or biological productivity potential. Many indices assign numerical values to trophic state based on multiple water quality parameters. The following are typical characteristics of various trophic states:

- **Oligotrophic** - lack of plant nutrients, low productivity, sufficient oxygen at all depths, clear water, often deeper lakes and can support trout.
- **Mesotrophic** - moderate nutrient concentrations and plant productivity, hypolimnion may lack oxygen in summer, moderately clear water, mostly mixed or warm water fisheries.
- **Eutrophic -** nutrient rich, blue-green algae dominate during summer, notable productivity, algae scums are probable at times, hypolimnion lacks oxygen in summer, poor transparency, rooted macrophyte problems may be evident.
- **Hypereutrophic** – excessive nutrient enrichment and likely imbalance, very high productivity, algal scums dominate in summer, few macrophytes, no oxygen in hypolimnion, fish kills possible in summer and under winter ice.

Alkalinity

Alkalinity, expressed in milligrams of calcium carbonate per liter (mg $CaCO_3$/L), measures the concentration of bicarbonates and carbonates in water, which are critical for buffering capacity. Buffering capacity refers to the water's ability to neutralize acids and resist changes in pH. This property is particularly important in aquatic systems, as it helps stabilize pH levels during processes like photosynthesis, where primary producers (e.g., algae and aquatic plants) remove carbon dioxide (CO_2) from the water. The U.S. Environmental Protection Agency (EPA) recommends a minimum alkalinity of 20 mg/L to support aquatic life, ensuring adequate buffering capacity to protect against harmful pH fluctuations.

Anions: Chloride and Sulfate

Anions, or negatively charged ions, such as chloride and sulfate, play a critical role in influencing water conductivity. These ions are typically derived from external sources, including human activities like de-icing roads, treated wastewater discharge, and stormwater runoff, as well as natural processes such as mineral dissolution in groundwater. Elevated levels of chloride and sulfate can signal potential pollution in the watershed but may also originate from groundwater in contact with certain geologic formations. Since these anions are highly soluble, their presence increases the total concentration of dissolved ions in the water, directly raising conductivity. Monitoring these parameters helps track changes in water quality and identify pollutant sources.

Cations: Calcium, Magnesium, Sodium, and Potassium

Cations, or positively charged ions, such as calcium, magnesium, sodium, and potassium, are key contributors to dissolved solids concentrations in water. In natural landscapes, these cations primarily originate from sources like weathering of rocks and minerals, but they can also indicate human-related pollution, including de-icing agents, treated wastewater discharges and stormwater runoff in urban areas. Starting in 2022, cation levels began being monitored at one reservoir site and three surface water sites twice annually. This ongoing monitoring helps identify the major contributors to conductivity and assess the relative influence of natural versus human-induced sources the watershed.

Suspended Solids

Total Suspended Solids (TSS) is the concentration of suspended sediments and other particulates in water. In lakes and reservoirs, TSS typically includes organic material such as algal cells and microorganisms, as well as inorganic particles like silt and clay. Suspended solids in streams also include larger inorganic particles such as coarser silt and sand. Volatile Suspended Solids (VSS) quantify the particulate organic material present in water which can be burned off at high temperatures during laboratory analysis.

Suspended solids can indirectly impact chl α concentrations by reducing light penetration, which limits photosynthesis by algae and other primary producers.

Organic Carbon

Organic carbon refers to carbon found in organic compounds within a water body, serving as a key indicator of the presence and type of organic matter in the system. Monitoring organic carbon in watersheds and reservoirs is essential for assessing carbon cycling, identifying sources of pollution, and managing water quality for ecological health and human use. Organic carbon is derived from both natural sources, such as decaying plant material, algae, and microbial biomass, and human-related activities, such as wastewater discharges, agricultural runoff, and stormwater inputs.

In aquatic ecosystems, total organic carbon (TOC) measures the complete pool of organic carbon, while dissolved organic carbon (DOC) specifically represents the fraction that is soluble in water. DOC often plays a significant role in water quality because it influences physical and chemical processes, such as nutrient cycling, light penetration, and the transport of metals and pollutants. Natural sources like plant-derived compounds can contribute to refractory organic carbon, which resists degradation and may impart a dark color to water, reducing light availability for photosynthesis. Degradable organic carbon from sources like algal blooms or organic waste can lead to oxygen depletion during microbial decomposition, impacting aquatic life.

2.2 WATER QUALITY ANALYSIS

The water quality data collected under CCBWQA's monitoring program are analyzed to identify short- and long-term trends, evaluate seasonal and spatial variability, and assess compliance with applicable water quality standards. The Cherry Creek watershed exhibits seasonal fluctuations driven by natural processes such as temperature changes, precipitation, and runoff, all of which influence water quality and its trends over time.

To better understand these dynamics, summary statistics are calculated for each parameter and monitoring location using the entire period of record (POR) or a specified subset. The POR establishes a baseline against which annual or seasonal changes can be compared. The statistics and associated graphs in this report highlight the median, 15th percentile, and 85th percentile of the POR data, along with water year (WY) 2024 values for reference.

- The median represents the middle value of the dataset, where half of the measurements fall below and half fall above, offering a central tendency that is less influenced by extreme outliers.
- The 85th percentile is the value below which 85% of the measurements fall, serving as an upper bound of typical conditions.
- The 15th percentile is the value below which 15% of the measurements fall, providing a lower bound of typical conditions.

Using the 15th and 85th percentiles as range indicators helps account for natural variability by including 70% of the dataset within this range. Values that fall outside of this range indicate more extreme deviations from expected conditions, which may signal unusual events, changing trends, or potential water quality concerns. This approach avoids the skewing effect of outliers caused by minimum or maximum values, offering a more robust context for evaluating annual data relative to historical patterns.

Additionally, the 15th/85th percentile framework aligns with methodologies used by CDPHE for standard ambient condition assessments, making it a relevant and effective tool for characterizing water quality in the watershed.

In addition to characterizing times series data using statistical summary values, it also is important to determine if there are statistically significant trends in long-term data sets. Since water quality data are typically non-parametric (do not conform to a normal distribution), a Mann Kendall trend analysis can be used to evaluate if time series data for a given location and parameter have a statistically significant trend. A p-value obtained from the Mann Kendall trend test of less than 0.05 provides evidence of a significant monotonic trend in the time series. Conversely, if the p-value is greater than 0.05, it suggests that there is not enough evidence to conclude the presence of a significant monotonic trend.

3.0 WATERSHED MONITORING RESULTS

The watershed monitoring program includes an analysis of the quantity and quality of potential nutrient source inputs to Cherry Creek Reservoir. During WY 2024, surface water and groundwater sites in the watershed were monitored either monthly, every other month, on a bi-annual frequency, and/or during storm events to characterize spatial and temporal variability and differences in base and stormflow conditions.

Some of the monitoring challenges from major flooding and damage along Cherry Creek and Cottonwood Creek in 2023 caused ongoing problems at some of the sites in WY 2024. As a result, some data and measurements normally collected are not available due to these factors outside of the CCBWQA's control. In order to account for these problems, changes to the monitoring program were required including; new monitoring locations, new monitoring equipment installation, development of new rating curves and alternative calculations for surface water inflows. It is expected that the inflow at the two sites upstream of Cherry Creek Reservoir on Cherry Creek and Cottonwood Creek will have on-site measurements to calculate flow for WY2025.

3.1 PRECIPITATION

Precipitation in the watershed and on the surface of the Reservoir plays a major role in water quality in the streams and overall Reservoir dynamics. Historically, precipitation in the Cherry Creek watershed has been measured at NOAA's Centennial Airport weather station (KAPA) at an elevation of 5,869 ft. The meteorological station at Cherry Creek State Park (CCSP) at an elevation of 5,631 ft was installed in 2021 (Figure 2). In WY 2024, the CCSP station measured a total of 9.7 inches of precipitation and the KAPA site measured 13.4 inches, both which were approximately one-third of precipitation in WY2023.Although March and April had above average precipitation, May, June, and July totals were all well below the monthly average (Figure 3).

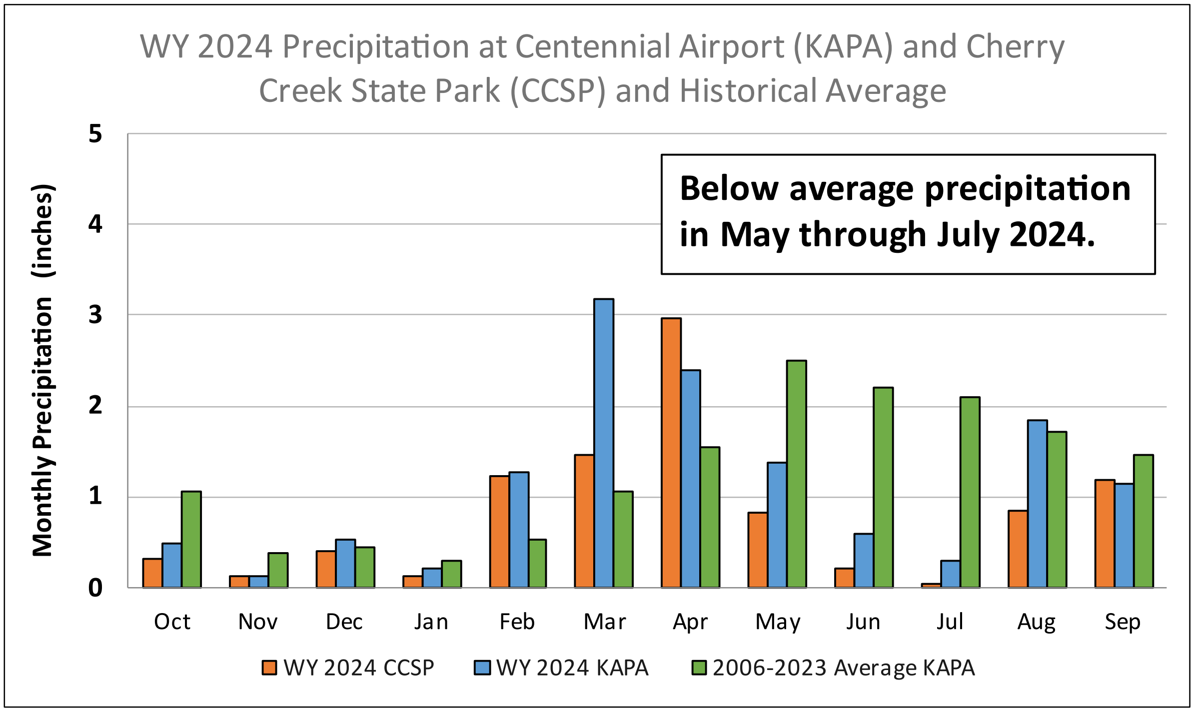


Figure 3. Monthly Watershed Precipitation in WY 2024 compared to (2006-2023) average.

Due to closer proximity to the Reservoir, the CCSP station should better represent the precipitation on the surface of the Reservoir and is used in water balance calculations. However, the KAPA site will continue to be used as a comparison and as a historical reference until a representative period of record can be developed for the CCSP site.

Additionally, when looking at NOAA's annual precipitation information, nearly all areas of the watershed received precipitation ranging between approximately 88-163 percent of normal when compared to the 30-year Parameter-elevation Regression on Independent Slopes Model (PRISM) normal from 1991-2020 (Figure 4). The watershed received approximately 139% of the 30-year average, while areas just around Cherry Creek Reservoir generally received less precipitation than the rest of the watershed. This data is based on observed National Weather Service (NWS) precipitation from the CONUS River Forecast Centers and is displayed as a gridded resolution of roughly 4x4 km using bilinear interpolation in GIS.

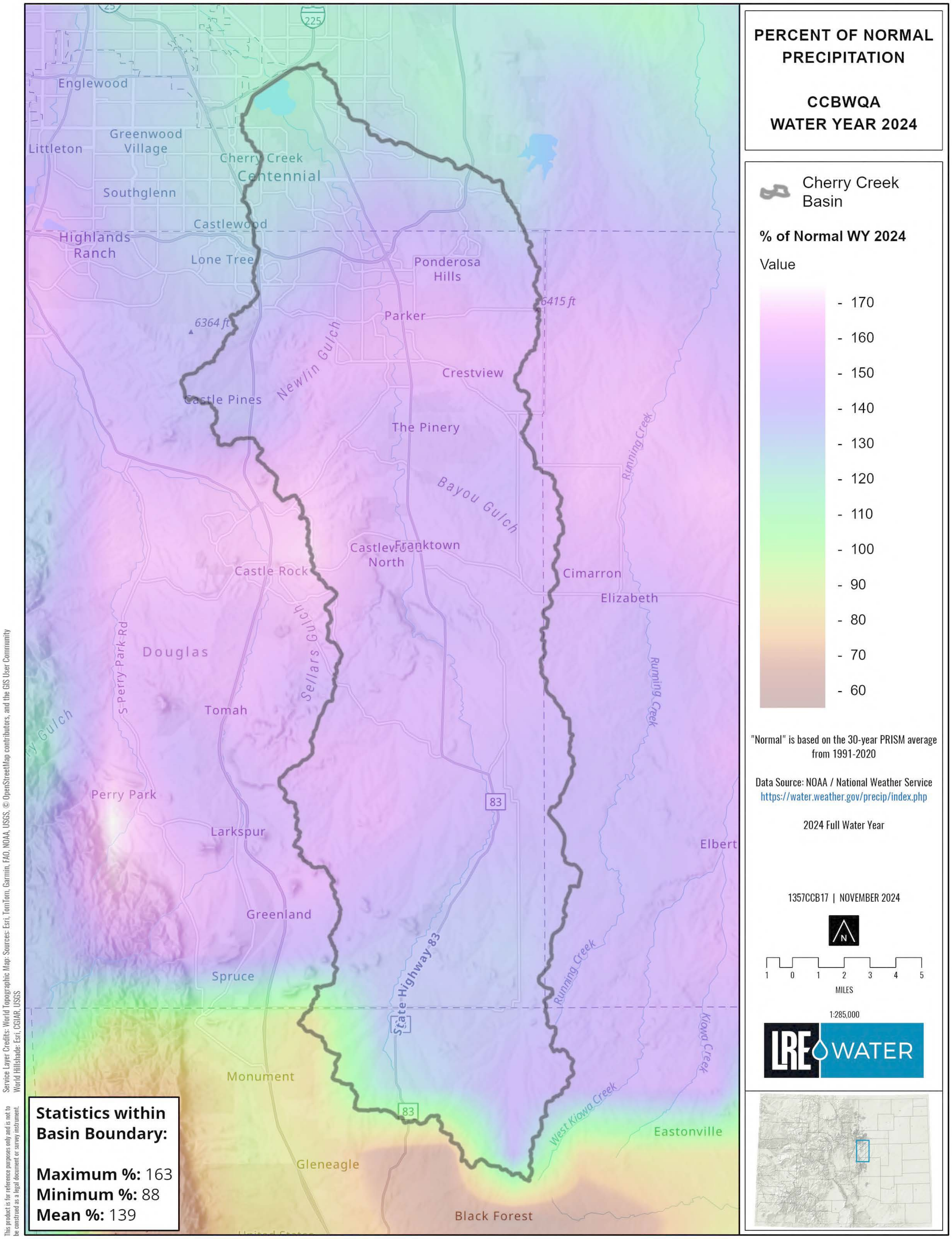


Figure 4. Percent of Normal Precipitation (30-year PRISM Average - 1991-2020)

3.2 STREAM FLOWS

The U.S. Geological Survey (USGS) operates two gauging stations on Cherry Creek upstream of the Reservoir which are used as surface water monitoring locations for the SAP. The “Cherry Creek Near Franktown, CO” station (0671200) has an 83-year period of record (POR) and the “Cherry Creek near Parker, CO” station (393109104464500) has a 32-year POR.

3.2.1 CHERRY CREEK NEAR USGS FRANKTOWN SITE

The USGS Cherry Creek Near Franktown station is in Castlewood Canyon State Park in Douglas County (Figure 2). The station, which represents the upper portion of the watershed, is 1.3 mi downstream from Castlewood Dam site, and 2.5 mi south of Franktown. The WY 2024 summary statistics for the USGS Franktown site include total annual flow of 3,987 AF, 62% of the long-term average at that site and 73% of the 32-year average (comparable to USGS Parker, section 3.3.2), also listed in the text box to the right. Figure 5 shows the estimated daily discharge along with the historical daily mean from the last 83 years.

USGS Gage - Cherry Creek near Franktown
Hydrologic Unit 10190003 (39°21'21", 104°45'46)
Drainage Area: 169 sq mi.
2024 Statistics
Total Annual Flow: 2,011 cfs/ 3,987 AF/ Year
Annual Mean Flow Rate: 5.49 cfs 10.9 AF/day
Percent of Long-term Average (1940-2024): 62%
Percent of 32-year average (1992-2024): 73%

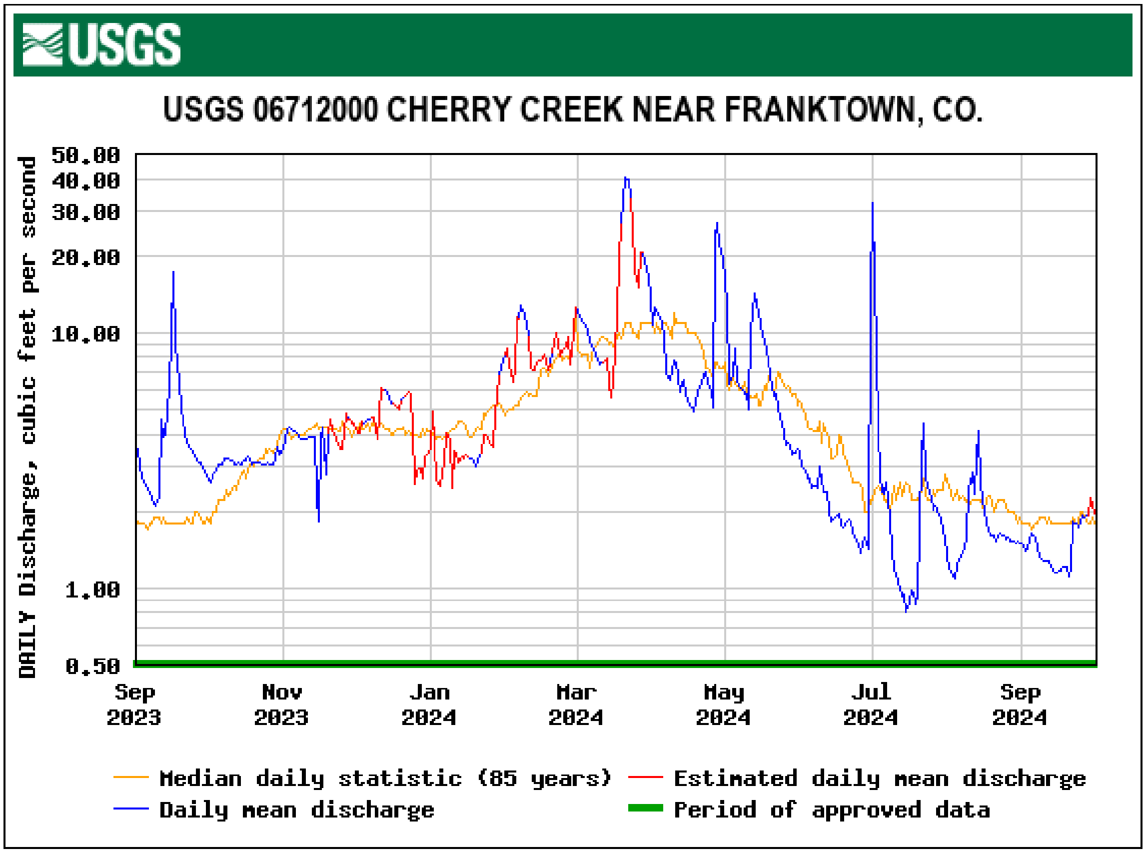


Figure 5. WY 2024 Daily Mean Discharge and Historical Median Flows for USGS Gauge near Franktown.

3.2.2 CHERRY CREEK NEAR USGS PARKER SITE

USGS Gage - Cherry Creek near Parker
Hydrologic Unit 10190003 (39°31'09",104°46'45")
2024 Statistics
Drainage Area: 287 sq mi
Total Annual Flow: 6,158 cfs/ 12,198 AF/year
Annual Mean Flow Rate: 16.8 cfs/ 33.3 AF/day
Percent of 32-year average (1992-2024): 146%

The USGS Cherry Creek near Parker station is located in Douglas County, 200 ft upstream from Main Street, 1,100 ft downstream from mouth of Sulphur Gulch, and 0.8 mi west of Parker Rd. This site is representative of the conditions in the middle of the watershed. The WY 2024 summary statistics for the USGS Parker site include total annual flow of 12,198 AF, 146% of the historical (32 year) average, also listed in the text box to the right. Figure 6 shows the estimated daily discharge along with the historical daily mean.

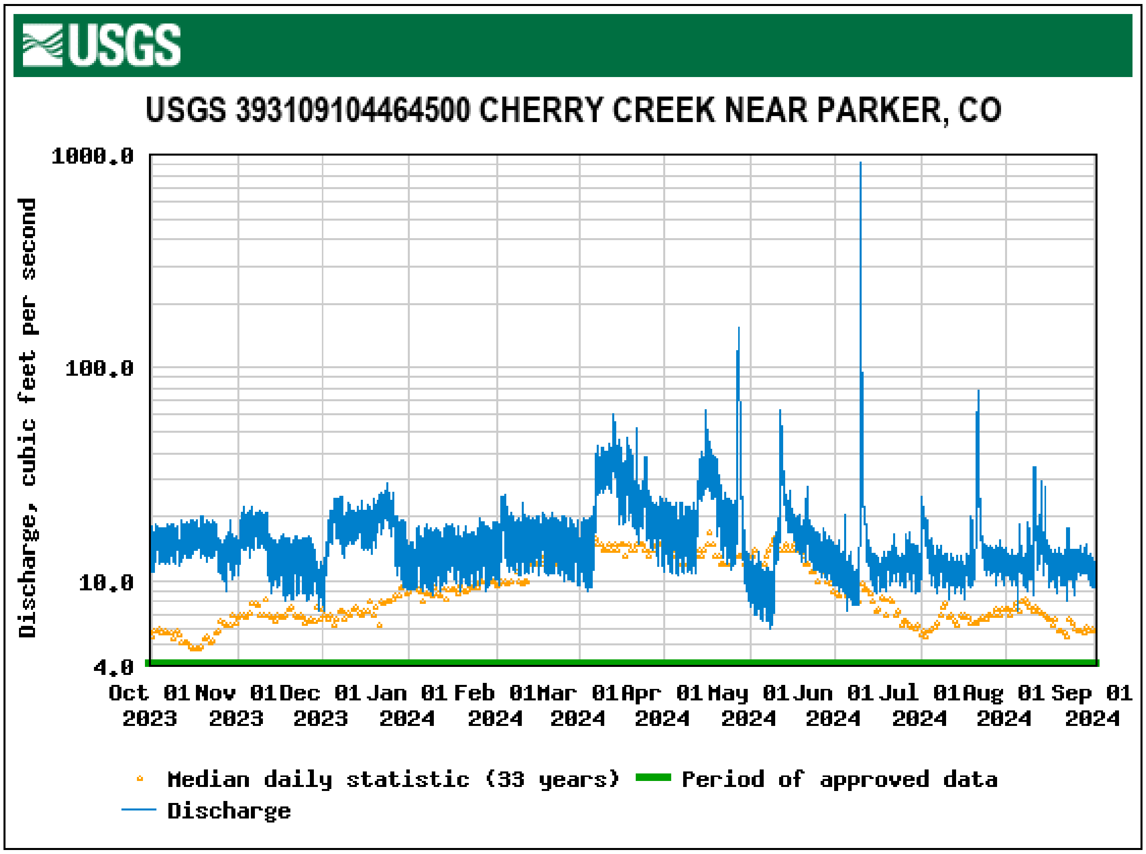


Figure 6. WY 2024 Daily Mean Discharge and Historical Median Flows for USGS Gauge near Parker.

3.2.3 CHERRY CREEK BELOW CHERRY CREEK LAKE

USGS Gage - Cherry Creek below Cherry Creek Lake
2024 Statistics:
Total Annual Flow: 10,600 cfs/ 21,017 AF
Annual Mean Flow Rate: 29 cfs/ 58 AF/day
Percent of 32-year average (1992-2024): 144%
Percent of 10-year average: 98% *2005-14 not available

Water is released from the Reservoir through the dam's outlet works. The USGS measures outflow at Station 06713000, Cherry Creek below Cherry Creek Lake, CO. The gauge is located approximately 2,300 ft downstream of the Reservoir. Other than releases from the Reservoir, there are no major surface water contributions to flow measured at this gauge. The WY 2024 summary statistics for the USGS site below Cherry Creek Lake include total annual flow of 21,017 AF, 144% of the 1992-2024 average and 98% of the last 10 year average, listed in the text box to the right. Figure 8 shows the historical average flows for all three sites.

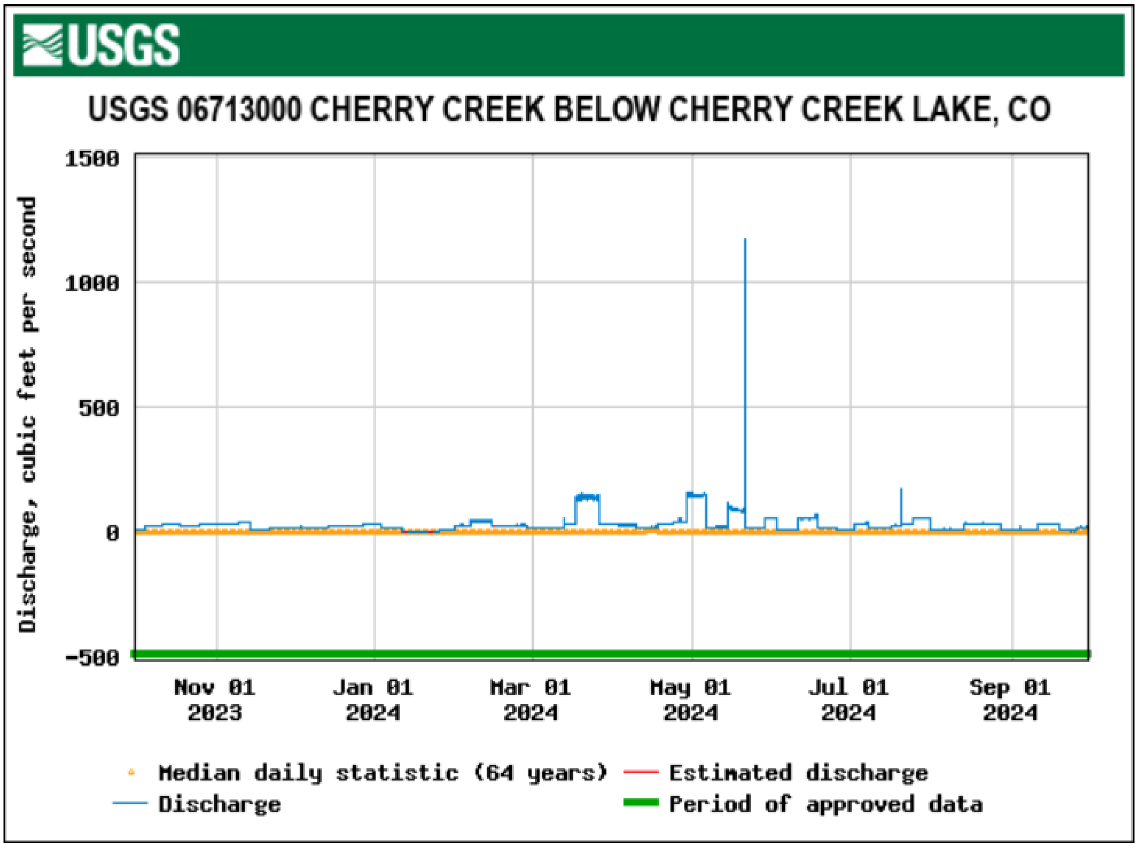


Figure 7. WY 2024 Daily Mean Discharge and Historical Median Flows for USGS Gauge Below Cherry Creek Lake.

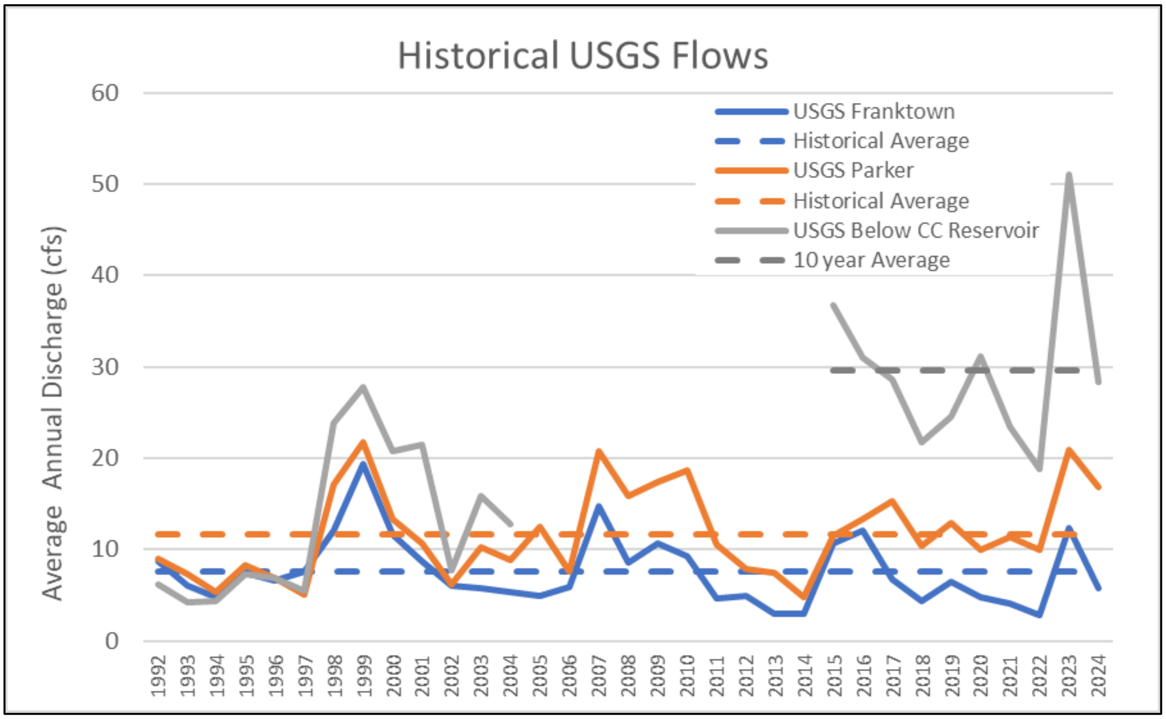
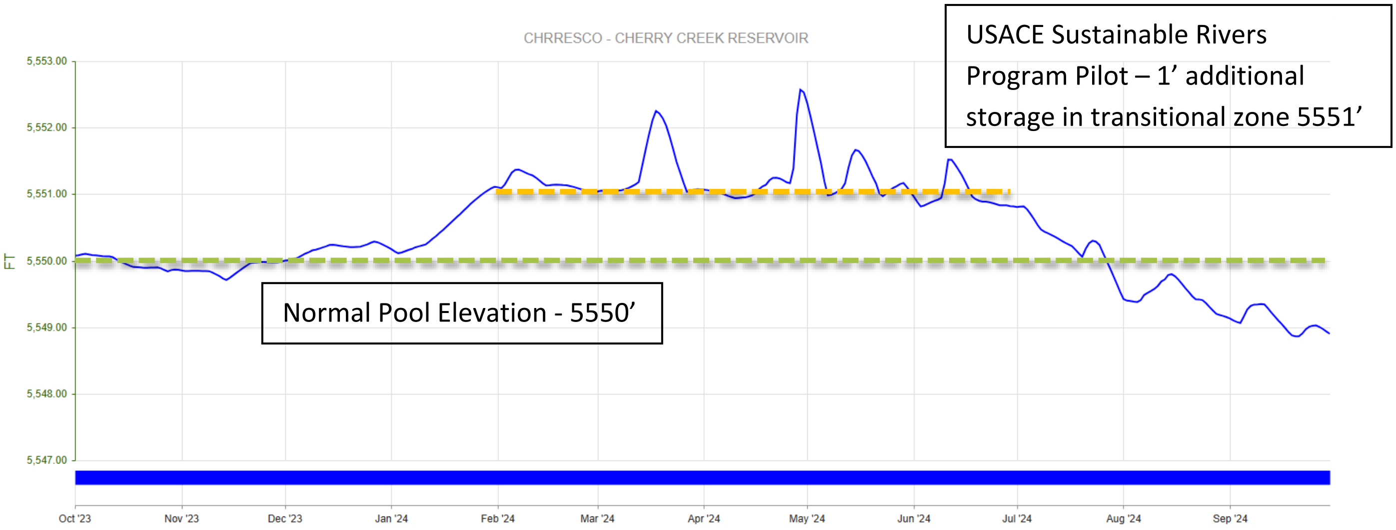


Figure 8. Average Annual Flow at the USGS Franktown, Parker and below Cherry Creek Lake sites (cfs) along with historical averages.

3.3 RESERVOIR INFLOWS

Chery Creek, the main inflow to Cherry Creek Reservoir, flows from south to north to the Reservoir through a 234,000-acre drainage basin. The basin includes various types of land use, including agriculture in the upper basin and higher-density development closer to the Reservoir, as well as permitted discharges to Cherry Creek and its tributaries. Cottonwood Creek has the second largest surface water input to Cherry Creek Reservoir with a sub-basin of 9,050 acres, which includes developed land use, and multiple wastewater dischargers.

In 2024, the USACE implemented the storage of one additional foot of water in Cherry Creek Reservoir under the Sustainable Rivers Program for release in July (Figure 9). The project aims to determine if releasing more water during the warm summer conditions in July when anoxic conditions are typically present at the bottom of the Reservoir could benefit water quality and reduce nutrient storage (Dinkel, 2023). Preliminary data analysis suggests that phosphorus concentrations of the outlet represented conditions from below the Reservoir hypolimnion and were within the normal concentrations typically released in July. (Seefus, 2024).



USACE Sustainable Rivers Program Pilot – 1’ additional storage in transitional zone 5551’

Normal Pool Elevation - 5550’

Figure 9. Reservoir Elevation WY2024 (CHRRESCO) (Colorado DWR).

3.3.1 CHERRY CREEK

CCBWQA monitors water quality at CC-10, which is the site upstream on Cherry Creek just before it enters the Reservoir that represents inflows from Cherry Creek. The other sites on Cherry Creek and monitoring results are discussed in Section 3.4 below.

The multiple large storm events in the Cherry Creek Watershed during 2023 affected stage measurements and associated flow calculations due to damaged equipment and inaccurate readings at the two stations on Cherry Creek and Cottonwood Creek upstream of the Reservoir that are used to calculate inflows (CC-10 and CT-2, respectively, see Section 3.1). The damaged equipment at CC-10 was replaced in late 2023 but was damaged again in the early spring of 2024 before any meaningful flow information could be calculated.

Due to the concerns of ongoing damage at this location due to the down cut area upstream and significant erosion, it was determined that flow measurement at this site would be discontinued, unless future restoration provides conditions for reliable measurements. As an alternative, a new site, CC-9.5, upstream near the section of Cherry Creek in the stabilized area where the Aurora waterline crosses, was installed in 2024 (Figure 2) to collect stream level by telemetry. Manual flow measurements were completed to develop the rating curve at this site so continuous flow can be calculated; however, this was not completed until fall of 2024 so measurements for WY 2024 are not available. As a result, inflows to Cherry Creek Reservoir have been estimated again in WY 2024, which also affects water balance calculations (see section 5.0).

3.3.2 COTTONWOOD CREEK

Cottonwood Creek is the second largest surface water input to Cherry Creek Reservoir. Cottonwood Creek has a sub-basin of 9,050 acres. Compared to Cherry Creek, the Cottonwood Creek sub-basin has more developed land use and multiple wastewater discharges. There are four monitoring sites on Cottonwood Creek. There are two sites upstream on Cottonwood Creek off Peoria St. (CT-P1 and CT-P2) and two sites in Cherry Creek State Park (CT-1 and CT-2). These sites are monitored regularly and have equipment to monitor stream levels and collect storm samples upstream and downstream of the PRF ponds and wetland systems (Figure 2).

CT-2 is the site upstream on Cottonwood Creek just before it enters the Reservoir, and it is representative of inflow water quality. The other Cottonwood Creek sites are discussed regarding the evaluation of the effects of the PRFs in section 3.5 below.

In WY 2024, the stage and flow measurements at CT-2 were not impacted by high flow or damaged equipment and the clogged outlet structure was cleared of organic debris on April 19th, 2024, prior to any major spring storms (Figure 10). The only missing data occurred between January 14th and February 20th when either the equipment was frozen or there was an issue with the datalogger. The level and flow during that period was estimated by interpolation of the average difference between the two measurements.

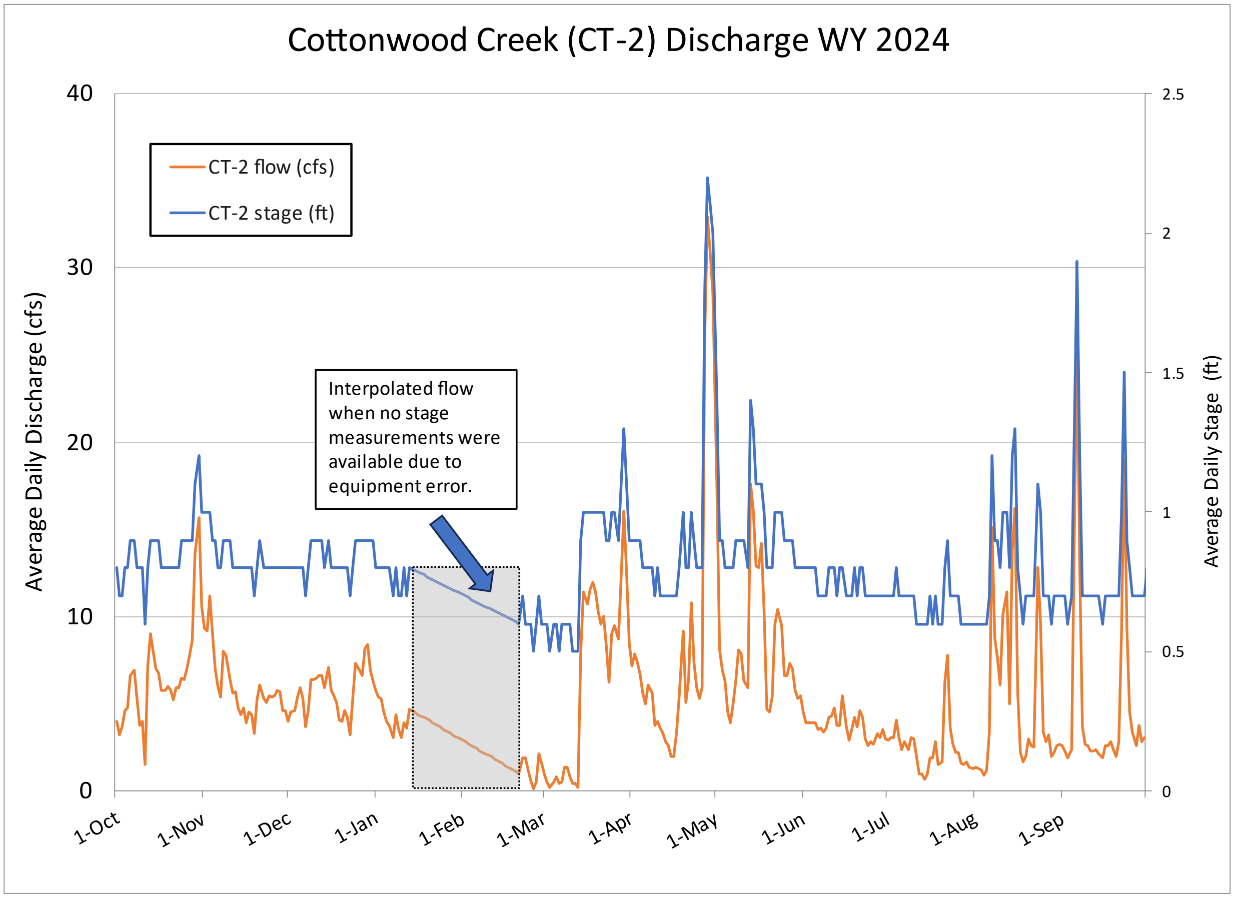


Figure 10. Cottonwood Creek Discharge at CT-2 upstream of Cherry Creek Reservoir.

3.4 WATERSHED WATER QUALITY

CCBWQA monitors Cherry Creek, Cottonwood Creek, Piney Creek, McMurdo Gulch and several alluvial groundwater wells at various frequencies in accordance with the SAP and as summarized in Table 1 and Figure 2 (section 2). A subset of sites is also monitored during storm flows. Table 1 also summarizes the period of record (POR) of monitoring at each site. The sections below outline the major parameters monitored, summary statistics, notable seasonal variation, and trends identified using a Mann Kendall trend analysis (see section 2.2) for the POR for each site.

Table 1. Watershed Monitoring Locations, Frequency, and Period of Record.
B-Bi-annual, EO – Every other Month, M-Monthly, 💧 - Storm

Location Name	#/Yr	LOCID	Earliest Sampling Event	Most Recent Sampling Event	POR (Years)
CC-USGSFRANKTOWN	B	USGS-Franktown	8/11/1994	5/8/2024	30
CC-1 - Cherry Creek Station 1	B	CC-1	8/10/1994	5/8/2024	30
CC-2 - Cherry Creek Station 2	B	CC-2	11/8/1994	5/8/2024	30
CC-USGSPARKER	B	USGS-Parker	5/9/2017	5/8/2024	7
CC-4 - Cherry Creek Station 4	B	CC-4	8/10/1994	5/8/2024	30
CC-5 - Cherry Creek Station 5	B	CC-5	8/9/1994	5/8/2024	30
CC-6 - Cherry Creek Station 6	B	CC-6	8/9/1994	5/8/2024	30
CC-7 - Cherry Creek Station 7	M / 💧	CC-7	5/15/2012	9/12/2024	12
CC-8 - Cherry Creek Station 8	B	CC-8	3/15/1995	5/8/2024	29
CC-9 - Cherry Creek Station 9	B	CC-9	8/8/1994	5/8/2024	29
CC-10 - Cherry Creek Station 10	M / 💧	CC-10	4/3/1992	9/12/2024	30
CC-Out - Cherry Creek Reservoir Outflow	M	CC-Out	4/3/1992	9/12/2024	32
CT-1 - Cottonwood Creek PRF Site 1	M / 💧	CT-1	4/9/1992	9/12/2024	32
CT-2 - Cottonwood Creek PRF Site 2	M / 💧	CT-2	4/2/1996	9/12/2024	28
CT-P1 - Cottonwood Creek PRF Site P1	M / 💧	CT-P1	5/24/2002	9/12/2024	22
CT-P2 - Cottonwood Creek PRF Site P2	M / 💧	CT-P2	2/20/2002	9/12/2024	22
MCM-1 - McMurdo Gulch Station 1	EO	MCM-1	1/18/2012	8/21/2024	12
MCM-2 - McMurdo Gulch Station 2	EO	MCM-2	1/18/2012	8/21/2024	12
PC-1 - Piney Creek	M / 💧	PC-1	4/25/2018	9/13/2024	6
Rain Sampler	💧	PRECIP	4/4/2014	8/14/2024	10
MW-1 Monitoring Well 1	B	MW-1	8/10/1994	5/8/2024	30
MW-5 Monitoring Well 5	B	MW-5	8/16/1994	5/8/2024	30
MW-9 Monitoring Well	B	MW-9	8/12/1994	5/7/2024	30
MW-Kennedy Monitoring Well	B	MW- Kennedy	6/1/1999	5/7/2024	25

PHYSICAL PARAMETERS

The stream sites in the Cherry Creek Watershed are monitored monthly for key physical conditions including temperature, pH, dissolved oxygen, and conductivity. This monitoring helps assess significant changes in water chemistry upstream to down, between streams and tributaries and over time.

TEMPERATURE

The water temperatures in the watershed vary seasonally and between locations (Figure 11). Cherry Creek (CC) and Piney Creek (PC) demonstrate less temperature variability than the sites on Cottonwood Creek (CT). The median water temperature in 2024 was at or below the baseline medians at most sites, except for the site on Piney Creek (PC-1), and just upstream of the Reservoir in Cherry Creek at CC-10, where it was slightly higher.

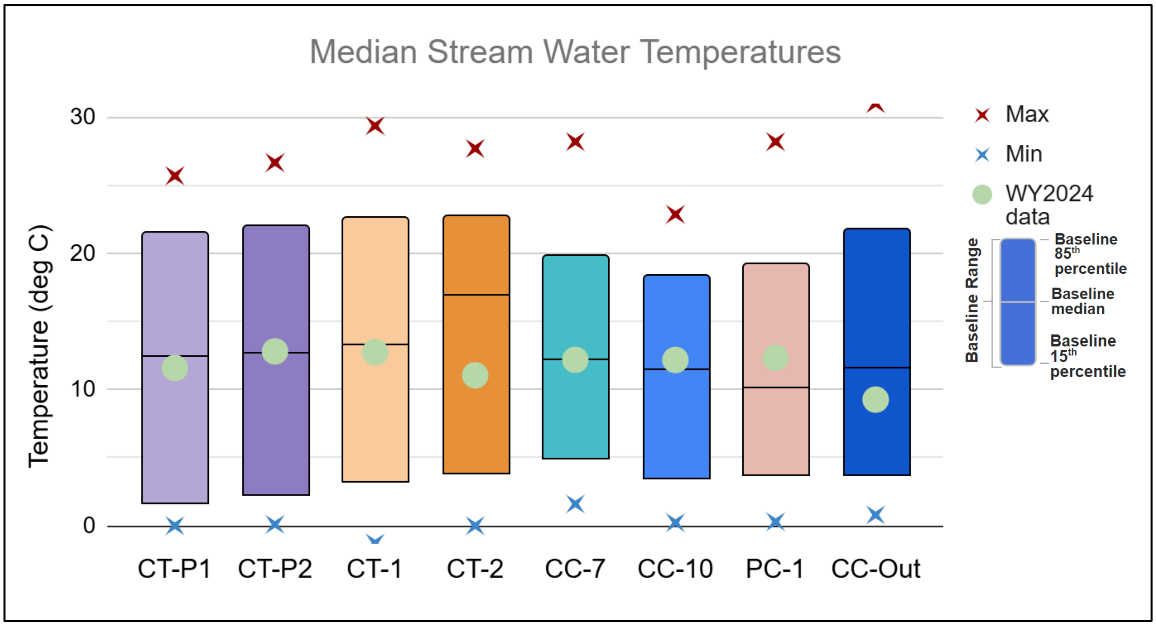


Figure 11. Stream Temperature Summary Statistics and WY 2024 medians.

PH

The pH in streams can affect aquatic life as well as alter the behavior of other pollutants in the water and sediment. Often, major changes in pH can be traced back to human activities in the watershed, but plants and algae can also increase the pH as they remove carbon dioxide from the water during photosynthesis or decrease pH as carbon dioxide is released during the decomposition of organic matter.

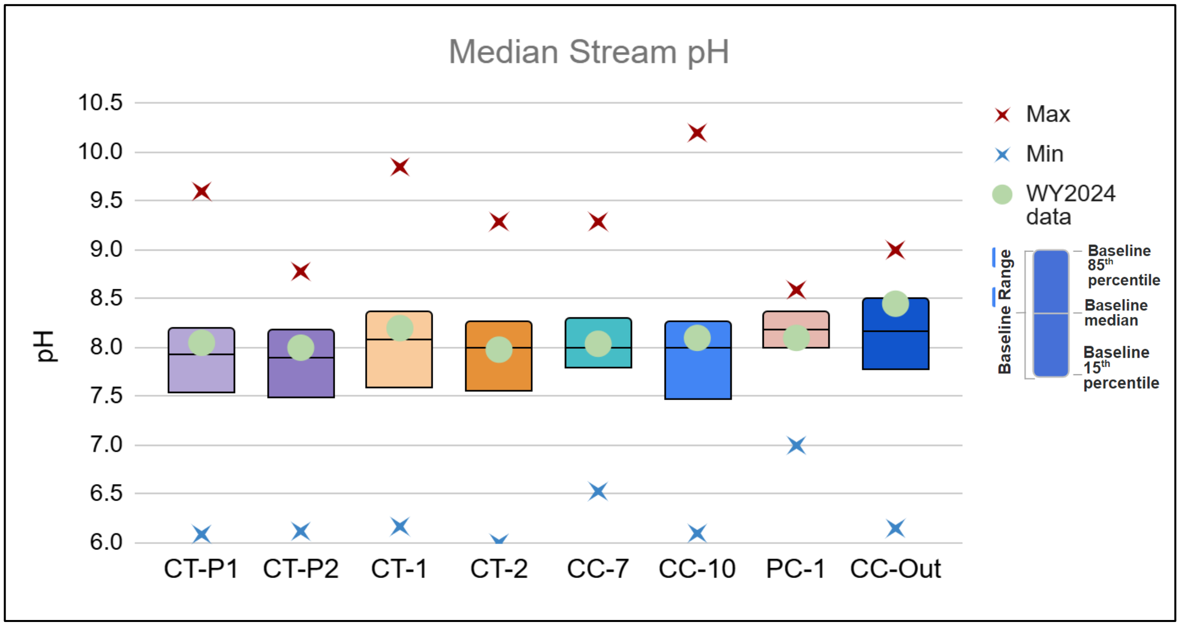


Figure 12. Stream pH Summary Statistics – POR Median and 15th/85th percentiles and WY 2024 Median.

As illustrated in Figure 12, the pH in the streams monitored monthly during WY 2024 did not demonstrate any major differences spatially or temporally and fall within the acceptable range for warm water aquatic life.

UPSTREAM TO DOWNSTREAM CHERRY CREEK

Figure 13 shows the pH upstream to downstream on Cherry Creek from the bi-annual monitoring events from WY 2024 along with POR summary statistics. pH was similar in November 2023 and May 2024 except for the outlet of the Reservoir, which was higher in November 2024. These pH values correlate with the fact that pH tends to be higher during the warmer months (e.g., May) as biological productivity in the water increases.

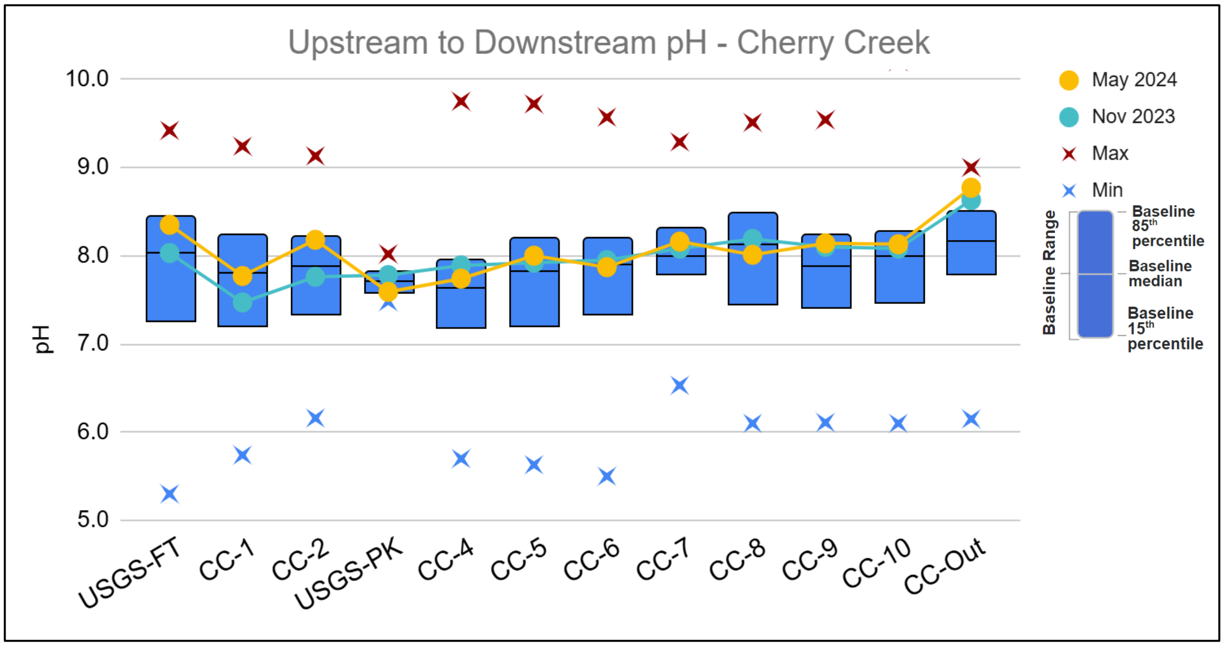


Figure 13. pH Upstream to Downstream on Cherry Creek, 1994-2024 and WY 2024 – Nov 2023 and May 2024.

DISSOLVED OXYGEN

Dissolved oxygen in the water is required for aquatic life and generally decreases as water temperatures increase in the warmer months. The DO concentrations in the watershed demonstrate some variability seasonally and between sites (Figure 14).

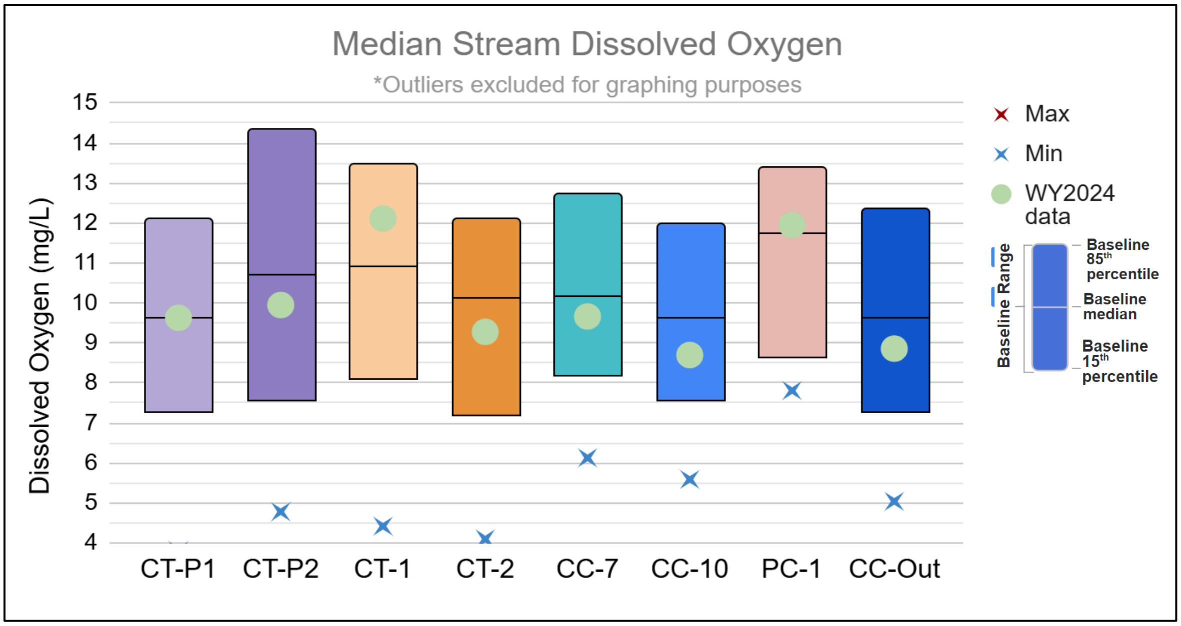


Figure 14. DO Concentration Summary Statistics - POR Median, 15th/85th percentile and WY 2024 Median.

MONTHLY STREAM SITES THROUGH THE WATERSHED

The baseline median DO concentration of the monthly stream sites is around 10 mg/L, and the WY 2024 median is slightly lower at 9.6 mg/L (Figure 15). Differences between years are likely the result of differing ambient temperatures.

UPSTREAM TO DOWNSTREAM CHERRY CREEK

Because higher water temperature decreases the solubility of oxygen in water, higher concentrations are usually observed in the colder months. In WY 2024, higher dissolved oxygen concentrations were observed in November during the bi-annual upstream to downstream monitoring event on Cherry Creek, except for CC-1 and CC-2 which were higher in May (Figure 15).

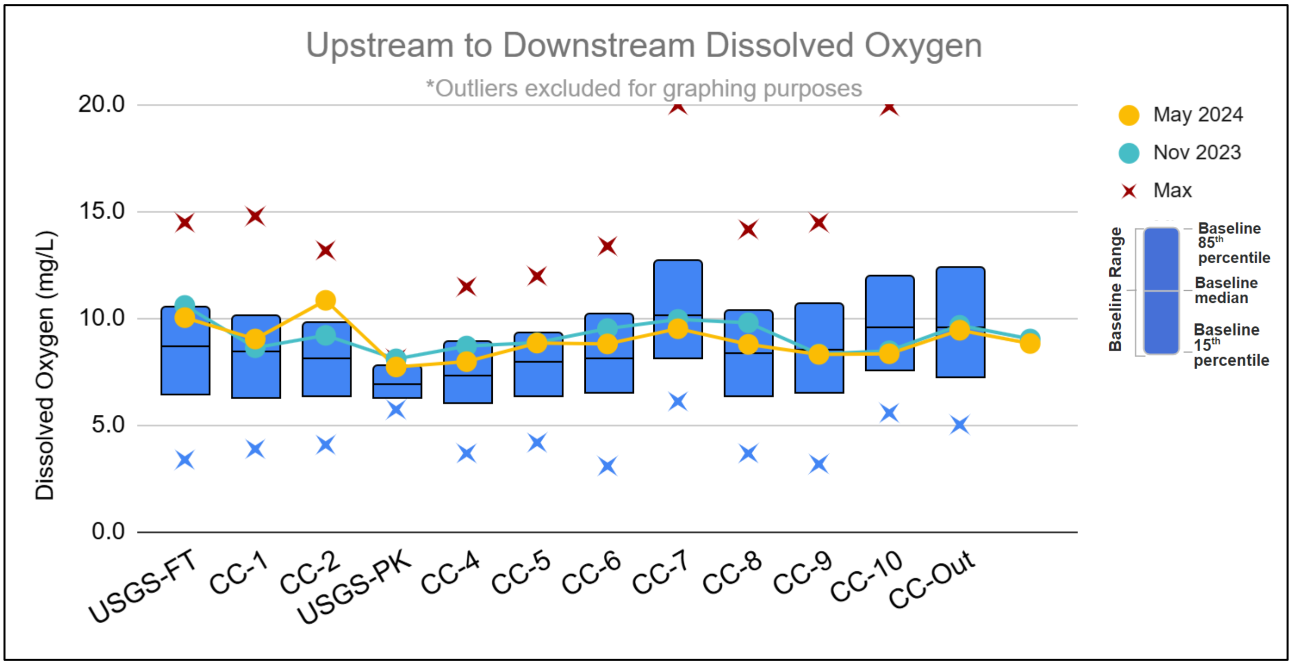


Figure 15. DO Concentrations Upstream to Downstream on Cherry Creek, POR Summary Statistics and WY 2024 – Nov 2023 and May 2024.

CONDUCTIVITY

Conductivity, which indicates dissolved solids (i.e., salts minerals, etc.), demonstrates spatial variability within the Cherry Creek watershed. Although there are no conductivity standards for streams in the basin, the US EPA considers levels above 1,500 µS/cm above average for most streams in the US.

Figure 16 depicts the specific conductance at the sites monitored monthly over the entire period of record as well as the median values observed in WY 2024, with the EPA benchmark displayed on the figure for reference. Over the POR, the highest conductivity values are observed at the furthest upstream sites (CT-P1 and CT-P2) on Cottonwood Creek and decrease downstream towards the Reservoir. High conductivity has also been recorded on Piney Creek although the POR is much shorter (2019-present). The lowest conductivity values are observed upstream on Cherry Creek at CC-7 and increase downstream at CC-10, just upstream of the Reservoir. The median conductivity at the outlet is slightly higher than Cherry Creek but lower than Cottonwood due to the relative inflow concentrations and mixing that occurs in the Reservoir. The WY 2024 median conductivity is similar to the baseline median at CC-7, but the WY 2024 medians are higher than the baseline medians for all other sites.

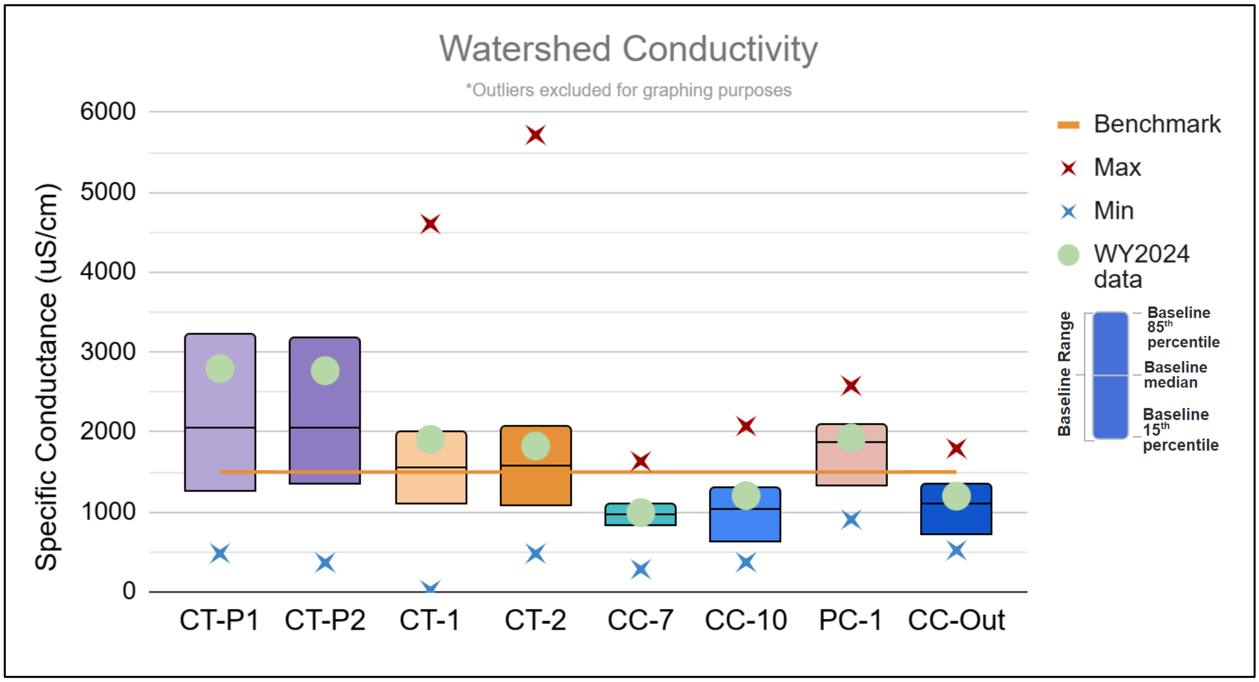


Figure 16. Watershed Stream Conductivity, Summary Statistics for POR and WY 2024 median.

MONTHLY STREAM SITES THROUGH THE WATERSHED

Conductivity within the watershed exhibits seasonal variability. Historically, February records the highest maximum conductivity, while January had the highest values during Water Year (WY) 2024 for Cherry Creek, Cottonwood Creek, and Piney Creek (Figure 17, Figure 18, and Figure 19).

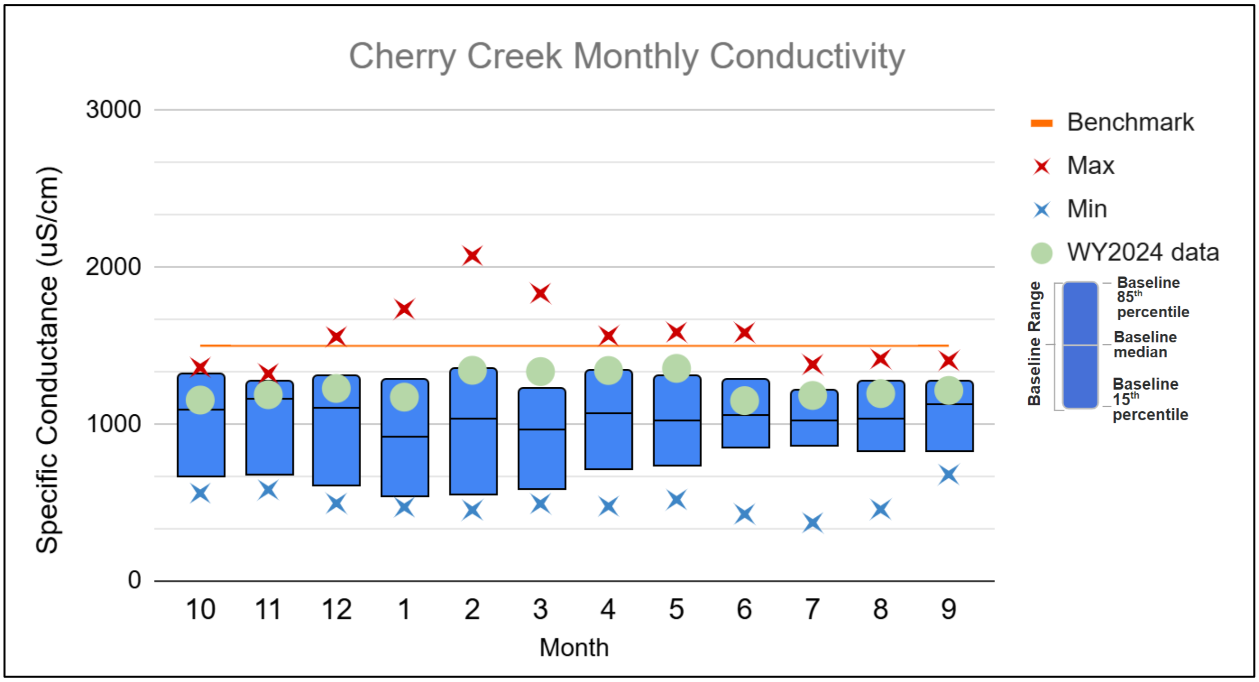


Figure 17. Monthly Conductivity on Cherry Creek at CC-10, POR Summary Statistics, and WY 2024.

Conductivity within the watershed exhibits seasonal variability. Historically, February records the highest maximum conductivity, while January had the highest values during Water Year (WY) 2024 for Cherry Creek, Cottonwood Creek, and Piney Creek (Figure 17) However, on Cottonwood Creek, median conductivity exceeded this threshold during most months, except for June, July, and September (Figure 18).

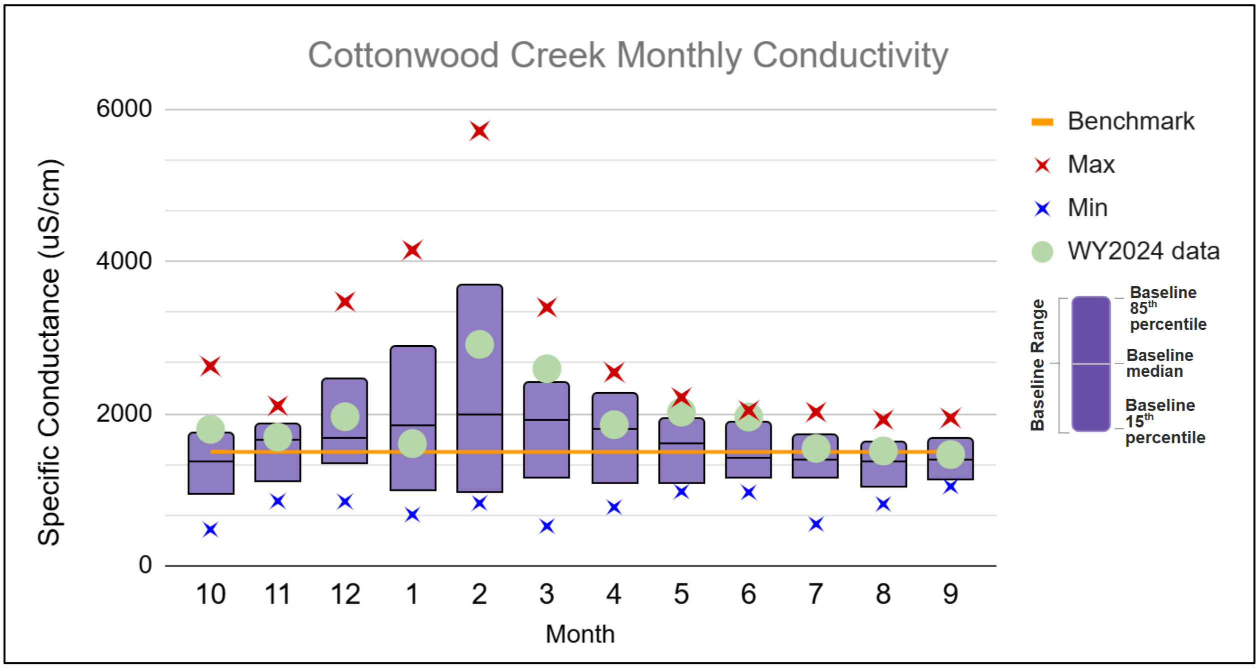


Figure 18. Monthly Conductivity on Cottonwood Creek at CT-2, POR Summary Statistics, and WY 2024.

Similarly, Piney Creek exhibited a pattern where only June and August values fell below the benchmark (Figure 19). Notably, conductivity during the fall, winter, and spring months (October through April, excluding February) was at or near the historical maximum observed on Piney Creek since monitoring began in 2018. While this report does not identify specific sources of elevated winter conductivity, the data suggests that road salt used for de-icing as the likely contributing factor. Since the majority of WWTFs that incorporate phosphorus removal utilize chemical precipitation (D Mulkerrins, et al. 2004), discharges may experience seasonal changes in conductivity, and effluent that may be warmer than the receiving stream in the winter months could also play a role.

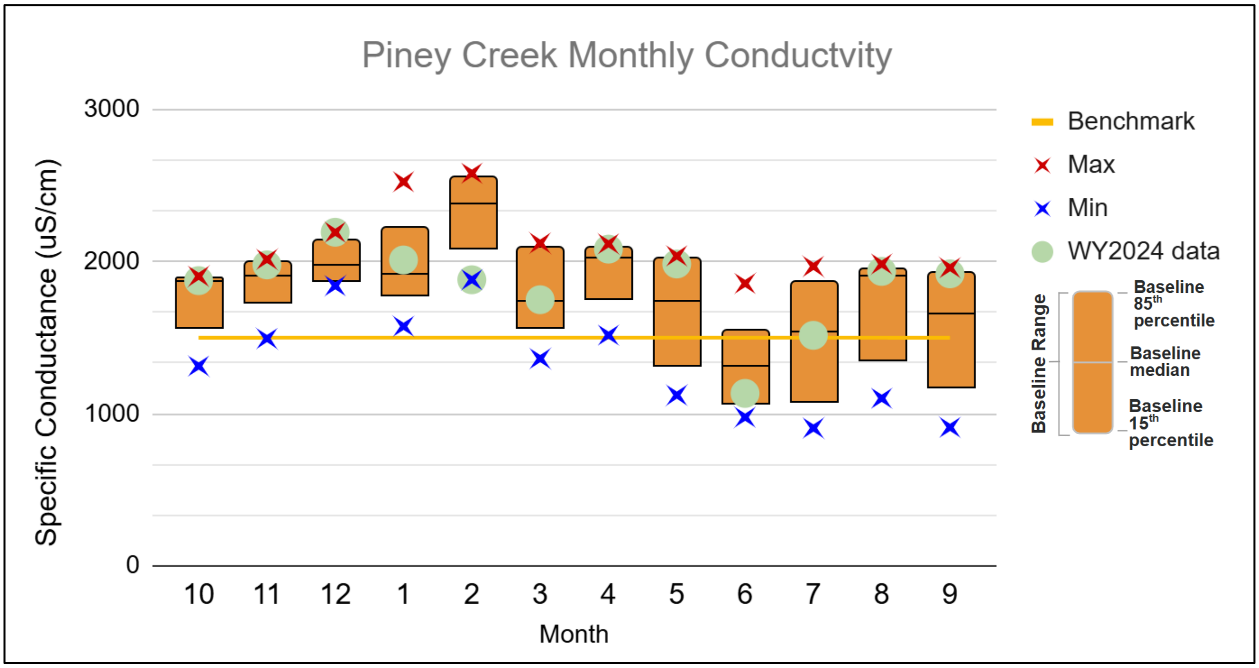


Figure 19. Monthly Conductivity on Piney Creek at PC-1, POR Summary Statistics, and WY 2024.

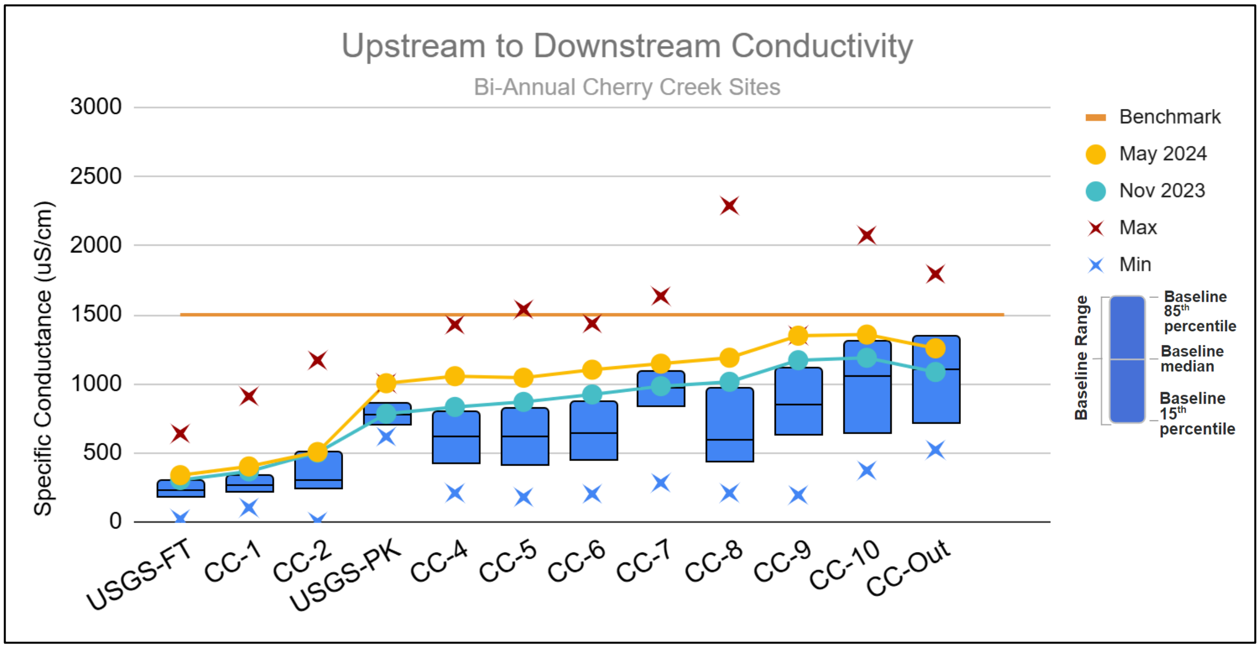


Figure 20. Conductivity Upstream to Downstream on Cherry Creek, Summary Statistics for POR and WY 2024 – Nov 2023 and May 2024.

Figure 20 presents the median conductivity measurements along Cherry Creek from upstream to downstream during November 2023 and May 2024, alongside summary statistics from the 1994–2024 period of record.

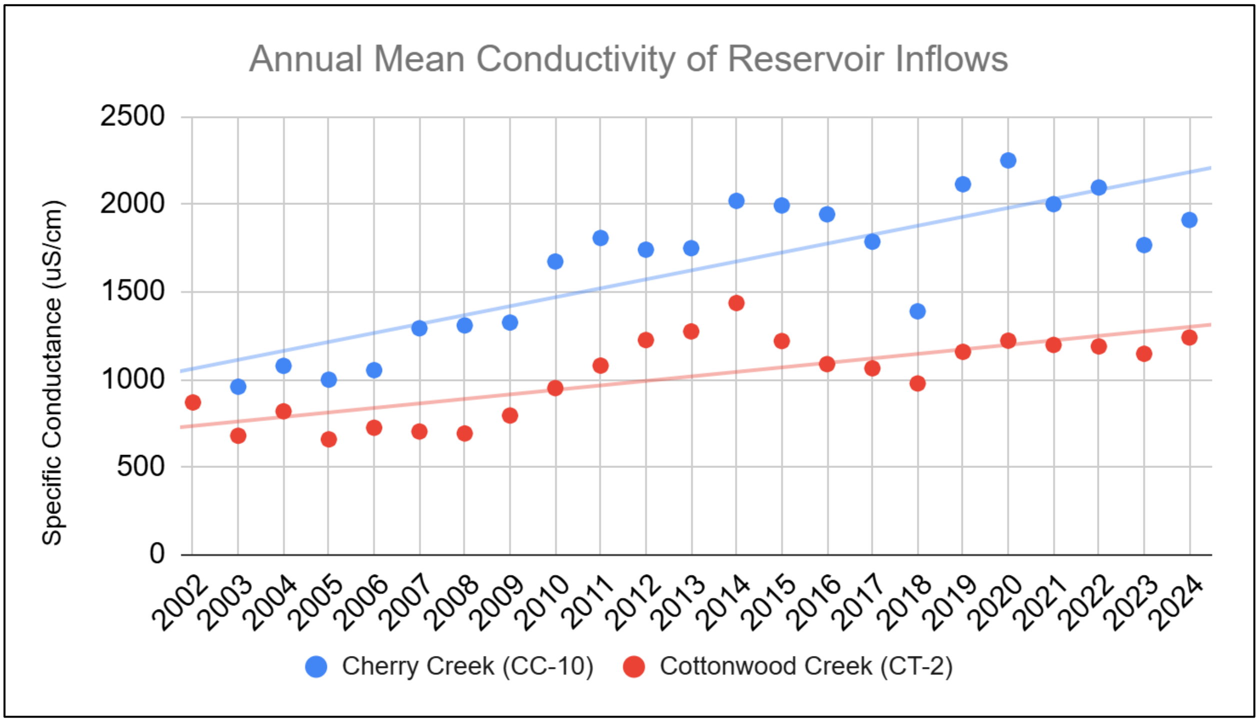


Figure 21. Historical Mean Conductivity on Cherry Creek and Cottonwood Creek.

A Mann-Kendall trend analysis indicates a significant increase in median conductivity moving from upstream to downstream during the baseline and water year (WY) 2024 monitoring periods. Furthermore, the analysis reveals a significant upward trend in the annual mean conductivity of both inflows to the reservoir, specifically at Cherry Creek (CC-10) and Cottonwood Creek (CT-2), over the period of record (Figure 21).

NUTRIENTS AND SUSPENDED SOLIDS

Nutrients and suspended solids in the streams in the Cherry Creek Watershed have a direct impact on the water quality in the Reservoir. Nutrients demonstrate variable patterns and trends among sites and flow conditions. High stream flow related to storm events increases suspended particles in the water, which is directly correlated to increased phosphorus concentrations. This is a key reason that CCBWQA supports stream stabilization projects and implementation of stormwater control measures in the watershed.

PHOSPHORUS

Figure 22 and Table 2 present the summary statistics for total phosphorus (TP) during the POR and WY 2024 base and stormflow medians for each of the monthly stream sites. Maximum TP concentrations were observed during storm events, with some extreme values excluded from graphs to enhance clarity. Consistent with typical patterns, WY 2024 median TP concentrations were elevated during stormflows compared to baseflows.

At Cottonwood and Piney Creek sites, median TP concentrations for WY 2024 were lower than the long-term baseline under both baseflow and stormflow conditions. Similarly, at Cherry Creek, median TP concentrations during baseflow were below the baseline. However, during stormflow, TP concentrations at Cherry Creek sites exceeded the historic baseline median, likely driven by substantial erosion caused by major storm events. Notably, the TP median at CC-10 was approximately 200 µg/L higher than at upstream CC-7, highlighting the influence of Piney Creek, the primary tributary entering Cherry Creek between these locations.

At the reservoir outlet (CC-0), WY 2024 median TP concentrations were also lower than the long-term baseline, reflecting improvements in downstream conditions. Although only minimal storm samples were collected during 2024, these samples continue to show that TP concentrations are higher during storm events, affirming the need for targeted strategies to mitigate phosphorus loading during stormflows, both in stormflow and as a result of channel erosion, particularly along Cherry Creek and Piney Creek.

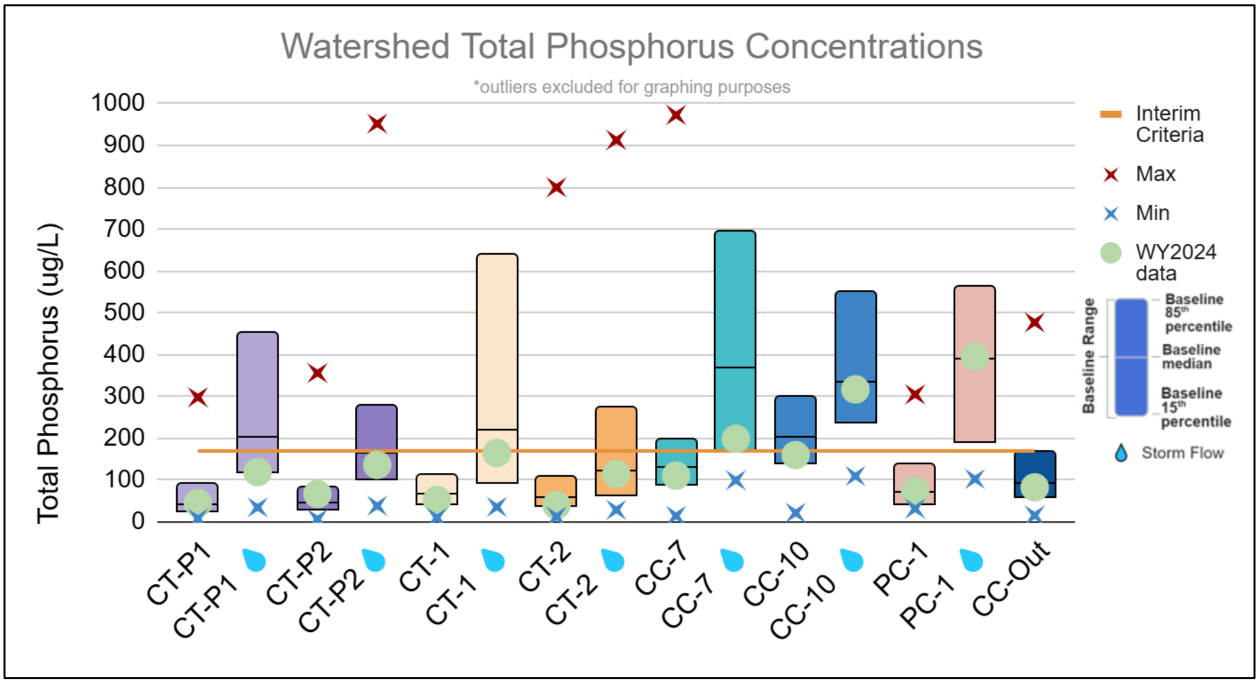


Figure 22. Watershed Phosphorus Concentrations (Base and Stormflow) POR Summary Statistics, and WY 2024.

Table 2. Total Phosphorus Concentration (µg/L) Baseline Summary Statistics and WY 2024, Base and Stormflow.

Site	**Site/ Flow**	**POR Min**	**POR Median**	**POR Max**	**Count**	**WY2024 Median**	**Count**
Cottonwood Creek PRF Site P1	CT-P1	8	47	298	252	46	12
Cottonwood Creek PRF Site P1	CT-P1 💧	35	207	2235	136	120	2
Cottonwood Creek PRF Site P2	CT-P2	7	50	356	250	67	12
Cottonwood Creek PRF Site P2	CT-P2 💧	39	167	952	126	137	2
Cottonwood Creek PRF Site 1	CT-1	10	68	1461	382	53	12
Cottonwood Creek PRF Site 1	CT-1 💧	36	222	3570	163	165	1
Cottonwood Creek PRF Site 2	CT-2	13	63	800	361	41	12
Cottonwood Creek PRF Site 2	CT-2 💧	29	127	913	164	115	1
Cherry Creek Station 7	CC-7	15	134	973	136	111	12
Cherry Creek Station 7	CC-7 💧	100	374	2684	44	199	1
Cherry Creek Station 10	CC-10	22	206	2532	389	160	11
Cherry Creek Station 10	CC-10 💧	110	336	3110	147	317	2
Piney Creek	PC-1	32	74	305	72	74	12
Piney Creek	PC-1 💧	103	393	2250	14	395	1
Cherry Creek Res Outflow	CC-Out	3	94	477	352	81	12

Stormflow indicated with 💧 after site name.

*Values in *italics* were excluded from Figure 26 for graphing purposes.

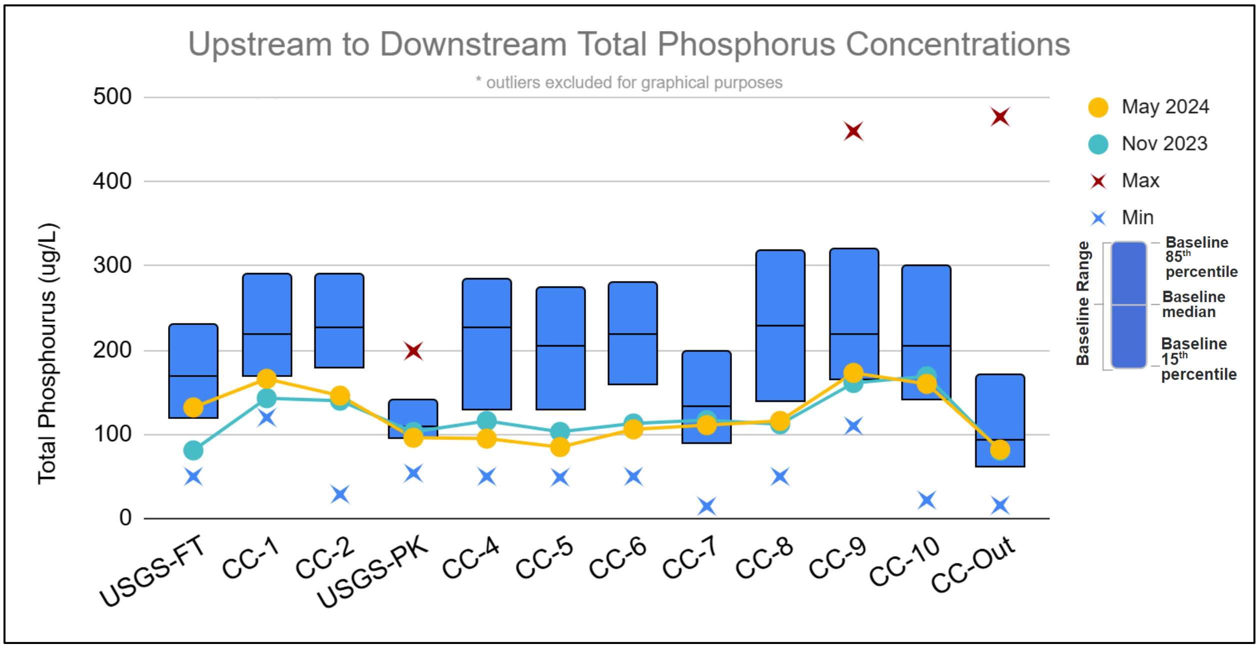


Figure 23. Upstream to Downstream Total Phosphorus Concentrations on Cherry Creek, Summary Statistics for POR and WY 2024 – Nov 2023 and May 2024.

Although the upstream sites at USGS Franktown and CC-1 had higher TP concentrations in May, the TP during the rest of the upstream to downstream monitoring events in WY 2024 were similar in November 2023 and May 2024 (Figure 23). Both events had TP concentrations that were lower than the respective baseline medians except for CC-7 and the outlet (CC-0) to the Reservoir in May.

NITROGEN

Nitrogen concentrations in the streams vary spatially throughout the watershed, seasonally and with different flow conditions. Figure 24 and Table 3 show the total nitrogen (TN) POR summary statistics and WY 2024 base and stormflow medians for each of the monthly stream sites. In contrast to TP, the maximum TN concentrations were not always observed during storm events (Table 2). The WY 2024 median TN concentrations were higher than the baseline median at three sites on Cottonwood Creek (CT-P1, CT-1, and CT-2) during baseflows and during storm events at CT-2. The WY 2024 median TN on Cherry Creek at CC-10 and the outlet to the Reservoir (CC-0) were also higher than the baseline medians during baseflow conditions.

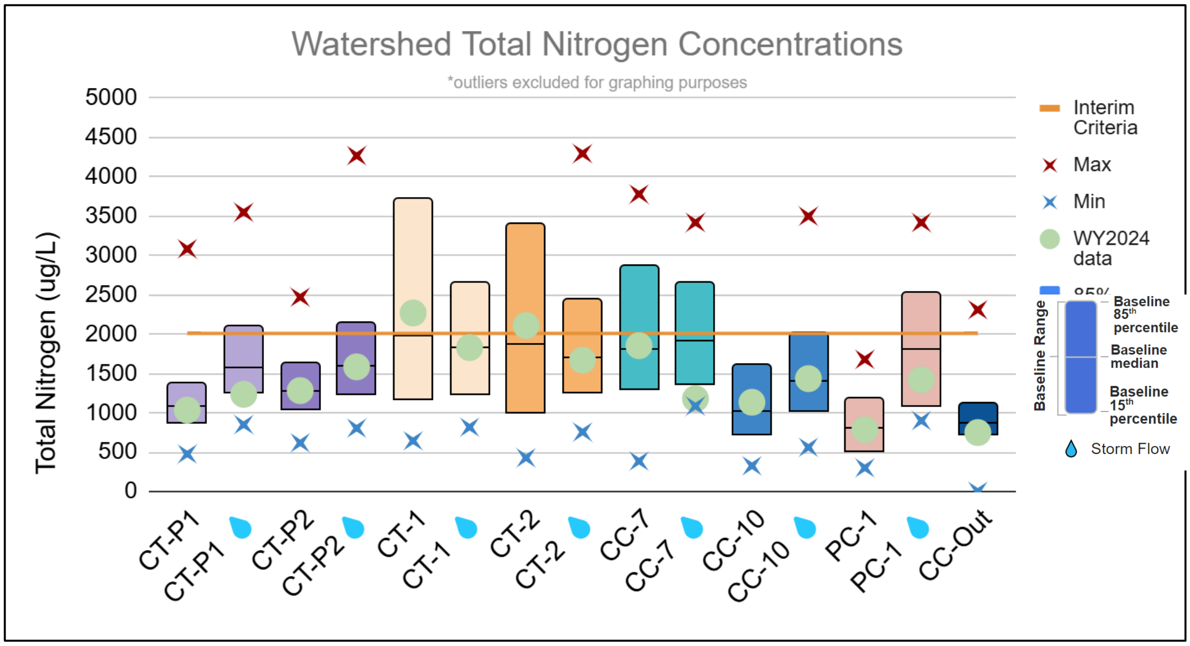


Figure 24. Watershed Nitrogen Concentrations (Base and Stormflow) Baseline Summary Statistics, and WY 2024.

Table 3. Total Nitrogen Concentration (µg/L) Baseline Summary Statistics and WY 2024 values, Base and Stormflow.

Site	Site/ Flow	Min	Median	Max	Count	WY2024 median	Count
CT-P1 - Cottonwood Creek PRF Site P1	CT-P1	477	1093	3084	249	1135	12
CT-P1 - Cottonwood Creek PRF Site P1	CT-P1 💧	851	1580	3550	135	1210	7
CT-P2 - Cottonwood Creek PRF Site P2	CT-P2	619	1290	2470	247	1265	12
CT-P2 - Cottonwood Creek PRF Site P2	CT-P2 💧	806	1615	4270	125	1240	7
CT-1 - Cottonwood Creek PRF Site 1	CT-1	645	2000	6930	311	2770	12
CT-1 - Cottonwood Creek PRF Site 1	CT-1 💧	818	1840	7670	130	1490	7
CT-2 - Cottonwood Creek PRF Site 2	CT-2	428	1883	5761	306	2115	12
CT-2 - Cottonwood Creek PRF Site 2	CT-2 💧	756	1719	4295	148	1980	7
CC-7 - Cherry Creek Station 7	CC-7	386	1815	3780	128	1544	12
CC-7 - Cherry Creek Station 7	CC-7 💧	1086	1920	3420	43	1805	6
CC-10 - Cherry Creek Station 10	CC-10	327	1031	7980	322	1065	12
CC-10 - Cherry Creek Station 10	CC-10 💧	562	1422	3500	124	1860	6
PC-1 - Piney Creek	PC-1	301	815	1680	69	813	12
PC-1 - Piney Creek	PC-1 💧	902	1820	3420	13	1220	5
CC-Out - Cherry Creek Reservoir Outflow	CC-Out	412	881	2310	301	965	12

Stormflow indicated with 💧 after site name.

*Values in *italics* were excluded from Figure 28 for graphing purposes.

UPSTREAM TO DOWNSTREAM CHERRY CREEK

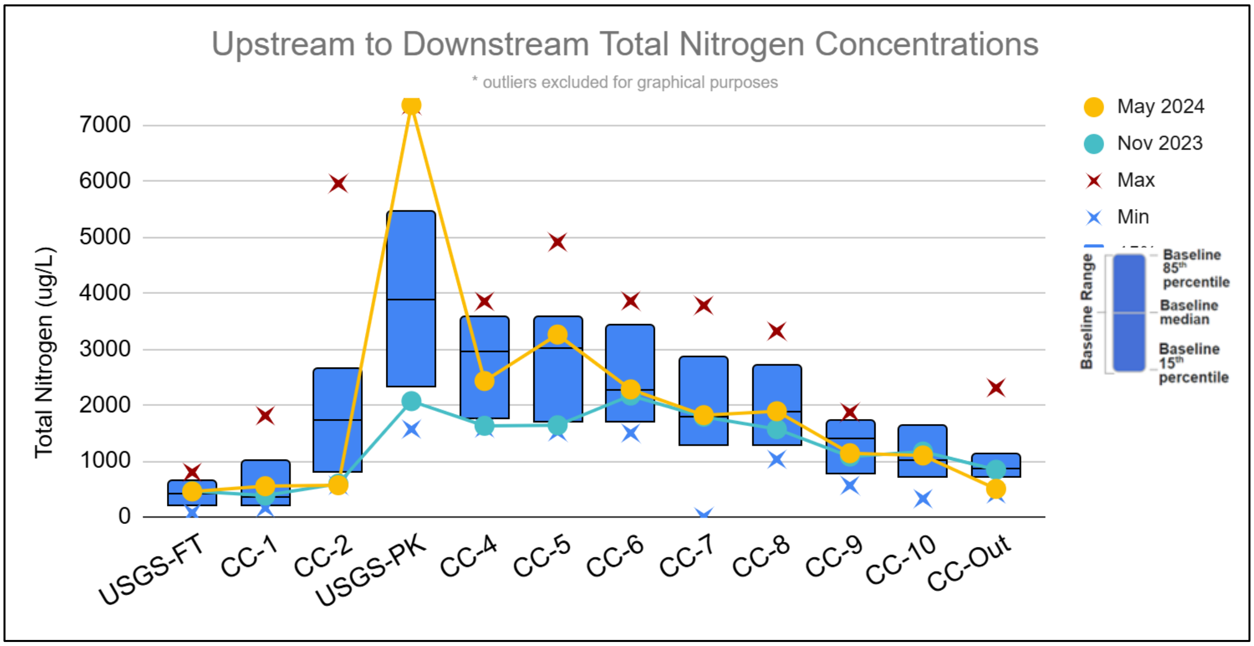


Figure 25. Upstream to Downstream Total Nitrogen Concentrations on Cherry Creek, Summary Statistics for POR and WY 2024 – Nov 2022 and May 2024.

During the upstream to downstream monitoring events in WY 2024, the TN concentrations were higher in May 2024 than in May 2023 (Figure 23) which is opposite of what is usually observed, but the values follow the same watershed pattern. TN concentrations were notably higher in May at the USGS Parker site but were more similar downstream at the CC-6 site. Both events had TN concentrations that followed a similar pattern to the baseline median with concentrations increasing between CC-2 and USGS Parker and then decreasing downstream towards the Reservoir. Along with seasonal variability affecting nitrogen cycling, discharges from WWTPs can impact stream nitrogen concentrations upstream to downstream and may vary seasonally.

SUSPENDED SOLIDS

Concentrations of TSS vary spatially throughout the watershed, seasonally and with different flow conditions. Figure 26 and Table 4 show the TSS POR summary statistics and WY 2024 base and stormflow medians for each of the monthly stream sites. Consistent with the POR, TSS concentrations are higher during storm conditions relative to baseflow conditions, which may be due to a combination of sediment transport in stormwater runoff and channel erosion. The WY 2024 median TSS concentrations were only higher than the baseline medians on Cherry Creek (CC-10) during the 2 storm events sampled (Table 4). The high TSS concentration during storm flows are common based on ongoing erosion to the stream channel in the lower portion of Cherry Creek, which was further destabilized following the 2023 flooding events. The WY2024 data supports prioritizing stream restoration (Cherry Creek Reach 1) just upstream of the Reservoir since phosphorus is associated with eroded sediment transported to the Reservoir.

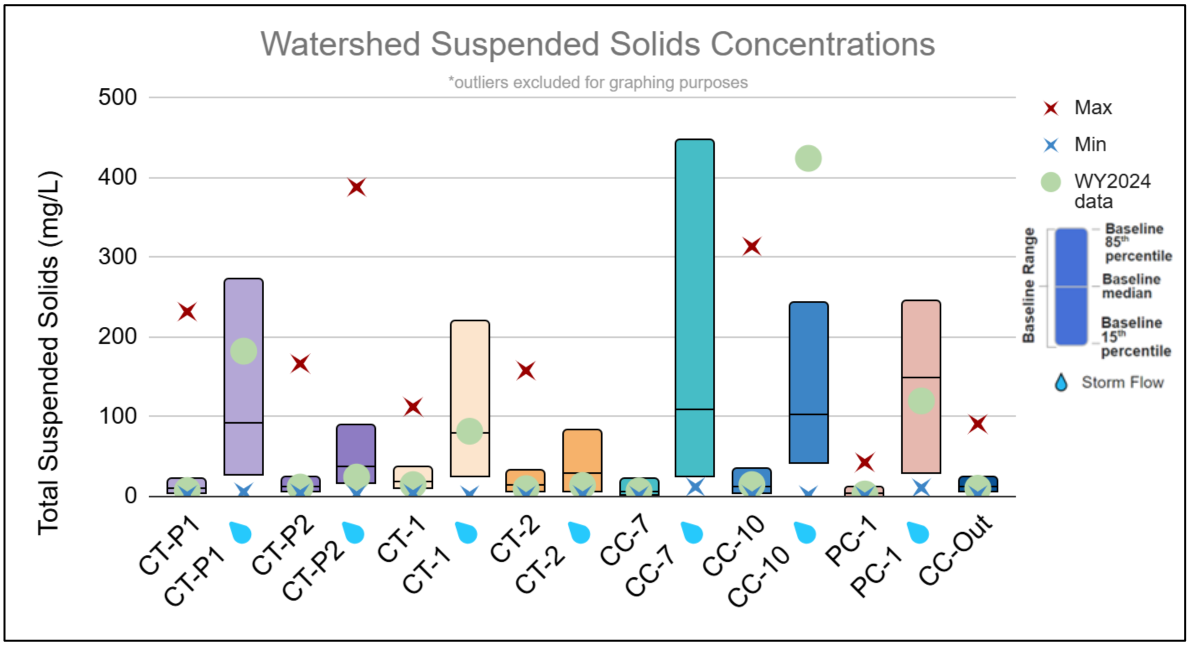


Figure 26. Median Suspended Solids Concentrations (Base and Stormflow Conditions) POR Summary Statistics, and WY 2024.

Table 4. Total Suspended Solids Concentration (mg/L) POR Summary Statistics and WY 2024 values.

Site	Site/ Flow	Min	Median	Max	Count	WY2024 median	Count
CT-P1 - Cottonwood Creek PRF Site P1	CT-P1	2	11	232	185	8	12
CT-P1 - Cottonwood Creek PRF Site P1	CT-P1 💧	6	94	1053	126	183	2
CT-P2 - Cottonwood Creek PRF Site P2	CT-P2	4	14	167	182	13	12
CT-P2 - Cottonwood Creek PRF Site P2	CT-P2 💧	3	40	388	116	25	2
CT-1 - Cottonwood Creek PRF Site 1	CT-1	4	21	113	204	16	12
CT-1 - Cottonwood Creek PRF Site 1	CT-1 💧	2	82	1337	111	82	1
CT-2 - Cottonwood Creek PRF Site 2	CT-2	1	15	158	209	10	12
CT-2 - Cottonwood Creek PRF Site 2	CT-2 💧	2	31	782	131	14	1
CC-7 - Cherry Creek Station 7	CC-7	1	8	1060	132	7	12
CC-7 - Cherry Creek Station 7	CC-7 💧	12	110	1360	43	-	0
CC-10 - Cherry Creek Station 10	CC-10	2	15	314	219	16	12
CC-10 - Cherry Creek Station 10	CC-10 💧	2	105	1660	112	425	2
PC-1 - Piney Creek	PC-1	1	5	43	72	4	12
PC-1 - Piney Creek	PC-1 💧	11	150	685	14	120	1
CC-Out - Cherry Creek Reservoir Outflow	CC-Out	2	14	91	208	11	12

Stormflow indicated with 💧 after site name.

*Values in *italics* were excluded from Figure 26 for graphing purposes.

3.5 POLLUTANT REDUCTION FACILITIES (PRFS)

The CCBWQA has completed multiple pollutant abatement projects, which include PRFs, in various locations through the watershed. WQCC CR 72 states:

> *"Pollutant Reduction Facility (PRF) means projects that reduce nonpoint source pollutants in stormwater runoff that may also contain regulated stormwater. PRFs are structural measures that include, but are not limited to, detention, wetlands, filtration, infiltration, and other technologies with the primary purpose of reducing pollutant concentrations entering the Reservoir or that protect the beneficial uses of the Reservoir."*

The SAP includes an assessment of the effectiveness of selected PRF projects in relation to nutrients and sediment concentrations as water moves downstream. The current monitoring program includes assessment of the PRFs on Cottonwood Creek and McMurdo Gulch. Monitoring of PRFs is conducted in accordance with CR 72.8.1(b).

Table 5. Significant Reductions in Nutrients and Suspended Solids in CCBWQA PRFs, WY 2024 and 2015-2024.*

PRF	**Cottonwood Treatment Train**		**Peoria Pond**		**Perimeter Pond**		**Cottonwood Creek btw Ponds**		**McMurdo Gulch**
Analyte	**Base**	**Storm**	**Base**	**Storm**	**Base**	**Storm**	**Base**	**Storm**	**Base**
Nitrate+ Nitrite		-	●	-	○	-			●
Ammonia		-		-	●	-			●
Nitrogen, Total		-	●	-	●	-			●
Phosphorus, Soluble Reactive		-		-	●	-			●
Phosphorus, Dissolved		-		-		-			▨
Phosphorus, Total		▨ -		▨ -	●	▨ -			●
Total Suspended Solids		▨ -		▨ -	●	▨ -			
Volatile Suspended Solids	▨	▨ -		▨ -	▨	▨ -	○		

**Legend:* ○ significant *reduction of upstream to downstream medians in WY 2024,* ▨ *significant reduction of upstream to downstream median (2015-2024),* ● *significant reduction upstream to downstream medians in WY 2024 and 2014-2024, blank cells indicate no significant reduction or an increase upstream to downstream.* - *statistically significant differences for WY 2024 storms were not calculated due to low number of samples.*

The Cottonwood Creek PRF is a series of wetland detention systems, along with an area where stream reclamation has been completed, collectively referred to as the Cottonwood Treatment Train (Figure 1). The monitoring program includes water quality samples during routine baseflow sampling and storm conditions above and below these sites. Table 5 summarizes whether median upstream-to-downstream concentrations significantly differ for each PRF for WY 2024 under base flows. The same comparison is provided for the last 10 years (2015-2024) for both base and storm flows. (section 3.5.1).

While the limited results from each water year are often not sufficient to complete a robust statistical analysis, annual calculations are included for reference. This analysis leverages the "PRF Statistics Tool" from the data portal to evaluate the statistical significance of changes above and below PRFs during WY 2024. The tool applies a non-parametric Wilcoxon signed rank test to assess whether differences are present between two data sets, with statistically significant differences indicated by p values less than 0.05.

Table 6,Table 7, N/A = unable to evaluate statistical significance for storm events in WY 2024 due to limited sample size.

Table 8, and N/A = unable to evaluate statistical significance for storm events in WY 2024 due to limited sample size.

Table 9 list the median difference of the upstream to downstream paired data (sampled on the same day), and hypothesis test results regarding whether the data for the current water year indicate that the median downstream concentrations are significantly lower than the upstream in base flows for WY 2024. The concentrations that are lower are notated with a negative (-) and are highlighted in green. The statistical analysis is not completed if an increase in the median concentrations were observed.

WY 2024 did not experience many storm events and as a result samples from only 1 or 2 events were captured depending on the site. For this reason, statistical analysis for WY 2024 storms could not be conducted for statistically significant differences and the focus of this discussion is on changes in base flow conditions.

During WY 2024, there were no significant trends observed downstream of Cottonwood Treatment Train as a whole (Table 6).

Dissolved nutrient forms are generally more challenging to remove than particulate forms, a finding supported by water quality data from the Cottonwood Creek PRFs and broader national datasets, such as the International Stormwater BMP Database (Clary et al., 2020). Furthermore, some nitrogen forms are already present at low concentrations, making further reductions unlikely. For instance, NO_2 + NO_3 concentrations at these sites are well below the nitrate standard of 10,000 µg/L. However, TN concentrations exceed CDPHE's interim TN guideline of 2,010 µg/L during fall and winter. (Note: the standard is evaluated as an annual median; therefore, elevated values in the fall and winter do not necessarily mean that the stream exceeds CDPHE's interim values, although in this case the annual median does exceed the interim guideline.) These elevated concentrations in cooler months may result from the decomposition of wetland vegetation. An additional complexity in system interpretation arises from Lone Tree Creek, carrying treated effluent from ACWWA which enters Cottonwood Creek between the two PRF ponds.

Table 6. Pollutant Reduction Analysis, Cottonwood Creek Treatment Train PRF, WY 2024.

Cottonwood Treatment Train	**Baseflow**				**Stormflow** 💧			
Site	**CT-P1**	**CT-2**	**Upstream to Downstream**		**CT-P1**	**CT-2**	**Upstream to Downstream**	
Events (n)	**12**	**12**			**1**	**1**		
Analyte	**Median Concentration**		**Median Difference**	**Significant**	**Median Concentration**		**Median Difference**	**Significant**
NO_2+NO_3, µg/L	343	1,280	937	-	184	325	141	
NH_3-N, µg/L	30	48	17	-	26	3	-24	N/A

TN, μg/L	1035	2,125	1134	-	933	1,670	737	
SRP, μg/L	6	5	-1	No	3	1	-3	N/A
TDP, μg/L	11	13	1	-	16	13	-3	N/A
TP, μg/L	46	41	-6	No	79	115	36	N/A
TSS, mg/L	8	10	1	-	343	14	-329	N/A
VSS, mg/L	3	2	0	-	306	6	-300	N/A

N/A = unable to evaluate statistical significance for storm events in WY 2024 due to limited sample size.

Performance of the two PRF ponds (Peoria Pond and Perimeter Pond Wetland System) were also evaluated individually as shown inTable 7 andN/A = unable to evaluate statistical significance for storm events in WY 2024 due to limited sample size.

Table 8. Peoria Pond demonstrated reductions in median concentrations of NH_3-N, SRP, and TDP; however, only the dissolved phosphorus fractions were significantly lower downstream . The Perimeter Pond demonstrated significant reductions in all nutrients and suspended solids with the exception NH_3-N and VSS,. The median concentrations of TP and TSS downstream of the Perimeter pond were significantly lower than upstream during WY 2024 base flow, which is similar to the long-term trends observed over time during both base and storm flows. (section 3.5.1).

Table 7. Pollutant Reduction Analysis, Peoria Pond PRF, WY 2024.

Peoria Pond	**Baseflow**				**Stormflow**			
Site	**CT-P1**	**CT-P2**	**Upstream to Downstream**		**CT-P1**	**CT-P2**	**Upstream to Downstream**	
Events	**12**	**12**			**2**	**2**		
Analyte	**Median Concentration**		**Median Difference**	**Significant**	**Median Concentration**		**Median Difference**	**Significant**
NO_2+NO_3, μg/L	343	503	128	-	296	317	21	
NH_3-N, μg/L	30	33	-2	No	30	41	11	
TN, μg/L	1035	1,283	170	-	1237	1,585	349	
SRP, μg/L	6	4	-1	**Yes**	27	8	-18	N/A
TDP, μg/L	11	9	-2	**Yes**	43	19	-24	N/A
TP, μg/L	46	67	8	-	120	137	17	
TSS, mg/L	8	13	4	-	183	25	-158	N/A
VSS, mg/L	3	4	1	-	157	5	-152	N/A

N/A = unable to evaluate statistical significance for storm events in WY 2024 due to limited sample size.

Table 8. Pollutant Reduction Analysis, Perimeter Pond PRF, WY 2024.

Perimeter Pond	**Baseflow**				**Stormflow**			
Site	**CT-1**	**CT-2**	**Upstream to Downstream**		**CT-1**	**CT-2**	**Upstream to Downstream**	
Events (n)	**12**	**12**			**1**	**1**		

Analyte	Median Concentration		Median Difference	Significant	Median Concentration		Median Difference	Significant
NO_2+NO_3, µg/L	1380	1,280	-210	**Yes**	323	325	2	-
NH_3-N, µg/L	35	48	19	-	3	3	0	-
TN, µg/L	2270	2,125	-335	**Yes**	1830	1,670	-160	N/A
SRP, µg/L	6	5	-1	**Yes**	1	1	0	-
TDP, µg/L	16	13	-2	**Yes**	11	13	2	-
TP, µg/L	53	41	-10	**Yes**	165	115	-50	N/A
TSS, mg/L	16	10	-5	**Yes**	82	14	-68	N/A
VSS, mg/L	3	2	0	No	20	6	-14	N/A

N/A = unable to evaluate statistical significance for storm events in WY 2024 due to limited sample size.

Table 9. Pollutant Reduction Analysis, Cottonwood Treatment Train between the PRF ponds, WY 2024

Cottonwood Ck btwn Pnds	Baseflow				Stormflow 💧			
Site	**CT-P2**	**CT-1**	**Upstream to Downstream**		**CT-P2**	**CT-1**	**Upstream to Downstream**	
Events (n)	**12**	**12**			**8**	**8**		
Analyte	**Median Concentration**		**Median Difference**	**Significant**	**Median Concentration**		**Median Difference**	**Significant**
NO_2+NO_3, µg/L	503	1,380	966	-	245	323	78	-
NH_3-N, µg/L	33	35	6	-	79	3	-77	N/A
TN, µg/L	1283	2,270	1122	-	1460	1,830	370	-
SRP, µg/L	4	6	1	-	1	1	0	-
TDP, µg/L	9	16	4	-	10	11	1	-
TP, µg/L	67	53	-11	No	127	165	38	-
TSS, mg/L	13	16	-1	No	28	82	54	-
VSS, mg/L	4	3	-1	**Yes**	3	20	17	-

N/A = unable to evaluate statistical significance for storm events in WY 2024 due to limited sample size.

There have been multiple stream restoration projects completed on Cottonwood Creek between the Peoria and Perimeter Ponds. When evaluating the Cottonwood treatment train between the two ponds (N/A = unable to evaluate statistical significance for storm events in WY 2024 due to limited sample size.

Table 9), the concentrations downstream were similar or higher than upstream for most nutrients. Although median TP concentrations were lower downstream, this difference was not significant. A limitation of this analysis is that loading from Lone Tree Creek, which includes ACWWA's discharge, is not accounted for in the table. It may be useful to compare the downstream site to pre-restoration concentrations or to remove add an estimate for ACWWA's load into the analysis.

Table 10. Pollutant Reduction Analysis, McMurdo Gulch, WY 2024.

McMurdo Gulch	Baseflow			
Site	MCM-1	MCM-2	Upstream to Downstream	
Events	6	6		
Analyte	Median Concentration		Median Difference	Significant
NO_2+NO_3, µg/L	654	184	-449	**Yes**
NH_3-N, µg/L	37	3	-22	No
TN, µg/L,	1070	435	-581	**Yes**
SRP, µg/L	261	197	-73	**Yes**
TDP, µg/L	266	214	-50	**Yes**
TP, µg/L	393	234	-81	**Yes**
TSS, mg/L	4	1	0	No
VSS, mg/L	1	0	0	No

One of the upper tributaries of Cherry Creek is McMurdo Gulch, which has had multiple reclamation projects co-sponsored by the Town of Castle Rock and CCBWQA completed early in the area's urbanization to install a proactive PRF designed to protect the gulch and reduce sediment and nutrient loading into Cherry Creek. In addition, over the last few years, other improvements have been completed in various reaches of the same area to further stabilize the channel. Routine water quality samples were collected every other month only under baseflow conditions from monitoring site MCM-1, upstream of the stream reclamation project area, and MCM-2, downstream.

In WY 2024, all median nutrients and suspended solids concentrations were similar or lower downstream of the multiple phases of the McMurdo stream reclamation projects (Table 10) when compared to the upstream site. The median concentrations of TN and TP were significantly lower downstream in WY 2024, which is similar to the long-term trend observed over the last 10 years (section 3.5.1).

3.6 LONG-TERM PRF EVALUATION

The long-term PRF evaluation also examines the statistical significance of changes above and below PRFs and over time using the non-parametric Wilcoxon signed rank test to assess whether the downstream concentrations are significantly lower than upstream during the period evaluated. Activities such as implementation of CMs and maintenance (e.g., dredging and wetland harvesting) may affect results during various time periods. If more detailed analysis is required to evaluate projects, maintenance activities, or other changes in the watershed, specific evaluations can be completed using the PRF Statistics Tool available on the CCBWQA data portal (https://www.ccbwqportal.org/prf-statistics-tool).

Using this tool, an analysis of upstream to downstream concentrations over the last 10 water years (WY 2015-2024) was completed to assess changes (Δ) in median concentrations during baseflow and stormflow conditions. Tables 11 through 15 summarize the median upstream and downstream concentrations, the median difference of the paired data, and if the statistical analysis indicates that the median downstream concentrations are significantly lower than the upstream during the specified time-period. The concentrations that are lower are notated with a negative (-) and are highlighted in green. The statistical analysis is not completed if an increase in the median concentrations were observed.

Since there were minimal storm samples collected in WY 2024, the same trends that are often observed under storm flow, were not apparent in WY 2024 but the long term trends are still apparent. The Cottonwood Treatment Train as a whole (Table 11), Peoria Pond (Table 12) and Perimeter Pond (Table 13) all showed statistically significant reductions of TP and TSS during stormflow conditions over the last 10 years. Additionally, the Perimeter Pond PRF demonstrated statistically significant reductions in median TP, TN, and TSS concentrations in baseflow conditions during the last 10 years and WY2024. There was no significant difference in base or stormflow concentrations upstream to downstream between the two ponds from WY 2015-2024 (Table 11). As noted above this may be due to the nutrients added from WWTP discharges to Lone Tree Creek in this reach, which confounds interpretation of the benefits of stream restoration in this reach.

Table 11. Pollutant Reduction Analysis of Cottonwood Treatment Train (2015-2024).

Cottonwood Treatment Train	**Baseflow**				**Stormflow**			
Site	**CT-P1**	**CT-2**	**Upstream to Downstream**		**CT-P1**	**CT-2**	**Upstream to Downstream**	
Analyte	**Median Concentration**		**Median Difference**	**Significant**	**Median Concentration**		**Median Difference**	**Significant**
TN, µg/L	1140	1,920	750	-	1760	1,750	120	-
TP, µg/L	48	49	-1	No	201	84	-115	**Yes**
TSS, mg/L	11	10	-1	No	109	10	-90	**Yes**

Table 12. Pollutant Reduction Analysis of Peoria Pond (2015-2024).

Peoria Pond	**Baseflow**				**Stormflow**			
Site	**CT-P1**	**CT-P2**	**Upstream to Downstream**		**CT-P1**	**CT-P2**	**Upstream to Downstream**	
Analyte	**Median Concentration**		**Median Difference**	**Significant**	**Median Concentration**		**Median Difference**	**Significant**
TN, µg/L	1135	1,325	205	-	1560	1,700	24	-
TP, µg/L	47	52	0	-	189	127	-25	**Yes**
TSS, mg/L	11	12	1	-	107	22	-43	**Yes**

Table 13. Pollutant Reduction Analysis of Perimeter Pond (2015-2024).

Perimeter Pond	**Baseflow**				**Stormflow**			
Site	**CT-1**	**CT-2**	**Upstream to Downstream**		**CT-1**	**CT-2**	**Upstream to Downstream**	
Analyte	**Median Concentration**		**Median Net Change**	**Significant**	**Median Concentration**		**Median Net Change**	**Significant**
TN, µg/L	2183	1,913	-300	**Yes**	1880	1,818	-41	No
TP, µg/L	60	50	-8	**Yes**	175	92	-86	**Yes**
TSS, mg/L	18	10	-7	**Yes**	95	10	-68	**Yes**

Table 14. Pollutant Reduction Analysis of Cottonwood Creek Between Ponds (2015-2024).

Cottonwood Ck btwn Pnds	**Baseflow**	**Stormflow**

Site	CT-P1	CT-P2	Upstream to Downstream		CT-P1	CT-P2	Upstream to Downstream	
Analyte	Median Concentration		Median Net Change	Significant	Median Concentration		Median Net Change	Significant
TN, µg/L	1330	2,254	1074	-	1735	1,922	193	-
TP, µg/L	53	59	3	-	127	183	38	-
TSS, mg/L	12	17	5	-	22	95	51	-

For the McMurdo Gulch PRF during WY 2015-2024 (Table 15), the upstream to downstream concentrations of TP and TN during baseflow conditions demonstrated a statistically significant reduction. Statistically significant changes during baseflow conditions were not present for TSS; however, TSS concentrations were extremely low.

Table 15. Pollutant Reduction Analysis of McMurdo Gulch (2015-2024).

McMurdo Gulch	Baseflow			
Site	MCM-1	MCM-2	Upstream to Downstream	
Analyte	Median Concentration		Median Net Change	Significant
TN, µg/L	571	390	-179	**Yes**
TP, µg/L	334	253	-89	**Yes**
TSS, mg/L	2	3	1	-

3.7 GROUNDWATER

Groundwater in the Cherry Creek watershed is monitored to gain insight into interactions with surface water and the impacts of groundwater on the Reservoir. Although additional wells have been monitored historically, there are currently four active wells sampled twice a year in the spring and fall. The wells are located throughout the basin, including the top of the basin (MW-1), the middle of the basin (MW-5), and just upstream (MW-9) and downstream of the Reservoir (MW-Kennedy) (Figure 2) (Table 1).

GROUNDWATER WATER QUALITY

Groundwater is monitored for physical parameters such as temperature, pH, and dissolved oxygen and chemical composition including nutrients and dissolved solids.

PH

pH in the Cherry Creek Watershed tends to be relatively stable in groundwater, ranging between 6 and 8.5. The pH at MW-1 was slightly below the historical 15th percentile during Nov 2023 and May 2024. However, although there has been more variability in the pH of monitoring wells historically, the pH during both upstream to downstream monitoring events were within or near the 15th and 85th percentile baseline ranges (Figure 27).

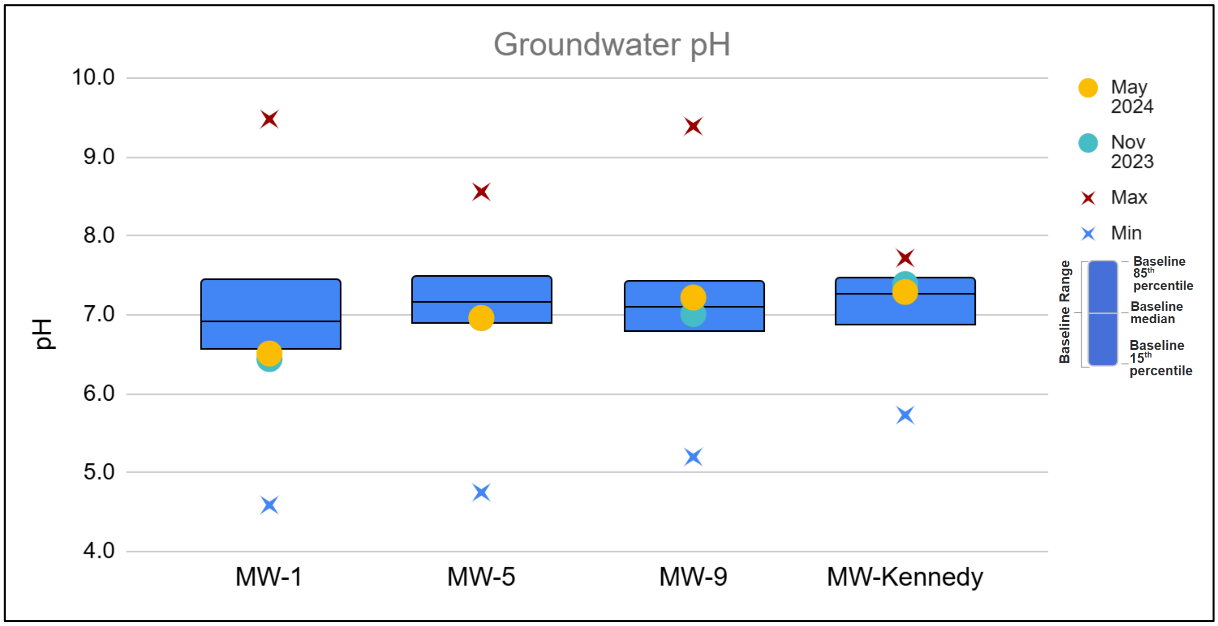


Figure 27. Median pH Groundwater Monitoring Wells

CONDUCTIVITY AND DISSOLVED SOLIDS

In addition to natural sources, conductivity in groundwater can be impacted due to interactions with surface water. Figure 28 shows the conductivity from the bi-annual monitoring events from WY 2024 along with POR summary statistics. All monitoring well results, with the exception of November MW-1, were higher than the 85th percentile POR value. A Mann Kendall trend analysis demonstrates that the increasing trend of the annual median conductivity of all monitoring wells upstream of the Reservoir as well as MW-Kennedy below the Reservoir is significant (Figure 29).

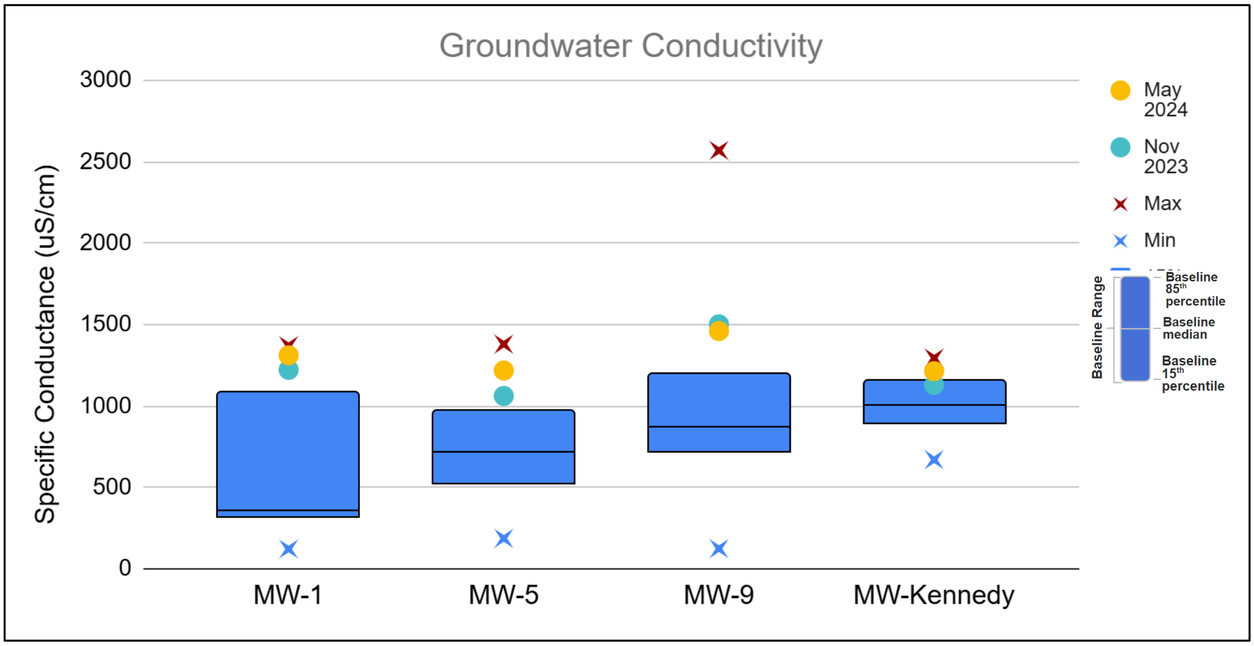


Figure 28. Groundwater Conductivity Summary Statistics and WY 2024 values (Nov 2023 and May 2024).

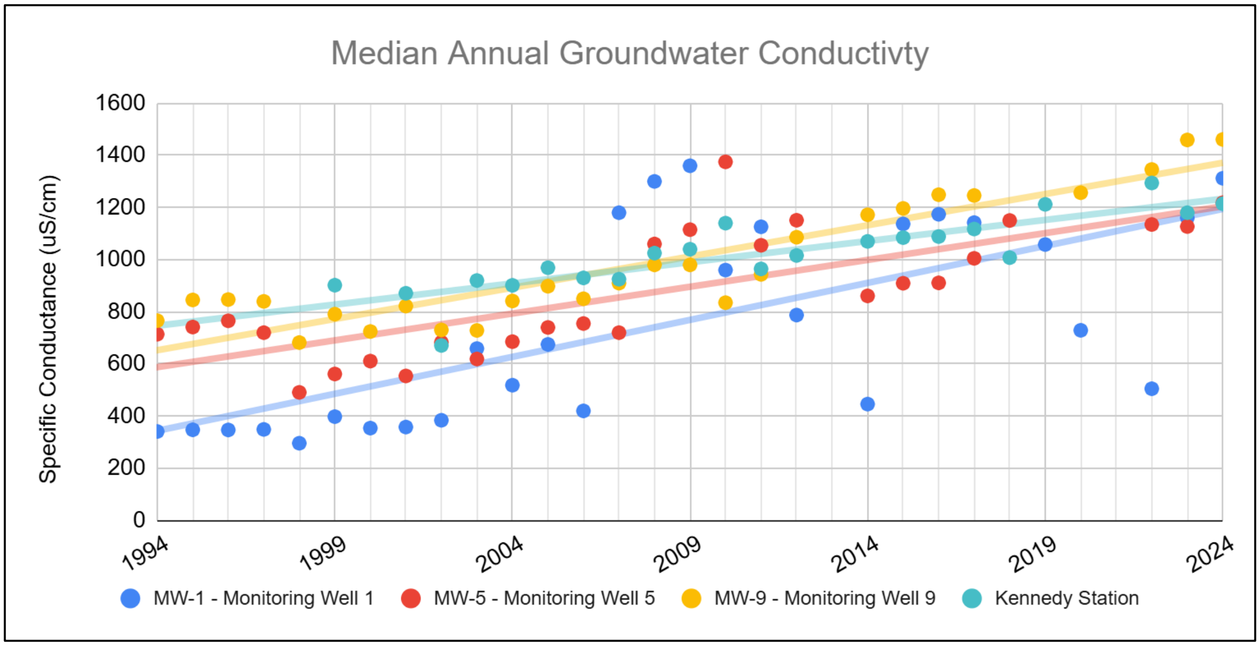


Figure 29. Historical Mean Conductivity in Groundwater Monitoring Wells

Two of the major dissolved solids components contributing to conductivity are chloride and sulfate. Chloride and sulfate concentrations from the monitoring wells are depicted in Figure 30 with the median from the two monitoring events in WY 2024. The WY 2024 median chloride concentrations were higher than the baseline median and above the 85th percentile for the POR. The WY 2024 median sulfate concentrations were above the baseline median at all sites and MW-9 was above the 85th percentile for the POR. Although these are not drinking water wells, the state water supply standard for both chloride and sulfate is 250 mg/L (5 CCR 1002-41.8). MW-9 approached but did not exceed this value in May 2024 with a concentration of 248 mg/L for sulfate.

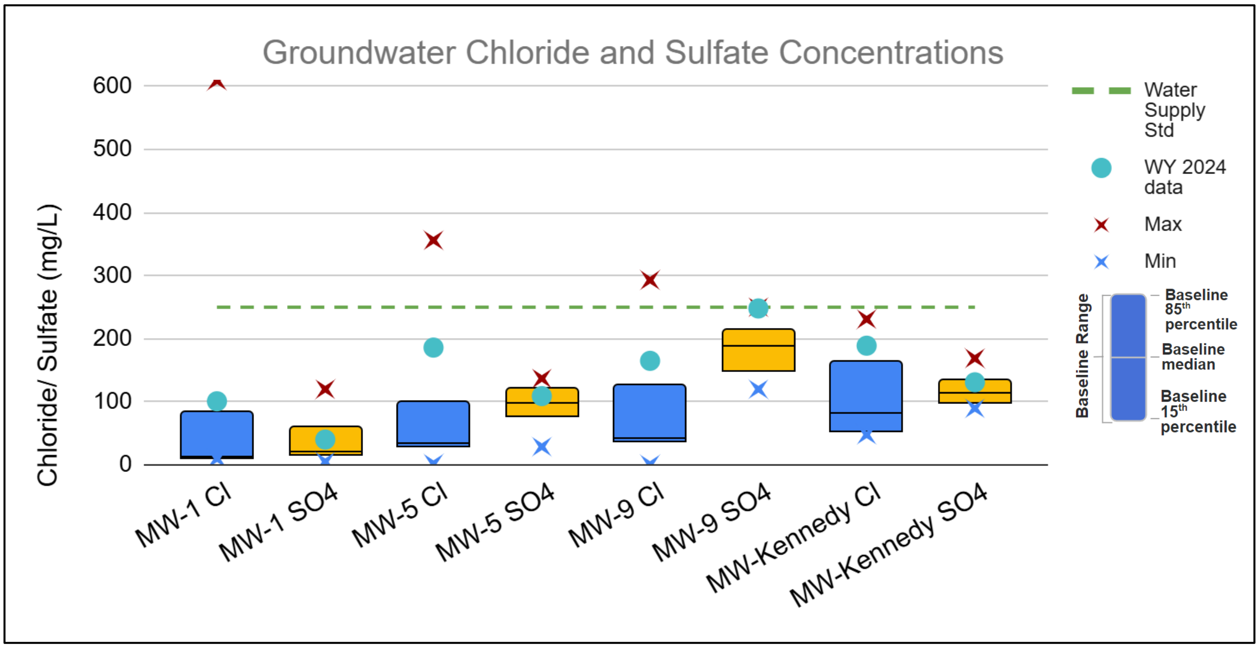


Figure 30. Groundwater Chloride and Sulfate Concentrations

PHOSPHORUS

Although total phosphorus is the form evaluated most frequently in surface water, total dissolved phosphorus (TDP) and soluble reactive phosphorus (SRP) concentrations are more useful to compare in groundwater. These forms also have a longer POR and provide more representative concentrations because manual bailing used to sample the wells can increase suspended solids containing particulate phosphorus that skew the results for TP.

Figure 31 and Figure 32 show the median groundwater TDP and SRP across all historically monitored wells, along with samples collected in November 2023 and May 2024. In both sampling events, TDP concentrations in the monitoring wells were generally lower than the long-term median, with the exception of MW-9 in November 2023 which exceeded the 85th percentile baseline value. SRP followed a similar trend, with most concentrations below or near the long-term median, with the exception of MW-9 which was elevated above the baseline 85th percentile value.

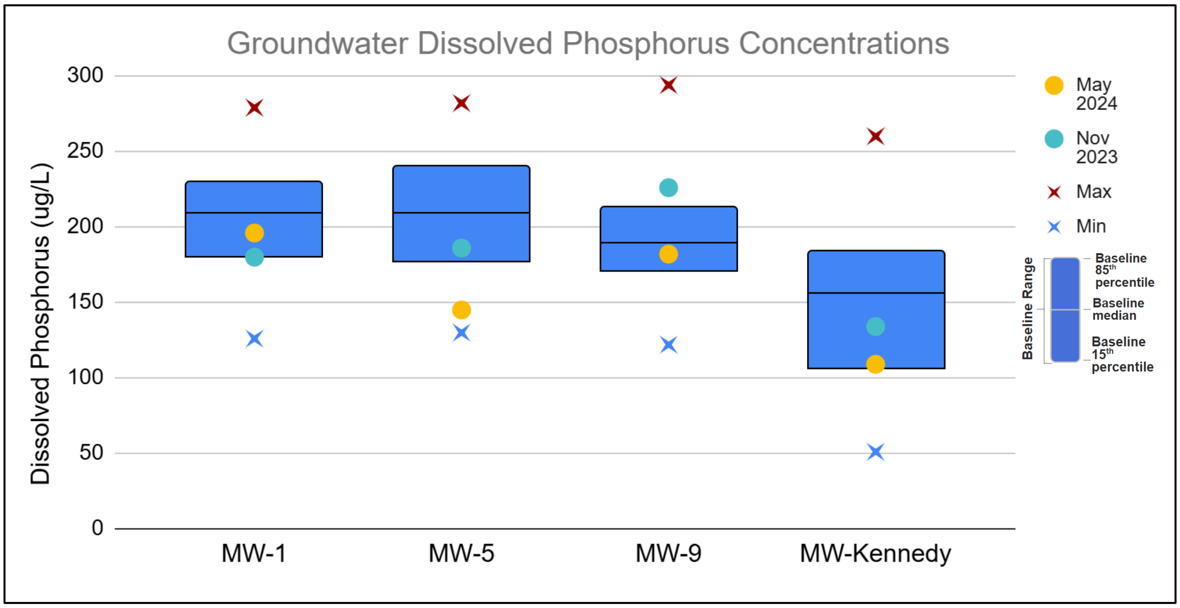


Figure 31. Groundwater Total Dissolved Phosphorus, POR Summary Statistics, and WY 2024 (Nov 23/May 24).

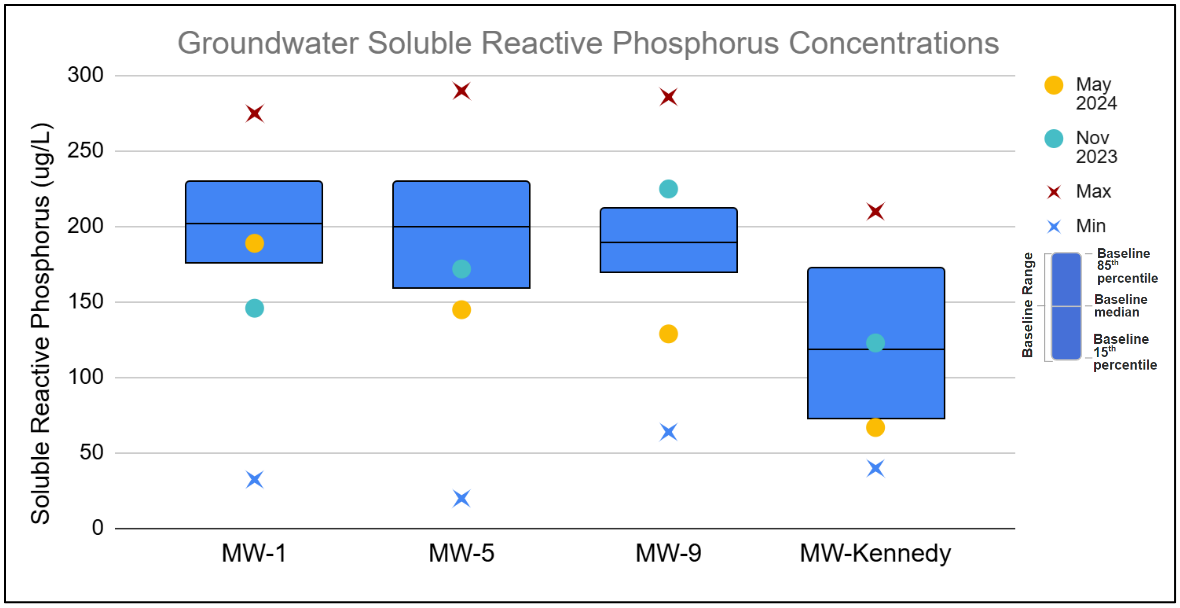


Figure 32. Groundwater Soluble Reactive Phosphorus, POR Summary Statistics, and WY 2024 (Nov 23/May 24)

On average, SRP makes up 86-88% of the TDP concentrations in MW-1 and MW-9 and 95% of the TDP concentration observed in MW-9 just upstream of the Reservoir. Table 16 includes the summary statistics for TDP concentrations for the POR and the median of the WY 2024 values.

Table 16. Groundwater Dissolved Phosphorus Concentrations (µg/L) Summary Statistics (1994-2024) and WY 2024 Median

Site	Site Abv.	Min	Baseline Median	Max	Count	WY 2024 median
MW-1 - Monitoring Well 1	MW-1	126	210	279	123	188
MW-5 - Monitoring Well 5	MW-5	130	210	282	122	166
MW-9 - Monitoring Well 9	MW-9	122	190	294	144	204
Kennedy Station	MW-Kennedy	51	156	260	43	122

Figure 33 depicts the annual mean TDP at the three monitoring wells upstream of the Reservoir. A Mann Kendall trend analysis demonstrates that there are statistically significant increases over time for TDP concentrations in the groundwater above the Reservoir (MW-9) (Figure 33), but not at the other two wells further upstream. However, it is notable that there is an obvious decrease in TDP concentrations observed since 2020.

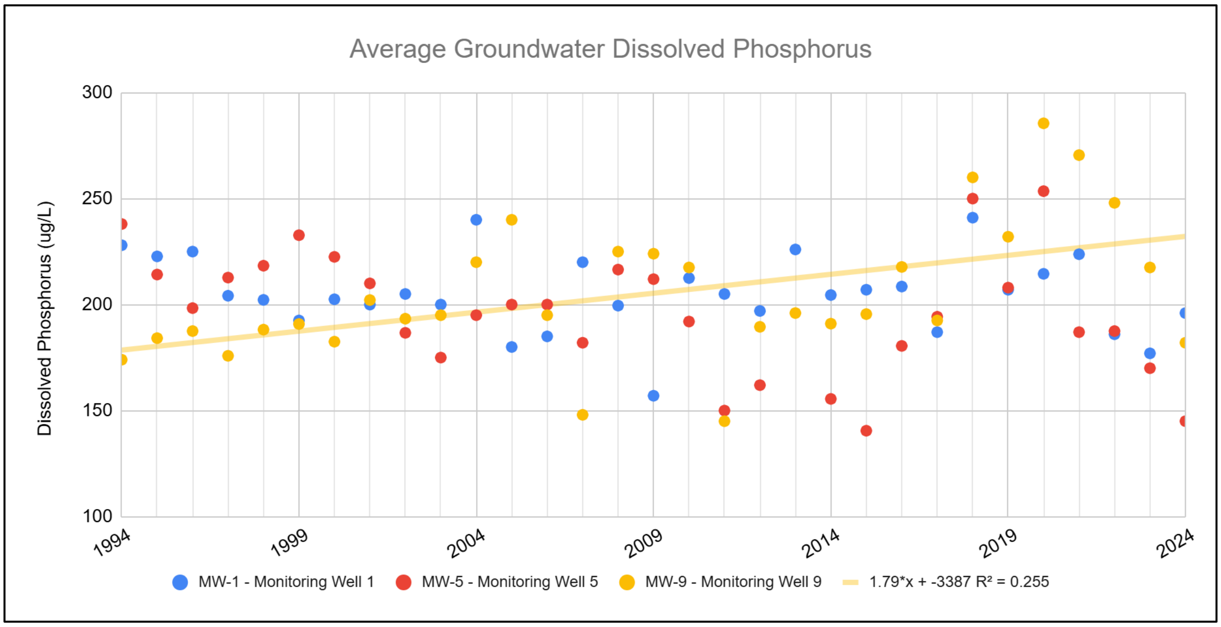


Figure 33. Annual Mean Dissolved Phosphorus in Groundwater Monitoring Wells Upstream of Cherry Creek Reservoir.

NITROGEN

Total Nitrogen (TN) in groundwater has been monitored since 2016 and Nitrate + Nitrite (NO_3+NO_2-N) since 2013. TN summary statistics for all the monitoring wells that have been monitored historically by CCBWQA in addition to the median concentrations from WY 2024 (November 2023 and May 2024) are depicted in Figure 34 and NO_3+NO_2-N is shown in Figure 35.

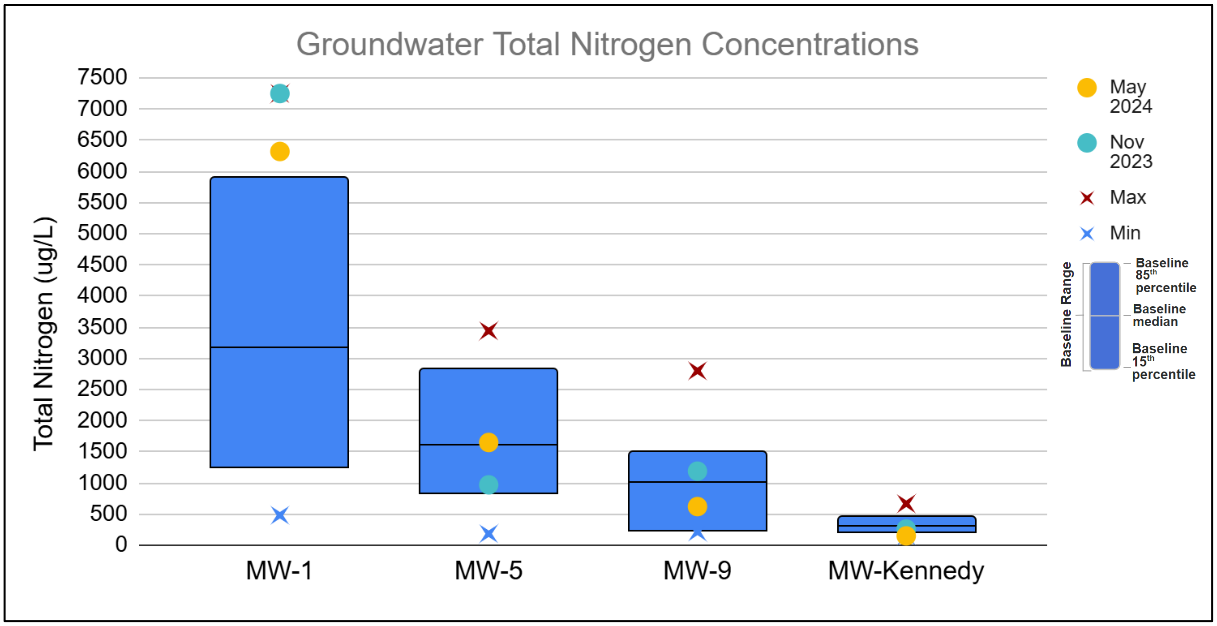


Figure 34. Groundwater Total Nitrogen Concentration Summary Statistics and WY 2024 values (Nov 2023 and May 2024).

Table 17 includes the summary statistics for TN concentrations for the POR and the median of the WY 2024 values. The median TN concentration at MW-1 in WY 2024 was above the 85th percentile and the concentration in November 2023 was the maximum that has been observed at that site since monitoring began in 2016.

Table 17. Groundwater Total Nitrogen Concentrations (µg/L) Summary Statistics (2016-2024) and WY 2024 Median.

Site	Site Abv.	Min	Baseline Median	Max	Count	WY 2024 median
MW-1 - Monitoring Well 1	MW-1	481	3195	7250	9	6785
MW-5 - Monitoring Well 5	MW-5	186	1640	3440	15	1310
MW-9 - Monitoring Well 9	MW-9	214	1020	2800	17	906
Kennedy Station	MW-Kennedy	151	334	666	17	206

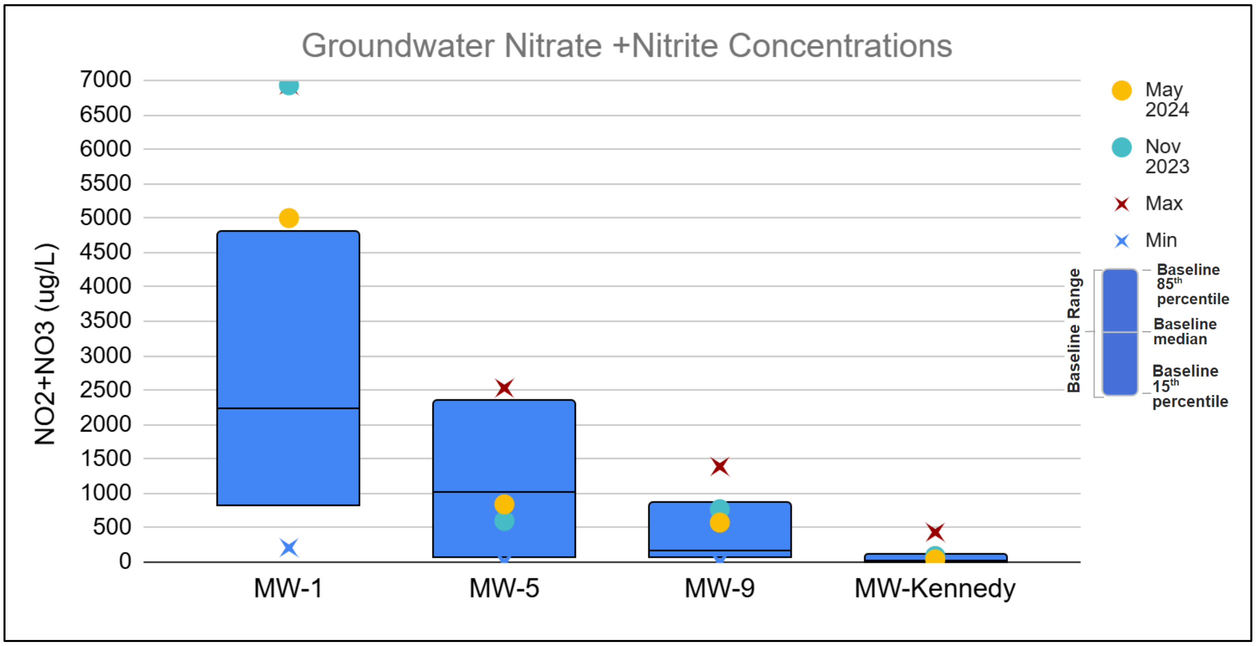


Figure 35. Groundwater Nitrate +Nitrite Concentration Summary Statistics (2013-2024), WY 2024 (November 2022 and May 2024).

The maximum and baseline median TN and NO2+NO3 concentrations decrease from upstream to downstream and below the Reservoir. The WY 2024 concentrations of TN and NO2+NO3 at MW-1 were higher than the baseline median and 85th percentile. The November concentration was the maximum observed at all sites. Ammonia has also been monitored in groundwater, but due to variability in detection limits and low concentrations, analysis is not as reliable.

4.0 RESERVOIR MONITORING RESULTS

Reservoir monitoring focuses on data collection to support regulatory requirements and maintaining the beneficial uses of aquatic life, recreation, water supply, and agriculture. The primary concerns are nutrients, including multiple species of phosphorus and nitrogen, and chl α.

Three sites in the Reservoir are included in the monitoring program: CCR-1, CCR-2, and CCR-3 (Figure 2). CCR-1, also called the “Dam site”, is located in the northwest area within the Reservoir. CCR-2, called the “Swim Beach site”, is located in the northeast area within the Reservoir nearest the swim beach and Reservoir outlet. CCR-3 is referred to as the “Inlet site” and corresponds to the south area within the Reservoir closer to where the streams enter the Reservoir.

Each site is sampled monthly though the year when ice-free conditions allow, and twice a month from May through September. Transparency, dissolved oxygen, temperature, and pH are included in the regular monitoring to support regulations protecting aquatic life and other beneficial uses.

Water quality samples are collected from the photic zone (0-3 m composite) at each site and from 4 m to the bottom at CCR-2. Physical parameters are measured at 1 m increments from the surface (0 m) to the bottom, which varied from 6.2 to almost 8 m during WY 2024. The depth profiles are also affected by the Reservoir elevation so some dates may have fewer values than others when water depth is lower at the monitoring locations.

In addition to the physical and chemical water quality monitoring, the analysis of reservoir plankton concentrations also helps determine the overall health of Cherry Creek Reservoir, the potential for environmental risks, and impacts on water quality. Plankton growth trends and population diversity through the seasons are analyzed through monthly sample collection throughout the year and twice a month through the summer months. Identification and enumeration are completed on all samples with biovolumes calculated on all phytoplankton samples and biomass calculated on all zooplankton samples.

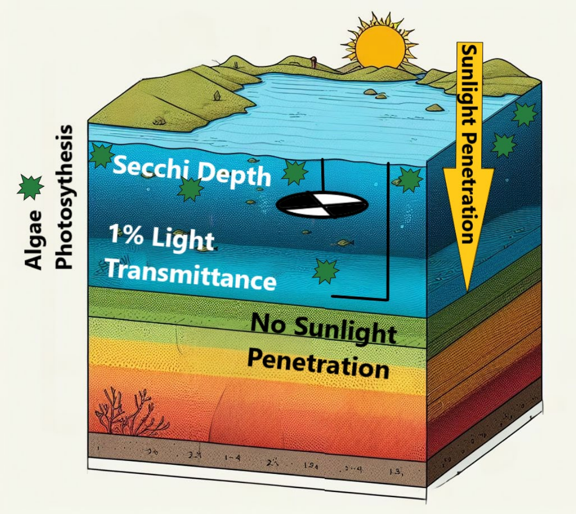
4.1 USACE RESERVOIR GATE EXERCISE ACTIVITY

The USACE completes an annual gate operation activity at the outlet of Cherry Creek Reservoir in late May to verify the proper operation of the outlet gates (Table 18, Seefus, 2024). It is assumed that this flushing exercise may release some of the nutrient-rich water and sediments from the bottom of the Reservoir which is the same assumption as the pilot study of the Sustainable Rivers Program that was completed in 2024.

Table 18. USACE Gate Exercise Activity.

9:00	Gate 3 release 150 cfs for 30 minutes.
9:30	Gate 3 release 1300 cfs for 10 minutes.
9:40	Gate 3 release 150 cfs for 40 minutes.
10:20	Gate 3 closed, 0 cfs.
10:25	Gate 1 release 1300 cfs for 10 minutes.
10:35	Gate 1 release 150 cfs for 40 minutes.
11:15	Gate 1 closed, 0 cfs.
11:20	Gate 2 release 1300 cfs for 10 minutes.
11:30	Gate 2 release 150 cfs for 40 minutes.
12:10	Gate 2 closed, 0 cfs.
12:15	Gate 4 release 1300 cfs for 10 minutes.
12:25	Gate 4 release 150 cfs for 40 minutes.
13:05	Gate 4 closed, 0 cfs.
13:10	Gate 5 release 1300 cfs for 10 minutes
13:20	Gate 5 release 150 cfs for 40 minutes
14:00	Gate 5 closed, 0 cfs.

4.2 TRANSPARENCY



Water transparency, characterized by Secchi depth, is used as an indicator for lake and reservoir water quality because primary productivity (algae) and turbidity of the water column reduce the depth at which light can penetrate. In addition, the photic zone, characterized by 1% Light Transmittance, is a measure of the depth at which light can penetrate the water column and algae can complete photosynthesis. Both Secchi depth and the 99% light attenuation (1% Light Transmission) were measured at all three Reservoir sites during each monitoring event

Figure 36 illustrates the WY 2024 median Secchi depths along with the 1992 to 2024 POR summary statistics for each Reservoir site. The Secchi depths are similar between the three Reservoir sites, and the WY 2024 median Secchi depth measurements were similar to the baseline medians. The Secchi Depth values in the Reservoir represent low transparency and eutrophic conditions that are similar to the median baseline conditions.

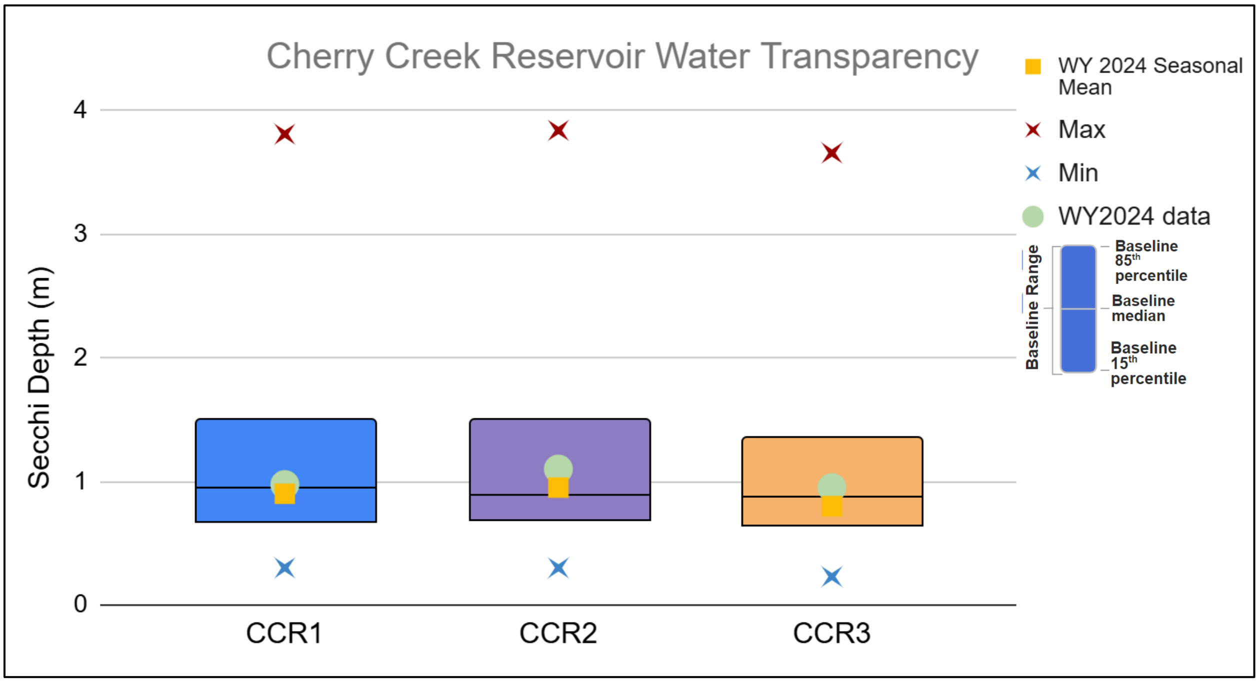


Figure 36. Cherry Creek Reservoir Water Transparency, Secchi Depth Summary Statistics and WY 2024 values.

Figure 37 shows monthly WY 2024 medians along with POR summary statistics. For the most part, the Secchi depth followed a similar seasonal pattern when compared to the historical monthly values. The Secchi depths were highest and above the baseline medians in May, June, and July 2024. Although the weather in WY2024 was average, high precipitation years with frequent storm events increase inflows to the reservoir, reduce water temperature, and likely assist with mixing, all of which reduce the potential for algae growth and increase water transparency. In addition, cloud cover responsible for reduced sunlight also limits the productivity of algae, which is the main factor reducing transparency in the Reservoir.

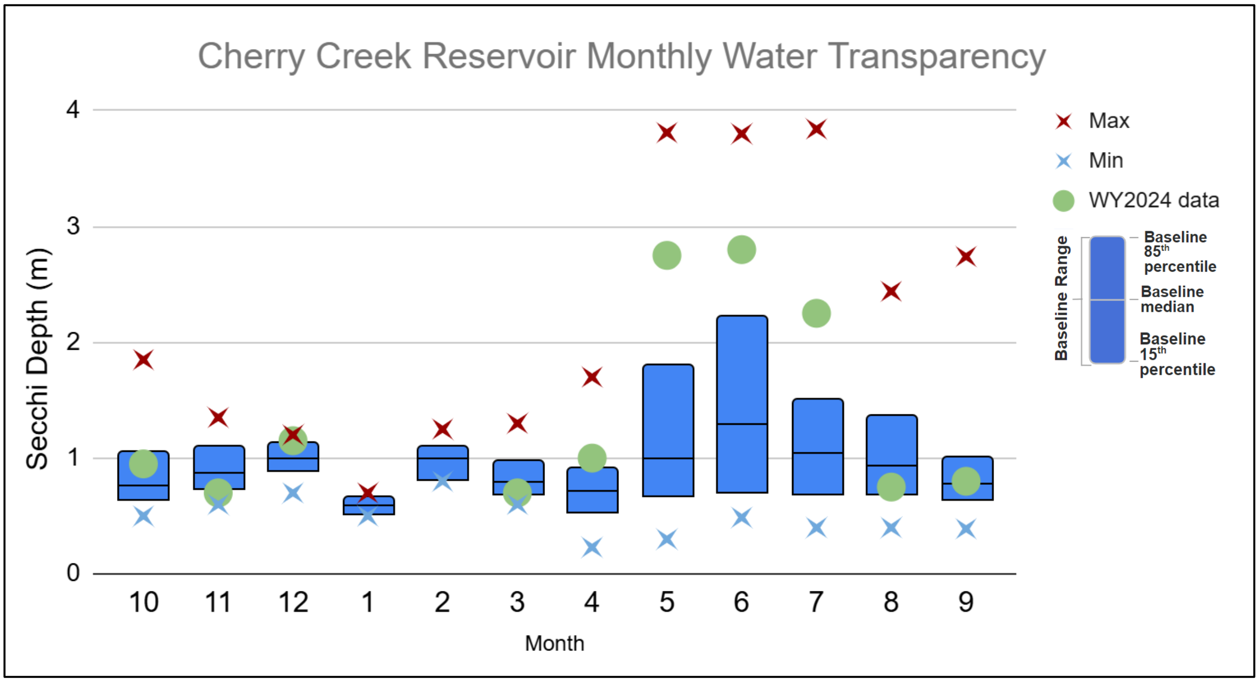


Figure 37. Monthly Medan Secchi Depth in Cherry Creek Reservoir from 1992-2022, Summary Statistics and WY 2024 values.

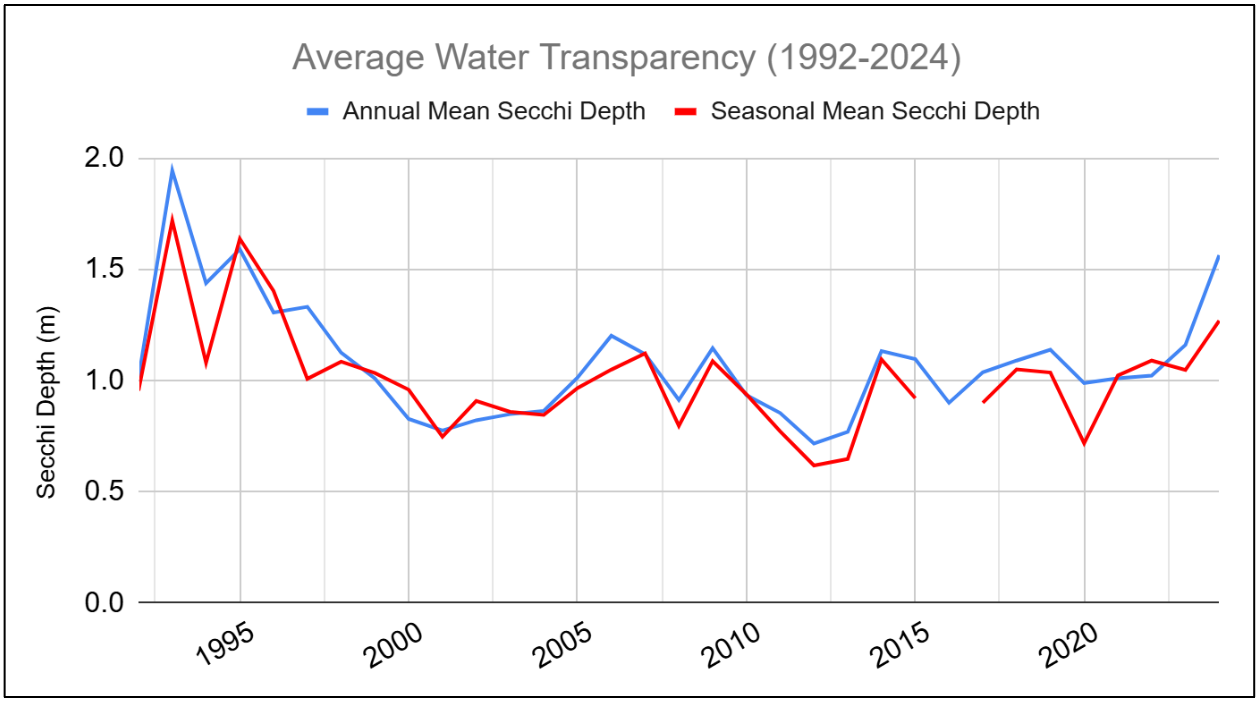


Figure 38. Annual and Seasonal Mean of Secchi Depth in Cherry Creek Reservoir from 1992-2024.

Figure 38 shows the historical annual and seasonal (July through September) mean Secchi depths for Cherry Creek Reservoir. From approximately 1998 to present, the annual mean Secchi depth has been in the eutrophic range, with all annual means less than 2 meters (See section 4.15). There are no significant increases or decreases over time in either annual or seasonal measurements.

The depth of 1% light transmittance is considered the photic zone, or the depth at which photosynthesis can occur; below that depth, primary productivity would be light limited. Like the Secchi depth measurements, the highest measurements of 1% light transmittance were observed in early spring and summer, decreasing through September (Figure 39). There is a clear relationship between the photic zone and water transparency; 1% light transmittance averages around three times the Secchi depth.

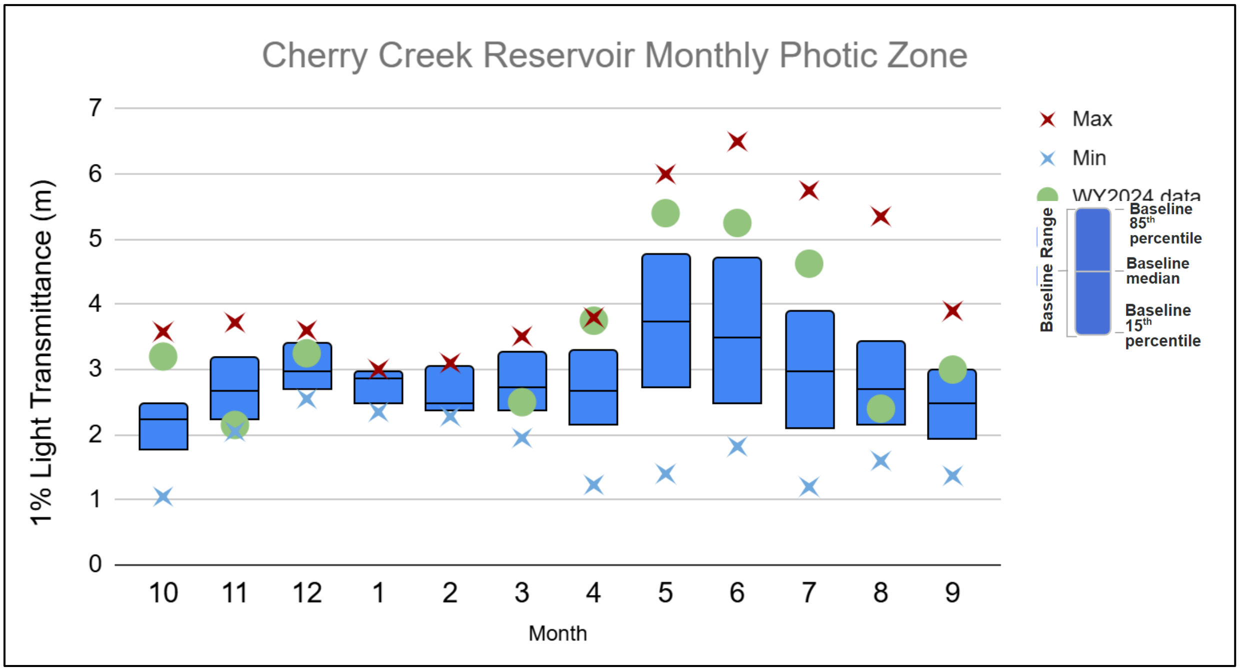


Figure 39. Cherry Creek Reservoir Monthly Photic Zone, Depth of 1% Light Transmittance Summary Statistics and WY 2024 median depths.

4.3 CHLOROPHYLL A

Cherry Creek Reservoir has a seasonal (July through September) chl α standard of 18 µg/L as set by WQCC Reg 38. During each sampling event in WY 2024, chl α levels were measured from composite samples collected from 0, 1, 2, and 3 meters below the surface at all three monitoring sites in the Reservoir. In WY 2024, no data were collected in January and February of 2024 due to ice on the Reservoir, which is normal.

Figure 40 displays the chl α concentration summary statistics for 1992-2024 and the WY 2024 median values. The WY 2024 medians are similar to the baseline medians. Figure 41 illustrates the monthly chl α for WY 2024 concentrations along with POR summary statistics. The WY 2024 seasonal chl α mean was 16.4 µg/L, which meets the Reg 38 standard of 18 µg/L (Figure 42). The standard only allows an exceedance frequency of once in five years; four of the last five (4/5) and seven of the last ten (7/10) years have exceeded this value. This means that the Reservoir is not meeting the chl α water quality standard, even though the numeric limit was met for WY 2024. For additional context, it is noteworthy that 6 of the last 10 years seasonal chl α concentrations were close to CDPHE's proposed standard of 20 µg/L for warm water lakes (even though this standard does not apply for the Reservoir).

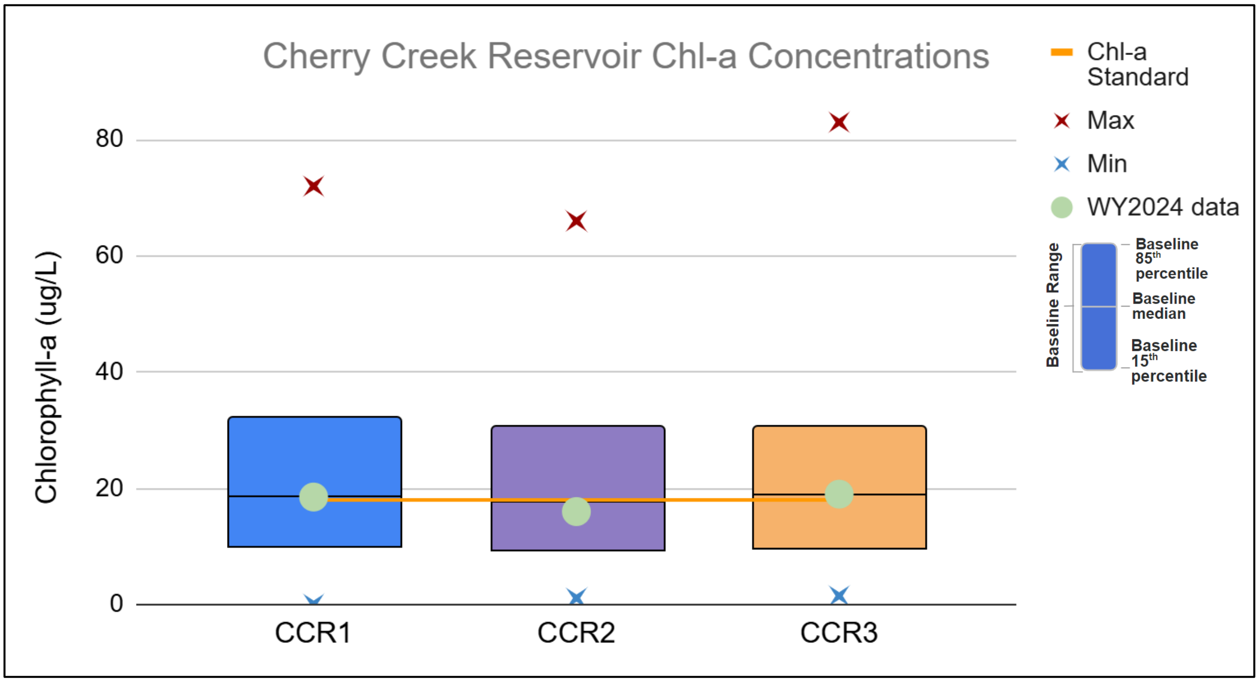


Figure 40. Cherry Creek Reservoir Chlorophyll α Concentrations, POR Summary Statistics and WY 2024 data.

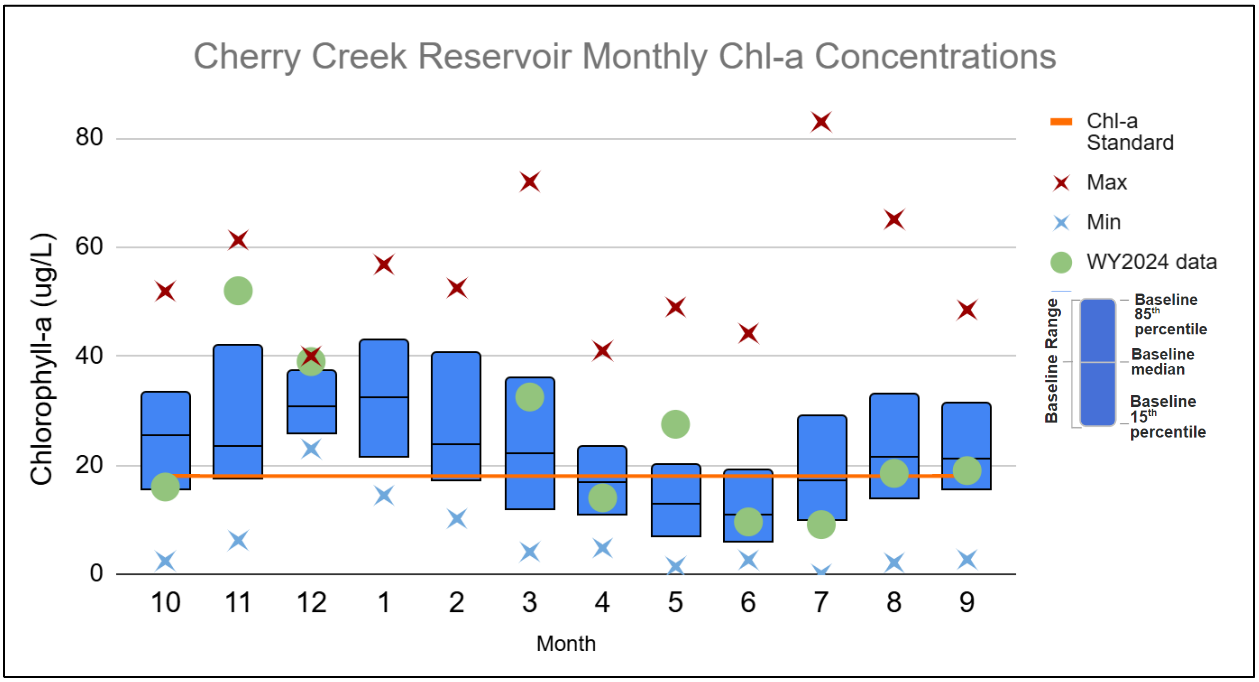


Figure 41. Monthly Median Chlorophyll α Concentrations in Cherry Creek Reservoir from 1992-2022, Summary Statistics and WY 2024 values.

The highest WY 2024 monthly median chl α concentrations were collected during the monitoring events in November and March and the lowest were observed in May, June, and July (Figure 41). The low chl α values coincided with the highest water transparency in the Reservoir. However, as soon as the weather started to warm and the heavy precipitation from spring and early summer stopped, algae concentrations increased.

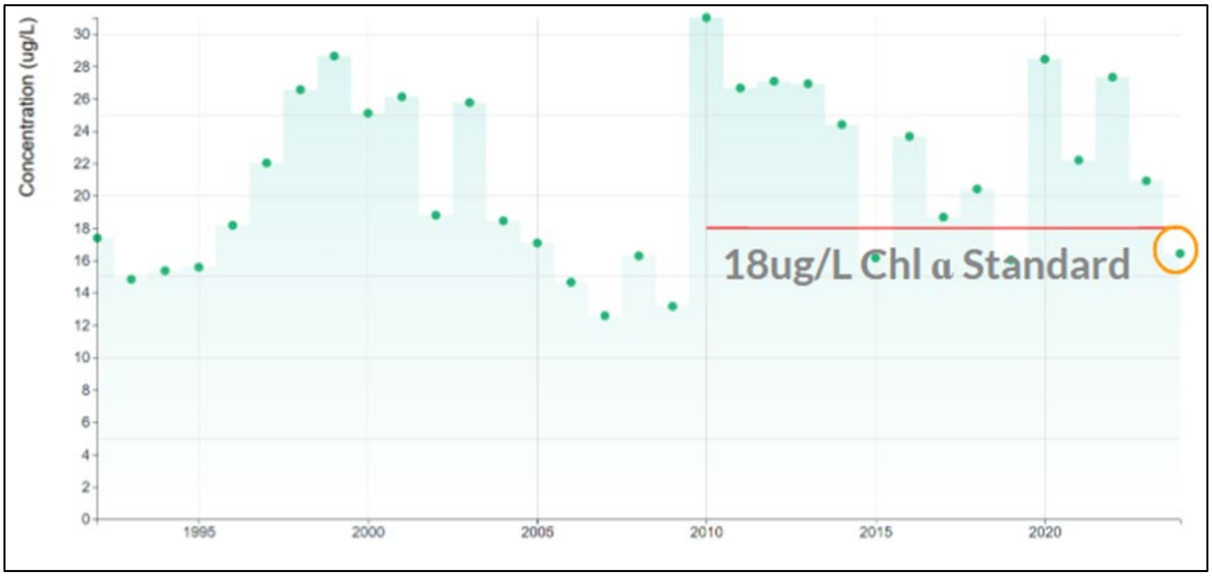


Figure 42. Seasonal Mean Chlorophyll *a* in Cherry Creek Reservoir WY 1991-2024.

Translating the impacts of chl α concentrations on water quality into terms that are meaningful to most recreational lake users is a complex task. Walmsley and Butty (1979) proposed some typical relationships between maximum chl α concentrations and observed impacts (Table 19) to describe perceptions of water quality by typical lake users.

Table 19. Impact of Chlorophyll *a* Concentrations on Perceived Water Quality

Chlorophyll *a* Concentration	Nuisance Value
0 to 10 µg/L	No problems evident
10 to 20 µg/L	Some algal scums evident
20 to 30 µg/L	Nuisance conditions encountered
Greater than 30 µg/L	Severe nuisance conditions encountered

The chl α concentrations in Cherry Creek Reservoir indicate that some algal scums to severe nuisance conditions are present throughout the year (Figure 41). When algal scums are evident, Colorado Parks and Wildlife monitors and tests for potential cyanobacteria toxins at multiple public areas.

On July 16th, a cyanobacteria bloom was observed and concentrations of toxin were detected at 36-40 ug/L above the recreational threshold for closure of 8 µg/L. Signs were posted in the area to inform the public and the Reservoir was closed to contact. Ongoing monitoring detected that the toxin had decreased to ~5 µg/L by July 23rd and the closure was lifted.

The pattern of short-duration cyanobacteria blooms is common for Cherry Creek Reservoir. There are many factors that drive and disrupt the blooms. Informing the public with appropriate signage in impacted areas is helpful to reduce risks associated with toxin.

4.4 TEMPERATURE

The Warm Water Aquatic Life classification for Cherry Creek Reservoir in Reg 38 has a chronic Maximum Weekly Average Temperature (MWAT) standard of 26.2˚C (79.2 ºF) and an acute Daily Maximum (DM) standard of 29.3˚C (84.6 ºF). Both of these standards were met in Cherry Creek Reservoir in WY 2024.

Continuous temperature monitoring is completed annually near site CCR-2 in Cherry Creek Reservoir. The temperature loggers are placed in even increments from one (1) meter of depth to the bottom of the Reservoir and are mounted on a marker buoy.

Temperature profiles were also collected during each monitoring event. Figure 43 illustrates the temperature profiles collected at Reservoir station CCR-2 during the routine monitoring events in WY 2024.

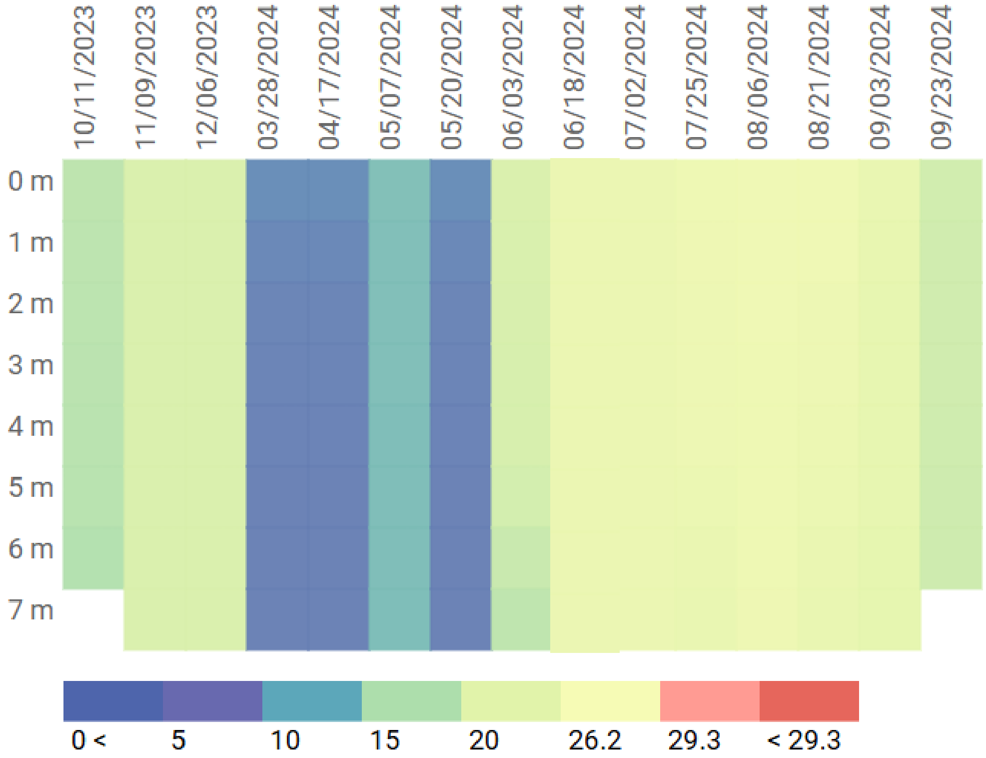


Figure 43. Temperature (˚C) Profile at CCR-2, Cherry Creek Reservoir, WY 2024.

Cherry Creek Reservoir did not exceed the MWAT or DM standards in WY 2024 and therefore was in attainment of the temperature standards. The maximum temperature measured at the surface during the Reservoir monitoring events was 24.3 ˚C at CCR-3 on Aug 21, 2024. On that same date, the temperature was 23.9 ˚C at CCR-2 and 24.0 ˚C at CCR-1. The maximum temperature recorded on the continuous loggers was 24.9 ˚C on August 2nd (Figure 44). The biggest temperature range measured in the vertical profiles during the monitoring events was 2.7˚C on June 3, 2024 (Figure 43).

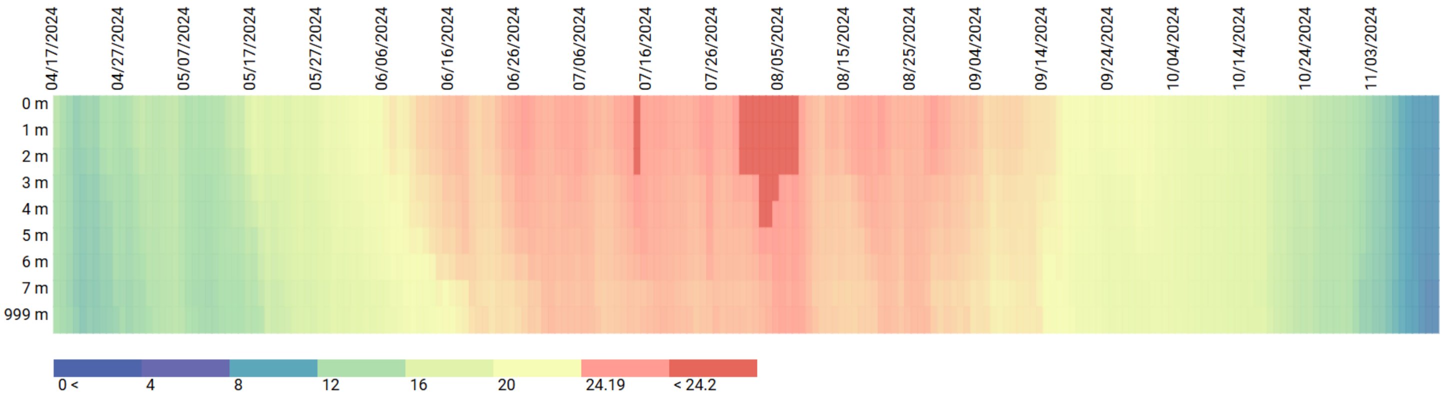
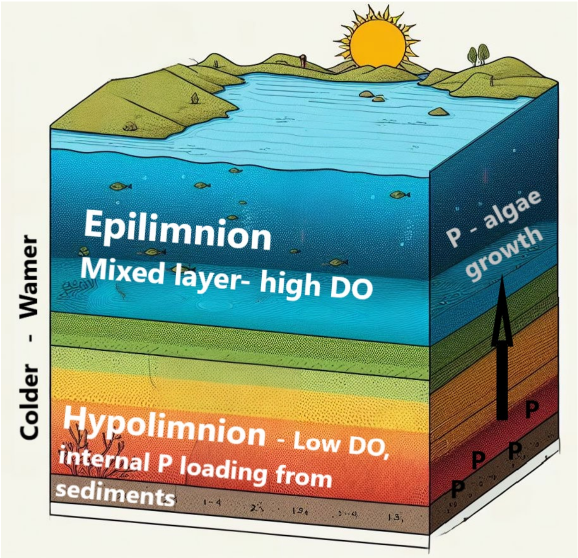


Figure 44. Daily Temperature Profile (˚C) on monitoring buoy, Cherry Creek Reservoir, WY 2024

Although Cherry Creek Reservoir has a destratification system, some of the characteristics of seasonal and mid-season turnover, or mixing events, still occur. However, it is difficult to determine the main turnover events since the Reservoir is considered to be polymictic, or able to mix multiple times a season. There was some variability in temperature from the surface to the bottom, which was much more apparent during the warmer summer months of July and August, but during the rest of the year thermal stratification was limited in the Reservoir. Thermal stratification can lead to anoxic bottom conditions that result in release of nutrients from sediments.

4.5 DISSOLVED OXYGEN

Reg 38 assigns a minimum chronic dissolved oxygen standard of 5.0 mg/L to the Reservoir. The standard requires DO to be at least 5.0 mg/L in the upper portion of a lake or reservoir and that if DO is below 5.0 mg/L, adequate refuge for aquatic life (with DO above 5.0 mg/L) needs to be available at other depths or locations in the Reservoir during the same time period. DO concentrations are measured at 1 m depth intervals throughout the water column during each monitoring event at each site. Cherry Creek Reservoir met the DO standard in WY 2024.



The epilimnion of a lake or reservoir is the mixed layer near the surface. This is the layer in which most photosynthesis occurs because of its higher relative temperature and sunlight penetration. Aquatic macrophytes or rooted plants grow in the littoral (near shore) zone, but most phytoplankton exist in the epilimnion layer. The hypolimnion, or bottom layer, is cooler and denser than the layers above. This layer is where suspended materials, dead algae and other aquatic organisms and plants settle to the bottom to decompose. During the decomposition process, bacterial oxygen consumption exceeds the concentrations in the water, so the DO levels decline. These anoxic conditions at the bottom of the Reservoir in the hypolimnion lead to internal loading of phosphorus from the sediments. When the reservoir mixes, either seasonally or due to high inflows or wind, these high phosphorus concentrations reach the epilimnion where warmer conditions and sunlight penetration drives algae growth.

The reservoir destratification system (RDS) at Cherry Creek Reservoir, which pumps air to the bottom of the reservoir through diffusers, helps to mix the water column and is most effective in the spring and fall when there is less thermal stratification.

Figure 45 illustrates the DO concentrations from the surface (0 m) to the bottom in the Reservoir at station CCR-2 during WY 2024. The profiles from the other two sites (CCR-1 and CCR-3) are available on the data portal. DO concentrations below 5.0 mg/L at or near the bottom of the Reservoir during the warm summer months are likely due to high microbial activity or decomposition in the hypolimnion and sediments that reduce DO concentrations. During these periods of low DO in the bottom of the Reservoir, internal loading of phosphorus from the sediments is likely. The internal loading patterns are affected by the thermal stratification of the water column.

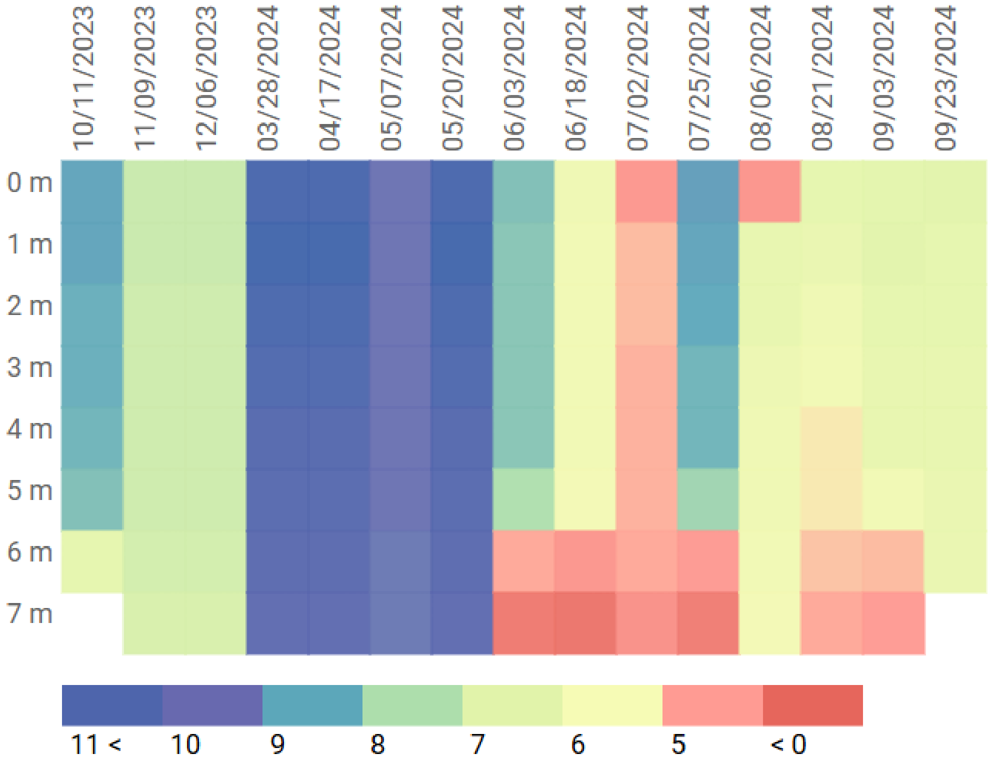


Figure 45. Dissolved Oxygen (mg/L) Profile at CCR-2, Cherry Creek Reservoir, WY 2024.

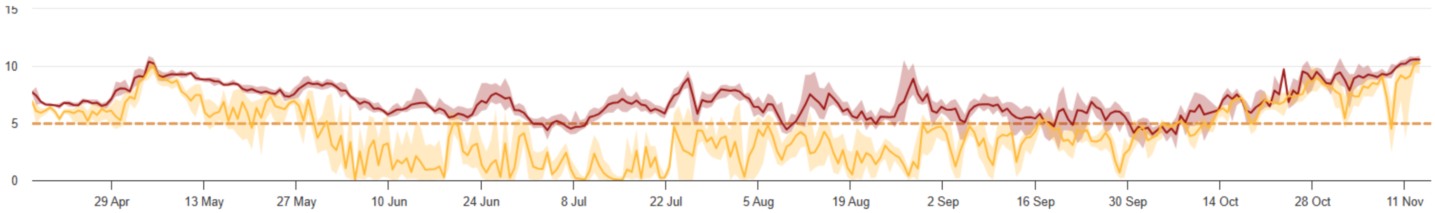


Figure 46. Continuous Dissolved Oxygen (mg/L), Cherry Creek Reservoir, WY 2024. Top (red) Bottom (yellow)

Figure 46 depicts the DO data collected on the real-time monitoring buoy at the surface and the bottom of the Reservoir. This additional monitoring allows a detailed analysis of periods of hypoxia or periods when the hypolimnion has dissolved oxygen concentrations below 2mg/L. The logger at the monitoring buoy site recorded 43 days of hypoxia at the bottom of the Reservoir indicating that these periods were likely responsible for internal loading of phosphorus that can be mixed into the water column by wind and possibly to some extent by the destratification system.

4.6 PH

Reg 38 assigns a pH standard for Cherry Creek Reservoir based on the acceptable pH range of 6.5 to 9.0 for protection of aquatic life.

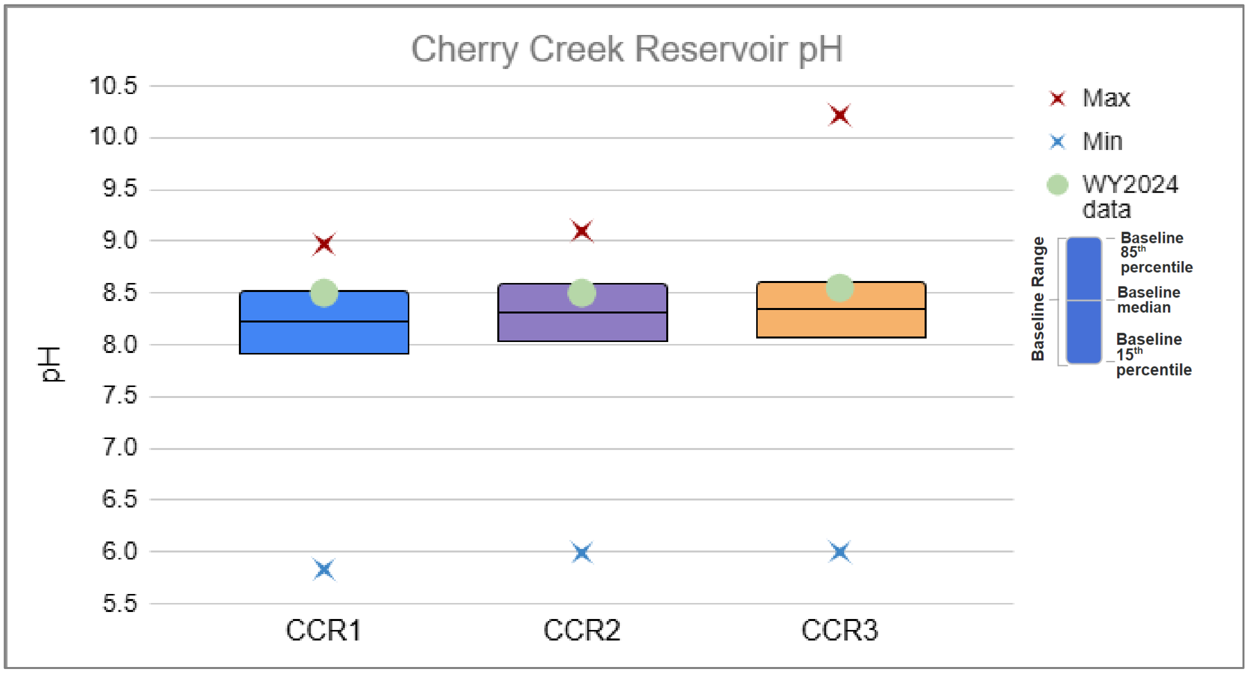


Figure 47. Cherry Creek Reservoir pH, Summary Statistics and WY 2024 medians.

Assessment of pH data is based on comparison of the 15th percentile of the data to a lower pH limit of 6.5 and comparison of the 85th percentile of the data to an upper pH limit of 9.0. Cherry Creek Reservoir attained the pH standard in WY 2024 although median values were above the baseline medians at each site (Figure 47).

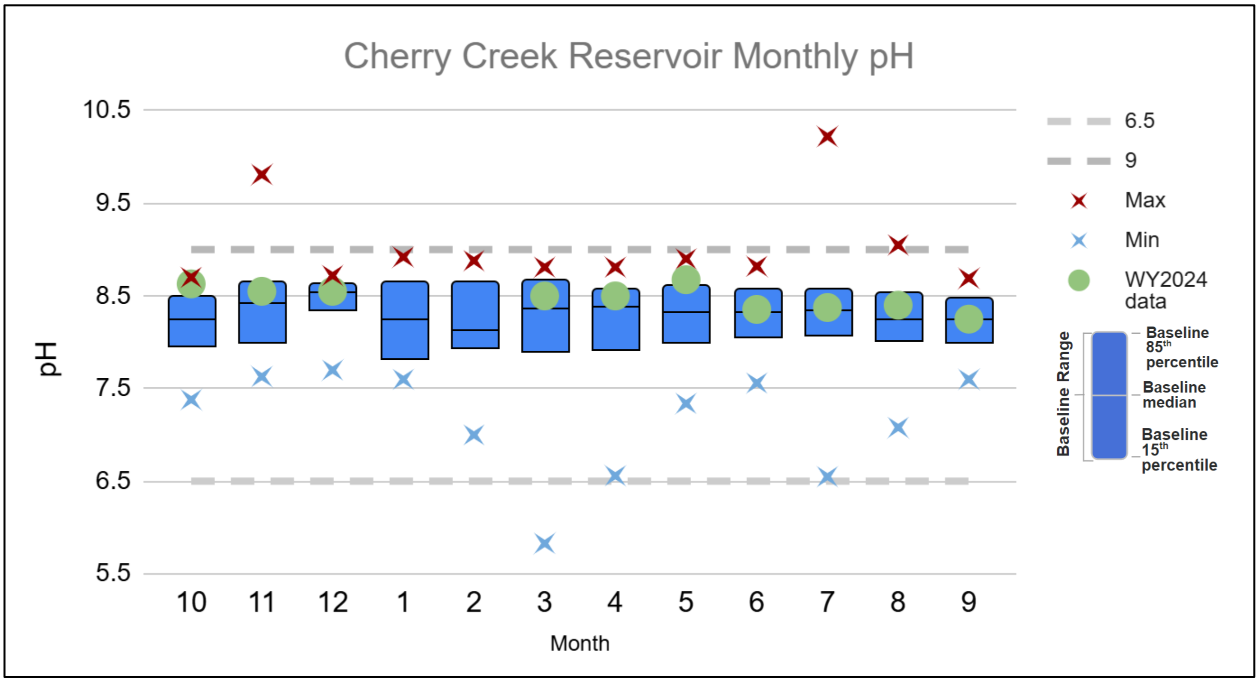


Figure 48. Cherry Creek Reservoir WY2024 Monthly Median pH.

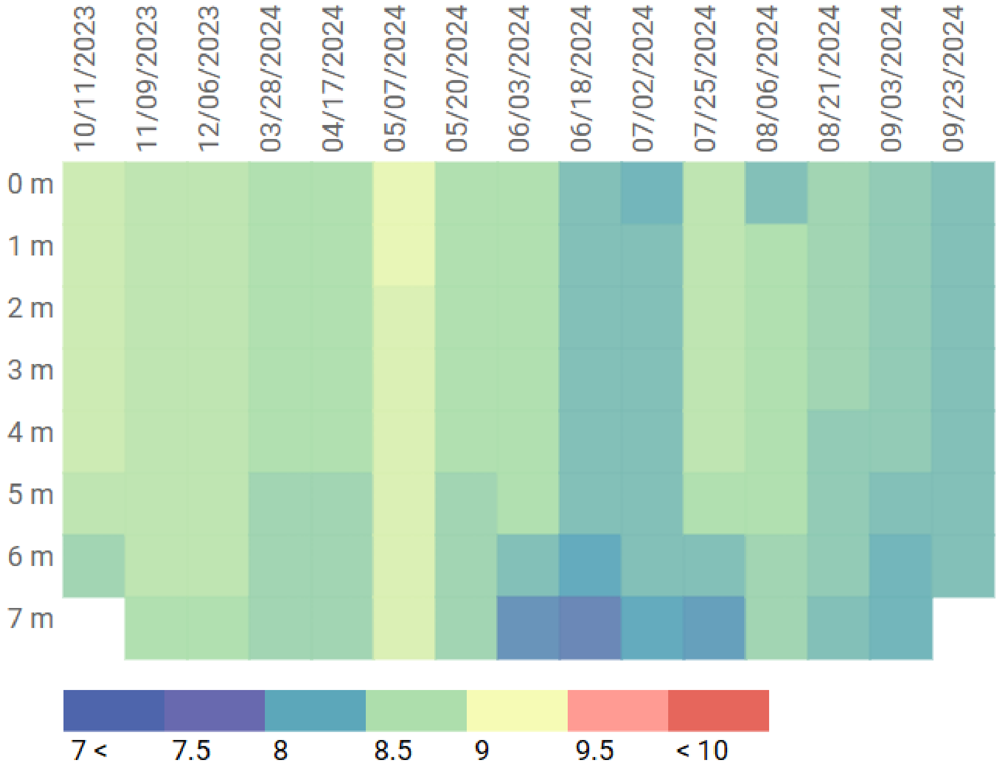


Figure 49. pH Depth Profile from CCR-2, Cherry Creek Reservoir, WY 2024.

The monthly median pH in WY 2024 was above the baseline median with the exception of July (Figure 48). Figure 49 illustrates the pH depth profile for CCR-2. Profiles for the other two Reservoir sites are available on the data portal. The lowest pH values were recorded during late June and early July, and again in late September. During increased algal productivity, the pH values observed were higher, but never exceeded 9.0. Lower pH values were present at or near the bottom of the Reservoir, which is typical.

Higher pH values are usually correlated with higher productivity and elevated chl α concentrations in the Reservoir. This occurs because photosynthesis removes carbon dioxide, a weak acid, from the water column. For example, the highest chl α concentration measured at CCR-2 in WY 2024 was 46 µg/L on May 7th, which coincided with a surface pH of 8.9 on the same date.

4.7 OXIDATION REDUCTION POTENTIAL

Figure 50 shows the Oxidation Reduction Potential (ORP) WY 2024 monitoring values from CCR-2. Higher ORP values indicate an oxidative state and increased potential to break down organic material, whereas low and negative values indicate a reducing environment.

During WY 2024, the ORP in the photic zone was lowest in November and December. In late July, the ORP at the bottom of the of the Reservoir was low, almost one third of the surface. Lower ORP values indicate a reducing environment at the bottom of the Reservoir, which usually coincides with lower DO and lower pH measurements. These lower values are an indication of decomposition processes in the sediments and the sediment-water interface, as well as seasonal trends normally seen in the Reservoir. Higher ORP values, indicating an oxidizing environment, were present during periods with higher DO levels and colder water temperatures.

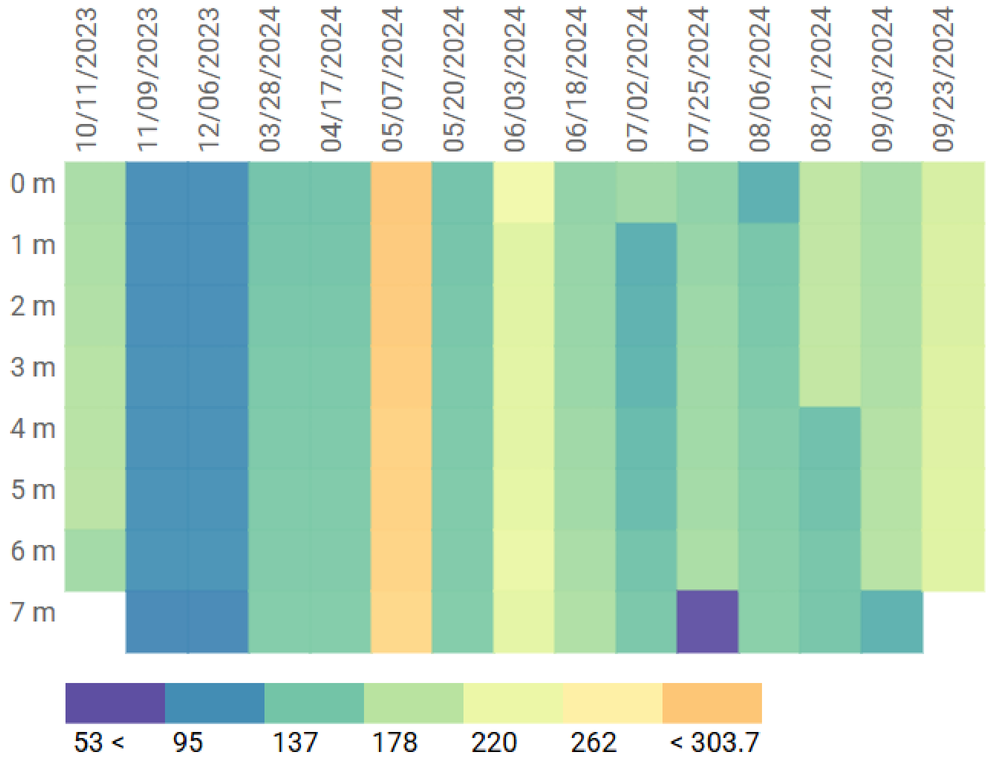


Figure 50. Oxidation Reduction Potential (mV) Depth Profile, CCR-2, Cherry Creek Reservoir, WY 2024.

4.8 CONDUCTIVITY

Specific conductance, or conductivity, is a representation of dissolved solids (e.g., salts, minerals) in Cherry Creek Reservoir. Figure 51 shows the annual median specific conductance WY 2024 values along with the POR statistics for the Reservoir monitoring sites compared to the EPA benchmark for streams. During WY 2024, the monthly conductivity (Figure 52) was below the historical median during the fall of 2023 but remained above the historical median from March through September 2024. Although conductivity differed throughout the year, there was limited variability observed from the top to bottom of the Reservoir and among the three monitoring sites (Figure 53). Median concentrations for WY 2024 were within the baseline range.

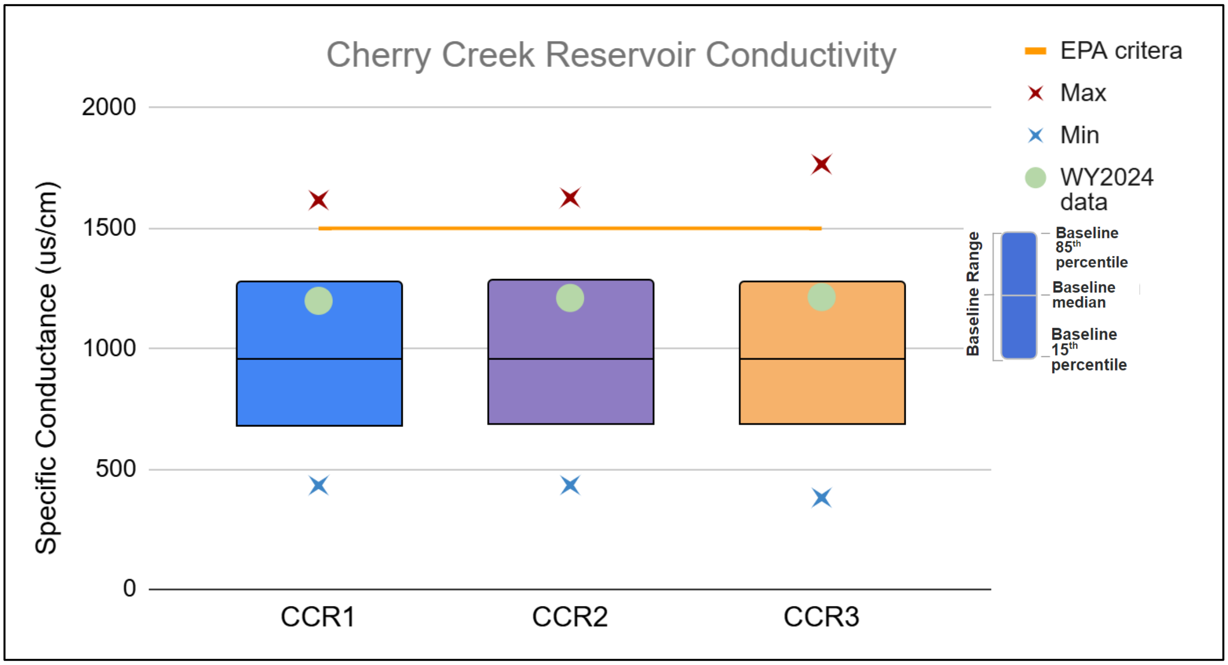


Figure 51. Cherry Creek Reservoir Conductivity, Summary Statistics (1999-2024), WY 2024 medians.

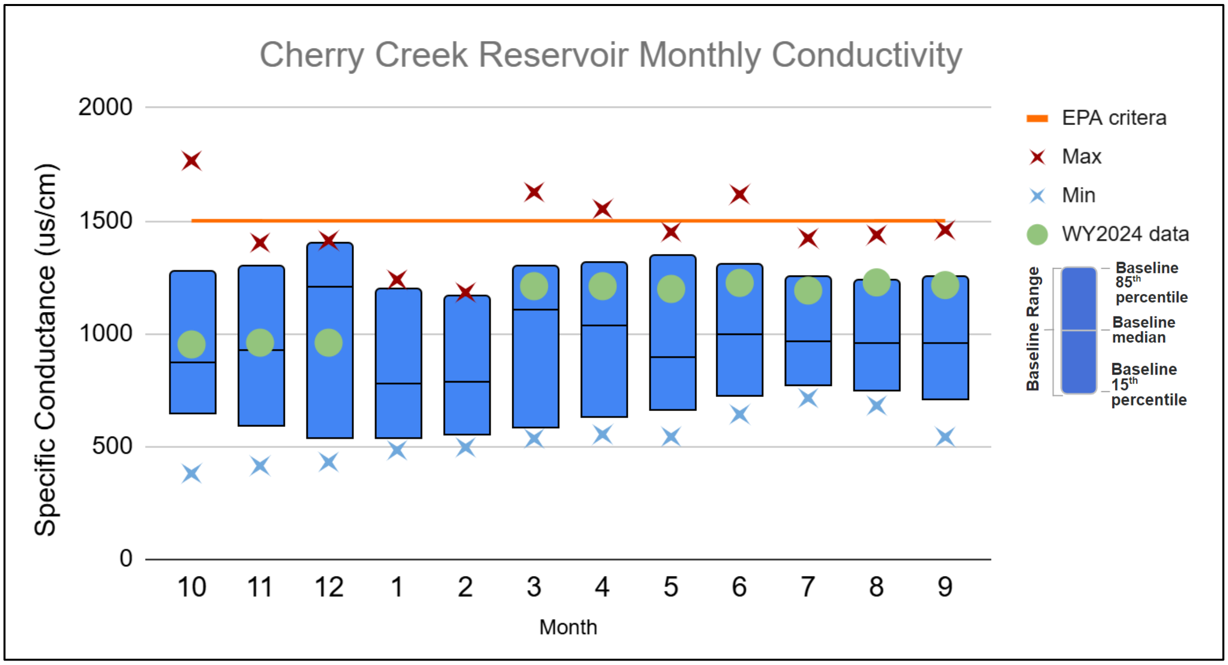


Figure 52. Monthly Conductivity in Cherry Creek Reservoir, Summary Statistics and WY 2024 medians.

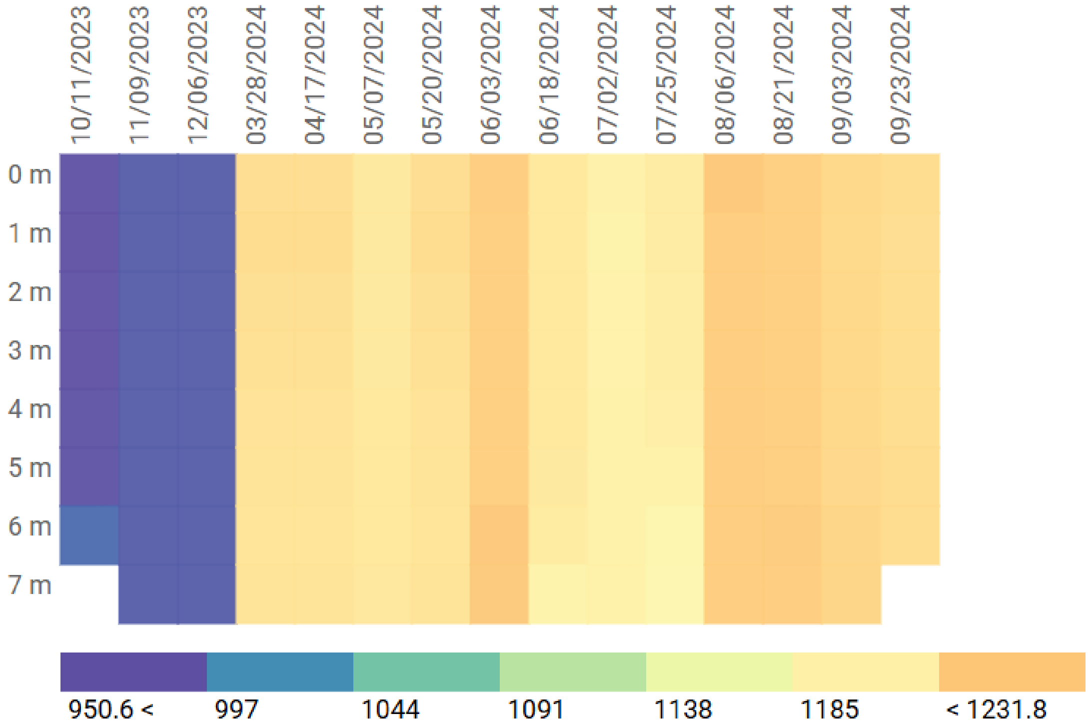


Figure 53. Conductivity (Specific Conductance µS/cm) Depth Profile, Cherry Creek Reservoir, CCR-2, WY 2024.

4.9 SUSPENDED SOLIDS

Total suspended solids (TSS) in a lake or reservoir represent all particles greater than 2 µm in the water column such as sand silt, clay, and algae. The TSS concentrations in Cherry Creek Reservoir impact water clarity and can indirectly affect chl α concentrations due to changes in depth of sunlight penetration.

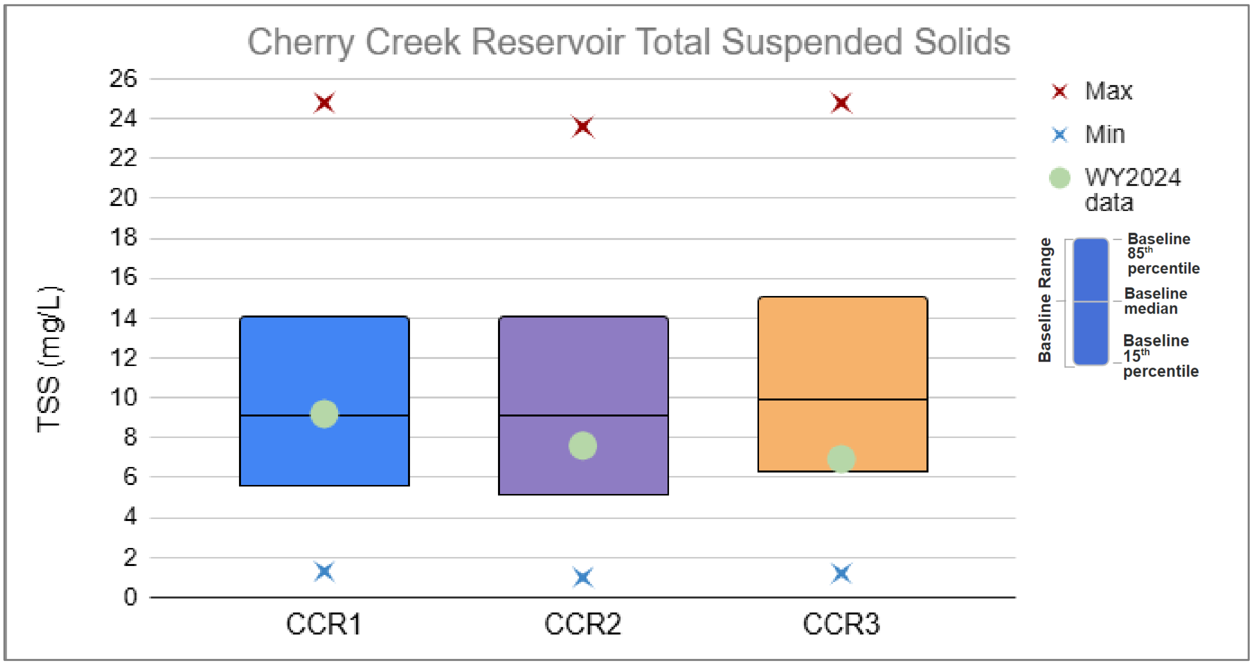


Figure 54. Total Suspended Solid Concentrations in Photic Zone, Cherry Creek Reservoir, Summary Statistics (1992-2024) and WY 2024 medians.

Although stormflows often have high TSS concentrations which can impact downstream lakes and reservoirs, the median TSS concentrations in WY 2024 were near or below the baseline median (Figure 54.). In addition, the monthly medians following the high spring inflows in May were lower than the baseline medians in June and July (Figure 55.).

Monthly conductivity in CCR along with historical min, max, and median confidence.

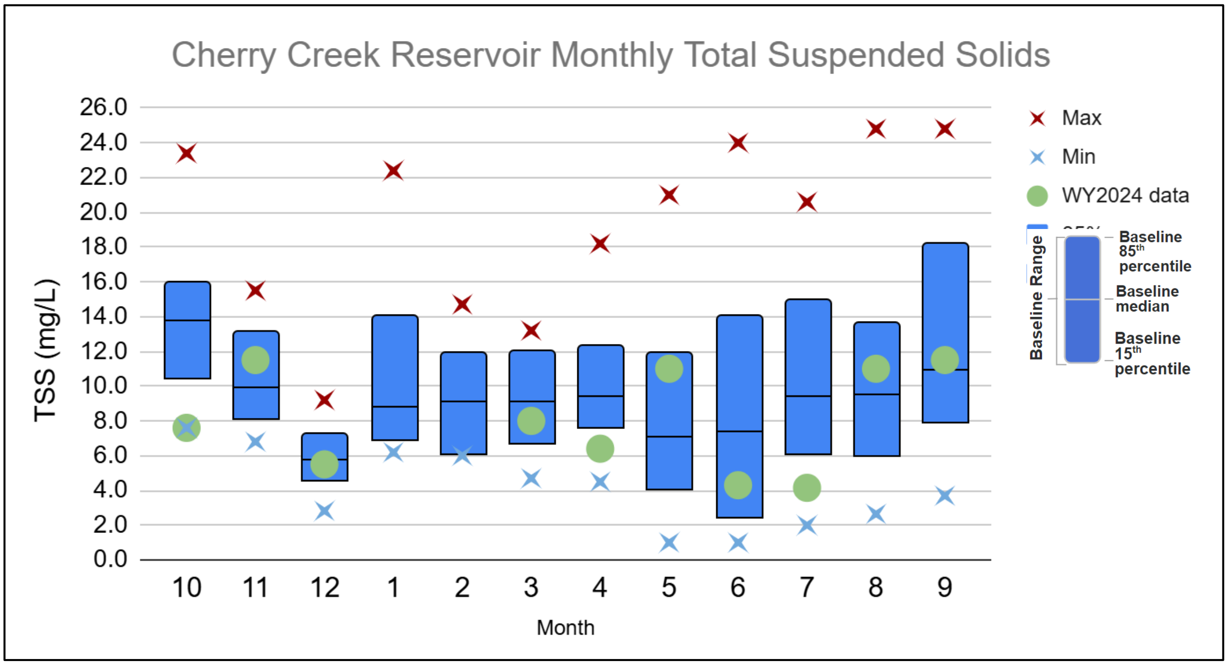


Figure 55. Monthly Total Suspended Solids in Cherry Creek Reservoir, Summary Statistics and WY 2024 medians.

4.10 TOTAL PHOSPHORUS

In many aquatic environments, phosphorus limits primary productivity or algal growth, but in eutrophic or nutrient-rich environments, like Cherry Creek Reservoir, phosphorus may not be limiting. Total phosphorus (TP) is made up of both particulate and dissolved phosphorus. Particulate phosphorus is what remains suspended in the water column instead of settling to the bottom of a lake or reservoir. It includes both inorganic material, such as soil particles and clay minerals, and organic phosphorus, which includes particulate forms such as algal cells and plant fragments.

Although there are no currently applicable standards for TP in Cherry Creek Reservoir, WQCC Regulation 31 (Reg 31) adopted nutrient criteria for warm water reservoirs greater than 25 acres. During the WQCC's April 2024 rulemaking hearing for lake nutrients, nutrient standards were adopted in all lakes and reservoirs upstream of domestic wastewater dischargers. For those lakes downstream of domestic wastewater dischargers, like Cherry Creek Reservoir, the standards were adopted with a delayed effective date of December 31, 2027. The CWQCC's originally proposed 2012 warm water TP criterion for large warm reservoirs was 83 µg/L TP as a summer (July 1-September 30) average in the mixed layer (median of multiple depths), with an allowable exceedance frequency of one-in-five years. The revised WQCC TP standard will be 47 µg/L for reservoirs like Cherry Creek, unless a site-specific standard that is being proposed by CCBWQA is adopted. Figure 56 shows the historical seasonal (July to September) median concentration and the WY 2024 median and mean for the three sites in the photic zone (0-3 m) plotted against the previous 2012 criteria represented by the orange line. The WY 2024 seasonal mean of 113 µg/L is lower than WY2023 but higher than the WY2022 and WY 2021 values. The long-term median seasonal phosphorus concentrations average 93 ug/L between the three sites in Cherry Creek Reservoir (Figure 57).

In WY 2024, the monthly median concentrations for TP were near or below the baseline median with the exception of July, which was at the 85th percentile (Figure 58). The WY 2024 TP concentrations in the Reservoir throughout the year are contributing to the ongoing eutrophic conditions.

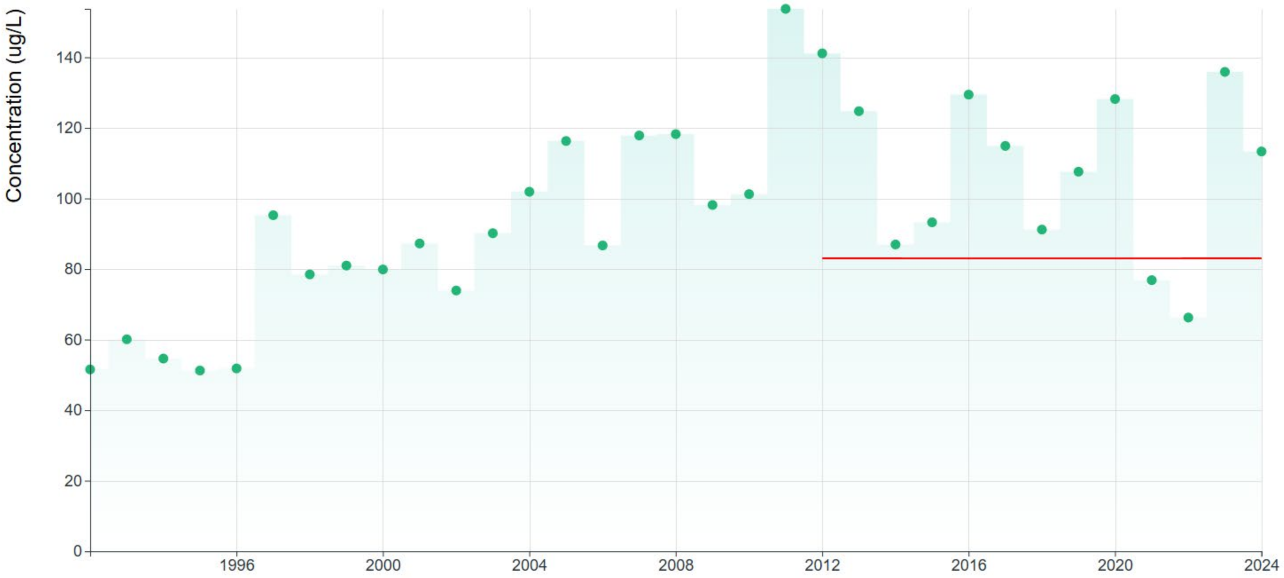


Figure 56. Seasonal Mean Total Phosphorus Concentrations in Cherry Creek Reservoir.

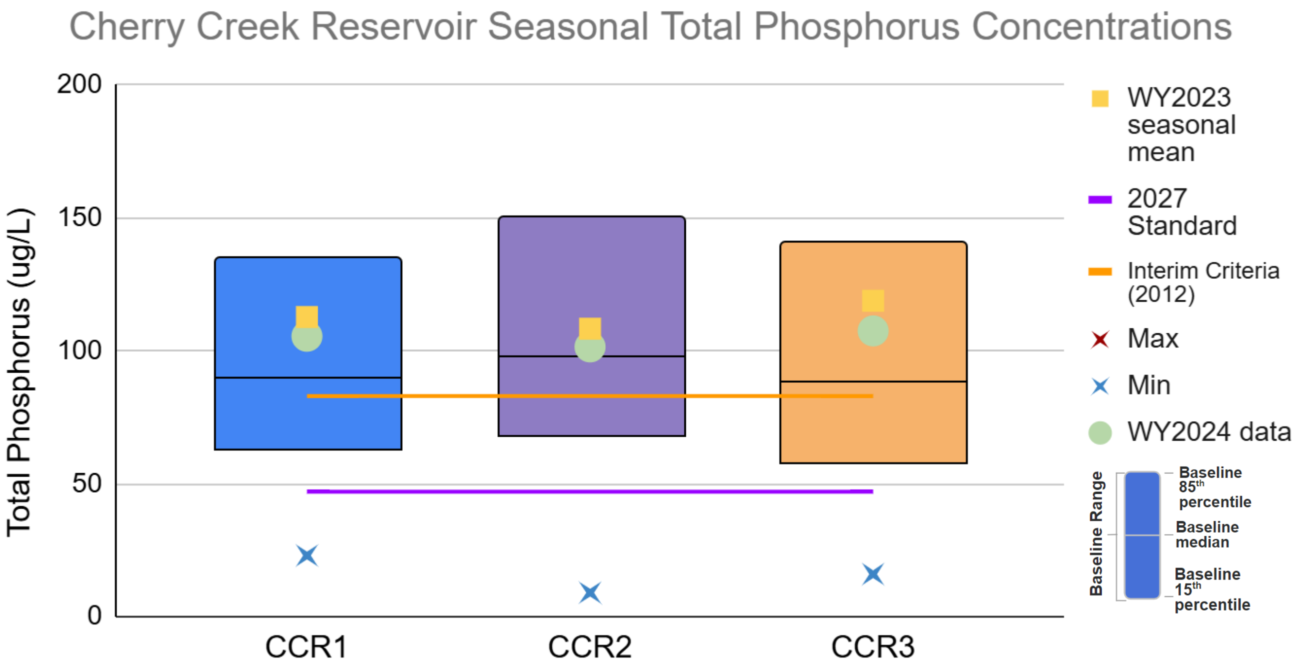


Figure 57. Seasonal TP Concentrations in Photic Zone, Cherry Creek Reservoir, Summary Statistics (1992-2024), WY 2024 medians and means.

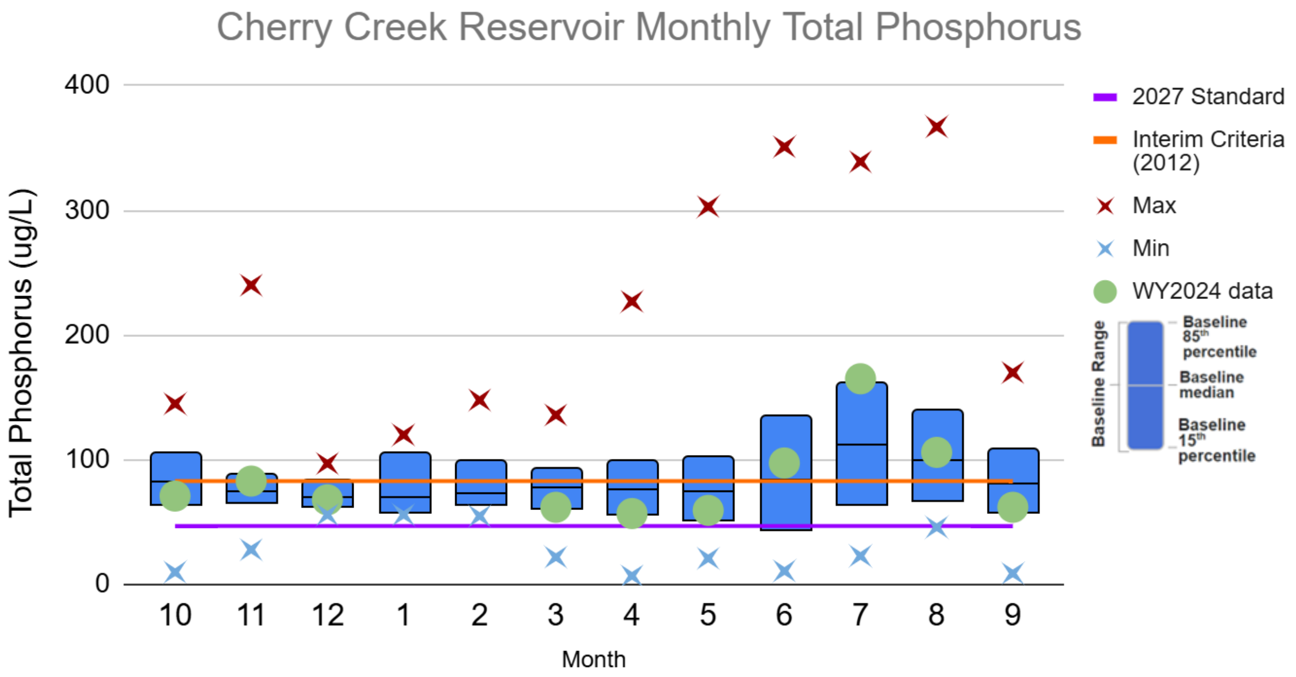


Figure 58. Monthly Median Total Phosphorus in Cherry Creek Reservoir, Summary Statistics and WY 2024 medians.

Figure 59 displays the TP concentrations depth variability through WY 2024 in Cherry Creek Reservoir. The highest concentrations in the photic zone (0-3 m) were seen during the late spring and summer of 2024. The samples from below the photic zone had TP concentrations generally increasing with depth and were highest in bottom samples from late May through September. The TP depth profiles at Reservoir monitoring station CCR-2 and the concentrations from the photic zone composite at CCR-1 and CCR-3 are available on the data portal, showing similar results.

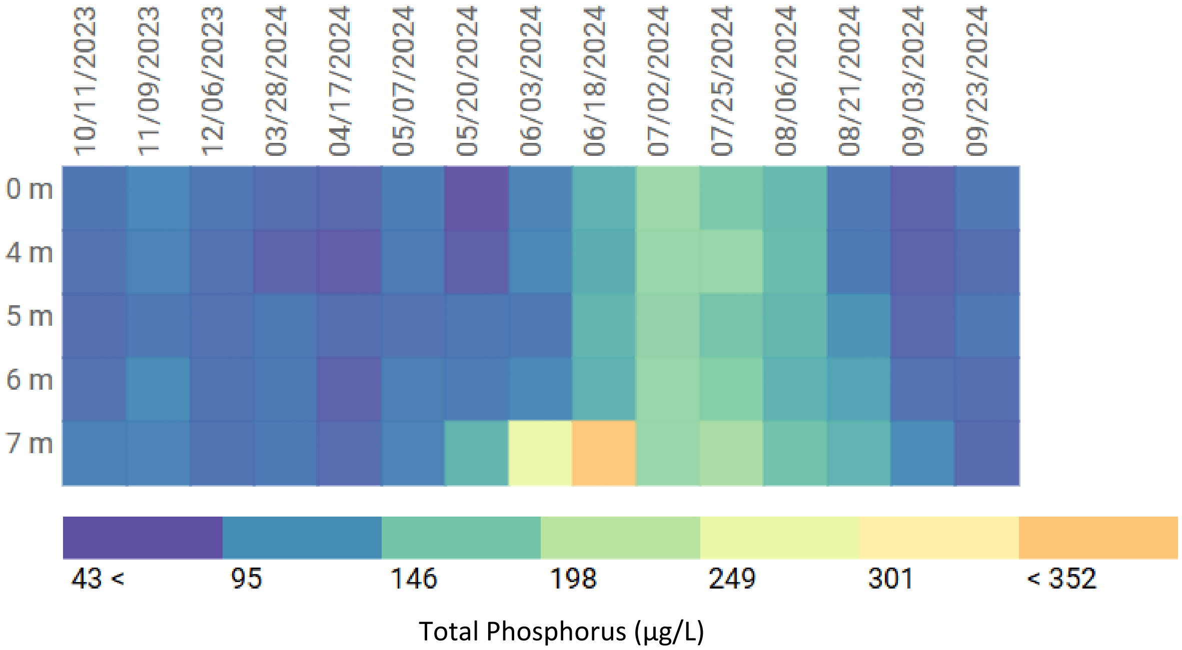


Figure 59. Total Phosphorus Profile at CCR-2, Cherry Creek Reservoir, WY 2024.

Phosphorus increases in the hypolimnion can be caused by internal legacy sediment loading or result from the decomposition of algal cells and other organic matter settling from higher levels in the water column. Inflows of cold runoff water, which has a higher density than warmer surface waters and sinks to the bottom as it enters a lake, can also directly increase hypolimnetic nutrient concentrations. In years with limited stormflows, the higher nutrient concentrations at depth are more likely due to organic deposition and decomposition or internal loading.

4.11 DISSOLVED AND SOLUBLE REACTIVE PHOSPHORUS

Total dissolved phosphorus (TDP) includes dissolved organic and inorganic material. Dissolved inorganic phosphorus is usually reported as soluble reactive phosphorus (SRP), which represents the bioavailable form of phosphorus that is readily available for uptake by algae.

Figure 60 and Figure 61 depict the profiles of TDP and SRP from site CCR-2 during WY 2024. Monthly median TDP concentrations average approximately 30% of the total phosphorus concentrations and SRP averages approximately 15%.

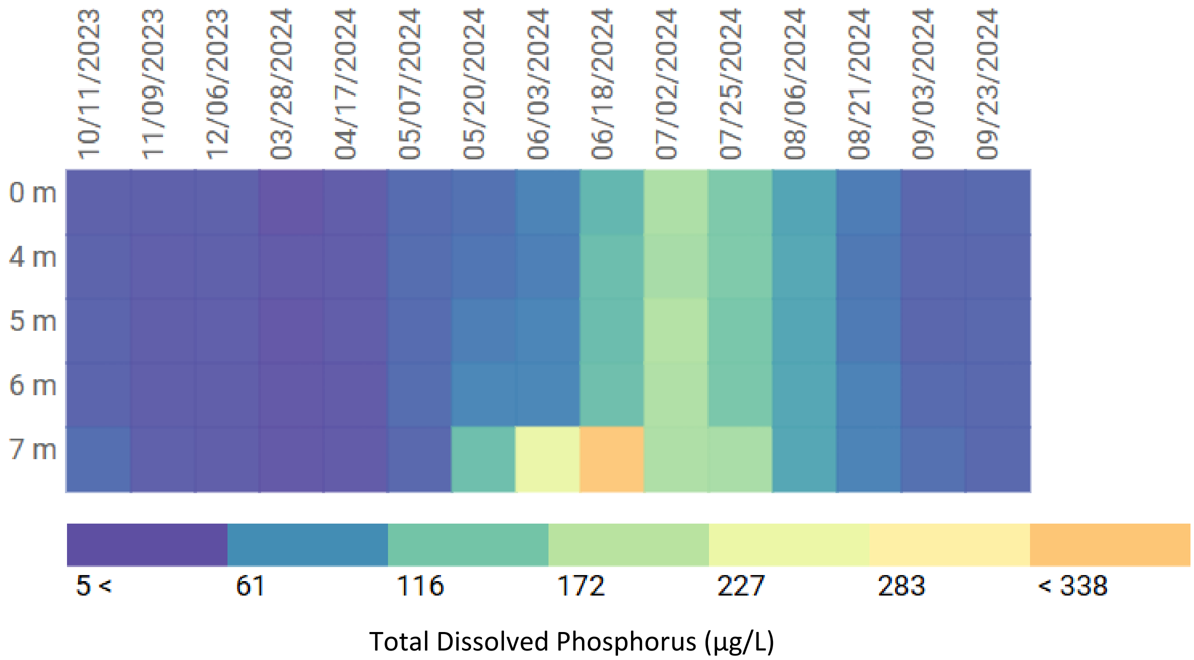


Figure 60. Total Dissolved Phosphorus Profile at CCR-2, Cherry Creek Reservoir, WY 2024.

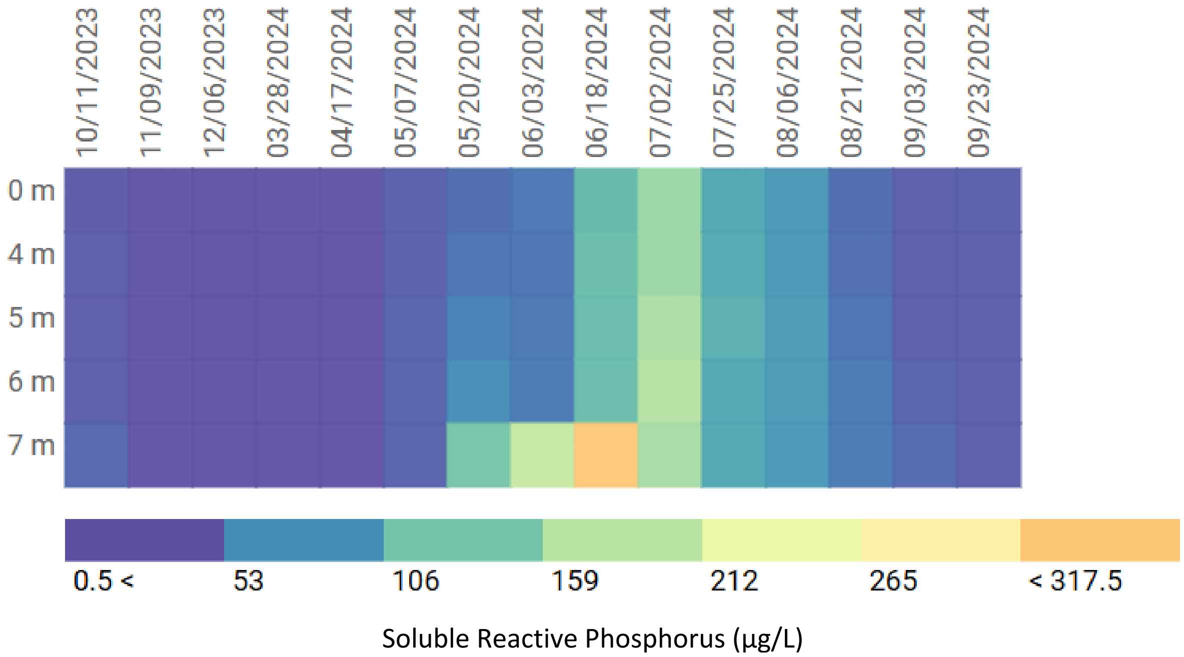


Figure 61. Soluble Reactive Phosphorus Profile at CCR-2, Cherry Creek Reservoir, WY 2024.

During WY 2024, both TDP and SRP remained relatively constant through late fall and winter, but levels throughout the water column show much more variability as the temperatures warm and the season progresses. Since SRP is the bioavailable form of phosphorus, it is typical to see decreases in SRP concentrations in the photic zone through the summer months as productivity increases and phytoplankton and other organisms incorporate SRP into cell material. There was an association of lower levels of TDP and SRP during events when DO levels were low and pH was elevated. Similar patterns of internal loading are observed with these forms of phosphorus during the warmer summer month when DO concentrations are low at the bottom of the Reservoir. As the season progressed, primary productivity in the photic zone was utilizing the available forms of phosphorus as they were released and mixed throughout the water column.

4.12 TOTAL NITROGEN

Nitrogen in aquatic systems comes from many possible natural and anthropogenic sources, including fertilizers, animal and human waste, organic plant matter, and even the air. Nitrogen is often abundant in lakes and reservoirs but when limited, cyanobacteria can utilize (or "fix") nitrogen gas diffused in the water from the atmosphere that provides a competitive advantage over other algae species.

Although there are no currently applicable standards for TN in Cherry Creek Reservoir, WQCC Regulation 31 specifies nutrient criteria for warm water reservoirs greater than 25 acres. Like TP, TN standards were adopted in all lakes and reservoirs upstream of domestic wastewater dischargers. After December 31, 2027, standards adopted will become effective in Cherry Creek Reservoir unless site specific standards proposed by CCBWQA are developed and adopted by the WQCC. The 2012 warm water total nitrogen criterion for large reservoirs was 910 µg/L TP as a summer (July 1-September 30) average in the mixed layer (median of multiple depths), with an allowable exceedance frequency of one-in-five years. The WQCC standard for TN will be 640 µg/L when adopted in the absence of a site-specific standard.

Figure 62 shows the historical seasonal mean (July to September) TN concentration from the three sites in the photic zone (0-3 m) plotted against the 2012 criteria represented by the red line. The WY 2024 seasonal mean of 748 µg/L is lower than the last three years and the long-term median of 854 µg/L.

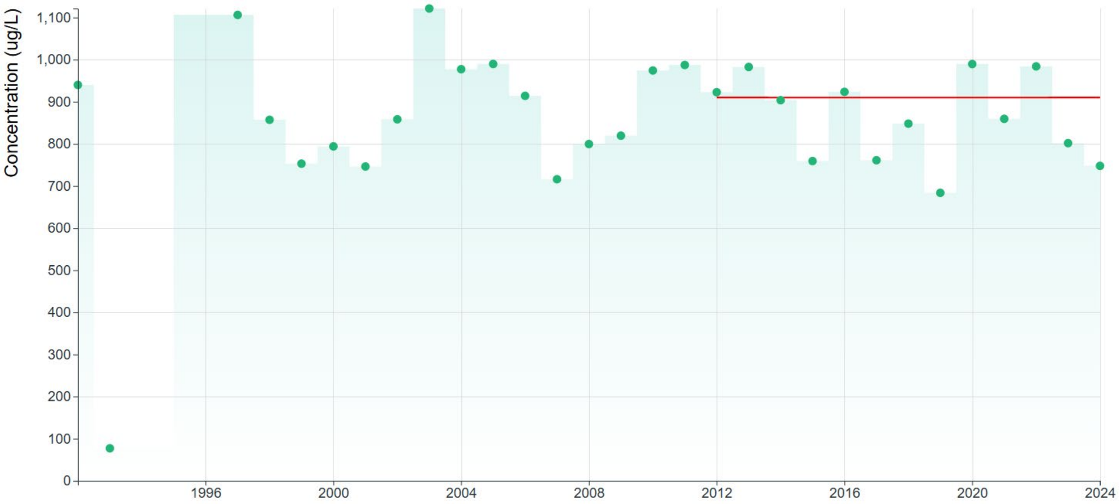


Figure 62. Seasonal Mean Total Nitrogen Concentrations in Cherry Creek Reservoir.

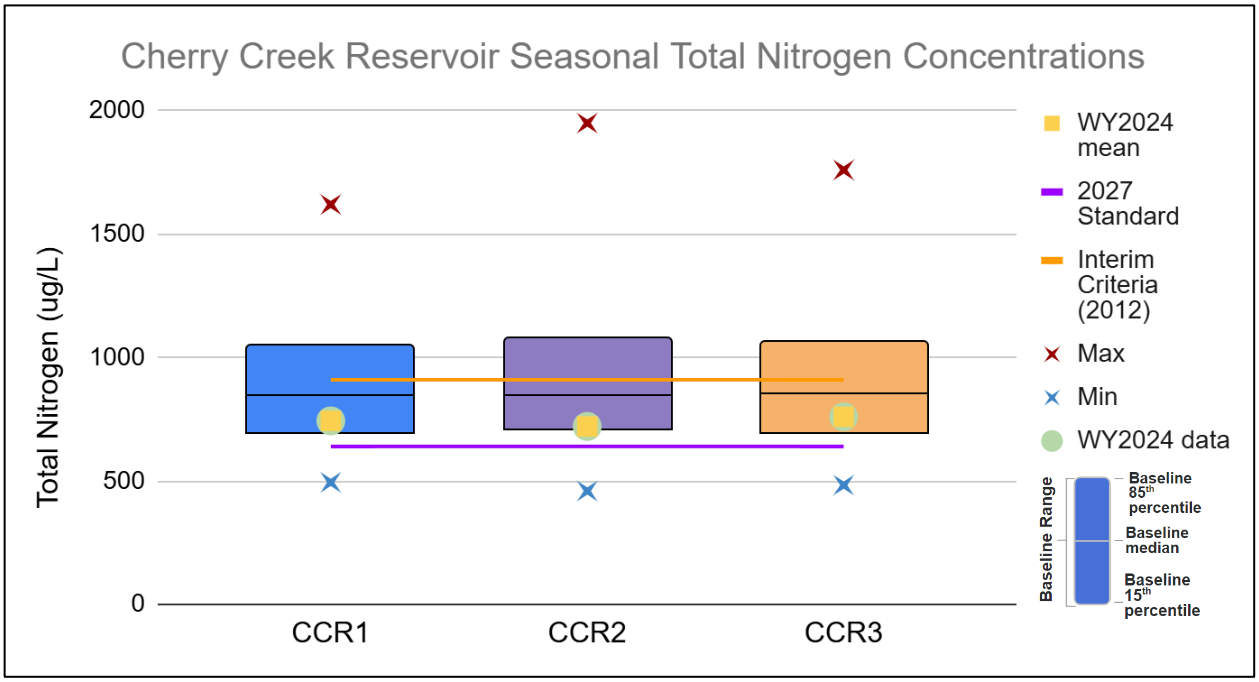


Figure 63. Seasonal Total Nitrogen Concentrations in the Photic Zone, Cherry Creek Reservoir, Summary Statistics (1992-2024), WY 2024 medians and means.

During WY 2024, the monthly median TN concentrations were below or near baseline monthly medians with the exception of December 2023 when TN exceeded the historical median but was within the range of baseline conditions (Figure 64). Concentrations were much lower than the baseline range in early May. When evaluating TN with depth from the samples collected at CCR-2 during WY 2024 (Figure 65), the seasonal changes observed were consistent throughout the water column. The data from the other two monitoring sites from the photic zone are available on the data portal.

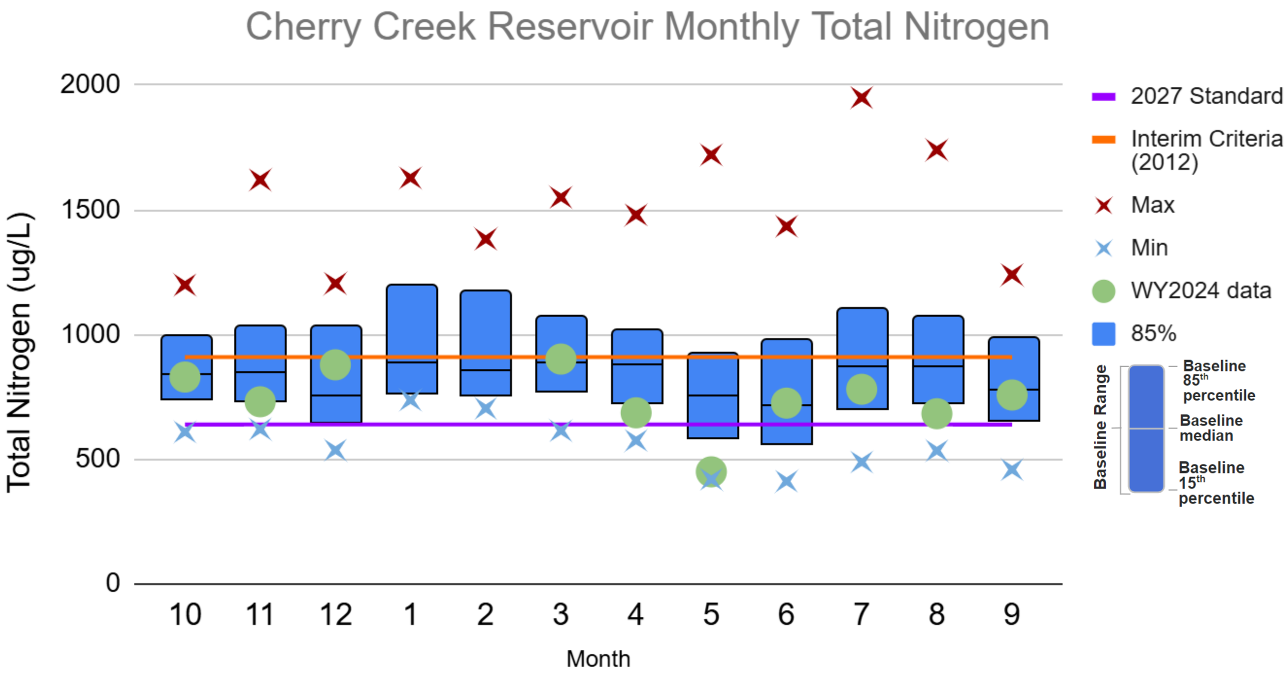


Figure 64. Monthly Total Nitrogen Concentrations, Summary Statistics and WY 2024 medians.

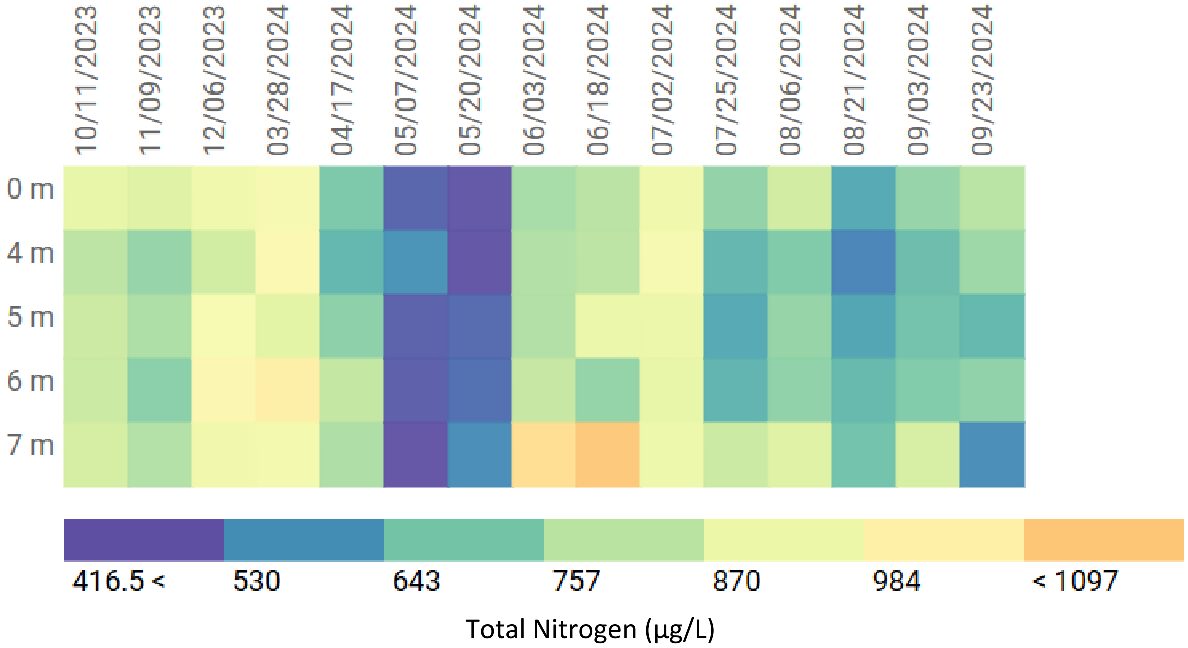


Figure 65. Total Nitrogen Depth Profile at CCR-2, Cherry Creek Reservoir, WY 2024.

4.13 TOTAL INORGANIC NITROGEN

Total Inorganic Nitrogen (TIN) is calculated as the sum of nitrate-nitrite-N (NO_3+NO_2-N) and ammonia-N (NH_3-N) concentrations and represents the forms of nitrogen that are immediately available for algal growth. Figure 66 and Figure 67 illustrate NO_3+NO_2-N and NH_3-N concentrations separately, but both were very low and often below the detection limit during WY 2024. TIN concentrations were elevated in June and July at the deeper sampling sites. Possible reasons for the high TIN concentrations in the hypolimnion are decomposition processes and internal nitrogen loading.

Nitrate is the predominant form of inorganic nitrogen when oxygen is present, and ammonia is the predominant form in the absence of oxygen. Phytoplankton can incorporate ammonia directly into cellular material but readily convert nitrate to ammonia when nitrate dominates.

Nitrate concentrations in the water column, (Figure 67) were highest in late July, and above detection limits in November, April and late June. The rest of the monitoring dates had nitrate concentrations below the detection limit (5 µg/L) in the photic zone and at least one other depth in the water column which is an indication of a highly productive reservoir utilizing readily available forms of nitrogen for algal growth.

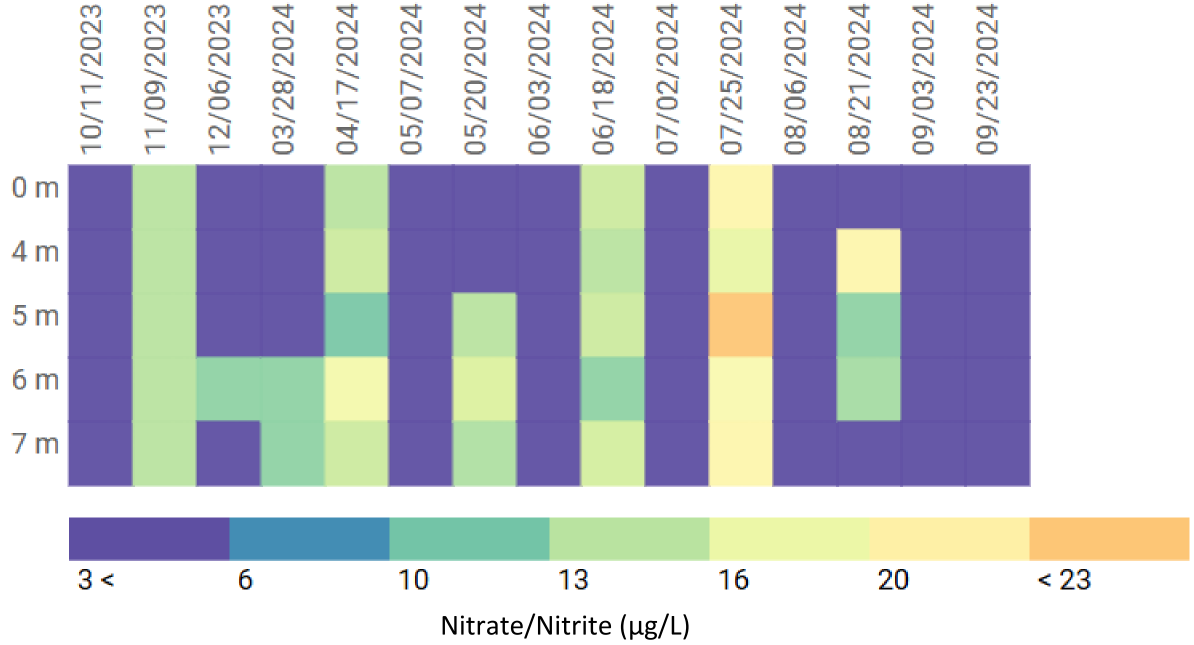


Figure 66. Nitrate/Nitrite Depth Profile at CCR-2, Cherry Creek Reservoir, WY 2024.

Ammonia concentrations in the water column, shown as NH_3-N (Figure 67) were highest in late July and also above the detection limit in November 2023, April, late June and late July. The rest of the monitoring dates had low ammonia concentrations with many below the detection limit in the photic zone or one other depth in the water column, which is an indication of a highly productive reservoir utilizing available forms of nitrogen. Ammonia, like nitrate, is a readily available form of nitrogen for algal growth. The increases in ammonia concentrations in the deeper layers also correlated to the periods of lower oxygen at the bottom of the Reservoir. These elevated ammonia values also corresponded to the dates of the lower chl α concentrations. These concentrations are likely due to the release of ammonia from phytoplankton as the bloom that was present died off following an extended period of precipitation.

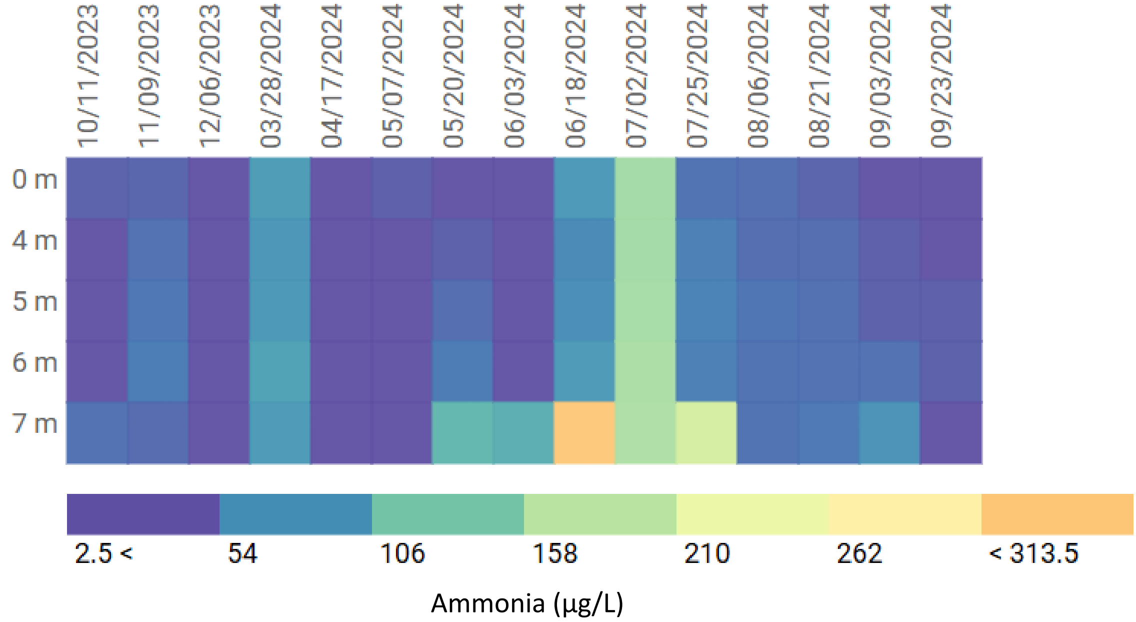


Figure 67. Ammonia Depth Profile at CCR-2, Cherry Creek Reservoir, WY 2024.

4.14 LIMITING NUTRIENT

Nitrogen and phosphorus are the nutrients that usually limit algal growth in natural waters. Both the relative concentrations of nitrogen and phosphorus and the absolute concentrations of these nutrients play important roles in structuring phytoplankton communities (Schindler, 1977; Reynolds, 1986). The average nitrogen to phosphorus (N:P) ratio of healthy, growing algal cells is about 7 to 1 by weight (or about 16 to 1 by molar ratio). This value, known as the Redfield ratio, is generally assumed to be the ratio in which these nutrients are ultimately required by algal cells (Reynolds, 1986). Generally, large N:P ratios (>7) indicate that the growth of the phytoplankton community will be limited by the concentration of phosphorus present, while small N:P ratios (<7) indicate that growth will be limited by nitrogen concentrations (Schindler, 1977). The ratios of total inorganic nitrogen (TIN = nitrate + nitrite-N + ammonia-N) to SRP may be more meaningful than the ratio of TN to TP because the inorganic nutrient forms are more directly available to support the growth of aquatic organisms. The potential for cyanobacteria to fix atmospheric nitrogen may be one of the main factors leading to a phytoplankton community dominated by cyanobacteria (see section 5.1). In lakes and reservoirs with nitrogen limitation, cyanobacteria populations have an advantage over other types of algae and can easily dominate populations and limit diversity.

Figure 68 plots the nutrient mass ratios of TN:TP (in blue), TDN:TDP (in green), and TIN:SRP (in orange). The lines indicate the mass ratio of nitrogen to phosphorus indicating whether nitrogen or phosphorus is limiting. Chl α is plotted on the secondary axis in a red dotted line and the point of limitation is the purple dotted line.

The graph shows that all forms of nitrogen were limited in Cherry Creek Reservoir during most of the growing season. Although there was some variability, the concentrations of chl α had relatively higher values following limitation of one or more forms of nitrogen. (See Phytoplankton section 4.15).

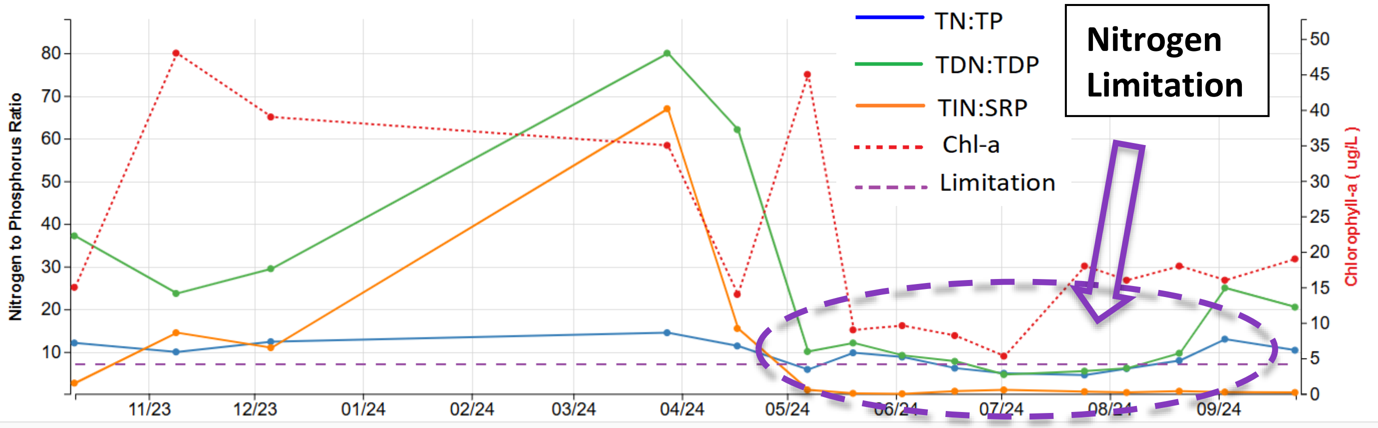


Figure 68. Nutrient Ratios for and Chlorophyll *a* in Cherry Creek Reservoir in WY 2024.

4.15 TROPHIC STATE ANALYSIS

The trophic state index (TSI) of a lake is a relative expression of the biological productivity of a lake. Two approaches to TSI are presented below, one based on the Carlson index and one based on EPA criteria.

Carlson Index

The TSI developed by Carlson (1977) is among the most commonly used indicators of lake trophic state. This index is expressed as three separate indices based on observations of TP concentrations, chl α concentrations, and Secchi depths from a variety of lakes. TP is used in the index because phosphorus is often the nutrient limiting algal growth in lakes. Chl α is a plant pigment present in all algae and is used to provide an indication of the algal biomass in a lake. Secchi depth is a common measure of the transparency of lake water. The three are related in many lakes because transparency is often limited by algal growth and algal growth can be limited by phosphorus in productive lakes. However, the high phosphorus concentrations in Cherry Creek Reservoir often indicate nitrogen limiting conditions.

Mean values of TP, chl α, and Secchi depth for an individual lake are logarithmically converted to a scale of relative trophic state ranging from 1 to 100. Elevated values for the TSI are indicative of higher productivity. A TSI of less than 35 indicates oligotrophic conditions, a TSI between 35 and 50 indicates mesotrophic conditions, and a TSI greater than 50 indicates eutrophic conditions. Hypereutrophic, or excessively productive lakes, have TSI values greater than 70. Higher numbers are associated with increased probabilities of encountering nuisance conditions, such as algal scum.

TSIs for Cherry Creek Reservoir from WY 2024 are presented in Table 20. These values were calculated using the average of the photic zone (0-3 m) composite samples collected at stations CCR-1, CCR-2, and CCR-3 during the months of May through September because Carlson (1977) suggested that summer average values may produce the most meaningful results.

Table 20. Trophic State Indices for Cherry Creek Reservoir WY 2018-2024.

Year	Trophic State Index (TSI)		
	Total P	Secchi Depth	Chlorophyll α
2024	71	52	59
Trophic State	**Hypereutrophic**	**Eutrophic**	**Eutrophic**

Figure 69 displays the historical TSI for Cherry Creek Reservoir for each of the parameters for the May-September averages for TP, Secchi depth, and chl α from 2002 to 2024. Based on this index, Cherry Creek Reservoir is considered eutrophic for Secchi depth and chl α, and ranges between eutrophic and hypereutrophic based on TP concentrations. The TSI has shown variability over time and fluctuated between eutrophic and hypereutrophic since 2002. It is noteworthy that the TSI values for TP and Secchi depth both decreased in WY2024.

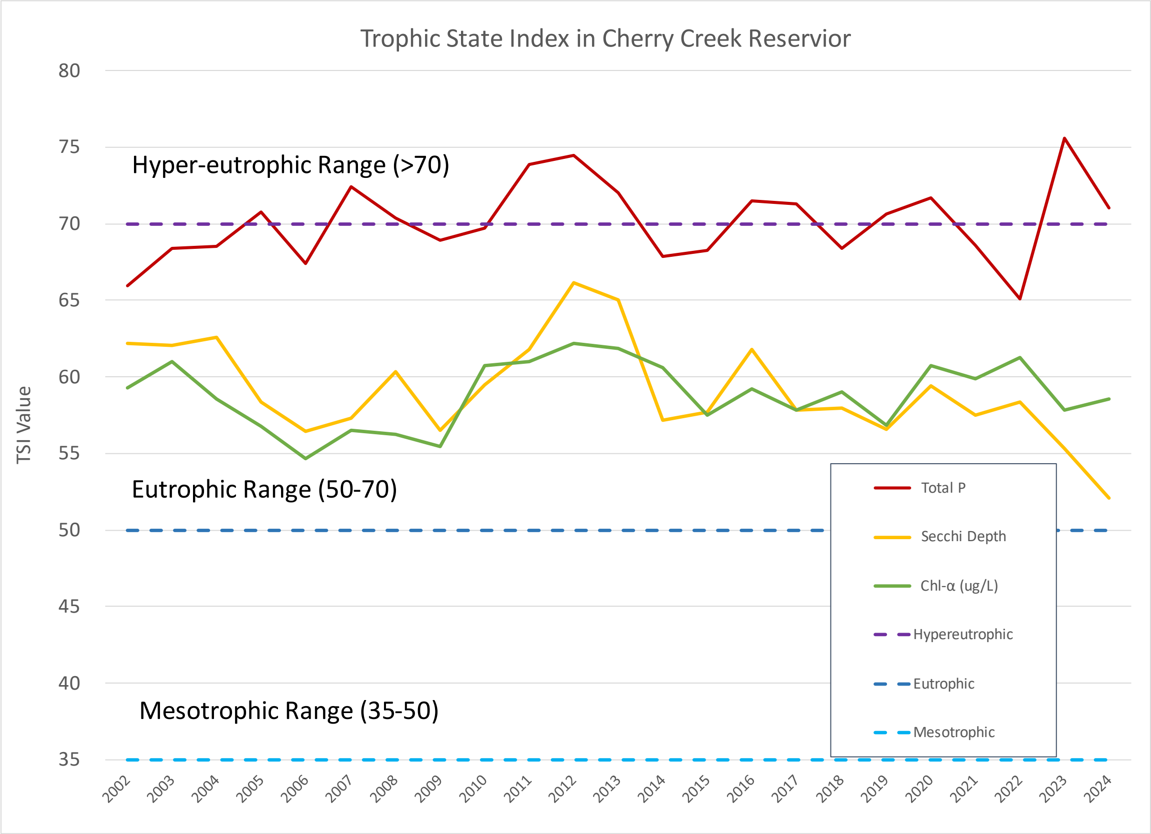


Figure 69. Trophic State Index for Cherry Creek Reservoir (2002-2024).

EPA Trophic State Criteria

Trophic state can also be assessed by comparing monitoring data to trophic state criteria, such as those developed by the U.S. EPA (1980). Table 19 presents a comparison of Cherry Creek Reservoir monitoring data from WY 2024 (May-September) to EPA trophic state criteria. Values for the various parameters were the same averages used to calculate the trophic state indices.

Table 21. Comparison of Cherry Creek Reservoir Monitoring Data to EPA Trophic State Criteria WY 2024.

Trophic State	Characteristic			
	Total P (mg/L)	Chlorophyll *a* (µg/L)	Secchi Depth (m)	Relative Productivity
Oligotrophic	< 0.005	< 2.0	> 8	Low
Mesotrophic	0.005 -0.030	2.0 - 6.0	4 – 8	Moderate
Eutrophic	0.030 - 0.100	**6.0 - 40.0**	2 – 4	High
Hypereutrophic	**> 0.100**	> 40.0	**< 2**	Excessive
Cherry Creek Reservoir	**0.103**	**17.3**	**1.73**	**High**

The trophic state criteria in Table 21, like calculated trophic state indices, are based on somewhat arbitrary concentrations that are typically found when the average lake user perceives that water quality problems exist.

Comparison of monitoring data from Cherry Creek Reservoir to the EPA trophic state criteria indicate that conditions in Cherry Creek Reservoir are in the eutrophic range for chl α concentrations and hypereutrophic for TP and Secchi depth.

The trophic state based on the EPA criteria is slightly different than the Carlson index calculations. It is important to consider that sometimes the trophic state related to Secchi depth alone can be misleading since conventional trophic state criteria assume that Secchi depth is related primarily to algal turbidity. Inorganic turbidity can be a more important factor in determining water clarity for many reservoirs, where Secchi depth does not always provide a good indication of trophic state since these measurements cannot distinguish between algal productivity and inorganic suspended sediment. Inorganic turbidity plays a role in water transparency and associated Secchi depths in Cherry Creek Reservoir as well.

Although these two methods use slightly different calculations and ranges, both the Carson Index and EPA criteria indicate eutrophic to hypereutrophic conditions of Cherry Creek Reservoir for each of the individual parameters evaluated.

4.16 NUTRIENT CONCENTRATIONS IN DIRECT PRECIPITATION

The rain that falls in the watershed ending up in the streams also falls directly on the Reservoir, serving as a nutrient source; therefore, it is considered an inflow in the nutrient balance. The TP and TN baseline median, summary statistics and median concentrations for the samples collected from the storms in WY 2024 are displayed in Figure 70. The baseline median is used to calculate the TP and TN added to the Reservoir based on daily precipitation and surface area. There is a high variability of the nutrient concentrations found in the precipitation samples collected. TP and TN concentrations measured in WY 2024 exceeded the 2027 CDPHE proposed lake nutrient standards, which is not uncommon.

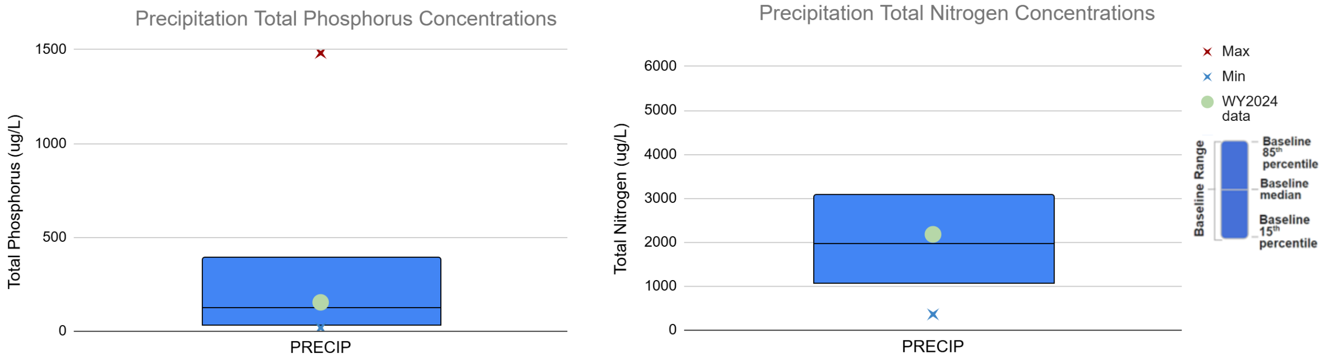


Figure 70. Total Phosphorus and Nitrogen in Precipitation, Summary Statistics and WY 2024.

4.15 PLANKTON SAMPLES

Phytoplankton and zooplankton samples were analyzed to assess biological conditions in Cherry Creek Reservoir during WY 2024. Both numbers of individuals (cells/mL for phytoplankton and animals/L for zooplankton) and biovolume (µm^3/mL for phytoplankton) or biomass (µg/L for zooplankton) were reported.

4.15.1 PHYTOPLANKTON

Phytoplankton are photosynthetic organisms that are the primary producers in aquatic systems. They form the base of aquatic food chains and are grazed upon by zooplankton and herbivorous fish. A healthy lake should support a diverse assemblage of phytoplankton, representing many algal groups.

In many environmental instances, algal numbers (cells/mL) and algal biovolume (µm^3/mL) closely correlate with one another, but that is not always the case. It is possible, and a common occurrence, for a phytoplankton community to have a large number of very small-sized algal cells, particularly in systems such as Cherry Creek Reservoir that have high numbers of cyanobacteria (Cyanophyta), commonly referred to as blue-green algae. At other times, the phytoplankton community can be dominated by a few algal species that are very large in size like the Bacillariophyta (Diatom) blooms that have been observed in Cherry Creek Reservoir the last two years.

Phytoplankton samples were collected at site CCR-2 from the photic zone (0-3 m composite sample) and analyzed to identify and quantify the populations present on each sampling date. The results from WY 2024 indicate high productivity with diverse populations and seasonal plankton dynamics.

In WY2024, phytoplankton populations in Cherry Creek Reservoir had an average of 23 species present on each sampling date, which is less than the last three years that ranged from 26-40. Higher numbers of species were present when water temperatures were lower in the spring and fall. Although the number of species present decreased during the summer months, the population and biovolume were higher, indicating that the excess nutrients likely provide a competitive advantage to some species over others.

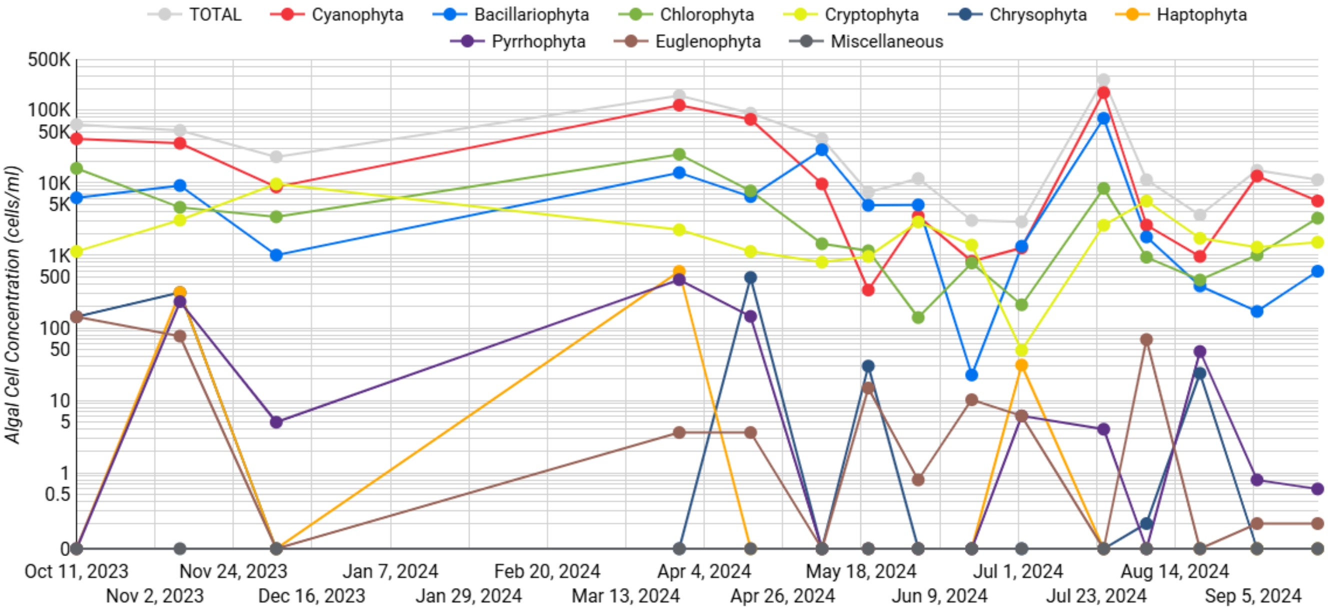


Figure 71. Phytoplankton Concentrations in Cherry Creek Reservoir, WY2024.

Chlorophytes (green algae) are usually the most diverse algal group in Cherry Creek Reservoir. Many chlorophyte species are larger than all but the largest cyanophytes. Green algae made up 9% of the total algal counts and represented ~4% of the total biovolume in WY 2024 (Figure 74).

Cyanophytes (commonly called blue green algae or cyanobacteria) are probably responsible for most nuisance algal blooms that occur in freshwater ecosystems and some species are also capable of producing algal toxins resulting in harmful algal blooms (HABs). Cyanophytes have the ability to use atmospheric nitrogen as a nutrient source and can also regulate their position within the water column by altering their buoyancy with the use of gas vacuoles. These characteristics give cyanobacteria a competitive advantage over other groups of phytoplankton. Nuisance blooms of cyanobacteria usually occur in neutral to alkaline waters that are relatively warm and have low N:P ratios, which are all characteristics of Cherry Creek Reservoir.

Several species of cyanobacteria that can produce toxins have been observed in Cherry Creek Reservoir. Those observed more frequently during WY 2024 include *Dolichospermum* sp. (May through August), *Eucapsis sp.* (Nov-Sept) *Microcystis aeruginosa* (July), and *Pseudoanabaena limnetica (*various*)*. Two of these potentially toxin-producing cyanobacteria, *Dolichospermum* and *Microcystis,* were present with elevated biovolume on July 25th. Figure 72 demonstrates the diversity of the cyanobacteria species observed in the Reservoir in WY 2024. On July 23rd Colorado Parks and Wildlife (CPW) issued a closure of the Reservoir to contact after verification that toxin was present. However, as usual, the bloom dissipated relatively quickly, and when toxin levels had decreased, recreation could continue.

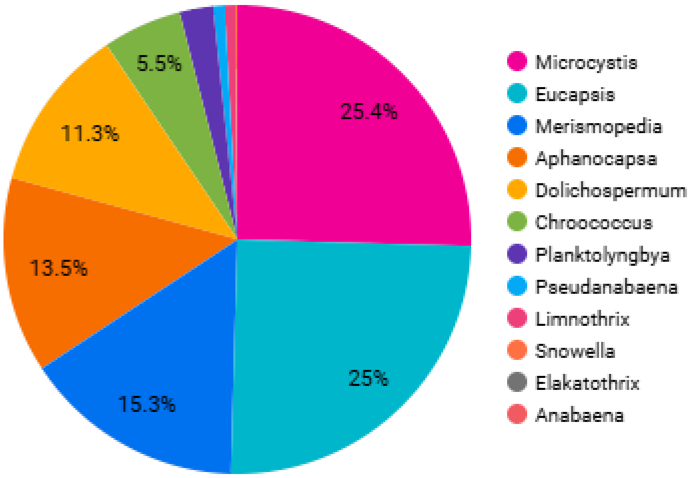


Figure 72. Cyanobacteria Relative Populations WY2024

As in previous years, cell counts were dominated by the cyanophytes (65%), which were usually present in higher numbers than any of the other group. There were a few exceptions in May and early June with diatoms were the most prevalent (Figure 71). Cyanobacteria were diverse and averaged 64% of the total algal cell counts for all of WY 2024 (Figure 74), which was less than recent years.

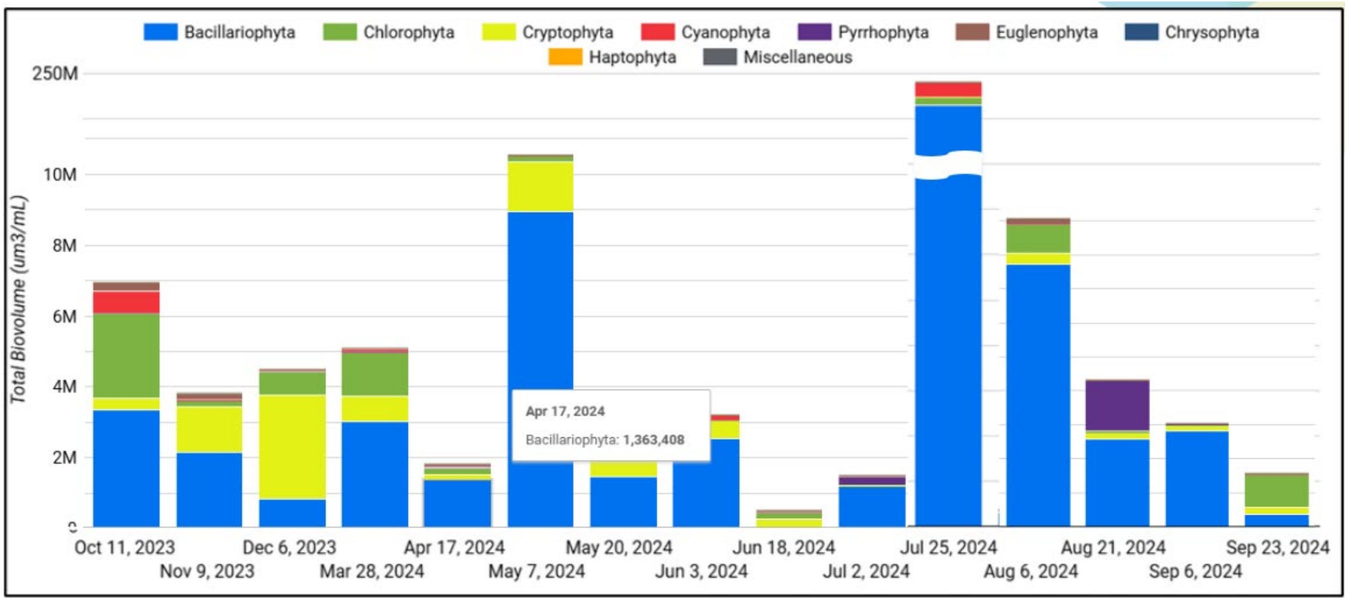


Figure 73. Phytoplankton Biovolumes in Cherry Creek Reservoir in WY 2024.

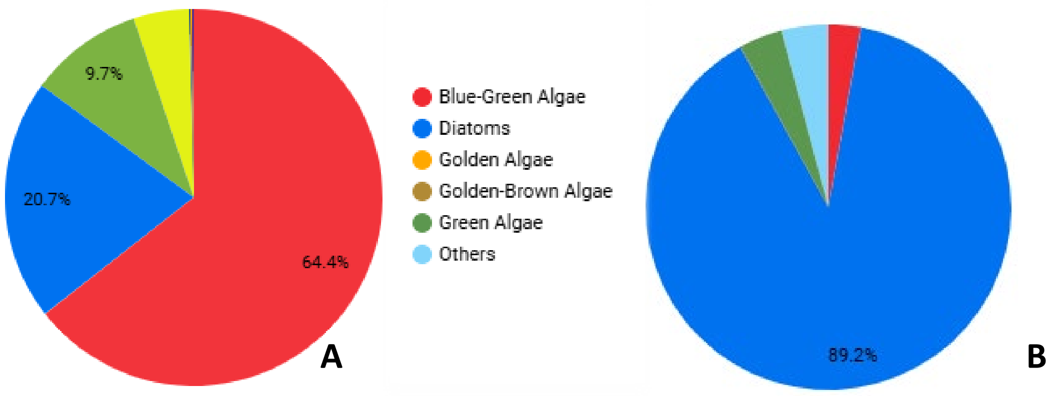


Figure 74. Relative Phytoplankton Concentration (A) and Biovolume (B), WY 2024.

Cyanobacteria range from very small unicellular picoplankton (≤1 µm) to larger macroscopic filaments or multicellular colonies that are several millimeters in size. Many cyanophytes are smaller than other algal species, which is evidenced by the higher contribution of other algal groups to the total biovolume on most sampling dates.

Due to unforeseen circumstances, a change in plankton taxonomy labs was required in mid-2023 and the smallest cyanobacteria species (picoplankton) were not identified to the same resolution as prior years' analyses after May 2023. Although this change in analysis may have some impact on the data, the effects are limited since picoplankton contribute a relatively insignificant percentage of the biovolume, and are not often responsible for "bloom" conditions when there is elevated biovolume. Plankton with large cell size or smaller types that form multi-cellular colonies can easily be responsible for visible nuisance blooms which often correlates to high biovolume.

Bacillariophytes (diatoms) can also be responsible for nuisance blooms, but those relate mainly to taste and odor problems in drinking water supplies, and those issues are not as common as nuisance cyanobacteria blooms. Diatom blooms typically are most common during the spring or fall months when water temperatures are relatively low. Total diatom counts in Cherry Creek Reservoir in WY 2024 made up 21% of the total and 89% of the annual biovolume in WY2024. On July 25th there was a significant diatom bloom (Figure 73). Diatoms represented almost 95% of the total biovolume, which was the highest biovolume observed since July 2014 during a cyanobacteria bloom.

Less common populations included pyrrhophytes (dinoflagellates) and the haptophytes (golden algae). Haptophytes (golden algae) are widely distributed in brackish and marine waters and can also occur in freshwater systems, particularly those with higher salinities. They are of potential concern because they can produce toxins that are harmful to fish and other aquatic life, but this has not appeared to be the case in Cherry Creek Reservoir. The conditions required for toxin production are not well understood, but high N:P ratios may be involved. The haptophyte, *Chrysochromulina parva*, a lesser-known golden alga, but a known toxin producer that can be responsible for fish kills, was first noted in Cherry Creek Reservoir in March 2016 and has been present in most samples since that date. The remaining groups, euglenophytes and miscellaneous microflagellates, were much less common.

Except for the diatom and cyanobacteria bloom in mid-late July, Cherry Creek Reservoir had a relatively balanced algal population during WY2024 and did not experience elevated chl α concentrations. Although a balanced ecosystem is made up of primarily algal species like diatoms and green algae, increases in algal biovolume usually result in elevated chl α concentrations.

4.15.2 ZOOPLANKTON

Zooplankton are microscopic animals that consume algae and bacteria in the water column. Some types of zooplankton feed on algae, some on other zooplankton, and some take in both plant and animal particles. Monitoring zooplankton populations is important because larger zooplankton can exert a significant grazing pressure on algal cells; however, they are also subject to predation as they are a food source for larger crustaceans, aquatic insects, and fish. Zooplankton populations in lakes vary with temperature, food supply, and other environmental factors, with reported populations ranging from a few to several hundred individuals per liter (Hutchinson, 1967). Very little detailed information is available on zooplankton dynamics and populations in reservoirs, although turbidity, increased flow, and other factors probably reduce their numbers to below those observed in natural lakes (Marzolf, 1990).

Most freshwater zooplankton are part of only three phyla: *Arthropoda*, which includes cladocerans, copepods, and ostracods; *Rotifera*; and *Protozoa*. Cladocerans and copepods are microscopic crustaceans that feed primarily on phytoplankton, while ostracods are omnivores and eat both small phytoplankton and other organic material. Larger organisms in the arthropod group can be an important food source for fish and can also exert grazing pressure on phytoplankton populations when present in high enough numbers. Rotifers are microscopic animals that feed on detritus and smaller organisms, such as bacteria. They can also serve as a food source for larger zooplankton. Protozoans are single-celled organisms that feed on other microorganisms, organic matter, and debris.

Zooplankton samples were collected as vertical tows from a depth of 6 m to the surface at Station CCR-2 on each sampling date. Zooplankton numbers and diversity were both low compared to average phytoplankton populations in freshwater lakes.

The zooplankton in Cherry Creek Reservoir averaged ~12 species/ event which is typical of most Colorado lakes. A classic study by Pennak (1957) found there were rarely more than one to three copepods, two to four cladocerans, and three to seven rotifers present in any given lake. Cherry Creek Reservoir had four to eight copepods, two to five cladocerans, one to seven rotifers and even ostracods on a few dates in WY2024 which represents above average diversity.

Copepods were the zooplankton present in the highest numbers in Cherry Creek Reservoir during WY 2024 (Figure 75) except for five dates. Copepods represented 43% of the annual population with up to eight different species. Cladocerans were present in Cherry Creek Reservoir on all sampling dates during WY 2024 and averaged 32% of the total zooplankton population. Protozoans were not observed in WY 2024 but ostracods were observed on three dates during WY 2024.

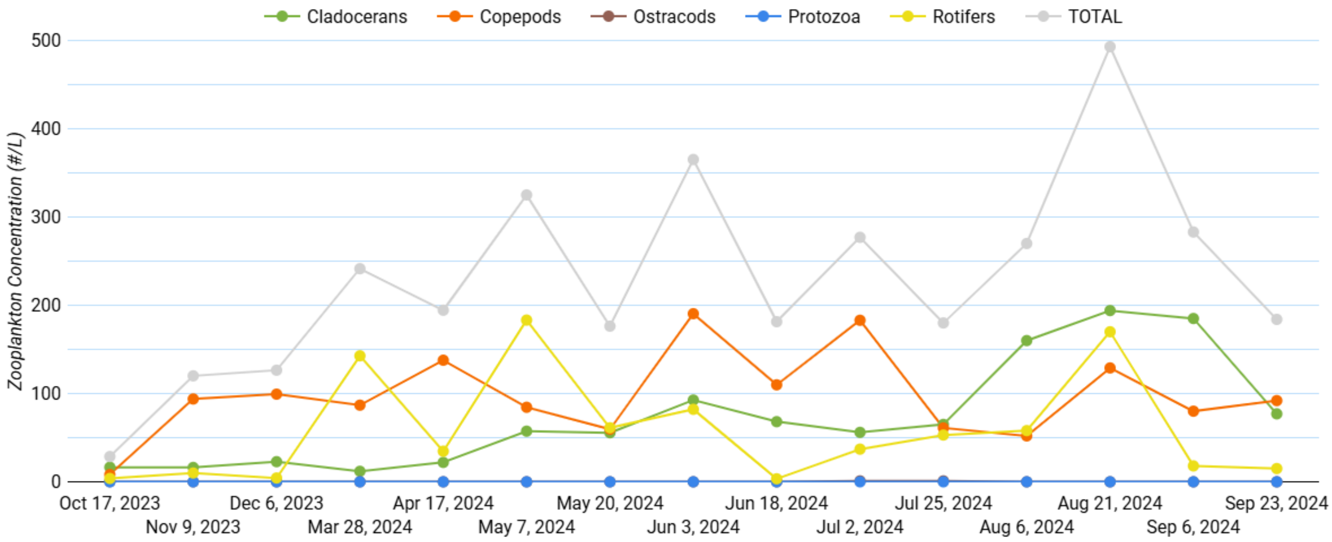


Figure 75. Total Zooplankton Concentrations – WY 2024.

Cladocerans made up the majority of the biomass in Cherry Creek Reservoir during the warmer months of May-July (Figure 76). Copepods often made up a smaller fraction of the total zooplankton biomass because they are generally smaller than the cladocerans.

In mid-June coinciding with the elevated cladoceran biomass, a notable zooplankton bloom was visually observed in the marina. Image 2 depicts a photo of a grab sample in a beaker where the high density and large size of the organisms are observed with only digital magnification. The bloom in the marina even encouraged very unusual behavior of common carp that were observed feeding on the zooplankton at the surface.

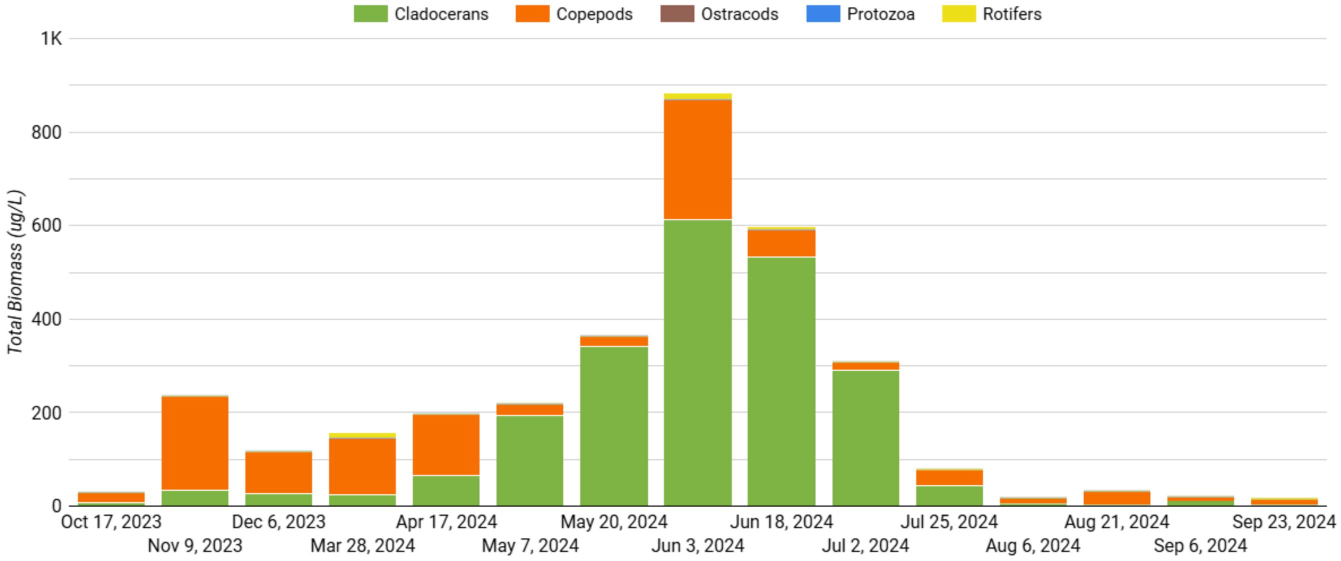


Figure 76. Total Zooplankton Biomass WY 2024

The cladoceran species present in Cherry Creek Reservoir typically include limited populations of the large-bodied Daphnia which are an important source of fish food in many lakes, but one species, *Daphnia geleata* was present March through September WY2024. The biovolume of these organisms increased through spring, peaking on June 3rd at 614 µm/L before decreasing in July and remaining stable through September. Other than the unusual bloom in WY 2024, the normal lack of larger zooplankton may be related to the presence of high populations of gizzard shad (*Dorosoma cepedianum*). Gizzard shad are an important part of the food base for the Cherry Creek Reservoir walleye (*Sander vitreus*) fishery, but they are also effective filter feeders on zooplankton, especially at the larval stage (Johnson, 2014).

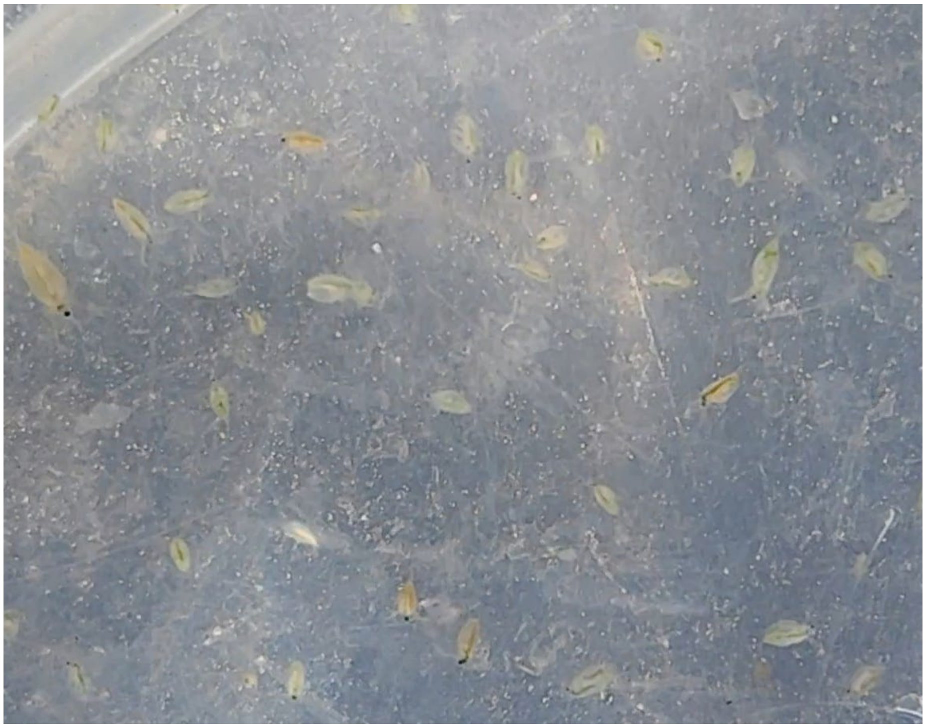


Image 2. Zooplankton bloom observed in marina, June 18, 2024.

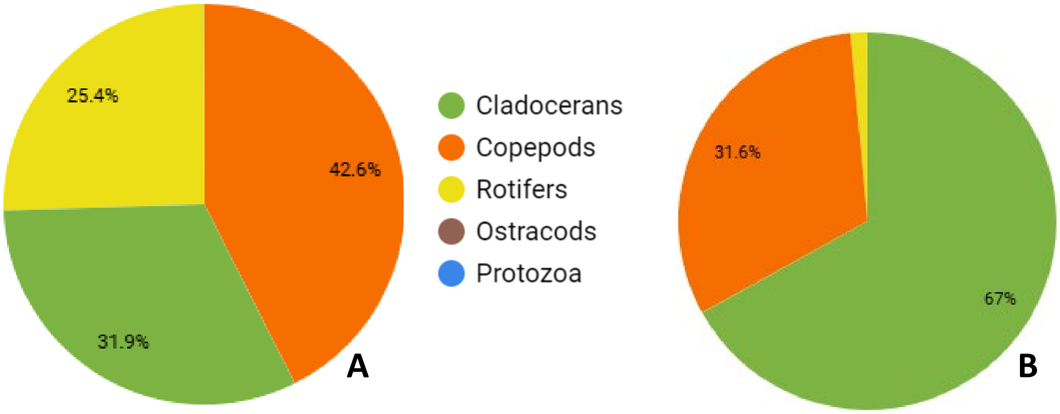


Figure 77. Relative Zooplankton Concentrations (A) and Biomass (B) in WY 2024.

Daphnia lumholtzi is an invasive Cladoceran species that is characterized by long spines that help it avoid predation. This species was first identified in Colorado in 2008 (USGS, Non-Indigenous Aquatic Species fact sheet) and in Cherry Creek Reservoir in 2011 (Johnson, 2014). *Daphnia lumholtzi* has been frequently identified in Cherry Creek Reservoir every year since 2018 and at times has had a large contribution to zooplankton biomass although it doesn't serve the same role as other Daphnia species.

Similar to phytoplankton, the zooplankton populations are highly variable seasonally and year to year which have significant effects on the entire biological food web. Monitoring the plankton trends in Cherry Creek Reservoir highlights how factors other than just water quality can also influence attainment of the chl α standard.

5.0 WATER BALANCE

Water balances in reservoirs are essential for assessing water availability, distribution, and usage/release patterns, which are critical for meeting various needs such as water supply, recreation, and ecological preservation. The following equation is used to calculate the water balance for Cherry Creek Reservoir

$$\text{Ending Storage}_{9/30/2024} + \sum \text{Reservoir Inflows} - \sum \text{Reservoir Outflows} - \text{Starting Storage}_{10/1/2023} = \Delta\ \text{Storage}$$

Storage was calculated based on daily surface elevations and area-capacity tables for Cherry Creek Reservoir provided by the USACE (Appendix A). The lake surface elevation and volume were 5,550.1 ft and 12,946 AF, respectively, on September 30, 2023, and 5,490 ft and 12,044 AF, respectively, on September 30, 2023. This results in a loss of storage of 1,013 AF (Δ Storage) during WY 2024. The WY 2024 Reservoir maximum surface area was 1028 on May 15th, 2024 and the minimum was 806 on Sept 30th, 2024 with a median of 849 surface acres.

The Colorado Division or Water Resources (DWR) also collects daily storage data for Cherry Creek Reservoir which represents a slightly lower loss of change in storage for WY 2024 of 717 AF, which is a difference of -∆ 295 AF relative to the USACE-based estimate. The average difference in the daily storage between the USACE and DWR for WY 2024 was ~1,234 AF. The difference in daily storage volumes recorded could be due to variability of measurements collected at different times of day and different methods used to calculate reservoir volume and storage.

The reservoir inflows (gains) considered in the water balance include:

1. Direct precipitation on the Reservoir surface.
2. Alluvial groundwater.
3. Cherry Creek surface water.
4. Cottonwood Creek surface water.
5. Ungauged inflows.

The reservoir outflows (losses) considered in the water balance include:

1. Evaporation.
2. Alluvial groundwater.
3. Reservoir releases.

Precipitation (Inflow 1) was calculated by multiplying the daily precipitation amounts reported at the new precipitation gauge at Cherry Creek State Park (CCSP, section 3.1) by the corresponding lake surface areas, as provided by the USACE, on the dates with measurable precipitation. A total of 9.7 inches (0.81 feet) of precipitation was recorded at the CCSP weather station during WY 2024.

Surface areas were based on elevations and area-capacity tables for Cherry Creek Reservoir provided by the USACE. Based on the daily surface area and precipitation, precipitation contributed an estimated 704.3 AF of water to the Reservoir during WY 2024.

Because there are only three years of historical data from the CCSP station, precipitation at the Centennial Airport (KAPA) precipitation gauge, which had been used for precipitation inflow calculations prior to 2022, was used for historical reference. A total of 13.4 inches of precipitation was recorded at the KAPA gauge during WY 2024, which was 92% of the long-term average for that station (see section 3.1).

Although there is annual variability, alluvial groundwater inflow (Inflow 2) is estimated at a constant 2,200 AF/year for the purpose of the water balance. This number is based on evaluations conducted by Lewis et al. (2005) and used by Hydros (2015) in the reservoir model.

During years where all information collected is able to be used for the water balance calculations, surface water inflows are based on the two sites just upstream of the Reservoir on Cherry Creek (CC-10) and Cottonwood Creek (CT-2). Historically the CCBWQA had two stations to measure water levels at 15-minute intervals on Cherry Creek: CC-10 just upstream of the Reservoir and another just upstream of Lakeview Drive. A rating curve developed for Station CC-10 converted water surface elevation measurements to discharge for flows less than 350 cfs.

Following the repair of Lakeview Drive, reinstallation of the level logging equipment, a new survey and modeling conducted by RESPEC (2024) will be used to estimate events that overtop Lakeview Drive and bypass the CC-10 site during high flow (>350 cfs).

However, after the major storms in 2023 damaged the gaging station at CC-10 and washed-out Lakeview drive, it was determined that it would be ideal to install a new site at a more stable cross section for the low flows. A new site CC-9.5 was installed just upstream of the bridge crossing Cherry Creek on the Pipeline trail. After Lakeview Drive was repaired, a new level sensor was installed at Lakeview Drive and a new survey was completed (RESPEC 2024) to model high flows that may bypass the main channel at the new CC-9.5 location. It is important to note that the new site is above the confluence of Shop Creek so the additional discharge will need to be accounted for in the water balance and estimates calculated to represent these ungauged flows.

Discharge at CT-2 (Inflow 4) is calculated from the recorded elevations at Station CT-2 with weir calculations provided by Bill Ruzzo (2014, unpublished, included in Appendix D of GEI, 2016). The calculated 15-minute flows for both CC-10 and CT-2 are used to produce daily flows that can be used in conjunction with the Lakeview Drive measurements.

Until measurements can be collected and a new rating curve can be developed at the new site, relative inflows have to be estimated, as was the case in both WY 2023 and WY 2024. To provide the best estimated volume entering the Reservoir from surface water sources based on the period of missing data with the highest flow, the inflow values provided by the USACE were used to determine surface water flows for WY 2024. The total surface water inflows were calculated as:

Total surface Inflows = Reservoir Inflows $_{\text{USACE}}$ – Precipitation $_{\text{CCSP}}$ – Groundwater

Total surface Inflows= Cottonwood Inflow $_{\text{CALC}}$ + Cherry Creek Inflow $_{\mathbf{CALC}}$

The total surface inflows were apportioned between Cherry Creek and Cottonwood Creek based on the average relative inflow over the last five years. The mean 5-year stream inflow contribution apportionment is 71% for Cherry Creek and 29% for Cottonwood Creek.

WY 2024 Inflows were estimated at:

- Cherry Creek: 14,296 AF
- Cottonwood Creek: 3,839 AF

All of the gauging stations with measured stage and calculated flow are available on the CCBWQA’s data portal.

Evaporation estimates (Outflow 1) are typically provided by the USACE on a daily basis. The estimated evaporative losses from the Reservoir were 3,751 AF during WY 2024, or approximately 4.4 feet (53 inches) per acre at the median surface area of ~849 acres.

Water is released from the Reservoir through the dam's outlet works. The USGS measures outflow (Outflow 3) at Station 06713000, Cherry Creek below Cherry Creek Lake, CO (section 3.2.3, Figure 8). The gauge is located approximately 2,300 ft downstream of the Reservoir. Other than releases from the Reservoir, there are no major surface water contributions to flow measured at this gauge. The WY 2024 annual outflow at the USGS gauge below the Reservoir was 21,017 AF.

The Reservoir WY 2024 water balance is summarized in Table 22. Following methods developed by TetraTech (2018), the net ungauged inflow(+)/outflow(-) calculated results in a loss of water storage of 1013 ac-ft reported by the USACE for WY 2024 (Appendix B). Components included in this calculated term include data from the USACE, as well as ungauged surface water inflows into the Reservoir, groundwater seepage from the Reservoir through the dam, and measurement uncertainties.

The net influence of ungauged surface water inflows and groundwater losses through seepage (inflow item 5 *less* outflow item 2) is calculated based on the difference between the measured and estimated inflows and outflows, and the net inflow calculated from changes in lake volume based on data provided by the USACE. The calculated net ungauged inflows for WY 2024 were 715 AF.

Previous practice apportioned the ungauged inflows between Cherry Creek and Cottonwood Creek to adjust the inflows. Based on the unadjusted inflows for WY 2024, Cherry Creek contributed 62%, Cottonwood Creek contributed 25%, and the groundwater constant represents 10% of the total inflows to Cherry Creek Reservoir for WY 2024. The ungauged inflows were calculated and allocated based on the daily values for all inflows and outflows used in the allocation equations, resulting in increases in surface inflows of 508 AF for Cherry Creek and 207 AF for Cottonwood Creek. **Error! Reference source not found.**Table 22 lists all inflows, as well as the adjusted values based on the ungauged inflows based on relative contribution of each source.

Table 22. WY 2024 Cherry Creek Reservoir Water Balance

Water Source	**Water Volume (AF)**	
Inflows	**Unadjusted**	**Adjusted**
Cherry Creek (CC-10)	14,296	14,804
Cottonwood Creek (CT-2)	5,839	6,047
Precipitation	704	704
Alluvial groundwater	2,200	2,200
Total Inflows	**22,771**	**23,485**
Outflows		
Evaporation	-3,751	-3,751
Reservoir releases	-21,017	-21,017
Total Outflows	**-20,773**	**-24,768**
Net Ungauged Flows		
Calculation	**715**	**Apportioned**
WY 2024 Change in Storage	-1013	

*Note: Values are rounded to the nearest AF.

Although there is some uncertainty in the inflow values since they were calculated vs. measured, they appear to be representative based on the average precipitation for WY 2024 and the measured Reservoir elevations and storage values. The adjusted relative inflows to the Reservoir from Cherry Creek, Cottonwood Creek, groundwater, and precipitation for WY 2024 are shown in Figure 78.

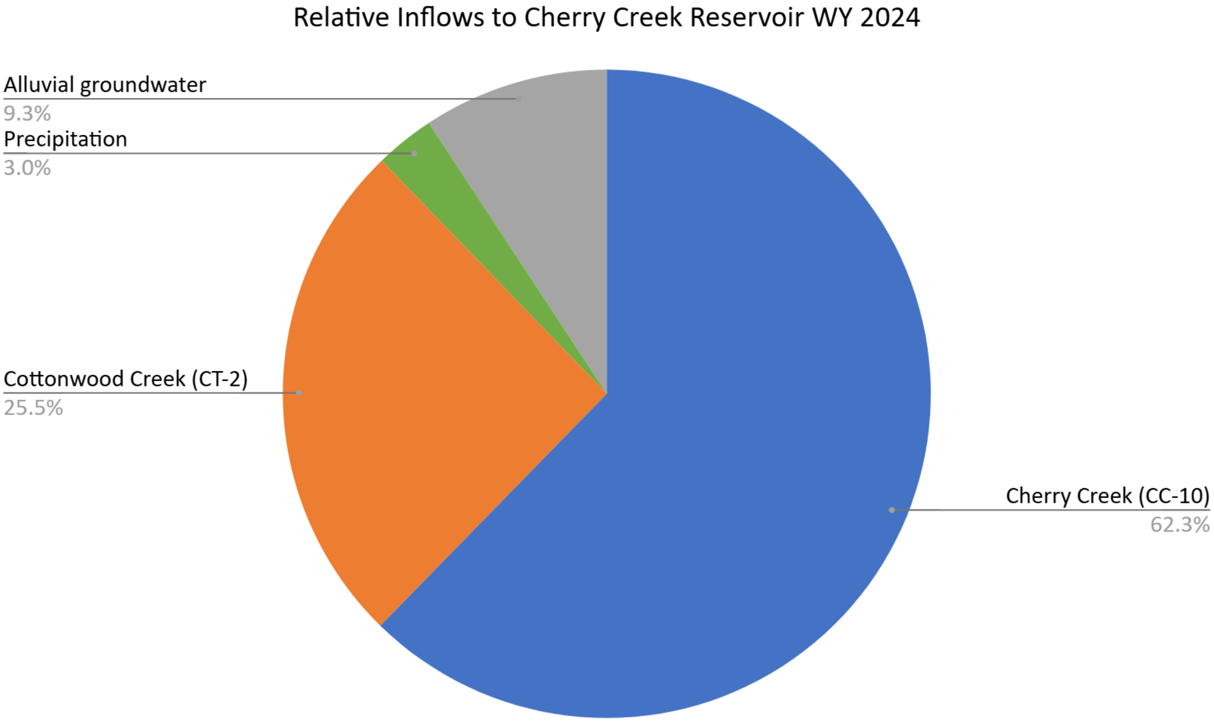


Figure 78. Relative Inflows to Reservoir Water Balance in WY 2024.

6.0 FLOW WEIGHTED NUTRIENT CONCENTRATIONS

Surface water nutrient concentrations for Cherry Creek and Cottonwood Creek were calculated by interpolating nutrient concentrations across sampling dates, then multiplying these values by daily inflows (adjusted for ungauged inflows) to estimate daily nutrient loads. The total annual nutrient load was divided by annual inflow volumes to determine annual flow-weighted inflow concentrations. Table 22 presents the median flow-weighted nutrient concentrations for WY 2024, WY 2023, and the 5-year historical dataset.

Table 23. Surface Water Flow-Weighted Nutrient Concentrations at CC-10 and CT-2.

Location	**Cherry Creek**		**Cottonwood Creek**	
Median	Total Phosphorus	Total Nitrogen	Total Phosphorus	Total Nitrogen
Water Year	Concentration (µg/L)			
WY 2019-2023	217	1,565	65	2,401
WY 2023	469	1,879	96	2,401
WY 2024	**185**	**1,386**	**50**	**2,393**

In WY 2024, Cherry Creek's flow-weighted TP concentration (185 μg/L) was 14% lower than the historical median and Cottonwood Creek's flow-weighted TP concentration (50 μg/L) was 23% lower. The WY 2024 TN concentrations were 12% lower than the historical median at Cherry Creek but similar in Cottonwood Creek. The lower TP and TN concentrations compared to WY 2023 and the historical medians can be explained by the notable differences in water quality conditions during average years and those with major storm events sampled. Comparisons between Cherry Creek and Cottonwood Creek show that TP concentrations are consistently higher in Cherry Creek, while TN concentrations remain significantly higher in Cottonwood Creek.

The median groundwater concentrations of 190 μg/L of dissolved phosphorus and 1030 μg/L of total nitrogen for the period 2016-2024 were used in the calculation of flow-weighted nutrient concentrations in groundwater for WY 2024. A longer period of record was not used because TN was not analyzed in groundwater prior to WY 2016.

The median nutrient concentrations in precipitation samples for the period of 2001-2024 of 130 μg/L for total phosphorus and 1,980 μg/L for total nitrogen were used to calculate flow-weighted concentrations in precipitation.

Flow-weighted nutrient concentrations for all inflows and the flow-weighted total concentration based on the relative inflow contributions to Cherry Creek for WY 2024 are summarized in Table 24.

Table 24. Total Flow-Weighted Inflow Concentrations of TN and TP, WY 2024.

		Source				
	Nutrient	**Cherry Creek**	**Cottonwood Creek**	**Alluvial Groundwater**	**Precipitation**	**Weighted Total**
Relative Inflow Concentration (μg/L)	Total Phosphorus	115	13	18	4	149
	Total Nitrogen	863	609	94	59	1,626
% of Total Inflow*		62%	26%	9%	3%	100%

**rounded values*

The flow weighted influent phosphorus goal, derived as part of the 2009 Regulation 38 rulemaking process, as necessary to achieve the 18 μg/L chl α standard, is 200 μg/L. The flow-weighted TP concentration for all inflows (149 μg/L) and TN concentration (1,626 μg/L) in WY2024 were both approximately half of the values recorded in WY 2023 and lower than the 5-year and historical averages (Table 25).

Following the high flow events and multiple storms that were collected in WY 2023, the WY 2024 flow weighted nutrient concentrations were in back line with those of a more average year.

Table 25. Flow-Weighted Nutrient Concentrations for Surface Water Inflows to Cherry Creek Reservoir.

Water Year	**Total Flow-Weighted Nutrient Concentrations (μg/L)**	
Median	Total Phosphorus	Total Nitrogen
WY 2000-2018	201	1,401
WY 2019-2023	176	1,401
WY 2023	**351**	**1,964**

WY 2024	**149**	**1,626**

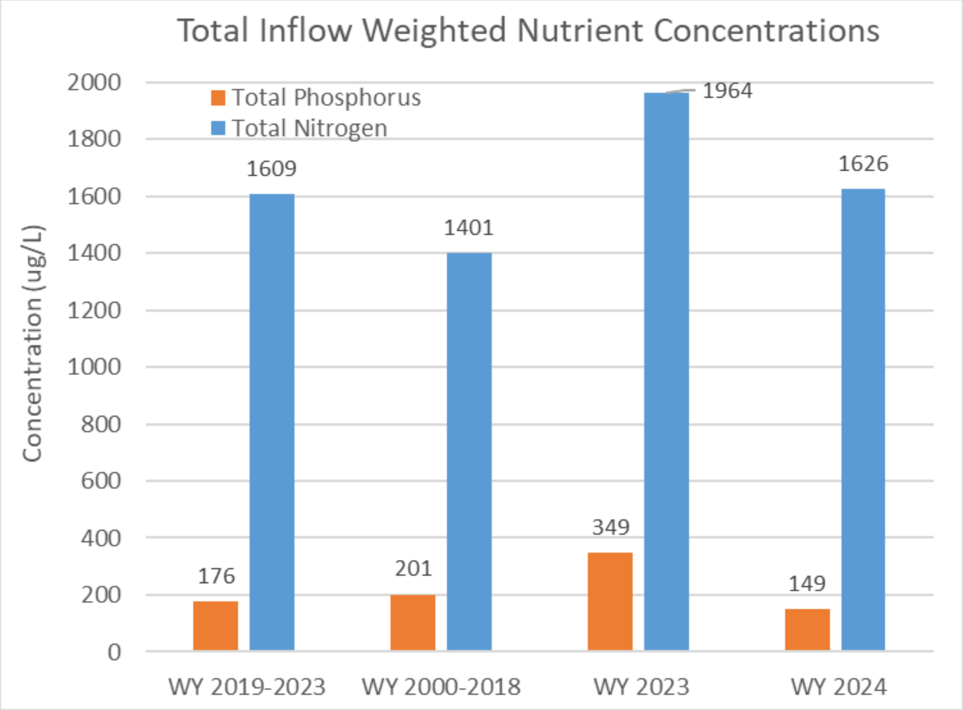


Figure 79. Total Inflow Weighted Nutrient Concentrations

In addition to the previously described inflow sources, both phosphorus and nitrogen can enter Cherry Creek Reservoir by atmospheric deposition (dry deposition) or through internal nutrient loading from bottom sediments. While estimates for dry deposition and internal nitrogen loading are not currently available, these contributions are expected to be less significant compared to other nutrient sources.

Nürnberg and LaZerte (2008) estimated internal phosphorus loading for the period 1992–2006 at an average of 1,895 lbs/year and a median of 1,383 lbs/year. Internal nutrient loading is highly variable and influenced by factors such as:

- Annual water and air temperatures
- Stratification patterns
- Biological productivity
- Inflow volumes
- Lake mixing dynamics

Tracking the internal cycling of nutrient release and biological uptake is challenging, and using a fixed value for internal loading as an inflow would be misleading. While the estimates by Nürnberg and LaZerte provide a range for potential internal phosphorus contributions, these values should be interpreted as a potential range for magnitude of internal loading, not an annual load. The CCBWQASampling and Analysis Plan (SAP) captures inflow, reservoir, and outflow concentrations annually, providing a broader context for nutrient dynamics.

Nitrogen can enter the reservoir via nitrogen fixation, a process in which cyanobacteria utilize atmospheric nitrogen as a nutrient source. This process is difficult to measure, and no specific estimates for nitrogen fixation in Cherry Creek Reservoir are available. Given the relatively small magnitude of nitrogen fixation compared to other sources, it is excluded from the mass balance and flow-weighted calculations.

Nitrogen losses through evaporation are assumed to be negligible. However, nitrogen can be lost through denitrification, which occurs under anaerobic conditions when nitrate is converted to nitrogen gas. Due to consistently low nitrate concentrations in Cherry Creek Reservoir and the difficulty in quantifying denitrification losses, these are not included in the nutrient balance.

Water exits the reservoir through the outlet at the Cherry Creek Reservoir dam, where flow is measured at a downstream USGS gauge, and through surface evaporation. Table 26. provides the flow-weighted nutrient concentrations for reservoir outflows (losses) during WY2024.

Table 26. Flow-Weighted Nutrient Concentrations at CC-0 and Evaporation, WY 2024.

Nutrient	Concentration (µg/L)	
	Cherry Creek Outflow	**Evaporation**
Total Phosphorus	104	0
Total Nitrogen	834	0

7.0 NUTRIENT BALANCES

The calculated WY 2024 phosphorus and nitrogen balances in Cherry Creek Reservoir were calculated using a mass-balance approach:

$$\sum \text{Reservoir Inflows}_{\text{Nutrient}} - \sum \text{Reservoir Releases}_{\text{Nutrients}} = \Delta\ \text{Storage}_{\text{Nutrients}}$$

A positive change in storage ($+\Delta\ \text{Storage}_{\text{Nutrients}}$) indicates that inflows exceed releases and that nutrients are being retained (stored) within the Reservoir. A negative change in storage ($-\Delta\ \text{Storage}_{\text{Nutrients}}$) would suggest that previously stored nutrients are being exported from the Reservoir.

The Reservoir's inflows (nutrient loads) considered in the WY 2024 nutrient balance are:

- Precipitation (incident to the Reservoir's surface).
- Alluvial groundwater.
- Cherry Creek and Cottonwood Creek surface water.

The only physical release mechanism considered from the nutrient mass balance is surface water released through the dam's outlet works. Nutrient loss through evaporation is considered zero as the evaporating water is assumed to not contain any nutrients. The net ungauged outflows were accounted for nutrient loading concentrations calculated in Table E based on the flow adjustments described in Section 3.0.

7.1 SURFACE WATER LOADS

CCBWQA collects water quality samples on a monthly basis at surface water monitoring stations CC-10, CT-2, and CC-Out. The Authority also periodically collects storm event samples at CC-10 and CT-2 that are analyzed for TP and TN.

The nutrient concentrations in samples collected at CC-10, CT-2 and CC-Out in WY 2024 are summarized in Table 23 and 26. Nutrient concentrations were combined with the WY 2024 daily flows to calculate annual total phosphorus and total nitrogen loads for the surface water inflows and outflows (releases) to/from the Reservoir (Table 22). The Cherry Creek and Cottonwood Creek loads presented in 3 were adjusted to apportion the ungauged inflows as discussed in Section 5.0. Table 27 outlines the TP and TN loading from Cherry and Cottonwood Creek and leaving the Reservoir.

Table 27. Surface Water Nutrient Loads to Cherry Creek Reservoir, WY 2024.

Site	WY 2024 Nutrient Loading	
	Total Phosphorus (Pounds)	Total Nitrogen (Pounds)
Inflows		
Cherry Creek	7,425	55,749
Cottonwood Creek	816	39,328
Releases		
USGS Gage & CC-Out	-5,916	-47,605

7.2 PRECIPITATION LOADS

Annually, TP and TN are analyzed from the rain collected at the PRECIP site located in Cherry Creek State Park during storm sampling events. These values represent atmospheric loading and dry deposition. Table 28 lists nutrient concentrations in the precipitation samples collected in WY 2024 and the updated historical mean values which were used to calculate the total loading from precipitation during WY 2024. The median TP and TN concentrations in precipitation for WY 2024 were greater than the historical medians.

Table 28. Cherry Creek Reservoir WY 2024 Precipitation Nutrient Concentrations and Loads.

	WY 2024	
PRECIP	Total Phosphorus	Total Nitrogen
WY 2024 Median Concentration (µg/L)	154	2,180
Updated Historical Median (µg/L)	130	1,995
Inflow WY 2024 (AF)	973	
Total Loading (lbs)	**334**	**5281**

Nutrient loads from precipitation were calculated by multiplying the historical median concentrations to account for the variability in concentrations and limited measurements collected annually. Daily precipitation loads were calculated by multiplying the lake surface area on each day with measurable precipitation by the amount of precipitation (Table 28).

7.3 ALLUVIAL GROUNDWATER LOADS

Water samples from monitoring well MW-9 just upstream of Cherry Creek Reservoir are collected twice a year and are analyzed for dissolved phosphorus and total nitrogen to account for nutrient loading from groundwater sources. Nutrient loads from groundwater were calculated using the historical median values due to variability in concentrations and limited measurements collected annually. The updated long-term median total phosphorus and total nitrogen concentrations were combined with the estimated adjusted inflow to calculate the nutrient loads from the alluvial groundwater inflow to the Reservoir. The results are summarized in Table 29.

Table 29. Cherry Creek Reservoir WY 2024 Groundwater Nutrient Concentrations and Loads.

	WY 2024	
MW-9	**Dissolved Phosphorus**	**Total Nitrogen**
WY 2024 Median Concentration (µg/L)	204	906
Updated Historical Median (µg/L)	190	1,020
Inflow (AF)	2,200	
Total Loading (lbs)	**1,137**	**6,102**

8.0 NUTRIENT MASS BALANCES

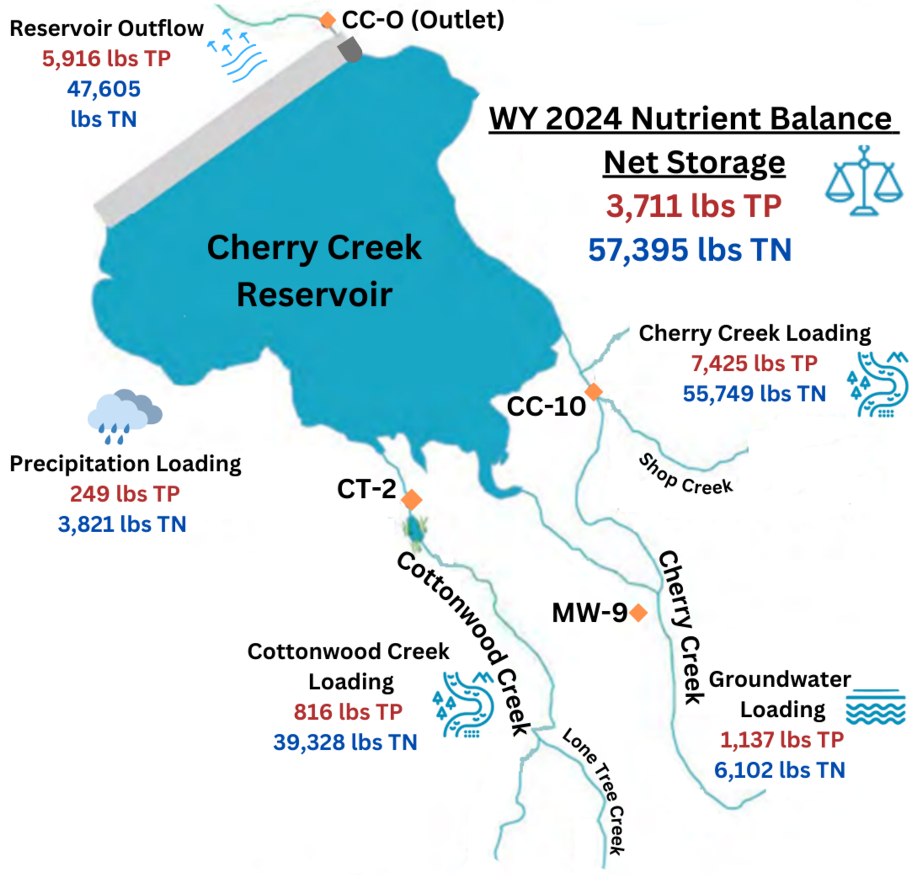
As summarized in Table 30, the phosphorus and nitrogen loading to the Reservoir is derived from four external sources: surface water from Cherry and Cottonwood Creeks, precipitation, and alluvial groundwater. The total nutrient balances are calculated from the inflows and releases as outlined in Tables 23 through Table 29.

Table 30. Total Phosphorus and Nitrogen Mass Balance in Cherry Creek Reservoir WY 2024.

Water Source	Total Phosphorus Mass (pounds)	Total Nitrogen Mass (pounds)
Inflows		
Cherry Creek (CC-10)	7,425	55,749
Cottonwood Creek (CT-2)	816	39,328
Precipitation	249	3,821
Alluvial groundwater	1,137	6,102
Total Inflows	**9,627**	**100,500**
Outflows		
Evaporation	0	0
Reservoir releases	-5,916	-47,605
Total Outflows	-5,916	-47,605
WY 2024 Storage	**3,711**	**57,395**

Mass balances for TP and TN for Cherry Creek Reservoir based on the inflow and the outflow loads (Δ $\text{Storage}_{\text{Nutrients}}$) indicate the net storage retained in the Reservoir in WY 2024. The net storage for TP and TN were calculated from the data presented in Sections 4.1 through 4.3 and are summarized in Table 30. The relative contributions of the inflow sources of phosphorus and nitrogen loading to the Reservoir in WY 2024 are represented in **Error! Not a valid bookmark self-reference.**.

Figure 80. Representation of Nutrient Loading and Storage in Cherry Creek Reservoir during WY 2024.



As noted previously, inputs from internal nutrient loading and nitrogen fixation and losses from denitrification are not included in the mass balances since collecting the data required to evaluate these factors were beyond the scope of this program. Previous studies (Nurnberg and LaZerte, 2008; AMEC et al. 2005) provided estimates of internal phosphorus loading ranging from 810 to 2,000 lbs of phosphorus/year, or 11.8 – 29.0% of the phosphorus loading from external sources listed in **Error! Reference source not found.**. Internal phosphorus loading may have been high in WY 2024 because there were low dissolved oxygen levels in the hypolimnion during the summer months that were accompanied by high phosphorus levels in the lower part of the water column.

Table 31 presents the current total nutrient mass loads, outflows and resulting storage in Cherry Creek Reservoir in comparison to previous years and the long-term average, and Figure 14 shows a graphical representation.

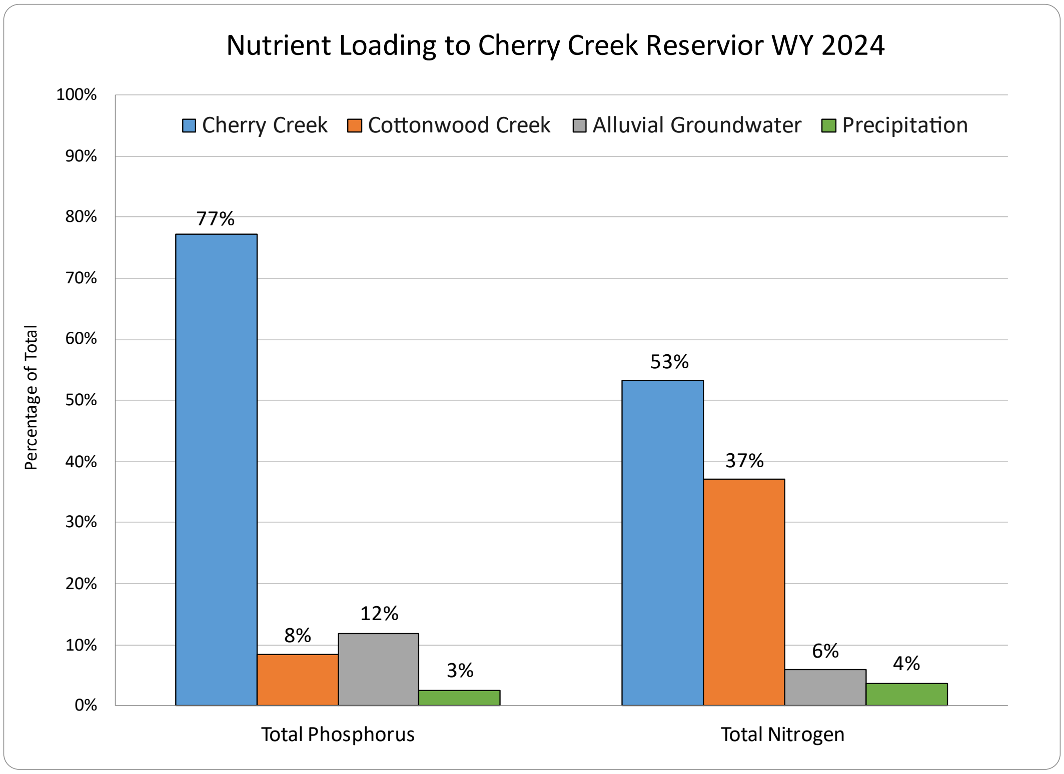


Figure 81. Nutrient Loading Percentages by Source to Cherry Creek Reservoir, WY 2024.

Table 31. Historical Comparison of Total Phosphorus and Nitrogen Loading to Cherry Creek Reservoir.

		Inflows (pounds)				Outflow (pounds)	Δ Storage (pounds)
Analyte	Period Mean	Surface Water	Alluvial Groundwater	Precipitation	Total Inflows		
Phosphorus	1993-2022	8,325	1,095	358	9,794	-4,535	5,561
Nitrogen		62,693	2,512	6,179	71,437	-38,137	33,323
Phosphorus	2018-2022	7,387	1,365	231	8,983	-4,416	4,747
Nitrogen		70,406	3,293	4,312	77,873	-39,279	38,732
Phosphorus	WY 2018	8,724	1,137	280	10,143	*-4,622*	5,519
Nitrogen		77,173	2,572	3,637	82,695	*-35,373*	48,010
Phosphorus	WY 2019	9,141	1,364	230	10,736	*-5,287*	5,449
Nitrogen		84,748	2,453	4,579	91,779	*-41,319*	50,461
Phosphorus	WY 2020	5,327	1,388	136	6,851	-2,826	4,025
Nitrogen		53,867	2,573	2,668	59,108	-28,225	30,883
Phosphorus	WY 2021	8,223	1,418	266	429,399	-5,210	4,697
Nitrogen		71,251	3,428	5,888	80,567	-47,953	32,614
Phosphorus	WY 2022	5,518	1,520	242	7,280	-4,133	3,177
Nitrogen		64,991	5,438	4,786	75,215	-43,526	32,002
Phosphorus	WY 2023	43,350	1,560	555	45,465	-15,347	30,118
Nitrogen		306,481	7,043	8,451	321,975	-100,643	221,332
Phosphorus	**WY 2024**	**8,241**	**1,137**	**249**	**9,627**	**-5,916**	**3,711**
Nitrogen		**95,077**	**6,102**	**3,821**	**105,00**	**-47,605**	**57,395**

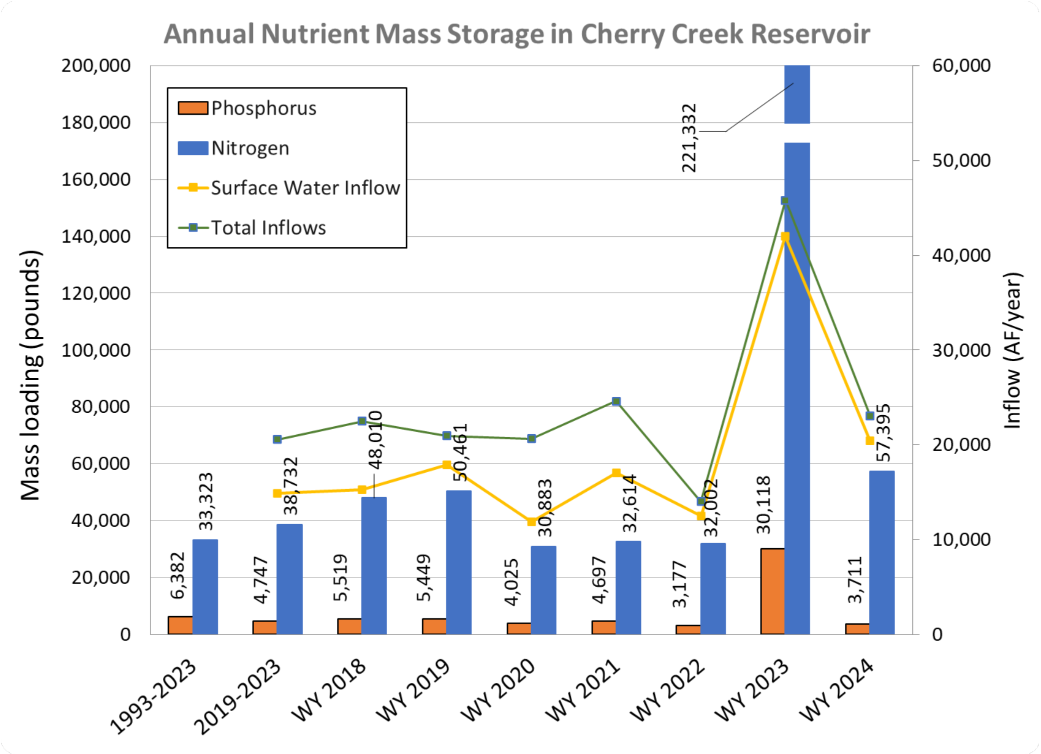


Figure 82. Current and Historical Phosphorus and Nitrogen Loading to Cherry Creek Reservoir.

9.0 WY 2024 WATER QUALITY SUMMARY

The CCBWQA's comprehensive monitoring program and WY 2024 data provide insight into current conditions and long-term trends in the watershed and Cherry Creek Reservoir.

- Cherry Creek Reservoir met the chl α seasonal standard and the Reg 38 standards for temperature, pH, and dissolved oxygen to support the Class 1 Warm Water Aquatic Life classification.
- Cherry Creek Reservoir continues to remain eutrophic to hypereutrophic in regard to total phosphorus, chl α, and transparency of the water.
- Phytoplankton dynamics in the reservoir are influenced by the nutrient-enriched conditions and can favor nitrogen-fixing cyanobacteria when nitrogen is limited.
- There was a cyanobacteria bloom in late-July resulting in posting of signage to inform the public of closures to recreational users of the Reservoir due to risk or presence of toxin. During this period, phosphorus was elevated but so were nitrate+nitrite, forms of nitrogen readily available for algal uptake. This also corresponded to the presence of Microcystis, a non-nitrogen fixing cyanobacteria, which is often responsible for toxin production.
- Continuous water quality data collection in WY 2024 provided accurate calculations of anoxic conditions, or low dissolved oxygen at the bottom of the Reservoir, which were present 43 days. Anoxic conditions facilitate internal loading of phosphorus from the sediments.
- Surface water flows are the main contributor of nutrient loading of the reservoir. The WY 2024 weather and precipitation in the watershed directly impacted the water quantity and quality of Reservoir inflows, internal Reservoir dynamics, and the overall water exchange rate.

- While internal and atmospheric nutrient contributions are recognized, they are not easily quantified or consistent enough to incorporate into the nutrient balance as fixed values. Continued monitoring and adaptive management are essential to understanding and managing nutrient dynamics in Cherry Creek Reservoir.
- There continue to be notable differences in water quality between Cherry Creek, Cottonwood Creek, and Piney Creek. Cherry Creek has much higher concentrations of phosphorus, and Cottonwood Creek has higher concentrations of nitrogen. Piney Creek continues to demonstrate lower concentrations of nutrients and suspended solids when compared to Cherry Creek during baseflow conditions. Stream characteristics vary in terms of stream channel morphology, flow patterns, wetlands, vegetation growth patterns, effects of storm events, watershed development, number of permitted wastewater treatment facility discharge outfalls, and differences in runoff from the watersheds. All of these factors play a role in water quality.
- There are notable upstream to downstream patterns observed from the upper to lower watershed in Cherry Creek and the nearby groundwater monitoring wells, including increasing conductivity and phosphorus.
- Conductivity in the streams and groundwater is significantly increasing over time, which impacts Reservoir water quality and dynamics and can impact aquatic life.
- In WY 2024, the constructed wetland PRF ponds on Cottonwood Creek functioned effectively to remove phosphorus and suspended solids during stormflow conditions. In addition, the PRF ponds on Cottonwood Creek have been functioning effectively when evaluating upstream to downstream concentrations on a long-term basis. The stream reclamation PRFs on McMurdo Gulch are also performing well.
- Due to monitoring equipment damage, inflows for Cherry Creek and Cottonwood were again calculated based on relative contributions from previous years based on the storage information from the USACE; these estimates seem to be representative.
- Nutrient storage calculations demonstrate the significant potential high flows associated with storm events can have on the nutrient loading. WY 2024 storage was within the average range when compared to the elevated nutrient loading to Cherry Creek Reservoir during WY 2023.

10.0 REFERENCES

AMEC, Earth and Environmental, Inc., Alex Horne Associates, and Hydrosphere Resource Consultants, Inc. 2005. Cherry Creek Reservoir Destratification. Feasibility report prepared for the Cherry Creek Basin Water Quality Authority.

Carlson, R.E. 1977. A trophic state index for lakes. Limnol. Oceanogr. 22:361-369.

Colorado Division of Water Resources, Cherry Creek Reservoir Elevation (CHRRESCO). https://dwr.state.co.us/

Cherry Creek Basin Water Quality Data Portal. LRE Water. https://www.ccbwqportal.org/

Cherry Creek Reservoir Destratification Facilities Operation and Maintenance Annual Report, 2024.

Clary, Jane, J. Jones, M. Leisenring, P. Hobson, and E. Strecker. 2020. *International Stormwater: BMP Database 2020 Summary Statistics*. Water Research Foundation. Project No. 4968.

Dinkle, Brett. Cherry Creek Reservoir Sustainable Rivers Program (slide presentation), 2023.

EPA. National Recommended Water Quality Criteria - Aquatic Life Criteria Table.

GEI Consultants, Inc. February 2016. *Cherry Creek Reservoir 2015 Water Year Aquatic Biological Nutrient Monitoring Study and Cottonwood Creek Pollutant Reduction Facilities Monitoring.* Prepared for the Cherry Creek Basin Water Quality Authority.

Goldman, C. R., and A. J. Horne. 1983. Limnology. McGraw-Hill Book Co., New York. 464p.

Halepaska and Associates, Inc. 1998 -2006. *Annual Reports, Baseline Water Quality Data Collection Study for the Upper Cherry Creek Basin*. Prepared for the Cherry Creek Basin Water Quality Authority.

Hutchinson, G. E. 1967. *A Treatise on Limnology, Volume 2, Introduction to Lake Biology and the Limnoplankton*. John Wiley and Sons, Inc., New York.

Hydros Consulting Inc. July 31, 2015. *Technical Memorandum, Key Findings to Tasks 3 and 3a, Cherry Creek Reservoir Water Quality Modeling Project: Model Calibration and Sensitivity Analyses.*

Johnson, B. 2014. Environmental Conditions for Walleye in Cherry Creek Reservoir. Prepared for the Cherry Creek Basin Water Quality Authority. (Attachment A in Cherry Creek Reservoir Model Documentation April 5, 2017. Prepared for The Cherry Creek Basin Water Quality Authority by C. Hawley and J.M. Boyer, Hydros Consulting, Inc, Boulder, CO.

Lewis, W. M. Jr. 1983. *A Revised Classification of Lakes Based on Mixing*. Can. J Fish. Aquat. Sci. 40:1779-1787.

Lewis, W. M., and J. F. Saunders. 2002. *Review and Analysis of Hydrologic Information on Cherry Creek Watershed and Cherry Creek Reservoir*. Prepared for the Cherry Creek Basin Water Quality Authority.

Lewis, W. M., J. F. Saunders, and J. H. McCutchan. 2004. *Studies of Phytoplankton Response to Nutrient Enrichment in Cherry Creek Reservoir, Colorado.* Prepared for Colorado Department of Public Health and Environment, Water Quality Control Division.

Lewis, W. M., J. H. McCutchan, and J. F. Saunders. 2005. *Estimation of Groundwater Flow into Cherry Creek Reservoir and its Relationship to the Phosphorous Budget of the Reservoir*. Prepared for the Cherry Creek Basin Water Quality Authority.

LRE Water. CCBWQA Annual Monitoring Report, WY 2022.

LRE Water. CCBWQA Annual Monitoring Report, WY 2023.

Marzolf, G. R. 1990. Reservoirs as environments for zooplankton. pp. 195-208, In K. W. Thornton, B. L. Kimmel, and F. E. Payne (eds.), Reservoir Limnology. John Wiley and Sons, Inc., New York.

D Mulkerrins, A.D.W Dobson, E Colleran, Parameters affecting biological phosphate removal from wastewaters, Environment International, Volume 30, Issue 2, 2004, Pages 249-259, ISSN 0160-4120, https://doi.org/10.1016/S0160-4120(03)00177-6.

NOAA. National Weather Service. Advanced Hydrologic Prediction Service. https://water.weather.gov/precip/

NOAA.

Nürnberg, G., and LaZerte, B. 2008. *Cherry Creek Reservoir Model and Proposed Chlorophyll Standard*. Prepared for the Cherry Creek Basin Water Quality Authority.

Pennak, R.W. 1957. Species composition of limnetic zooplankton communities. Limnol. Oceanogr. 2:222-232.

Preisendorfer, R.W. 1986. Eyeball optic of natural waters: Secchi disk science. NOAA Tech. Memo. ERL PMEL 67. 90 p. NTIS PB86 224060/AS.

RESPEC. 2021. Monitoring Station CC-10 and Lakeview Drive Flow Ratings. External Memorandum prepared for the Cherry Creek Basin Water Quality Authority.

Reynolds, C.S. 1986. *The Ecology of Freshwater Phytoplankton*. Cambridge University Press, New York.

Schindler, D.W. 1977. Evolution of Phosphorus Limitation in Lakes. Science 195:260-262.

Seefus, Kathryn. Cherry Creek Reservoir Sustainable Rivers Program (slide presentation), 2024.

Solitude Lake Management. CCBWQA Annual Monitoring Report, WY 2018.

Solitude Lake Management. CCBWQA Annual Monitoring Report, WY 2019.

Solitude Lake Management. CCBWQA Annual Monitoring Report, WY 2020.

Solitude Lake Management. CCBWQA Annual Monitoring Report, WY 2021.

Standard methods for the analysis of water and wastewater, 20th Edition. 1998. APHA, AWWA, WEF. Washington, D.C.

Tetra Tech. February 2018. Water Year 2017 Cherry Creek Monitoring Report.

Tetra Tech. January 2017. 2016 Cherry Creek Monitoring Report.

TSTool. 2022. Colorado's Decision Support Systems. https://cdss.colorado.gov/software/tstool

U.S. EPA. 1980. Clean lakes program guidance manual. Report No. EPA-440/5-81-003. U.S. EPA, Washington, D.C.

US EPA. 2016. Policies and Guidelines. Available online: https://www.epa.gov/nutrient-policy-data/guidelines-and-recommendations (accessed on 15 December 2016).

US Geological Survey, Flows for *USGS Gage Cherry Creek below Cherry Creek Lake*. *https://waterdata.usgs.gov/nwis*

US Geological Survey. *Streamflow for USGS Gage Cherry Creek Near Franktown, CO.*

US Geological Survey. *Streamflow for USGS Gage Cherry Creek Near Parker, CO.* *https://waterdata.usgs.gov/nwis*

Vollenweider, R.A. 1968. The scientific basis of lake and stream eutrophication, with particular reference to phosphorus and nitrogen as eutrophication factors. Technical Report OAS/DSI/68.27. Organization for Economic Cooperation and Development. Paris.

Walmsley, R.D. and M. Butty. 1979. Eutrophication of rivers and dams. VI. An investigation of chlorophyll-nutrient relationships for 21 South African Impoundments. Contributed Report, Water Res. Comm., Pretoria, South Africa.

Water Quality Control Commission, 2015. Cherry Creek Control Regulation No. 72, 5-CCR-1002-72.

Water Quality Control Commission, 2022. South Platte Standards and Use Classifications, Regulation No. 38, 5-CCR-1002-38.

Water Quality Control Commission, 2017. Nutrient Control Regulation No. 85, 5-CCR-1002-85.

Water Quality Control Commission, 2021. The Basic Standards and Methodologies for Surface Water. Regulation No. 31, 5-CCR-1002-31.

Water Quality Control Commission, 2024. The Basic Standards and Methodologies for Surface Water. Regulation No. 31, 5-CCR-1002-31.

Water Quality Control Commission, 2020. The Basic Standards for Ground Water. Regulation No. 41, 5-CCR-1002-41.

Welch, E. B., J. M Jacoby. 2004. *Pollutant Effects in Freshwater, Applied Limnology*. 3rd ed. Spoon Press.

Wetzel, R. G. 2001. *Limnology*, 3rd Edition. Academic Press, San Diego, CA.

APPENDICES

APPENDIX A - Cherry Creek Basin Water Quality Authority Monitoring Data, WY 2024.

APPENDIX B – WY 2024 Cherry Creek Reservoir Daily Inflow and Outflow Data and Monthly Summary Information

Appendix A – Cherry Creek Basin Water Quality Authority Monitoring Data for Water Year 2024

Table 1. Cherry Creek Reservoir, Physical Parameters, Water Year 2024[1].

Constituent	*Units*	*Site Abbrev.*	10/11/2023	11/9/2023	12/6/2023	3/28/2024	4/17/2024	5/7/2024[2]	5/20/2024	6/3/2024	6/18/2024	7/2/2024	7/25/2024	8/6/2024	8/21/2024[3]	9/3/2024	9/23/2024
Chlorophyll-a	ug/L	CCR-1	13	37	41	34	12	44	10	9	8	5	21	21	16	19	18
Chlorophyll-a	ug/L	CCR-2	15	48	39	35	14	45	9	10	8	5	18	16	18	16	19
Chlorophyll-a	ug/L	CCR-3	17	56	39	30	14	49	10	12	10	6	9	19	25	19	25
Conductivity	uS/cm	CCR-1	958	959	959	1,199	1,199	1,198	1,199	1,225	1,199	1,183	1,190	1,228	1,227	1,216	1,211
Conductivity	uS/cm	CCR-2	951	960	960	1,211	1,211	1,197	1,211	1,227	1,198	1,185	1,193	1,232	1,226	1,217	1,212
Conductivity	uS/cm	CCR-3	953	960	960	1,245	1,245	1,196	1,245	1,227	780	1,189	1,193	1,227	1,226	1,233	1,214
Dissolved Oxygen	mg/L	CCR-1	7.5	6.7	6.7	11.5	11.5	9.6	11.5	8.6	6.4	5.4	9.3	6.2	6.5	6.8	6.9
Dissolved Oxygen	mg/L	CCR-2	9.1	7.5	7.5	11.4	11.4	9.9	11.4	8.6	6.4	4.3	9.2	4.1	6.8	6.9	7.0
Dissolved Oxygen	mg/L	CCR-3	9	8	8	11	11	10	11	9	6	2	9	6	7	7	7
Light Transmittance [99% Attenuation][4]	m	CCR-1	3	2	3	3	4		5	5	6	5	4	2		3	3
Light Transmittance [99% Attenuation]	m	CCR-2	3	2	3	3	4	2	6	5	6	6	5	2		3	2
Light Transmittance [99% Attenuation]	m	CCR-3	3.2	2.1	3.0	2.5	3.5		5.4			4.8	3.8	2.5		3.0	
Light Transmittance [Secchi Depth]	m	CCR-1	0.9	0.7	1.0	0.7	1.1	0.6	3.7	1.7	2.8	2.5	1.6	0.8		0.9	0.8
Light Transmittance [Secchi Depth]	m	CCR-2	1.1	0.8	1.1	0.7	1.0	0.7	3.3	1.8	3.0	2.9	2.0	0.8		0.9	0.6
Light Transmittance [Secchi Depth]	m	CCR-3	0.9	0.7	1.2	0.6	1.0	0.6	2.8		2.9	2.8	1.4	0.7		0.8	0.6
pH	None	CCR-1	8.6	8.5	8.5	8.5	8.5	8.8	8.5	8.5	8.2	8.2	8.7	8.4	8.4	8.3	8.2
pH	None	CCR-2	8.7	8.6	8.6	8.5	8.5	8.9	8.5	8.5	8.2	8.1	8.6	8.2	8.4	8.3	8.2

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[1] Blank fields indicate that measurement was not collected or was the bottom of the Reservoir.

[2] Light Transmittance measurements were not recorded on May 7, 2024 at CCR-1 and CCR-3 due to high winds.

[3] Light Transmittance measurements were not recorded on August 21, 2024 due to high winds.

pH	None	CCR-3	8.6	8.6	8.6	8.6	8.6	8.8	8.6	8.6	8.2	7.9	8.6	8.4	8.4	8.4	8.2
Total Suspended Solids	mg/L	CCR-1	10	10	3	9	10	20	1	5	4	4	5	11	8	10	9
Total Suspended Solids	mg/L	CCR-2	8	12	6	8	6	18	3	5	2	2	3	11	13	11	13
Total Suspended Solids	mg/L	CCR-3	8	15	6	8	6	21	4	5	1	4	5	14	6	12	13
Total Volatile Suspended Solids	mg/L	CCR-1	3.6	2.8	2.1	4.8	3.6	4.9	1.3	1.6	3.6	1.4	1.9	2.2	2.4	3.5	2.7
Total Volatile Suspended Solids	mg/L	CCR-2	4.2	5.0	4.0	4.0	2.4	5.6	0.2	2.6	0.8	1.4	2.0	2.0	6.8	3.2	5.3
Total Volatile Suspended Solids	mg/L	CCR-3	3.2	6.7	4.0	4.4	2.4	4.7	3.3	2.0	0.8	1.1	2.9	5.6	3.7	3.2	4.0
Water Temperature	deg C	CCR-1	15.7	18.8	18.8	7.2	7.2	11.9	7.2	19.1	22.0	22.6	23.4	23.9	24.0	21.7	18.2
Water Temperature	deg C	CCR-2	16.3	19.1	19.1	7.6	7.6	12.0	7.6	19.1	39.6	22.6	23.6	23.7	23.9	22.2	18.3
Water Temperature	deg C	CCR-3	16.0	19.5	19.5	8.2	8.2	12.0	8.2	19.3	22.1	22.4	23.3	23.3	24.3	22.6	19.0

Table 2. Cherry Creek Reservoir Nutrients and Chemical Parameters, Water Year 2024.

Constituent	*Units*	*Site Abbrev.*	10/11/2023	11/9/2023	12/6/2023	3/28/2024	4/17/2024	5/7/2024	5/20/2024	6/3/2024	6/18/2024	7/2/2024	7/25/2024	8/6/2024	8/21/2024	9/3/2024	9/23/2024
Dissolved Nitrogen as N	ug/L	CCR-1	563	355	486	508	441	211	411	676	631	794	540	418	347	563	468
Dissolved Nitrogen as N	ug/L	CCR-2	558	332	442	400	621	243	351	424	748	742	656	480	387	500	452
Dissolved Nitrogen as N	ug/L	CCR-3	543	327	711	447	410	228	390	576	683	772	555	464	355	574	442
Dissolved Organic Carbon	mg/L	CCR-2	6.1	5.8	6.0	5.2	5.0	5.7	5.6	5.2	6.0	6.1	6.3	6.2	6.6	6.3	6.2
Dissolved Phosphorus	ug/L	CCR-1	27	12	11	6	10	25	28	39	94	156	104	75	34	20	21
Dissolved Phosphorus	ug/L	CCR-2	15	14	15	5	10	24	29	46	96	159	120	78	40	20	22
Dissolved Phosphorus	ug/L	CCR-3	19	13	44	5	9	26	28	44	99	152	112	81	42	20	20
Nitrate + Nitrite as N	ug/L	CCR-1	3	22	3	3	3	3	3	3	11	3	13	3	3	3	3
Nitrate + Nitrite as N	ug/L	CCR-2	3	13	3	3	13	3	3	3	14	3	19	3	3	3	3
Nitrate + Nitrite as N	ug/L	CCR-3	3	3	3	3	3	3	3	3	17	3	10	3	3	3	3
Soluble Reactive Phosphorus as P	ug/L	CCR-1	17	3	1	2	2	12	21	24	90	132	89	53	22	10	8
Soluble Reactive Phosphorus as P	ug/L	CCR-2	6	2	1	1	1	12	22	31	91	134	72	60	22	9	12

Soluble Reactive Phosphorus as P	ug/L	CCR-3	9	2	18	1	1	13	21	28	95	138	74	61	26	9	7
Total Ammonia as N	ug/L	CCR-1	20	11	3	53	15	14	3	3	67	149	14	26	11	48	18
Total Ammonia as N	ug/L	CCR-2	13	16	3	64	3	10	3	3	61	139	28	24	15	3	3
Total Ammonia as N	ug/L	CCR-3	3	3	3	64	3	13	3	3	68	149	3	35	13	13	3
Total Nitrogen as N	ug/L	CCR-1	830	669	871	860	739	506	454	730	831	933	675	973	535	812	623
Total Nitrogen as N	ug/L	CCR-2	849	828	879	902	650	446	420	721	753	875	687	799	575	691	751
Total Nitrogen as N	ug/L	CCR-3	794	731	939	931	687	446	496	687	694	929	648	755	611	823	765
Total Organic Carbon	mg/L	CCR-2	6.2	6.6	6.0	5.4	5.3	6.0	5.8	5.7	6.5	6.1	6.5	6.8	6.7	6.7	6.6
Total Phosphorus	ug/L	CCR-1	74	75	63	66	83	106	46	66	113	193	144	136	70	75	58
Total Phosphorus	ug/L	CCR-2	70	83	71	62	57	76	43	82	122	174	148	131	72	53	72
Total Phosphorus	ug/L	CCR-3	71	85	68	61	56	73	46	77	120	223	156	134	81	53	66
Total Suspended Solids	mg/L	CCR-1	10	10	3	9	10	20	1	5	4	4	5	11	8	10	9
Total Suspended Solids	mg/L	CCR-2	8	12	6	8	6	18	3	5	2	2	3	11	13	11	13
Total Suspended Solids	mg/L	CCR-3	8	15	6	8	6	21	4	5	1	4	5	14	6	12	13

Table 3. Cherry Creek Watershed Streams Sites Physical Parameters, Water Year 2024.

Constituent	*Units*	*Site Abbrev.*	10/10/2023	11/6/2023	12/11/2023	1/17/2024	2/20/2024	3/28/2024	4/10/2024	5/7/2024	5/8/2024	6/12/2024	7/11/2024	8/21/2024
Dissolved Oxygen	mg/L	CC-1		8.6							9.1			
Dissolved Oxygen	mg/L	CC-10	8.9	8.5	10.8	11.3	10.8	9.4	9.6		8.4	7.1	7.8	7.5
Dissolved Oxygen	mg/L	CC-2		9.2							10.9			
Dissolved Oxygen	mg/L	CC-4		8.7							8.0			
Dissolved Oxygen	mg/L	CC-5		8.9							8.9			
Dissolved Oxygen	mg/L	CC-6		9.5							8.8			
Dissolved Oxygen	mg/L	CC-7	8.5	10.0	10.2	11.6	10.1	9.9	9.8		9.5	7.6	9.4	7.7
Dissolved Oxygen	mg/L	CC-8		9.8							8.8			
Dissolved Oxygen	mg/L	CC-9		8.4							8.3			
Dissolved Oxygen	mg/L	CC-Out	8.2	9.7	11.5	8.3	10.9	10.3	9.6	9.5		7.0	7.3	7.1
Dissolved Oxygen	mg/L	CT-1	9.5	10.0	12.1	13.1	12.6	14.3	13.1	12.1		9.4	8.5	8.1

Dissolved Oxygen	mg/L	CT-2	8.3	9.2	10.9	11.1	10.6	9.3	8.9	10.2		7.6	7.2	7.6
Dissolved Oxygen	mg/L	CT-P1	9.3	9.8	11.5	12.2	11.4	10.5	9.5	10.7		7.8	6.7	7.7
Dissolved Oxygen	mg/L	CT-P2	9.0	8.8	11.2	12.4	12.1	10.5	10.5	11.7		9.4	7.2	8.4
Dissolved Oxygen	mg/L	PC-1	12.1	16.1	12.3	14.0	13.5	11.8	13.5	9.4		8.0	10.6	8.7
Dissolved Oxygen	mg/L	USGS-Franktown		10.6							10.1			
Dissolved Oxygen	mg/L	USGS-Parker		8.1							7.7			
Dissolved Oxygen, Saturation	%	CC-1		92							94			
Dissolved Oxygen, Saturation	%	CC-10	101	98	101	99	106	104	112		101	96	102	95
Dissolved Oxygen, Saturation	%	CC-2		97							115			
Dissolved Oxygen, Saturation	%	CC-4		100							98			
Dissolved Oxygen, Saturation	%	CC-5		102							108			
Dissolved Oxygen, Saturation	%	CC-6		111							108			
Dissolved Oxygen, Saturation	%	CC-7	98	115	98	105	100	114	106		114	97	131	96
Dissolved Oxygen, Saturation	%	CC-8		115							108			
Dissolved Oxygen, Saturation	%	CC-9		98							102			
Dissolved Oxygen, Saturation	%	CC-Out	103	106	104	72	104	104	103	109		94	103	101
Dissolved Oxygen, Saturation	%	CT-1	113	97	116	113	128	164	157	141		138	116	109
Dissolved Oxygen, Saturation	%	CT-2	96	89	100	95	103	100	99	115		112	99	103
Dissolved Oxygen, Saturation	%	CT-P1	115	94	111	106	116	109	105	126		110	87	112
Dissolved Oxygen, Saturation	%	CT-P2	111	84	106	108	124	111	121	139		135	100	123
Dissolved Oxygen, Saturation	%	PC-1	136	186	112	120	128	138	147	116		103	153	110
Dissolved Oxygen, Saturation	%	USGS-Franktown		104							102			
Dissolved Oxygen, Saturation	%	USGS-Parker		96							92			
pH	None	CC-1		7.5							7.8			
pH	None	CC-10	8.0	8.1	8.2	8.0	8.1	8.1	8.2		8.1	8.0	8.1	8.0
pH	None	CC-2		7.8							8.2			
pH	None	CC-4		7.9							7.7			
pH	None	CC-5		7.9							8.0			
pH	None	CC-6		7.9							7.9			
pH	None	CC-7	7.9	8.1	7.9	8.1	8.0	8.2	8.0		8.2	8.0	8.3	8.0
pH	None	CC-8		8.2							8.0			
pH	None	CC-9		8.1							8.1			

pH	None	CC-Out	8.5	8.6	8.7	8.1	8.1	8.5	8.5	8.8		8.0	8.3	8.4
pH	None	CT-1	8.1	8.1	8.3	8.2	8.2	8.5	8.3	8.3		8.1	8.2	8.1
pH	None	CT-2	7.7	8.0	8.1	7.9	7.9	7.8	7.8	8.2		8.0	8.0	8.1
pH	None	CT-P1	8.0	7.9	8.1	7.8	8.1	8.1	8.0	8.3		8.0	7.9	8.2
pH	None	CT-P2	7.9	7.9	8.0	7.8	8.0	8.0	8.1	8.2		8.0	8.0	8.0
pH	None	PC-1	8.0	8.4	8.1	8.1	8.1	8.4	8.2	8.2		8.1	8.2	7.9
pH	None	USGS-Franktown		8.0							8.4			
pH	None	USGS-Parker		7.8							7.6			
Specific Conductance	uS/cm	CC-1		366							402			
Specific Conductance	uS/cm	CC-10	1,155	1,189	1,229	1,173	1,344	1,336	1,343		1,357	1,151	1,184	1,196
Specific Conductance	uS/cm	CC-2		501							507			
Specific Conductance	uS/cm	CC-4		833							1,055			
Specific Conductance	uS/cm	CC-5		869							1,044			
Specific Conductance	uS/cm	CC-6		923							1,102			
Specific Conductance	uS/cm	CC-7	961	983	973	965	1,104	1,102	1,062		1,146	899	969	1,003
Specific Conductance	uS/cm	CC-8		1,015							1,189			
Specific Conductance	uS/cm	CC-9		1,171							1,349			
Specific Conductance	uS/cm	CC-Out	962	1,086	1,038	1,123	1,343	1,201	1,232	1,257		1,075	1,198	1,224
Specific Conductance	uS/cm	CT-1	1,871	1,654	1,949	1,610	2,630	2,258	2,046	1,983		2,023	1,519	1,524
Specific Conductance	uS/cm	CT-2	1,796	1,694	1,962	1,608	2,912	2,592	1,857	2,022		1,958	1,545	1,512
Specific Conductance	uS/cm	CT-P1	2,497	2,991	3,235	4,301	4,072	2,533	3,124	2,842		2,746	2,604	2,246
Specific Conductance	uS/cm	CT-P2	2,513	2,999	3,639	4,039	4,232	2,573	3,026	2,855		2,683	1,546	2,185
Specific Conductance	uS/cm	PC-1	1,875	1,978	2,193	2,011	1,881	1,750	2,082	1,984		1,134	1,516	1,936
Specific Conductance	uS/cm	USGS-Franktown		304							339			
Specific Conductance	uS/cm	USGS-Parker		783							1,004			
Water Temperature	deg C	CC-1		8.4							7.8			
Water Temperature	deg C	CC-10	11.2	11.6	4.1	0.9	5.8	10.4	12.8		14.3	19.8	17.8	18.7
Water Temperature	deg C	CC-2		7.9							8.6			
Water Temperature	deg C	CC-4		11.1							14.9			
Water Temperature	deg C	CC-5		11.4							14.7			
Water Temperature	deg C	CC-6		12.0							14.6			
Water Temperature	deg C	CC-7	12.1	11.5	5.0	2.3	6.0	12.3	9.5		13.8	17.5	22.0	17.9

Water Temperature	deg C	CC-8		12.1							15.0			
Water Temperature	deg C	CC-9		12.1							14.8			
Water Temperature	deg C	CC-Out	15.9	9.4	2.6	0.8	4.5	6.9	9.2	11.9		19.9	22.7	23.3
Water Temperature	deg C	CT-1	13.3	5.9	4.8	0.4	7.1	12.2	14.3	12.2		23.9	20.7	21.2
Water Temperature	deg C	CT-2	12.1	5.3	3.0	0.3	5.1	8.9	11.0	11.1		23.9	21.2	22.1
Water Temperature	deg C	CT-P1	15.1	5.0	4.7	0.3	7.0	7.9	10.4	12.8		21.4	18.4	23.9
Water Temperature	deg C	CT-P2	15.1	4.9	3.9	0.3	6.9	8.4	12.3	13.3		23.1	21.2	24.2
Water Temperature	deg C	PC-1	11.1	11.5	3.1	0.3	4.2	13.2	10.1	15.2		17.2	23.5	18.7
Water Temperature	deg C	USGS-Franktown		4.9							6.7			
Water Temperature	deg C	USGS-Parker		12.5							13.7			

Table 4. Cherry Creek Watershed Streams Sites Nutrients and Chemical Parameter Concentrations, WY 2024, Baseflow.

Constituent	*Units*	*Location Name*	10/19/2022	11/7-8/2022	12/6/2022	1/10/2023	2/14/2023	3/14/2023	4/12/2023	5/3-4/2023	6/15/2023	7/10/2023	8/9/2023	9/13/2023
Nitrate + Nitrite as N	ug/L	CC-10	313	277	684	915	827	345	259	361	*	352	516	502
Nitrate + Nitrite as N	ug/L	CC-7	765	710	1,430	1,190	1,290	490	471	572		512	675	839
Nitrate + Nitrite as N	ug/L	CC-Out	3	3	18	123	165	16	3	3		171	3	16
Nitrate + Nitrite as N	ug/L	CT-1	1,410	1,450	2,810	1,680	2,030	2,950	1,010	1,182		844	1,410	1,580
Nitrate + Nitrite as N	ug/L	CT-2	1,250	1,250	2,530	1,770	2,070	2,820	472	491		495	459	679
Nitrate + Nitrite as N	ug/L	CT-P1	368	326	495	620	508	331	152	173		185	422	439
Nitrate + Nitrite as N	ug/L	CT-P2	544	402	599	708	536	518	327	259		270	618	590
Nitrate + Nitrite as N	ug/L	MCM-1	309		555		709		539				334	
Nitrate + Nitrite as N	ug/L	MCM-2	3		126		306		13				36	
Nitrate + Nitrite as N	ug/L	PC-1	152	77	197	304	151	200	28	92		355	404	405
Total Ammonia as N	ug/L	CC-10	3	3	3	18	3	22	3	23	*	21	16	26
Total Ammonia as N	ug/L	CC-7	10	10	3	19	13	22	3	34		11	22	35
Total Ammonia as N	ug/L	CC-Out	15	36	9	248	361	167	3	3		253	3	62
Total Ammonia as N	ug/L	CT-1	13	15	24	33	374	88	101	46		38	17	28
Total Ammonia as N	ug/L	CT-2	56	50	19	33	276	99	42	37		42	42	68

Total Ammonia as N	ug/L	CT-P1	22	14	14	21	13	66	22	3		31	3	43
Total Ammonia as N	ug/L	CT-P2	24	3	3	12	3	39	22	3		15	37	53
Total Ammonia as N	ug/L	MCM-1	3		3		3		14				3	
Total Ammonia as N	ug/L	MCM-2	3		3		3		3				3	
Total Ammonia as N	ug/L	PC-1	3	3	3	13	3	20	3	3			3	43
Dissolved Nitrogen as N	ug/L	CC-10			1,220	1,570	1,420	800	900		*	1,010	1,320	810
Dissolved Nitrogen as N	ug/L	CC-7			2,140	2,530	2,050	587	1,310			1,300	1,500	1,270
Dissolved Nitrogen as N	ug/L	CC-Out			553	1,130	1,390	710	790			1,070	720	320
Dissolved Nitrogen as N	ug/L	CT-1			3,810	3,690	3,280	3,240	2,210			1,950	2,720	2,250
Dissolved Nitrogen as N	ug/L	CT-2			3,680	3,730	3,240	2,820	1,380			1,430	1,400	1,230
Dissolved Nitrogen as N	ug/L	CT-P1			1,060	1,290	1,150	890	910			920	1,250	850
Dissolved Nitrogen as N	ug/L	CT-P2			1,200	1,500	1,120	1,050	1,130			1,060	1,560	1,010
Dissolved Nitrogen as N	ug/L	PC-1			658	930	810	480	540			1,143	1,280	557
Total Nitrogen as N	ug/L	CC-10	814	776	1,320	1,680	1,460	810	970	768	1,480	1,160	1,580	960
Total Nitrogen as N	ug/L	CC-7	1,430	1,657	2,220	2,600	2,120	920	1,350	1,250	1,960	1,400	1,750	1,350
Total Nitrogen as N	ug/L	CC-Out	841	1,060	924	1,310	1,610	980	1,270	748	950	1,280	920	560
Total Nitrogen as N	ug/L	CT-1	2,770	3,560	3,970	3,780	3,640	3,430	2,500	2,090	1,900	2,280	2,770	2,520
Total Nitrogen as N	ug/L	CT-2	2,520	2,940	3,860	3,830	3,400	2,990	1,710	1,190	1,510	1,570	1,580	1,350
Total Nitrogen as N	ug/L	CT-P1	1,060	1,130	1,200	1,510	1,230	970	960	660	1,380	1,140	1,390	980
Total Nitrogen as N	ug/L	CT-P2	1,210	1,220	1,280	1,510	1,410	1,250	1,300	840	1,800	1,170	1,700	1,200
Total Nitrogen as N	ug/L	MCM-1	737		983		1,230		1,170		900		1,020	
Total Nitrogen as N	ug/L	MCM-2	293		418		810		520		815		705	
Total Nitrogen as N	ug/L	PC-1	669	506	766	1,070	860	500	750	530	1,120	1,250	1,400	930
Soluble Reactive Phosphorus as P	ug/L	CC-10	128	126	92	87	73	83	95	170	*	218	196	155
Soluble Reactive Phosphorus as P	ug/L	CC-7	71	78	52	51	41	42	49	124		164	168	114
Soluble Reactive Phosphorus as P	ug/L	CC-Out	1	5	2	31	65	15	1	24		162	90	49
Soluble Reactive Phosphorus as P	ug/L	CT-1	3	3	3	2	4	5	5	8		29	20	10
Soluble Reactive Phosphorus as P	ug/L	CT-2	5	5	3	2	3	4	4	7		39	31	20
Soluble Reactive Phosphorus as P	ug/L	CT-P1	6	3	4	3	4	6	5	3		35	23	26
Soluble Reactive Phosphorus as P	ug/L	CT-P2	4	2	3	2	3	4	4	8		31	45	21
Soluble Reactive Phosphorus as P	ug/L	MCM-1	387		261		193		198				418	
Soluble Reactive Phosphorus as P	ug/L	MCM-2	248		145		157		134				366	

Soluble Reactive Phosphorus as P	ug/L	PC-1	43	42	45	47	37	31	34	54		119	116	101
Dissolved Phosphorus	ug/L	CC-10	136	129	93	91	83	85	96	174	*	224	205	156
Dissolved Phosphorus	ug/L	CC-7	82	82	58	57	48	44	56	126		174	169	117
Dissolved Phosphorus	ug/L	CC-Out	13	16	13	41	77	26	8	30		178	111	61
Dissolved Phosphorus	ug/L	CT-1	9	9	9	12	12	12	12	13		54	30	20
Dissolved Phosphorus	ug/L	CT-2	13	12	8	13	10	11	10	13		52	41	30
Dissolved Phosphorus	ug/L	CT-P1	9	9	8	11	10	10	8	8		50	33	34
Dissolved Phosphorus	ug/L	CT-P2	7	8	6	10	9	8	7	15		44	54	30
Dissolved Phosphorus	ug/L	MCM-1	411		274		193		210				419	
Dissolved Phosphorus	ug/L	MCM-2	270		171		182		140				380	
Dissolved Phosphorus	ug/L	PC-1	49	46	46	49	47	33	36	61		126	129	103
Total Phosphorus	ug/L	CC-10	172	150	112	102	102	105	121	194	245	297	370	250
Total Phosphorus	ug/L	CC-7	102	98	71	72	71	61	76	162	241	218	287	149
Total Phosphorus	ug/L	CC-Out	85	91	64	97	116	99	68	118	178	228	158	106
Total Phosphorus	ug/L	CT-1	41	36	32	35	45	43	49	52	79	85	77	66
Total Phosphorus	ug/L	CT-2	34	46	23	25	31	39	48	44	86	74	76	54
Total Phosphorus	ug/L	CT-P1	64	42	40	31	36	41	30	45	87	95	72	64
Total Phosphorus	ug/L	CT-P2	38	29	19	27	43	41	41	62	83	91	102	70
Total Phosphorus	ug/L	MCM-1	429		333		196		241		337		446	
Total Phosphorus	ug/L	MCM-2	291		180		194		142		345		411	
Total Phosphorus	ug/L	PC-1	66	46	70	61	77	45	50	87	146	151	174	122
Total Alkalinity	mg/L	CC-10						228						232
Total Alkalinity	mg/L	CT-2												165
Total Alkalinity	mg/L	CT-P1						281						201
Calcium	mg/L	CC-10						114						121
Calcium	mg/L	CT-2												121
Calcium	mg/L	CT-P1						293						157
Magnesium	mg/L	CC-10						17						17
Magnesium	mg/L	CT-2												25
Magnesium	mg/L	CT-P1						68						35
Potassium	mg/L	CC-10						8						8
Potassium	mg/L	CT-2						7						6

Potassium	mg/L	CT-P1						8						8
Sodium	mg/L	CC-10						109						97
Sodium	mg/L	CT-2												133
Sodium	mg/L	CT-P1						492						167
Total Chloride	mg/L	CC-10						166						160
Total Chloride	mg/L	CT-2												224
Total Chloride	mg/L	CT-P1						904						295
Total Organic Carbon	mg/L	CC-10	5	4	4	5	5	4	4	5	7		6	6
Total Organic Carbon	mg/L	CT-2	7	7	6	7	6	7	7	7	7		8	9
Dissolved Organic Carbon	mg/L	CC-10	4	4	4	4	4	4	4	4	6		6	6
Dissolved Organic Carbon	mg/L	CT-2	7	7	6	7	6	7	7	7	6		8	9
Total Sulfate as SO4	mg/L	CC-10						122						123
Total Sulfate as SO4	mg/L	CT-2												160
Total Sulfate as SO4	mg/L	CT-P1						529						250
Total Suspended Solids	mg/L	CC-10	16	4	3	4	6	5	9	12	34	29	68	45
Total Suspended Solids	mg/L	CC-7	4	2	2	3	2	3	3	7	22	14	49	8
Total Suspended Solids	mg/L	CC-Out	13	12	6	3	3	5	7	7	10	15	14	17
Total Suspended Solids	mg/L	CT-1	11	6	11	13	13	12	14	8	8	18	17	18
Total Suspended Solids	mg/L	CT-2	13	5	7	6	7	10	9	8	6	5	4	4
Total Suspended Solids	mg/L	CT-P1	20	18	17	10	7	9	6		12	5	8	10
Total Suspended Solids	mg/L	CT-P2	12	8	5	8	6	9	12	10	10	9	14	15
Total Suspended Solids	mg/L	MCM-1	0		1		1		13		9		5	
Total Suspended Solids	mg/L	MCM-2	0		0		4		1		13		5	
Total Suspended Solids	mg/L	PC-1	5	3	11	6	5	4	1	4	8	3	19	5
Total Volatile Suspended Solids	mg/L	CC-10	1	1	1	1	1	1	1	3	6	5	6	7
Total Volatile Suspended Solids	mg/L	CC-7	0	0	1	0	1	1	1	2	4	3	9	2
Total Volatile Suspended Solids	mg/L	CC-Out	5	6	4	3	2	3	6	4	3	4	3	3
Total Volatile Suspended Solids	mg/L	CT-1	1	1	1	2	2	3	3	2	3	4	4	8
Total Volatile Suspended Solids	mg/L	CT-2	3	1	2	1	1	2	2	4	2	4	1	2
Total Volatile Suspended Solids	mg/L	CT-P1	3	4	5	2	2	3	2		4	3	2	2
Total Volatile Suspended Solids	mg/L	CT-P2	2	2	1	2	1	2	4	4	3	4	3	0
Total Volatile Suspended Solids	mg/L	MCM-1	0		1		1		3		2		1	

Total Volatile Suspended Solids	mg/L	MCM-2	0		0		1		0		2		1	
Total Volatile Suspended Solids	mg/L	PC-1	0	1	2	1	1	1	1	2	1	2	4	2

Table 5. Cherry Creek Watershed Streams Sites Nutrients and Chemical Parameter Concentrations, WY 2024, Stormflow.

Constituent	*Units*	*Location Name*	5/13/2024	8/14/2024
Dissolved Phosphorus	ug/L	CC-10	101	
Dissolved Phosphorus	ug/L	CT-1	11	
Dissolved Phosphorus	ug/L	CT-2	13	
Dissolved Phosphorus	ug/L	CT-P1	16	70
Dissolved Phosphorus	ug/L	CT-P2	10	28
Dissolved Phosphorus	ug/L	PC-1	83	
Nitrate + Nitrite as N	ug/L	CC-10	228	561
Nitrate + Nitrite as N	ug/L	CC-7	285	
Nitrate + Nitrite as N	ug/L	CT-1	323	
Nitrate + Nitrite as N	ug/L	CT-2	325	
Nitrate + Nitrite as N	ug/L	CT-P1	184	408
Nitrate + Nitrite as N	ug/L	CT-P2	245	388
Nitrate + Nitrite as N	ug/L	PC-1	103	
Soluble Reactive Phosphorus as P	ug/L	CC-10	96	103
Soluble Reactive Phosphorus as P	ug/L	CC-7	102	
Soluble Reactive Phosphorus as P	ug/L	CT-1	1	
Soluble Reactive Phosphorus as P	ug/L	CT-2	1	
Soluble Reactive Phosphorus as P	ug/L	CT-P1	3	50
Soluble Reactive Phosphorus as P	ug/L	CT-P2	1	16
Soluble Reactive Phosphorus as P	ug/L	PC-1	70	
Total Ammonia as N	ug/L	CC-10	3	3
Total Ammonia as N	ug/L	CC-7	25	

Total Ammonia as N	ug/L	CT-1	3	
Total Ammonia as N	ug/L	CT-2	3	
Total Ammonia as N	ug/L	CT-P1	26	33
Total Ammonia as N	ug/L	CT-P2	79	3
Total Ammonia as N	ug/L	PC-1	101	
Total Nitrogen as N	ug/L	CC-10	1,270	1,600
Total Nitrogen as N	ug/L	CC-7	1,180	
Total Nitrogen as N	ug/L	CT-1	1,830	
Total Nitrogen as N	ug/L	CT-2	1,670	
Total Nitrogen as N	ug/L	CT-P1	933	1,540
Total Nitrogen as N	ug/L	CT-P2	1,460	1,710
Total Nitrogen as N	ug/L	PC-1	1,420	
Total Phosphorus	ug/L	CC-10	337	297
Total Phosphorus	ug/L	CC-7	199	
Total Phosphorus	ug/L	CT-1	165	
Total Phosphorus	ug/L	CT-2	115	
Total Phosphorus	ug/L	CT-P1	79	160
Total Phosphorus	ug/L	CT-P2	127	146
Total Phosphorus	ug/L	PC-1	395	
Total Suspended Solids	ug/L	CC-10	736	113
Total Suspended Solids	ug/L	CT-1	82	
Total Suspended Solids	ug/L	CT-2	14	
Total Suspended Solids	ug/L	CT-P1	343	22
Total Suspended Solids	ug/L	CT-P2	28	21
Total Suspended Solids	ug/L	PC-1	120	
Total Volatile Suspended Solids	ug/L	CC-10	562	17
Total Volatile Suspended Solids	ug/L	CT-1	20	
Total Volatile Suspended Solids	mg/L	CT-2	6	
Total Volatile Suspended Solids	mg/L	CT-P1	306	8
Total Volatile Suspended Solids	mg/L	CT-P2	3	8
Total Volatile Suspended Solids	mg/L	PC-1	20	

Table 6. Cherry Creek Watershed Groundwater Monitoring Data, WY 2024.

Constituent	*Units*	*Location Name*	November 2023	May 2024
Dissolved Organic Carbon	mg/L	Kennedy	2	2.8
Dissolved Organic Carbon	mg/L	MW-1	4	4.9
Dissolved Organic Carbon	mg/L	MW-5	2.9	4.0
Dissolved Organic Carbon	mg/L	MW-9	2.2	2.6
Dissolved Oxygen	mg/L	Kennedy	5.8	6.6
Dissolved Oxygen	mg/L	MW-1	4.4	5.6
Dissolved Oxygen	mg/L	MW-5	0.6	2.1
Dissolved Oxygen	mg/L	MW-9	1.4	0.6
Dissolved Phosphorus	ug/L	Kennedy	109.0	134.0
Dissolved Phosphorus	ug/L	MW-1	196.0	180.0
Dissolved Phosphorus	ug/L	MW-5	145	186
Dissolved Phosphorus	ug/L	MW-9	182	226
Nitrate + Nitrite as N	ug/L	Kennedy	41	90
Nitrate + Nitrite as N	ug/L	MW-1	5000	6930
Nitrate + Nitrite as N	ug/L	MW-5	841	600
Nitrate + Nitrite as N	ug/L	MW-9	576	770
pH	None	Kennedy	7	7
pH	None	MW-1	7	6
pH	None	MW-5	7.0	7.0
pH	None	MW-9	7.2	7.0
Soluble Reactive Phosphorus as P	ug/L	Kennedy	67.0	123.0
Soluble Reactive Phosphorus as P	ug/L	MW-1	189.0	146.0
Soluble Reactive Phosphorus as P	ug/L	MW-5	145	172
Soluble Reactive Phosphorus as P	ug/L	MW-9	129	225
Specific Conductance	uS/cm	Kennedy	1214	1130
Specific Conductance	uS/cm	MW-1	1312	1223
Specific Conductance	uS/cm	MW-5	1,218	1,062
Specific Conductance	uS/cm	MW-9	1,461	1,502
Total Ammonia as N	ug/L	Kennedy	39	102
Total Ammonia as N	ug/L	MW-1	44	3
Total Ammonia as N	ug/L	MW-5	49.0	2.5
Total Ammonia as N	ug/L	MW-9	2.5	2.5
Total Chloride	mg/L	Kennedy	164.0	155.0
Total Chloride	mg/L	MW-1	23.4	152.0

Total Chloride	mg/L	MW-5	17	155
Total Chloride	mg/L	MW-9		187
Total Nitrogen as N	ug/L	Kennedy	151	260
Total Nitrogen as N	ug/L	MW-1	6320	7250
Total Nitrogen as N	ug/L	MW-5	1,650	970
Total Nitrogen as N	ug/L	MW-9	621	1,190
Total Organic Carbon	mg/L	Kennedy	3	3
Total Organic Carbon	mg/L	MW-1	4	5
Total Organic Carbon	mg/L	MW-5	3.4	4.3
Total Organic Carbon	mg/L	MW-9	2.8	2.8
Total Phosphorus	ug/L	Kennedy	275.0	233.0
Total Phosphorus	ug/L	MW-1	290.0	189.0
Total Phosphorus	ug/L	MW-5	146	205
Total Phosphorus	ug/L	MW-9	185	233
Total Sulfate as SO4	mg/L	Kennedy	86	110
Total Sulfate as SO4	mg/L	MW-1	121	66
Total Sulfate as SO4	mg/L	MW-5	146	78
Total Sulfate as SO4	mg/L	MW-9		261
Water Temperature	deg C	Kennedy	12	12
Water Temperature	deg C	MW-1	12	12
Water Temperature	deg C	MW-5	10	15
Water Temperature	deg C	MW-9	11	11

Table 7. Cherry Creek Watershed Precipitation Nutrient Concentrations, Water Year 2024.

Constituent	*Units*	*Location Name*	8/14/2024
Total Nitrogen as N	ug/L	Rain Sampler	4,020
Total Phosphorus	ug/L	Rain Sampler	420